The inheritance of heat tolerance in wheat

By

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Declaration of Originality

This thesis, to the best of my knowledge, contains no material which has been accepted for the award of any other degree or diploma in any university, and contains no material previously published except where due references are made in the text.

Duygu Karabork

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Abstract

The frequency of extreme cold weather has decreased across most of Australia, while the frequency of warm weather has increased. These episodes of heat stress have been and continue to be a major threat to wheat production and grain quality by impacting morpho-anatomical, physiological and biochemical properties resulting in reduced plant growth and development and lower yield.

This study explored the effects of heat stress on bread and durum wheats. Bread wheat was assessed by evaluating 20 genotypes across two years and two sowing dates in field and laboratory experiments. The field experiments were conducted in 2014 and 2015 at Narrabri to determine genotype tolerance to high temperature stress. Two sowing dates (May and July) were used to create a differential in temperatures. Irrigation was applied as required to avoid excessive drought stress and to model, as much as possible, the average yield for this location. Yield, physiological, phenological, grain quality and dough rheological properties were assessed each season. All field experiments took place at the University of Sydney's Plant Breeding Institute, Narrabri NSW and dough rheological experiments were determined at Tamworth Agricultural Institute, Calala NSW. Late sowing was effective in identifying genotypes that tolerated heat stress and replicated actual farm conditions. Heat stress reduced grain yield between 4.3-5.5%, hastened plant development 26.8-30.7%, reduced biomass accumulation between 2.6-4.9%, reduced seed size between 2.6-4% and increased flour protein between 5-18.3%. However, overall flour quality was reduced. Several genotypes had stable yield and quality and could be used for future breeding of heat tolerant bread wheat.

A bread wheat genome-wide association study (GWAS) was also conducted using multi-year, multienvironment data. The set of 282 genotypes represented significant diversity for heat tolerance. Putative quantitative trait loci (QTLs) regulating this relationship were identified using marker trait associations (MTAs). Traits such as grain yield, thousand kernel weight (TKW) and screenings% with and without heat stress were assessed. DNA was extracted and plants genotyped using a 90 K SNP Infinium genotyping assay to develop single nucleotide polymorphisms (SNPs) and GWAS subsequently performed to identify significant MTAs. Significant heat tolerant QTLs were found on chromosomes 4A and 6B (2) for yield, chromosomes 3B and 4A for screenings and chromosomes 2B, 3B (2) and 5A for TKW. The QTL on chromosome 4A was common for both yield and screenings%. These QTL must be validated in different material, after which fine mapping will improve their utility in marker-assisted selection for heat tolerance in bread wheat.

To examine the effect of heat stress on durum wheat, 120 durum genotypes with two replications were sown in field experiments with two times of sowing in 2014 and four times of sowing in 2015 at the University of Sydney's Plant Breeding Institute, Narrabri, to assess heat tolerance during the crucial reproductive and grain-filling periods of development. Irrigation was applied to avoid excessive water stress. Late sowing reduced grain yield between 11-62%, grain weight between 1-28%, dough properties (increasing mixograph dough development time with more rapid dough breakdown) and flour milling yield and increased grain protein content between 1-14%. Late sowing identified genotypes that tolerated heat stress while maintaining industrial quality.

The more tolerant durum genotypes based their heat susceptibility index tended to be shorter in plant height between 82.46-62.43cm and had longer days of grain-fill between 27.5-31.64. Significant negative correlations were observed between plant height, days to heading, mixograph resistance break down (RBD) and semolina yield and significant positive correlations observed between width at 8 minutes (WA8), width at peak (WAP), yellow pigment, days to grain-fill, mean peak height (MPH) and grain protein under heat stress. Genetic variation in genotype response was observed and this diversity could be incorporated in future durum breeding.

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Chapter 1: General introduction

Strategies to improve heat tolerance of wheat are crucial for effective wheat improvement. The development of higher-yielding crops under heat stress is an effective method to stabilise and increase wheat production under current and future climatic conditions.

Human generated climate change is already influencing many weather and climate extremes in all regions worldwide. Climate prediction models project that there will be an increase in global warming by 1.5°C between 2030 and 2052 (IPCC, 2018). The observed climate change is affecting food security through temperature increases, changing precipitation patterns, and increases in the occurance of extreme events (IPCC, 2019). Increases in ambient temperature can cause heat stress, which is a severe threat to wheat production, especially during the reproductive and grain-filling stages (Farooq et al., 2011). Furthermore, climate prediction models have shown that in New South Wales, episodes of increased temperatures during the reproductive stages of the wheat crop have adverse effects on grain yields (IPCC, 2019; Innes et al., 2015). The special report by IPCC on global warming of 1.5°C stated that with an increase of 1.5°C in global warming, climate-related risks to food security will also increase and this will be further amplified with increases of 2°C (IPPC, 2019).

Winter wheat crops in Australia are mostly sown in autumn, with intensive heat stress periods from August through to December. This critical heat stress period commonly encompasses the plant growth stages from stem elongation to booting, which includes inflorescence emergence, anthesis, grain development and grain-filling to plant maturity (Zinn et al., 2010). Heat stress is considered as day temperatures greater than 30°C. Thus, the critical heat stress period is when temperatures above 30°C occur during reproductive development; the most susceptible stage of development to heat stress (Zinn et al., 2010). Heat stress causes a reduction in the photosynthetic capacity of the plant by causing metabolic constraints and oxidative damage to chloroplasts, which is linked to reductions in dry matter accumulation and grain yield. Photosynthesis is the most sensitive physiological process to heat stress. The most affected plant structures are the stoma and thylakoid lamellae (Sharma et al., 2020). Heat stress inactivates both stomal enzymes and the photorespiratory electron transport chain, thus decreasing rubisco activity and leading to a reduction in leaf photosynthesis rate (Sharma et al., 2020). Studies have shown that genotypes that exhibit heat shock (short periods of high temperature > 35 °C) proteins are more tolerant to heat stress since they protect proteins from heat damage (Farooq et al., 2011). As previously stated, heat stress during the reproductive stage had the most severe effect on the plant. Heat stress during the reproductive phase and early grain-fill decreased grain number by 63% and reduced grain yield by 78% (Gibson and Paulsen 1999). Each 1°C increase in temperature results in a 6% reduction in wheat yield (Asseng et al., 2014).

The ability of plants to survive and maintain normal growth when exposed to heat stress is known as heat tolerance (Wahid et al., 2007). In order to cope with heat stress, wheat has evolved mechanisms such as escape, avoidance, and/or tolerance including the stay-green trait (Wahid et al., 2007; Farooq et al., 2011). Wheat avoids heat stress by reducing grain-filling duration by accelerating grain-filling rate, thus consuming stem reserves to maintain yield. Avoidance mechanisms include the plant maintaining optimum water status by reducing water loss through stomatal closure, presence of trichomes, wax on leaves, leaf rolling, change in leaf angle, senescence of older leaves and manipulation of water availability through root architecture and growth (Sharma et al., 2020). The stay-green improves tolerance to reduced water potential, causes cooler canopies, maintains an active photosynthetic state to ensure supply of assimilate, improves radiation use efficiency, and increases grain-filling duration to maintain grain-filling under heat stress (Sharma et al., 2020).

Despite significant improvements in wheat production systems, limited progress has been made in improving genetic tolerance to heat stress. Tolerance to heat stress in wheat is a complex trait (Maulana et al., 2018), that is dependent on environmental and physiological factors. The polygenic nature of this trait makes selection for heat stress tolerance in field conditions problematic. Wheat growth and development is also influenced by genotype and genotype x environment interactions which adds to the complexity of selection for heat stress in field conditions (Maulana et al., 2018; Sharma et al., 2019).

1.1 Central research question

The main purpose of this study was to better understand the morphological, physiological and genetic factors in bread and durum wheat that influence grain yield and dough rheological properties under heat stress. The first component is a study of the phenotypic response to heat under contrasting sowing dates in north-western NSW (Narrabri). The second component was an in-depth analysis of the effect of heat stress on dough rheological properties for both bread and durum wheat. The third and final component was to identify genomic regions linked to bread wheat heat stress response using a genome wide association analysis.

This worked aimed to answer the question “Can yield losses in durum and bread wheat be alleviated by adapting fundamental physiological and genetic processes associated with tolerance to high temperature?”

1.1.1 Sub-questions

1. To what extent does heat stress impede grain quality and yield in bread wheat? (Chapter 4)

2. To what extent does heat stress impede grain quality and yield in durum wheat? (Chapter 5)
3. What are the genetic factors associated with heat stress tolerance in bread wheat? (Chapter 6)

1.1.2 Objectives

The broad objective of the research for this thesis was to develop an understanding of the key physiological and genetic processes regulating yield losses in bread and durum wheat under heat stressed conditions. The specific objectives of these experiments were to:

1. Determine the physiological basis of heat tolerance in durum germplasm
2. Determine the impacts of high temperature on grain quality in both bread and durum wheats.
3. Better understand the underlying genetic control of heat tolerance in bread wheat.

Chapter 2: Review of Literature

2.1 Climate change and the impact of high temperature on global wheat production

Climate change jeopardises global wheat production and food security, including Australia's wheat industry (Wang et al.,2017). Global climate change has dramatically altered crop growth and development, affected crop cultivation patterns and reduced potentially suitable planting regions. These impacts could potentially reduce the production of major crops such as wheat which is currently at an all-time high production (Wang et al., 2017). Global temperature trends suggest a continuous increase in temperature up to 2°C by mid-centur, which can potentially cause a further reduction in wheat yield if adaptation strategies are not applied (Asseng et al., 2015; Challinor et al., 2016). However, future elevated atmospheric CO_2 can potentially have a positive effect on crop growth and yields but its response is restricted by temperature, nitrogen (N), and water conditions (Alexandrov and Hoogenboom, 2000; Kimball et al., 2001; Hernandez Ochoa et al., 2018). The Australian grains belt is already warmer than optimal for wheat production (Hunt et al, 2018) and (Hochman et al., 2017) found that the impacts from climate change have resulted in a 27% decrease in potential wheat yield. As a result of climate change the areas suitable for growing wheat will reduce and wheat yields will deteriorate in north-eastern Australia (Wang et al., 2017). The years 2014 and 2015 had the warmest spring on record (Australian Bureau of Meteorology and CSIRO, 2016). In central New South Wales, a warm period during May 2014, just after crop emergence, led to faster crop development, which resulted in stem elongation occurring 11 days earlier than average (Australian Bureau of Meteorology, 2014; Hunt et al., 2018). As a result of the earlier stem elongation, crop biomass and grain yield diminished as the time for resource capture (light, water and nutrients) was reduced with hastened development.

It is predicted that for every 1˚C increase in temperature, global wheat yields will reduce by 4.1–6.4%, which can detrimentally affect global wheat production (Morgounov et al., 2018). Wheat grown in warmer regions can potentially have higher grain yield losses compared to wheat that is produced in colder areas. Also, the production of high latitude spring wheat could benefit from a warmer environment because of longer growing periods, especially if increased atmospheric carbon dioxide can enhance crop productivity at large spatial and temporal scales (Muller et al., 2015). In relation to Australia, the climatic situations between 2000-01 and 2014-15 (the latter is the period in which the current study took place) saw a reduction in national wheat yield of approximately 11.9% (Hughes et al., 2017). In New South Wales alone, the climatic conditions post 2000-01 resulted in a reduction of wheat yield by an average of 6.5% (Hughes et al., 2017). Australia's warmest years were between 2013 to 2019 with the warmest year being 2019 (State of the Climate 2020). Warming across the whole of Australia has been detected in all months including both day and night temperatures. This change in increased temperatures has been associated with more extreme nationally averaged daily heat events throughout all months (State of the Climate 2020). It is also important to note that 2020- 2022 experienced bumper crop production because of La Nina.

Ray et al., (2019) found that the impacts of climate change are mostly negative in Europe, Southern Africa and Australia but generally positive in Latin America. Precipitation patterns are also a contributing factor to the varying effects of climate change on different regions (Ray et al., 2019). The effects in Asia and Northern and Central America were found to be mixed. In relation to Australia, climate change had a significant negative impact on crop productivity in south-western Australia and south-eastern Australia (Hughes et al., 2017). The climate conditions in the southern hemisphere have been predicted to become less suitable for crop cultivation under future climatic conditions due to increases in heat and water stress (Wang et al., 2017). Wang et al (2017) also found that climate change can potentially affect the spatial distribution of crops in higher latitudes (e.g., in Russia) due to increased temperatures which could result in the expansion of growing regions resulting in increased crop yields.

Evaluation of climate change's impact on crop yields usually combines future climate scenarios and process-based crop models to project future yields for a limited number of crops for 2050 and beyond (Ray et al., 2019). These models were found to contain errors due to their structure and parameterisation, which leads to uncertainty in projections (Asseng et al., 2013). According to Asseng et al. (2013), uncertainty can be quantified using multi-model ensembles. Wang et al. (2017) found that crop modelling conducted by previous studies discovered that the negative effects of increased temperatures on wheat yields can potentially be partially offset by the positive effects of increased CO_2 concentrations.

Exposure to frequent high temperatures during critical growing periods like grain-filling and ripening can have detrimental effects on final grain yield (Scotti-Campos et al., 2014). For instance, Asseng et al. (2011) found that temperatures >30 °C post-anthesis caused significant reductions in grain yield due to a shortened grain-filling period and increased leaf senescence. The study also found that an increase in the mean growing season temperature by 2 °C can cause a considerable reduction in wheat production of up to 50% (Asseng et al., 2011).

Overall, growth and development across the wheat life cycle is most rapid at temperatures between 17-23°C. This temperature range corresponds to the thermal kinetic window (17-23°C) that describes the ideal range for enzyme performance in wheat as identified by Burke et al. (1988) and Hunt et al. (2018). Hunt et al. (2018) identified that wheat crop growth reduces at temperatures above 23°C and ceases once temperatures surpasses 37°C. The study also found that temperatures above 48°C can be lethal to the wheat crop. They also identified that heat stress at sowing can result in increased evaporation from the seed-bed leading to shorter coleoptiles and poor seedling establishment. Heat stress during the vegetative period can result in an acceleration of crop development causing crops to flower early when radiation is sub-optimal, which also increases risk of frost damage. Chronic heat stress during spike development can accelerate crop development relative to growth which can lead to reduced grain number. Heat stress before and during flowering can potentially kill pollen and developing embryos in the wheat crop, leading to sterile florets and decreased grain number (Hunt et al., 2018). Heat stress post flowering can result in scorched leaves, hastened senescence, particularly when solar radiation is strong, which leads to reductions in photosynthetic area both pre and post anthesis, ultimately causing reduced grain yield.

Climate mitigation measures that reduce atmospheric carbon dioxide concentrations may reduce the strength of climate change. However, adaptation measures through the efficient management of soil water during the growing season, cultivar selection, optimised sowing time and density and fertiliser supply and timing may counteract the effects of climate change. Nevertheless, it is not clear if these strategies will hold against future climate conditions (Wang et al., 2017). Therefore, the impact of climate change on agricultural production can be addressed both through mitigation strategies and by exploring opportunities to expand food production into new regions made productive by changed conditions (Mueller et al., 2015).

Australia's farming systems feed an estimated domestic population of approximately 22 million people, with enough surplus to export food to feed another 40 million people each year (Lawrence et al., 2013). However, it is projected that if the Australian population is to double over the next 40 years, and the world's population is expected to increase from 8 billion to 9 billion by 2037 and 10 billion by 2057, it is vital to increase food production in Australia (Lawrence et al., 2013)).

Increasing temperatures can potentially intensify the Australian wheat industry’s vulnerabilities (Wang et al., 2017). Agriculture is one of the most sensitive economic sectors to climate change because of the sector’s dependency on rainfall, making Australian agricultural industries among the most vulnerable in developed countries (Wang et al., 2020). Latest modelling conducted by Australian Bureau of Agriculture and Resource Economics (ABARES) (Hughes et al, 2021) has projected that because of changes in seasonal conditions between the periods 2001-2020, annual average cropping profits in northern, southern and western Australia reduced by 36, 22 and 27%, respectively.

Australia has produced approximately 36.24 million tonnes of wheat in 2021-2022 and has fallen to 26 million tonnes for 2023-2024 (Grain producers Australia, 2024).

2.2 Effect of heat stress on grain yield

Two components govern grain yield; the number of grains per m^2 and grain weight (Arora et al., 2017). Heat stress is a significant limitation to wheat productivity as it causes morphological and physiological changes at all stages of development which leads to extensive yield losses (Al-khatib and Paulsen 1990, Tahir and Nakata 2005, Tahir et al., 2006, Tewolde et al., 2006). Heat stress can cause a reduction in plant photosynthetic capability through metabolic limitations, and oxidative damage to the chloroplast, with associated decreases in dry matter accumulation leading to reductions in yield (Singh et al., 2017). Estimations in changes in wheat productivity and response to high temperatures was generated by the Agricultural Production Systems Modulator (APSIM) for the period 1984-2017 and has found that heat stress tends to result in reduction in grain weight more than grain number (Trethowan, 2022).

Chronic heat stress is defined by high temperatures through the duration of the growth cycle, with mean temperatures ranging between 18°C to 25°C and maximum daytime temperatures of 32°C during grain filling (Kumar et al., 2023). There is some evidence that chronic heat stress can be associated with reduction in kernel weight due to increase in protein concentration (Wardlow et al. 2002).

Heat shock is defined as temperatures exceeding 32°C during mid to late-reproductive stages of wheat, including grain filling (Kumar et al., 2023). Dough weakening effect during grain filling due to decrease in the size distribution of the glutenin polymer protein (Wardlow et al., 2002). The impact of heat shock on grain number is caused mostly by sterility and abortion of grains just before anthesis to 10 days after anthesis (Barlow et al., 2015). Heat shock causes cellular damage which results in grain size being affected (Barlow et al., 2015).

During anthesis, heat stress can cause an increase in floret abortion, pollen sterility, tissue dehydration, lower CO_2 assimilation, and increased photorespiration. However, the increased temperature can produce accelerated growth and earlier flowering. Thus, temperature increases >30°C during anthesis to maturity reduces the plant's time to capture resources, causing a decrease in grain yield (Farooq et al., 2011). This study also concurs with the finding that grain number and grain weight are both sensitive to temperature increases. The effect that temperature stress has on each of these components of grain yield is dependent on the developmental phase at which the temperature stress occurs. As temperature increases above 20°C during the developmental period between spike initiation and anthesis, grain yield can be reduced substantially as grain number per spike is diminished. Grain number is influenced by spikelet initiation, floral organ differentiation, male and female sporogenesis, pollination, and rates of fertilisation. Spike development accelerates with heat stress, which reduces spikelet number and hence, the number of grains per spike. Wilhem and McMaster (1996) reported higher sensitivity to heat as the spikelets begin to develop from ridges of tissue between ridges of undifferentiated leaf primordia, also known as the double ridge stage. The double ridge stage is followed by the production of florets from the meristem of each spikelet. Since heat stress causes a reduction in the amount of time between emergence to double ridge and double ridge to anthesis, spikelet number per spike and grain number per spikelet reduce. Table 2.1 illustrates studies conducted on the effect of heat stress on grain yield.

Table 2.1: Summary of research conducted on the effect of heat stress on grain yield

Researcher	Heat Stress and effect
Asseng et al., 2011; Ferris et at., 1998; Lobell et al., 2011	Temperature increases above 34°C following anthesis lead to reduction in grain weight
Elbashir et al., 2016	Temperature above 30°C during grain-filling resulted in reduced yield
Hlavacova et al., 2017; Saini and Aspinall (1982)	Temperature above 30°C at anthesis result in complete grain sterility
Wang et al., 2023	Temperature above 35 °C during grainfill reduced thousand grain weight by 14.9%
Thistlewaite et al., 2020	Temperature above 35 °C heat shock at meiosis reduced grain number Kernel weight was more impacted by heat stress during grainfill
Sattar et al., 2020	55.5% reduction in chlorophyll content
Kumar et al., 2023	Yield loss 51% under heat stress and 81% under extended heat stress environments

Floral initiation is clearly impacted by heat stress leading to reduced grain number (Fischer, 1985). This study reported that the grain number per spike decreased by 4% for every 1°C (from 15–22°C) increase in the 30 d post-anthesis. According to Abbate et al. (1995) and Demotes-Mainard and Jeuffroy (2004), grain number is determined by the availability of carbohydrates for floret development. Insufficient available assimilates can cause floret death.

Saini and Aspinall (1982) demonstrated that when a wheat plant was exposed to 30°C for three consecutive days, during the stage when pollen mother cells are dividing, heat stress can cause a dramatic reduction in grain set and ultimately grain yield. Wheat plants exposed to one day of 30°C, or for three days of day/night temperatures of 30/20°C also experienced a reduction in grain set. Decrease in grain set causing reduced grain yield is not compensated by increases in individual grain weight. The viability of anthers and pollen reduce, leading to poor fertilisation under heat stress. Mascarenhas and Crone, (1996) explained that pollen sensitivity to heat stress is related to lack of heat shock protein synthesis. (Calderini et al. (1999) showed that reduced grain number was also associated with pre-anthesis heat stress. A study by Rezaei et al. (2018) mentioned that there is increasing evidence that short episodes of very high temperatures during anthesis of cereal crops results in decrease of grain yield due to pollen abortion and sterile grains.

Every degree increase in temperature corresponds to a 6% loss in wheat yield (Akter and Islam., 2017). Heat stress can cause a significant reduction in seed germination and seedling growth by impacting cell turgidity, and plant water-use efficiency. At a cellular level, heat stress impacts cellular functions by generating unnecessary reactive oxygen species, which causes oxidative stress. Akter and Islam found that heat stress reduced grain number and size by reducing grain setting, assimilate translocation and duration and grain growth rate. Barutcular et al. (2017) showed that late sowing associated with high temperatures caused significant reductions in grain yield as heat stress causes biochemical and physiological changes that affect various cellular and metabolic processes that impact wheat yield. Heat stress reduces carbohydrate production and translocation and can cause an increase in carbohydrate starvation throughout periods of high respiration, particularly during high night temperatures.

Photosynthesis is the most heat-sensitive physiological process. Increased temperatures cause a reduction in photosynthesis, which directly affects grain yield. Heat stress disturbs the structure and function of chloroplasts and causes a decrease in chlorophyll content (Xu et al., 1995). Heat stress causes oxidative stress, which leads to inactivation of chloroplast enzymes and reduced the rate of leaf photosynthesis. Oxidative stress can also induce lipid peroxidation, leading to protein degradation, membrane rupture, and enzyme inactivation (Sairam et al., 2000). Increased photorespiration is also linked to heat stress and reduced photosynthesis reduces grain yield. Photorespiration occurs because of the solubility of CO_2 and O_2, and the kinetics of Rubisco is disturbed under increased temperatures (Long et al., 2004). Figure 2.1 from the study by Farooq et al. (2011) illustrates a plausible mechanism for how heat stress affects photosynthesis.

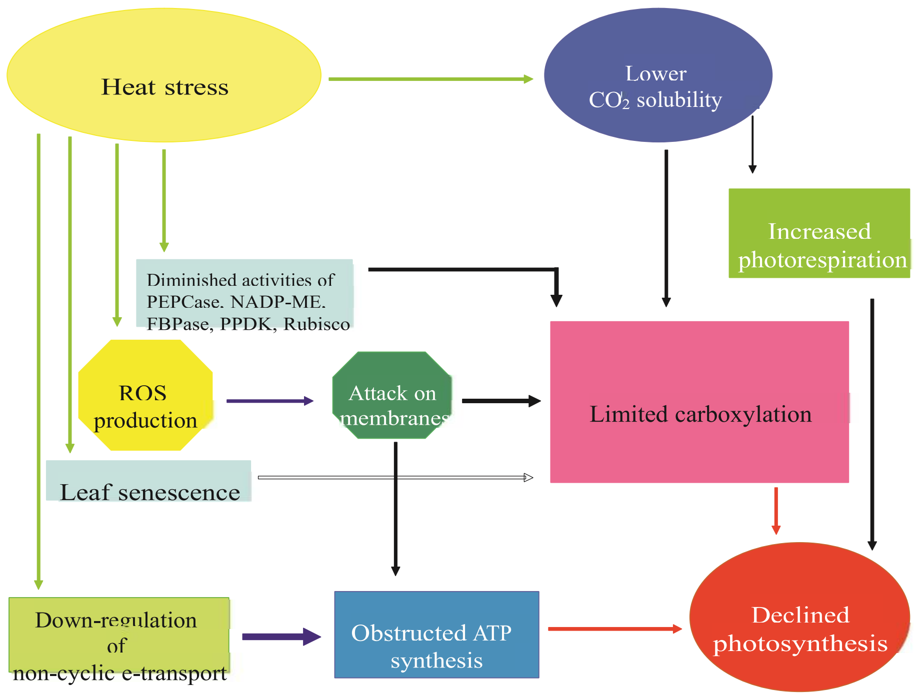


Figure 2.1: The impact of heat stress on photosynthesis (Farooq et al., 2011)

Figure 2.1 illustrates that heat stress causes an imbalance between the production of reactive oxygen species (ROS) and antioxidant defence, which leads to an accumulation of ROS, which induces oxidative stress. As ambient temperature increases, CO_2 solubility in water decreases, which reduces carboxylation and causes more electrons to form ROS, which leads to photorespiration. Severe heat stress restricts photosynthesis as the activities of ribulose-1, 5-bisphosphate carboxylase/oxygenase (Rubisco), phosphoenolpyruvate carboxylase (PEPCase), NADP-malic enzyme (NADP-ME), fructose-1, 6-bisphosphatase (FBPase) and pyruvate orthophosphate dikinase (PPDK) are reduced. Leaf senescence also increases under heat stress, which limits photosynthetic area. For the requirements of NADPH production to be met, non-cyclic electron transport becomes downregulated, leading to a reduction in ATP synthesis (Farooq et al., 2011).

The reduction in grain yield is a function of nutrient assimilation and mobilisation to several reproductive organs, accumulation of stem reserves, gametogenesis, fertilisation, embryogenesis, and endosperm formation in seed development (Sehgal et al., 2018). Heat stress reduces germination, vegetative growth, tiller production, dry matter partitioning, reproductive organ development and retards reproductive processes (Prasad et al., 2011)

Gupta et al. (2013) found that heat stress caused a significant reduction in shoot dry mass, root dry mass, shoot length, and root length. They also found that chlorophyll content and membrane stability index decreased. Others reported similar findings, that heat stress reduces leaf chlorophyll content by 27% (Awasthi et al., 2014).

Another study has found that heat stress can cause damage to cellular structure (Ni et al., 2018). Starch synthesis is exceptionally prone to damage caused by heat stress due to the susceptibility of soluble starch synthase in developing wheat kernels. These authors reported that starch accumulation in grains reduced by more than 30% at temperatures between 30℃ and 40℃. The ability to synthesise, store, and remobilise starch at high temperatures is a crucial determinant of grain sink strength (Ni et al., 2018). Starch is the main carbon reserve and accounts for 65 to 75% of wheat grain weight and 80% of endosperm weight and thus is a significant determinant of wheat yield. In the presence of heat, starch or flour up take of water to produce paste is influenced by the ratio of amylose to amylopectin, the size of starch granules and genotype tolerance to high temperature (Labuschagne et al., 2009).

Water relations are also impacted by increased temperatures. Leaf canopy temperature affects leaf relative water content (LRWC), leaf water potential, stomatal conductance and rate of transpiration (Farooq et al., 2009a, b). High temperatures in dry environments result in higher vapour pressure deficits, which drive higher evapotranspiration. The depletion in soil water causes LRWC and leaf water potential to decrease. Nevertheless, leaf surface evaporation boosts leaf and canopy cooling, therefore overheating can be reduced by increased rates of transpiration (Farooq et al., 2011). Despite there being trade-offs between stomatal regulation, heat balance and depletion rate of limited soil water, most plant species tend to conserve water over temperature regulation, especially when the ambient temperature is well over 30℃ (Martinez-Ballesta et al., 2009). Throughout the reproductive and grain-filling stages, water is needed for stem and peduncle elongation, cell expansion and growth, flowering, grain growth and development. For most of these processes, water flow involves crossing membranes, which is probably assisted by aquaporins. Increased temperatures generally increase hydraulic conductivity of membranes and plant tissues because of increased aquaporin activity, membrane fluidity and permeability (Martinez-Ballesta et al., 2009) and reduction in water viscosity (Cochard et al., 2007). The increase in hydraulic conductivity can be advantageous in leaves and roots by reducing the changes in leaf water potential so that the stomata can stay open for more extended periods. On the other hand, increases in the permeability of membranes can lead to the dehydration of flowers and grains, especially if the gradients controlling water flow into grains or flowers are unsettled by heat stress (Farooq et al., 2011).

In summary, daytime heat stress above 30℃ between or during booting and anthesis results in reduced grain number (Kaur and Behl, 2010; Ugarte et al., 2007; Wardlaw et al., 1989b; Wheeler et al., 1996) and temperatures between 30-35℃ post-anthesis and during grain-filling resulted in reduced grain weights (Shah and Paulsen, 2003; Talukder et al., 2010; Wardlaw et al., 1989b).

2.4 Effect of heat stress on grain quality

Grain quality of wheat is an amalgamation of various parameters including grain morphological properties, dough, and final product properties. These parameters are determined by the genotype, the environment, and their interactions (Hernández-Espinosa et al., 2018). The suitability of grain for endusers is vital as grain quality impacts on milling, baking, dough rheology, nutritional value, and storage capacity (Porter and Semenov 2005; Tajnšek et al., 2010). Wheat grain quality and yield are both vital in determining the value of the Australian crop in the wheat market (Alghabari et al., 2015).

The quantity and the type of storage proteins in the grain endosperm influence dough rheological properties. Significant rheological properties are considered to be viscosity and elasticity of flour, and this depends on the balance of the proteins, gliadins and glutenins. Starch is also an essential constituent of flour as it accounts for approximately 65-75% of wheat grain weight and has been known to surpass 80% of the endosperm weight, a major element of wheat yield (Labuschagne et al., 2009). The ability of starch or flour to take up water and produce a paste is a functional property of starch that is influenced by heat stress and by variation in the ratio of amylose to amylopectin and the size distribution of starch granules (Labuschagne et al., 2009). Starch production is limited under heat stress, and it was hypothesised that this is caused by inactivation of starch synthase, a crucial enzyme in the biosynthetic pathway of starch (Labuschagne et al., 2009).

Wheat used in bread-making will generally have a high protein concentration, high specific weight, protein quality conferring firm dough, reduced alpha-amylase activity, high sodium dodecyl sulphate (SDS) sedimentation volume which determines gluten strength, and the absence of black point and fungal contamination (Alghabari et al., 2015). Proteins are the key to wheat grain quality; however, when wheat yield increases this results in an adverse effect on protein quantity and quality. This inverse relationship is controlled by climatic, genetic and agronomic factors. Blumenthal et al (1991) found that high temperatures reduced the quantity of heat shock protein production, construction of complex protein aggregates and increased the gliadin to gluten ratio, which in turn caused a reduction in dough strength and flour mixing time.

Heat stress results in increased evaporative demand, leading to reduced transpiration efficiency. Hunt et al (2018) also found that heat stress can improve baking quality, however the study found that when temperatures exceeded 32°C for 100 h through grain-filling, then baking quality is degraded.

High temperatures during grain-filling stage can cause an increase in protein content. However, this can cause a reduction in protein functionality (Corbellini et al., 1997). Another study by Yildirim et al., (2018) has stated that heat stress during grain-filling has an adverse effect on grain quality as it forces the plant into early maturity resulting in shortened glutenin synthesis. This finding also concurs with Barakat et al., (2020) who showed that heat stress caused reduced UPP% (unextractable polymeric protein percentage), and glutenin to gliadin ratio which caused a reduction in grain quality, despite an increase in protein content. Nuttall et al. (2017) demonstrated that heat stress during grainfilling had a profoundly more significant impact on grain quality and in particular, starch concentration than at anthesis.

Sissons et al. (2017) concluded that heat stress (temperatures >30°C) improved dough and pasta quality, despite the heat stress having a negative impact on grain yield and grain physical characteristics. This study found that heat stress increased protein content, dough quality indicators and increased the amount of high molecular weight gluten polymer. Sissons et al. (2017) also found that heat stress improved pasta end-use traits, enhanced pasta yellowness, and firmness and decreased cooking loss. Other studies found that high temperatures during grain-filling can reduce the dough and baking quality of the grain in hexaploid wheat (Peterson et al., 1992).

Randall and Moss (1990) showed that wheat gluten strength increased up to 30 ˚C but decreased at temperatures beyond 30 ˚C. The impact of heat stress on the functionality of gluten was affected by the timing of high temperature and its effect on the polymerisation of glutenin (Irmak et al., 2008). Another study also confirmed that in both common wheat and durum wheat there was a decrease in polymeric protein and an increase in monomeric protein as a result of heat stress (Labuschagne et al., 2009).

A study on spring wheat varieties by Yildirim et al. (2018) concluded that grain protein content had a positive correlation with dry gluten content and Zelaney sedimentation volume, and a negative association with grain weight under heat stress conditions. The study also reported a significant negative relationship between grain starch content and grain protein content as a result of the adverse effects of heat and drought stress.

2.4 Genetic variation for key heat tolerance traits in wheat

Bread wheat (Triticum aestivum L.) is part of the tribe Triticeae. Triticeace has more than 150 different species and contains various ploidy which include bread wheat, durum wheat (T. turgidum L.), einkorn wheat (T. monococcum L.), rye (Secale cereale L.) and barley (Hordeum vulgare L.) The mentioned species and their close and distant relatives establish a vital reservoir of genetic resources that include 434,358 accessions collected and stored in 23 gene banks that potentially carry beneficial alleles for wheat improvement (Rasheed et al., 2018). Genetic variation or diversity is a crucial resource in plant breeding to enhance new cultivars with advantageous traits (Alipour et al., 2017). Emmer wheat is one of the first wheat species to be domesticated and contains significant variation for tolerance to abiotic stresses (Ullah et al., 2018). This study discovered new genetic variability for high-temperature tolerance in the hexaploid progeny crossed with emmer wheat. Exotic genetic resources such as wheat ancestors exhibit better adaptation towards stressful climatic conditions and encompass more diverse genes for stress tolerance (Ullah et al., 2018). Many wheat landraces have a superior level of tolerance to biotic and abiotic stresses and produce higher sustainable yields under low input agricultural conditions (Alipour et al., 2017). While current wheat varieties are derived from landraces in the distant past (Trethowan and Mujeeb-Kazi, 2008), there remains a substantial amount of unexploited variability for heat tolerance among landraces (Reynolds and Trethowan, 2007). Genetic diversity for biotic and abiotic stresses from these tetraploid varieties can be transferred to commercial cultivars (Hassan et al., 2016). Even though artificial selection during domestication and modern breeding has increased the frequency of desirable alleles regulating yield and input responses, other essential alleles such as abiotic and biotic stress resistance may have been excluded from breeding populations and cultivars. Consequently, the genetic diversity of bread wheat is relatively narrow in breeding programs, thus the preservation of landraces and their wild relatives is crucial to avoiding genetic erosion (Alipour et al., 2017).

Genotyping-by-sequencing (GBS) classed as next-generation sequencing (NGS) technology is a highthroughput and cost-effective molecular tool for regular breeding and screening in a variety of crops, including those with a large genome (Alipour et al., 2017). GBS-NGS technology has made it possible for breeders to select genetically distant parents for crossing in breeding programs and thus provides rich genetic sources to biotic and abiotic stress tolerance (Alipour et al., 2017).

Genetic variation in recent breeding programs has greatly improved wheat yield productivity through the introduction of dwarfing genes (Rht). The Rht genes provide a semi-dwarf stature to wheat and this has led to an increase in harvest index (Arora et al., 2017). Better understanding of the genes that impact flowering time and photoperiod response (Vrn and Ppd) has improved the matching of plant phenology to various environments (Arora et al., 2017). Wheat is an allohexaploid comprising of A, B, and D genomes provided by Triticum urartu, which is closely related to Aegilops speltoides and Aegilops tauschi. The Arora et al (2017) study focused on the rich source of genetic variability available on the D-genome of Ae. tauschii germplasm which is of agronomic importance such as high and low molecular weight glutenin subunits and gliadins using amplified length polymorphism (AFLP) and simple sequence repeat (SSR) marker. The diversity of the nucleotide sequence in the Dgenome is 30-fold higher in A. tauschii compared to Triticum aestivum (Caldwell et al., 2004). The International Maize and Wheat Improvement Center(CIMMYT) has focused on increasing Dgenome diversity in bread wheat and has produced over 1,200 synthetic hexaploid wheat lines by crossing elite tetraploid durum with A. tauschii to introgress economic traits of importance, including abiotic and biotic resistance (Trethowan and Mujeeb-Kazi, 2008).

The identification and quantification of high-temperature tolerance and its genetic control are essential for the development of new cultivars (Porter et al., 1995). Tolerance to abiotic stress traits is complicated, regulated by more than one gene, which are often impacted by environmental variation (Blum, 1988).

Saadalla et al. (1990) studied cell membrane thermostability (MTS) in wheat using a diallel analysis. The genetic control of heat tolerance was measured through electrolyte leakage from cell membranes within leaf tissue, which is observed by assessing electrical conductivity of the aqueous phase. An association was found between heat tolerance, measured as electrolyte leakage at the seedling stage and tolerance to post-anthesis high temperature stress (Saadalla et al., 1990). Thus, when leaf tissue is heat stressed, there is an increase in electrical conductivity, which is caused by damage to the cell membrane and solute leakage. Saadalla et al. (1990) used MTS to identify transgressive segregants in F5 progeny. They concluded that the parents contributed different genes for heat tolerance and that the heat tolerance trait was complex (Saadalla et al., 1990). Studies by Yang et al. (2002), Barakat et al. (2011) and Joukhadar (2021) each reported several important quantitative trait loci (QTL) linked to heat tolerance and associated markers.

Table 2.2 illustrates the potential traits that can be used to screen wheat for heat tolerance. Genotypes can be screened for heat tolerance using TTC, canopy temperature depression, flag-leaf stomatal conductance and photosynthetic rate, which are all strongly correlated with field performance and grain yield under heat stress (Reynolds et al.,1994, 1998; Amani et al., 1996; Farooq et al., 2011).

Table 2.2: Potential traits for screening wheat for heat tolerance (Farooq et al., 2011, Ullah et al., 2021)

Traits/characteristics	References
Photosynthesis, stomatal conductance, Photosynthesis rate	Reynolds et al. (1994); Radhika and Thind (2014), Dwivedi et al., (2017)
Leaf chlorophyll content, chlorophyll fluorescence	Reynolds et al. (1994)Bhusal et al., (2018); Pandey et al. (2015)
Canopy temperature depression	Reynolds et al., (1994, 1998); Amani et al. (1996); Blum et al. (2001) Paliwal et al. (2012); Sharma et al. (2018)
Membrane thermostability	Talukder et al. (2014); Dwivedi et al. (2017); Sharma et al. (2018)
Days to heading	Tewolde et al. (2006) Sharma et al., (2013); Sharma et al., (2018)
Days to maturity	Sharma et al. (2013); Sharma et al., (2018)
Number of tillers per plant, grain yield	Sharma et al. (2018)
Biomass production	Khan et al. (2015)
Stem carbohydrate remobilization	Cossani and Reynolds (2012); Dwivedi et al. (2017)

Antioxidant activity	Caverzan et al., (2016)
High- temperature index/heat susceptibility index, pollen viability	Rane and Nagarajan (2004); Dwivedi et al., (2017)
Spike photosynthesis	Cossani and Reynolds (2012)
Stay-green duration	Lopes and Reynolds (2012); Nawaz et al. (2013); Bahar et al. (2011)
Membrane stability	Dhanda and Munjal (2012); Talukder et al. (2014)
Number of fertile spikes	Khan and Kabir (2015); Bennani et al.(2016)
Harvest index	Laghari et al., (2016)
1000-grain weight	Laghari et al., (2016); Paliwal et al., (2012); Sharma et al., (2018)
Grain weight	Dias and Lidon (2009); Bennani et al. (2016); Sareen et al. (2012); Pandey et al. (2014)
Grain-filling rate	Nawaz et al. (2013); Song et al. (2015); Pandey et al. (2014); Khan and Kabir (2015)
Grain-filling duration	Song et al.(2015); Dwivedi et al. (2017); Nawaz et al. (2013)
Tetrazolium triphenyl chloride	Towil and Mazur (1974)

Leaf membrane stability (LMS) (Table 2.2) is another screening technology linked to tolerance to heat stress. Cultivars with increased cell viability have increased LMS and higher grain yield (Dhanda and Munjal, 2006). Dhanda and Munjal (2006) showed that LMS was positively correlated with heat response index and high temperatures at the seedling growth phase and that higher LMS reduced MTS.

Canopy temperature depression (CTD) is one of the most fundamental traits for screening for heat tolerance. CTD is calculated as the difference between air temperature and canopy temperature (CTD = air temperature [Ta] – canopy temperature [Tc]) (Balota et al., 2007). CTD measurements are recorded with a hand-held infrared thermometer or can be captured remotely using drones. CTD often correlates with yield depending on the environment and stage of development (Araus et al., 2002).

2.5 Genetic strategies for improving heat tolerance of wheat

Plant breeding programs are influenced by interactions of genotype x environment (G × E) and the correlations among traits that enhance yield and quality (Cooper and Podlich, 1999). Breeders typically aim to produce widely adapted varieties that minimise G ×E on agronomic and grain quality characters, by selecting for consistency in performance across the production areas (Chenu et al., 2011). The increased occurrences of high temperature due to climate change, particularly during the reproductive phase, have made it necessary to develop ideotypes with physiological, morphological and molecular traits linked to heat tolerance (Farooq et al., 2011). Selection for heat tolerance directly under field conditions is typically challenging because environmental factors are difficult to manage and can adversely impact the accuracy and repeatability of field trials (Wahid et al., 2007). Furthermore, fluctuations in the environment can be reduced through irrigation and different sowing dates. Additionally, stress tolerance is growth stage-specific, and heat stress at one stage of development might not be associated with tolerance at another developmental stage. Studies have proposed that oxidative stresses experienced by plants occur during the preliminary period of acclimation to any stress. Plant reaction to stresses advances from general to specific over time. Specific responses are defined as the continued expression of genes involved in processes specific to individual stresses (Yang et al., 2006). These responses facilitate a short-term tolerance to particular stresses. Nevertheless, genome malleability, which includes genetic and epigenetic modifications provides longer-term adaption to environmental changes and conditions (Joyce et al., 2003). These long-term adaptions are necessary for survival in various environmental conditions. However, acclimation to the environment or tolerance to stresses can be manipulated through multiple techniques under agricultural systems (Wahid et al., 2007). Genetic improvement of cultivars can reduce the adverse effects of abiotic stresses on agricultural productivity. However, adjustments to farm practices, such as planting time, planting density and soil and irrigation management can reduce the impact of abiotic stress (e.g., by matching the stress-sensitive stage of the plant with the most advantageous period of the season). A combination of genetic and agricultural practices must be used concurrently to improve agrarian productivity under stress. Heat tolerance strategies therefore need to comprise crop improvement (including molecular tools), agronomic and other management procedures (Farooq et al., 2011).

Some breeding strategies for improving heat tolerance include development of precise screening measures, identification and characterisation of genetic resources with heat tolerance, distinguishing the genetic source of heat tolerance at each phase of plant growth and development, development of effective phenotyping screens and linked markers to enable the transfer of genes for heat tolerance in large breeding populations to commercial cultivars (Siddique et al., 1999). The extension of genetic variability in the wheat gene pool is crucial for wheat breeding programs. One possibility is to cross the primary ancestors of wheat, Aegilops tauchii and Triticum durum (Trethowan and Kazi, 2008) to create primary hexaploid synthetic wheats.

Selection of genotypes with high yield under heat stress is an important strategy. However, this method is expensive because of the high costs associated with running yield trials in regulated environments. The traits used as selection criteria for heat tolerance need to be highly correlated with grain yield under heat stress, stable, easy to measure rapidly and highly heritable (Edmeades et al., 2001). Genetic engineering for heat tolerance is the process by which the introduction of individual genes of interest, into the selected genotypes improves tolerance against heat stress (Barnabas et al., 2008). Compared to other plant species, research into genetic modification has been hindered due to its complex genome (Farooq et al., 2011).

2.5.1 Genetic approaches

Heat stress results in the activation of genes that leads to an increase in the concentrations of various metabolites and proteins, which can be responsible for a certain level of protection against heat stress (Singh et al., 2012). Genetic improvement of heat tolerance is dependent on a better understanding of molecular alterations that occur in response to heat stress. The long-term adaption of plants to environmental changes and or conditions is influenced by genome plasticity in plants, including direct mutation and epigenetic effects such as methylation, chromatin remodelling and histone acetylation (Singh et al., 2012). The use of biotechnological methods is, however, dependent upon knowledge of the mechanisms of tolerance. Advances in genomic sequencing have increased the understanding of heat tolerance in crops. Methods employing recombinant DNA (rDNA) technology have made it possible to tackle issues associated with complex genetic traits. The application of QTL mapping in particular, has made it possible to understand the genetic basis of tolerance to stresses (Singh et al., 2012).

Selecting heat tolerant genotypes under field conditions is difficult due to environmental factors that influence responses, including responses at different stages of development. Traditionally, breeders select heat tolerant genotypes in heat prone environments. However, late sowing to induce higher levels of heat stress can be difficult to interpret as biomass accumulation is generally truncated and observed responses may be an artefact of delayed sowing. This problem can be overcome with glasshouse screening which provides control of temperature and duration, air movement and humidity (Singh et al., 2012). Nonetheless, traditional breeding imposes difficulties in the efficient and reliable selection and screening of heat tolerant genotypes. Various other selection approaches have been implemented such as heat tolerance index (HTI), which is a ratio of the increase in coleoptile length in non-heat stressed environments to the increase in coleoptile length after exposure to high temperature stress (Setimela et al., 2005). The HTI method is a cost-effective and easy-to-assay method for screening of heat tolerance. Pollen viability is used as in indirect selection tool for heat tolerance (Singh et al., 2012). TKW is also another trait used for selection of heat tolerance. Cultivars maintaining TKW under heat stress are considered to have heat tolerance and this trait can be applied with HTI. A study conducted at CIMMYT showed that physiological trait-based methods in breeding for abiotic heat stress are more effective compared to breeding for yield due to increased probability of effective crosses caused by additive gene action. Breeding programs may use physiological traits linked with wheat yield under heat stressed environments such as canopy temperature depression, membrane thermostability, leaf chlorophyll content during grain-filling, leaf conductance and photosynthesis (Singh et al., 2012), but not all traits correlated strongly with yield (Table 2.1). Conventional breeding for heat stress tolerance has used genetic variation from varietal germplasm, interspecific or intergeneric hybridisation, induced mutations and somaclonal variation in cell and tissue culture. However, progress is limited by a lack of suitable sources of genes in sexually compatible gene pools, the complexity of heat stress tolerance as a trait, lack of understanding of the genetic mechanisms of the high-temperature tolerance response, the low genetic variance of yield components under heat stress and lack of efficient selection techniques. Nevertheless, the effectiveness of conventional breeding is enhanced when combined with various biotechnological approaches (Singh et al., 2012).

2.5.2 Molecular approaches

The primary gene pool relatives in field crops can be used to develop new genetic variation for the enhancement of traits regulating heat tolerance (Ullah et al., 2023). The introgression of desirable alleles from close relatives of wheat into modern cultivars has been found to increase their abiotic stress tolerance (Ullah et al., 2018; Ullah et al., 2021). Trethowan et al (2014) has found that the gradual addition of wild alleles into modern wheat genome can improve environmental stress tolerance of crops without losing agronomically crucial traits.

The identification of quantitative trait loci (QTL) associated with heat tolerance can increase the effectiveness of breeding and selection by enhancing the rate of genetic progress (Ullah et al., 2021).

2.6 The application of Genome-Wide Association studies to heat tolerance

Heat tolerance is quite complex and polygenically controlled (Ahmed et al., 2022). The complexity of the heat stress mechanism arises from various factors including the variety, the intensity of the heat stress, the duration of the heat stress, the stages of plant growth during exposure to heat stress and the effect of genotype-by-environment interaction. (Ahmed et al., 2022). Breeding programs often select cultivars using multi-environment trials that include potential future environments or delayed sowing to induce heat stress (Joukhadar et al., 2021).

Multi-environment trials make it possible to detect stable genes governing commercial traits across different environmental conditions (Joukhadar et al., 2021). Recently, is has become possible to produce high density genotypes of wheat using single nucleotide polymorphism (SNP) markers and this has led to many genome-wide association studies (Ma'arup et al., 2020, Ullah et al., 2018, 2021)

GWAS is less expensive than traditional bi-parental linkage mapping and allows sampling of a wide range of genotypes in a population (Maulana et al., 2018).

GWAS aims to identify marker-trait associations across a diverse panel of genotypes (Figure 2.2). Most GWAS methods are constructed on single marker associations in genome-wide scans with population structure and polygenic background controls. To reduce the incidence of false positive associations, most studies adopt the Bonferroni correction. However, the application of this strict correction results in the omission of important loci, particularly given the large experimental error implicit in field experiments. To counter this, multi-locus GWAS methodologies have been used. In GWAS, existing historic recombination events in the population are leveraged resulting in higher mapping resolution compared to traditional linkage mapping. However, GWAS uses higher marker density compared to traditional QTL mapping as linkage disequilibrium is generally lower in GWAS populations. The marker density in GWAS is also dependent on the population sample, and in particular the standing genetic diversity and the amount of recombination that make that diversity (Brachi et al., 2011).

In GWAS, population structure can result in reductions in the power of the analysis leading to false negatives, especially when the traits examined are highly confounded (Brachi et al., 2011). When traits are filtered by environmental gradients that overlap with population structure patterns the population structure can be regulated, thus reducing association signals around crucial adaptive genes. However, a major flaw in GWAS is the lack of power to identify rare alleles associated with natural variation (Brachi et al., 2011). Another weakness of GWAS is the assumption of biallelic genetic control and that this explains quantitative genetic variation. GWAS that include SNPs that label multiple alleles in linkage disequilibrium with each other can lead to false positives (Brachi et al., 2011). Nevertheless, by adjusting the sampling strategy for GWAS some of the confounding effects of population structure can be evaded.

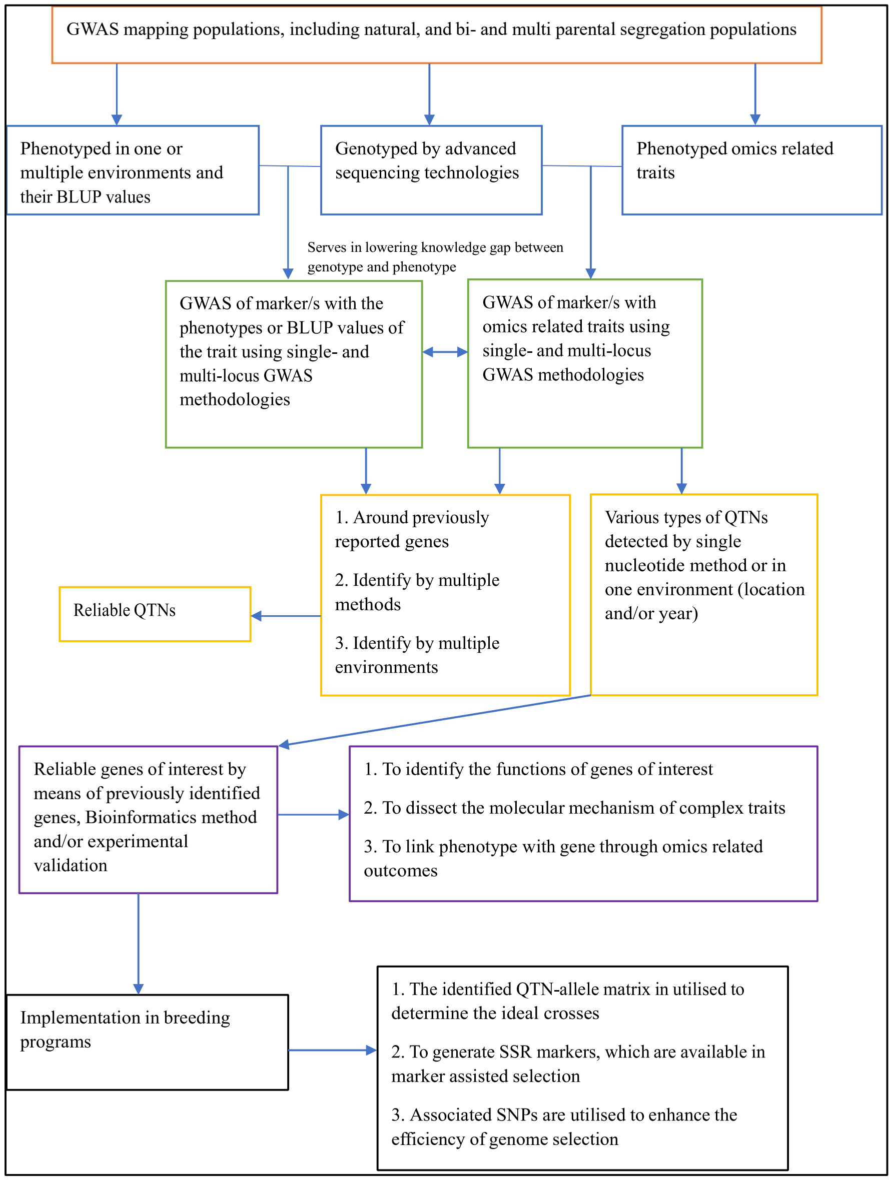


Figure 2.2: Genome-Wide Association Studies (GWAS) application framework adapted from Zhang et al, (2019)

The GWAS is a quantitative design, which assesses a variety of plant DNA with differing phenotypes for a single trait. SNPs are single base-pair variations in the DNA known as mutations and are units of genetic variation in the genome (Challa and Nellapu, 2018). Genotyping technologies allow for the capture of SNPs which can then be analysed or associated with phenotypes centred on the GWAS design (Challa and Neelapu. 2018).

2.7 Conclusions and future prospects

This review draws on knowledge of the physiological and biochemical responses of wheat to heat stress and how exposure to heat stress affects grain yield, quality and dough rheological properties. The frequency of high temperatures causing heat stress in wheat is projected to increase across the world. The effects of heat stress profoundly impact grain setting, duration and rate, which in turn affect final grain yield (Farooq et al., 2011) and grain quality. However, the timing, duration and intensity of heat stress ultimately determines the impact on grain yield. This review also focused on the importance of markers and genes for genetic improvement of wheat to heat stress. Through the development of heat-tolerant genotypes and agronomic approaches, the implications of heat stress can be reduced (Farooq et al., 2011). This review also draws on the conclusion that there are limited reports of heat tolerance examined in field conditions on large populations for physiological, phenological, quality and yield traits (Ullah et al., 2021)

Chapter 3: General Materials and Methods

3.1 Narrabri Site

The field experiments were conducted at the I.A. Watson Grains Research Centre in Narrabri. The research centre is located on the north-western slopes of NSW (30.3324°S,149. 7812°E and with an elevation of 212 m above sea level). The region is known for its highly productive winter and summer broad acre cropping both irrigated and dryland. Narrabri Plant Breeding Institute (PBI) is demonstrative of dryland farming operations implemented throughout north-west NSW. The experimental site has a long history of high productivity and has been under a controlled traffic system for several years. The dryland farming systems in Narrabri are traditionally cereal crop dominated, with summer crops (sorghum and dryland cotton) grown on an opportunity basis. In recent years farmers have been pushing to bring summer crops into a regular cropping rotation to utilise summer rainfall and to maximise crop gross margin returns.

3.2 Weather in 2014 and 2015 and long-term averages

The weather data for 2014 and 2015 growing season were collected from a portable weather station 500 m radius of the experimental sites. The long-term average maximum and minimum temperature and rainfall for the experimental site was collected from the Bureau of Meteorology Climate data online facility (http://www.bom.gov.au/climate/data/). Figures 3.1- 3.8, illustrate the daily minimum and daily maximum temperatures, rainfall and long-term averages for the 2014 and 2015 growing seasons.

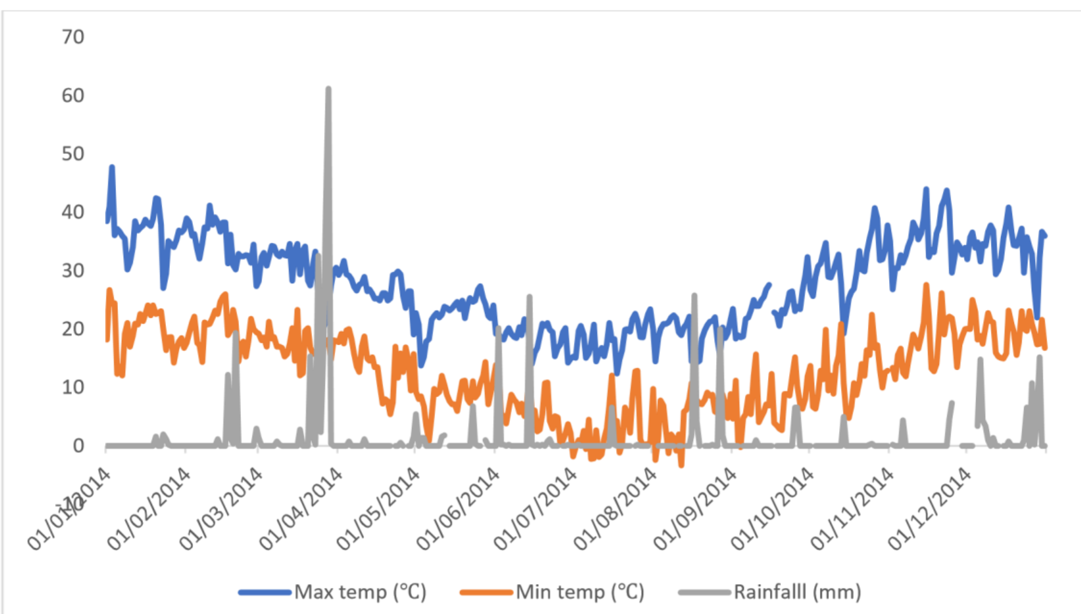


Figure 3.1: 2014 daily minimum and maximum temperature and rainfall

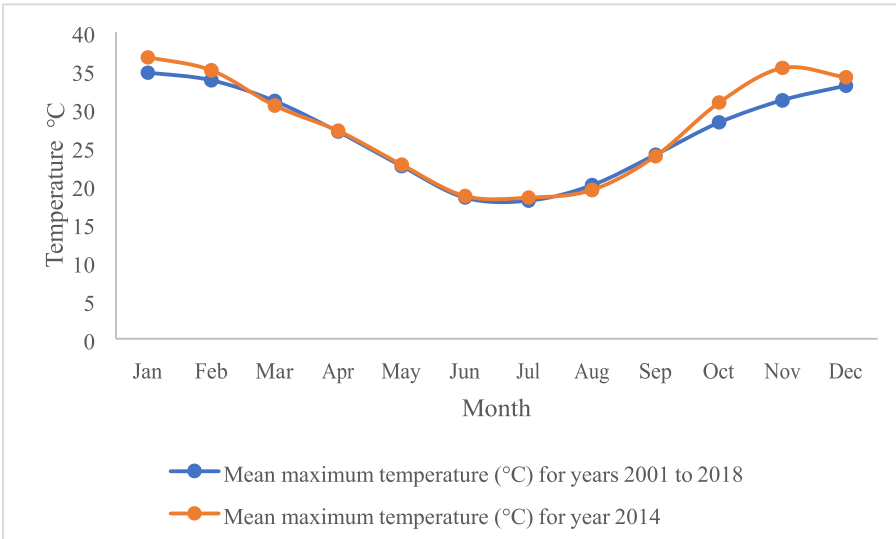


Figure 3.2: Long-term maximum average temperature against 2014 average maximum temperature

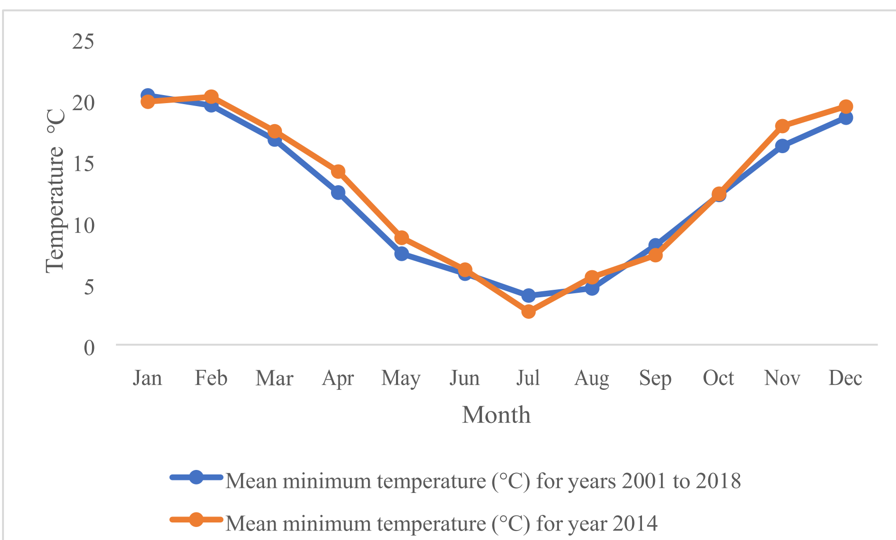


Figure 3.3: Long-term minimum average temperature against 2014 average minimum temperature

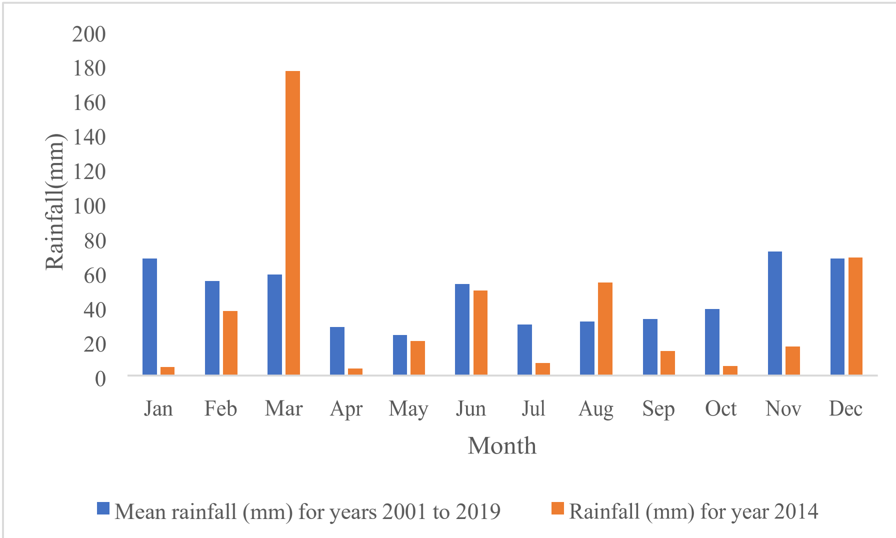


Figure 3.4: Long-term average rainfall against 2014 average rainfall

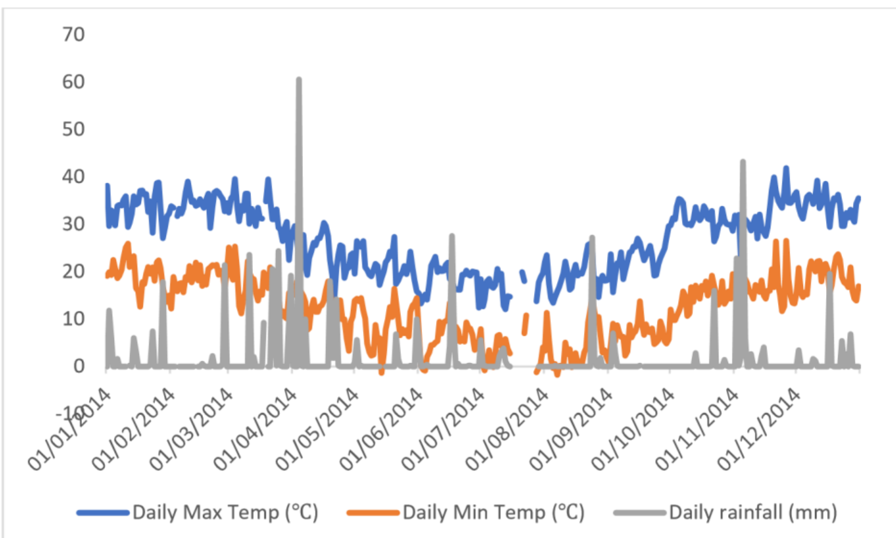


Figure 3.5: 2015 daily maximum, minimum temperature and rainfall

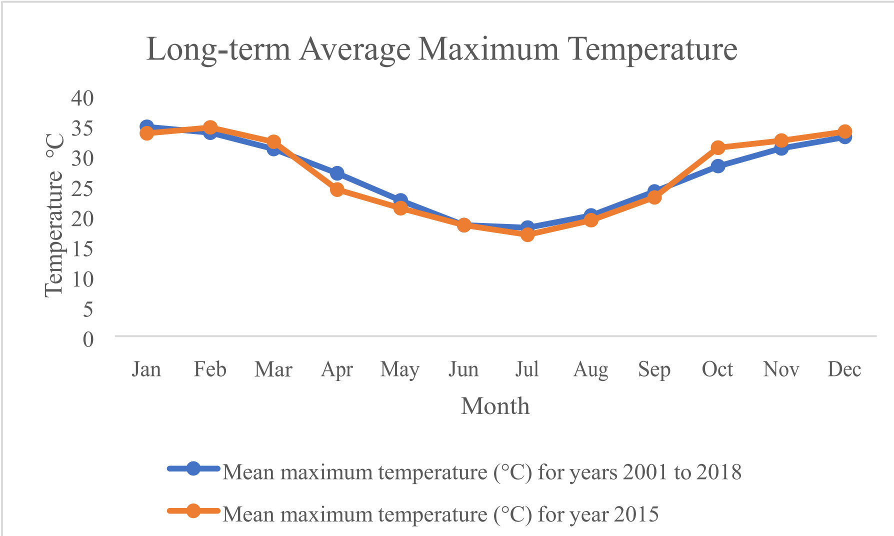


Figure 3.6: Long-term average maximum temperature against 2015 average maximum temperature

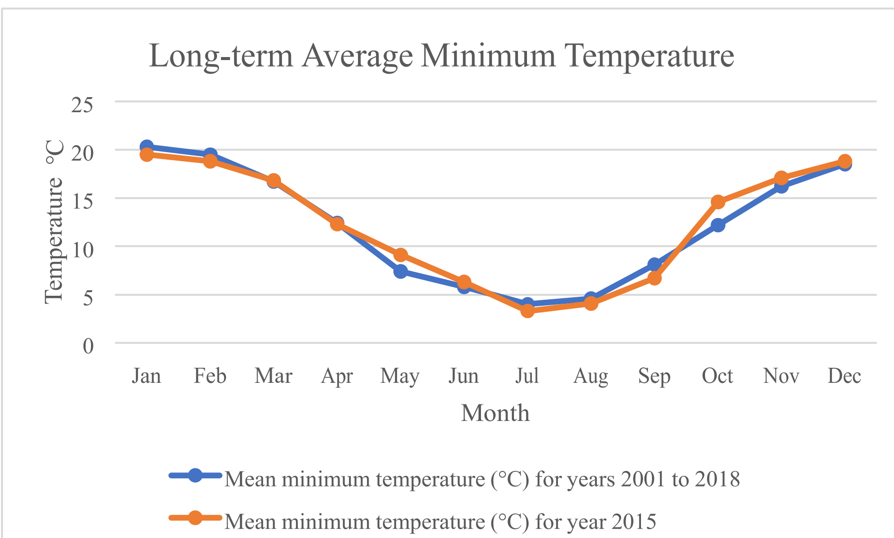


Figure 3.7: Long-term minimum average temperature against 2015 minimum average temperature

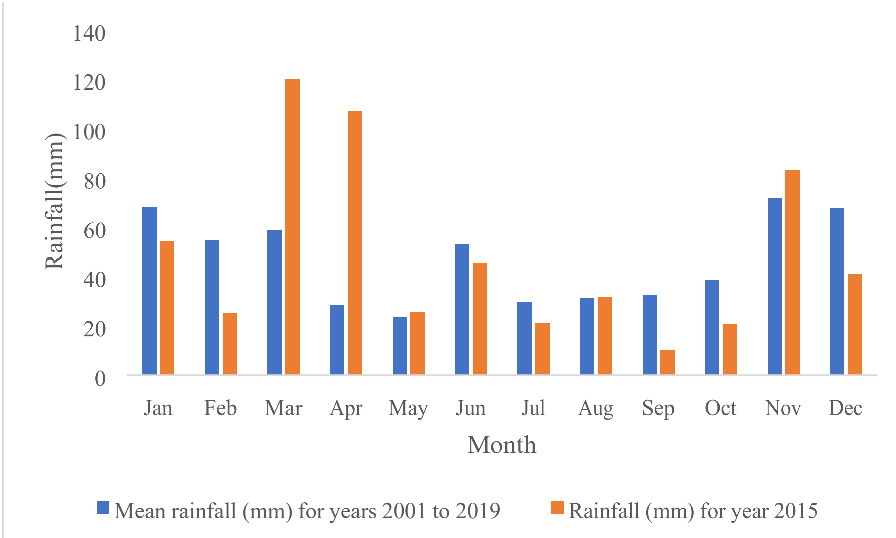


Figure 3.8: Long-term average rainfall against 2015 average rainfall

3.3 Bread wheat experiments

3.3.1 Germplasm information

Twenty genotypes were evaluated in 2014 and 2015, the complete list can be found in Table 3.1. The germplasm was sourced both internationally and domestically with most of the material supplied by CIMMYT and Australia. The wheat genotypes evaluated were hexaploid. The commercial check cultivars, Janz and EGA Gregory originated from Queensland DPI, Crusader originated from Longreach Plant Breeders and Livingston originated from Australian Grain Technologies (AGT).

Table 3.1: Bread wheat germplasm identifying genotypes and relative entry number in 2014 and 2015 including pedigree and designation

2014 Entry	2015 Entry	Pedigree	Designation
1	1	GOUBARA-1/2*SOKOLL	CMSA04M01020T-050Y-040ZTP0M-040ZTY040ZTM-040SY-12ZTM-02Y-0B
2	2	PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-1WGY-0B
3	3	CBRD-3/STORK X DICOCCOIDES	ICW99-0474-23AP-0AP-0AP-8AP-0AP
4	4	BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-35ZTM 02Y-0B

5	5	INQALAB 91*2/TUKURU//WHEAR	CGSS05Y00463S-0B-099Y-099M-099NJ-099NJ3WGY-0B
6	6	GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM040SY-12ZTM-01Y-0B
7	7	WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY0B-6B
8	8	PBW343	CM85836-4Y-0M-0Y-8M-0Y-0IND
9	9	JANZ	JANZ
10	10	N-ABYAD-13	ICW98.0028-3AP-0APS-030AP-2AP-1AP-0AP
11	11	WH 542	WH 542
12	12	CRUSADER	CRUSADER
13	13	SOKOLL	CMSS97M00316S-0P5M-0P5Y-42M-0Y
14	14	ZAKIA-10	ICW98.0030-1AP-0APS-030AP-8AP-1AP-0AP
15	15	SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY2ZTM-03Y-0B
16	16	BERKUT	CMSS96M05638T-040Y-5M-010SY-010M-010SY1M-0Y
17	17	LIVINGSTON	LIVINGSTON
18	18	FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY040M-040SY-11M-0Y
19	19	EGA GREGORY	EGA GREGORY
20	20	ATTILA*2/PBW65	CGSS96B00123F-099M-037Y-099M-26Y-0B-0SY

3.3.2 Experimental design

2014 time of sowing 1 was sown on 16-5-14 and time of sowing 3 was sown on 24-7-2014 (70 days gap between the two sowing dates). 2015 time of sowing 1 was sown on 15-5-15 and time of sowing 3 was sown on 21-7-2015 (68 days gap between the two sowing dates). The experimental design for each year was a randomised complete block design with two replicates arranged in a regular grid. The plot size in 2015 was 12 m^2 and 2014 was 24 m^2. The row spacing (distance between two rows) was 23.5 cm and the distance between each plot was 63 cm. Each plot comprised of 6 rows of 6 m or 12 m length depending on the year with 4 m or 10 m harvest, respectively. Target planting density was 100 plants /m^2 which equals to 50 g seed per 12 m^2 plot or 100 g seed per 24 m^2 plot.

3.3.3 Management

The experimental site contained black [AE] Vertosol (Isbell 2021) cracking clay as the principal type with high water retention. Irrigation was available and used to reduce the effects of moisture stress, especially in later sowing dates.

Minimum tillage was implemented at the experimental sites to maintain soil quality and moisture. Field traffic was controlled as much as possible with allotted roads and pathways and Global Positioning System (GPS) guidance on machinery.

Fertiliser application was maintained same level across years (Urea [46% N] 100 kg/ha and Cotton Sustain® [5% N, 10% P, 21% K, 1% Z] 80 kg/ha pre-planting). The experimental site was not found to have any soil deficiencies or nutrient imbalances from annual soil nutrient testing.

To minimise disease outbreak and maintain soil integrity, the experimental site had a summer fallow and rotated with a legume crop during alternate years.

Herbicide and fungicide were applied in accordance with agronomic advice and best practice for the north-western slopes cropping region. Chemical applications each year and the timing of each application is presented in Table 3.2.

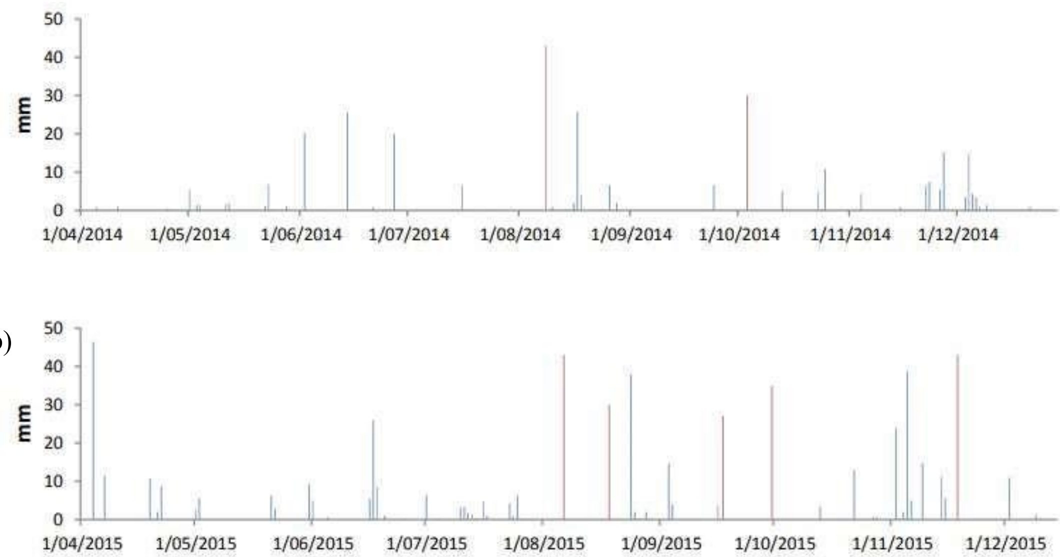
Table 3.2 Chemical spray applications for field tials at Narrabri from 2014-2015

Date	Chemical group	Commercial name	Usage
17/06/2014	I	Tordon	0.8 L/ha
17/06/2014	B	Ally	5 g/ha
28/07/2014	A	Axial	0.25 L/ha
28/07/2014	Adjuvant	Adigor	0.5 L/100 L water
29/06/2015	A	Axial	0.25 L/ha
29/06/2015	Adjuvant	Agidor	0.5 L/100 L water
7/07/2015	I	Tordon	0.8 L/ha
7/07/2015	I/B	Stinger	10 g/ha
18/09/2015	3	Folicur	0.145 L/ha

3.3.4 Irrigation and rainfall

The average rainfall and irrigation applications during the growing season for 2014 and 2015 are plotted in Figure 3.9.

(b)



(a)

Figure 3.9 Irrigation (red line) and rainfall (blue lines) measured in millimetres (mm) during the (a) 2014 and (b) 2015 growing seasons.

3.3.6 In-field crop measurements

3.3.6.1 Normalised Differential Vegetation Index (NDVI)

The assessment of the amount of green vegetation was taken each year at two critical growth stages at booting (DC41) and heading (DC65) using a GreenSeeker (NTech Industries, Canada) sensor. In 2015, GreenSeeker hand held crop sensor was used as a result of the equipment being unavailable for use earlier in the year. NDVI is calculated as the difference between the spectral reflectance in the near infra-red (NIR) and visible/red (VIS) spectrum. Therefore, NDVI is calculated as (NIR-VIS) / (NIR + VIS). Measurements of NDVI were taken between 10:00 and 14:00 hours on days of optimum environmental conditions and consistent throughout entire period of data collection. The device was held at the same height (500 – 600 mm) above the canopy of every plot and always directed towards the soil. A uniform walking speed of approximately 1 m per second was maintained for all plots.

3.3.6.2 Days to heading (DH)

Days to heading (DH) was taken at growth stage DC55 (the date at which 50% of the plot had 50% of its spikes visible). This date was then subtracted from the date of sowing to obtain the number of days.

3.3.6.3 Days to maturity (DM)

Days to maturity (DM)was recorded at growth stage DC87+ (defined as the date at which 50% of the plot had visibly reached physiological maturity and is also determined as loss of green colour from the spike and 10 cm of the peduncle). DM was then calculated as the number of days from sowing to maturity.

3.3.6.4 Plant height at maturity

Plant height at maturity is taken by measuring the main tiller measured at growth stage DC87+ in centimetres from the ground to the top of the spike excluding the awns at physiological maturity.

3.3.6.5 Grain yield

Plots were harvested at maturity using a combine harvester (Kinagroy Engineering Works Pty LTD). The threshed grain was then manually weighed and converted to kg/ha.

3.3.7 post-harvest measurements

3.3.7.1 Screenings

Screenings was measured using a grain Agtator. The unmillable material below a certified slotted screen size of 2.0 mm was obtained from a subsample of 400 g from the harvested grain of each plot before cleaning. The material left above the screen after 40 machine shakes was weighed and the percentage of unmillable material calculated. SCR = (400 – wt above screen)/400 *100

3.3.7.2 Thousand kernel weight (TKW)

One hundred (100) visibly viable seeds (excluding cracked, broken or diseased seed) were firstly counted and then weighed to obtain the weight per 1000 kernels (g).

3.3.7.3 Quadrumat junior milling

The samples were conditioned the night before evaluation using the moisture content from the NIR and adjusting to 15% for a 50 g sample. The bread wheat samples were analysed at Narrabri PBI using the AGT laboratory. With a warm-up sample, the mill was turned on and let to run for at least 30 minutes without the sieve. Once the mill was allowed to warm up and the room the temperature (21-22˚C) and humidity (70%) were at appropriate conditions the warm-up sample was cleaned out of the mill while the mill was still running using an air gun. The cleaning process starts by softly blowing air from the gun into the top of the feed hopper. This step ensures that no seeds are remaining behind.

The air gun was used around the outside of the cover plate and the shaft in the centre. From each hole, the air was blown in from the top down, and this was repeated until it was clean. The mill was then turned off, and the air was blown down from the bottom slot, the flaps were opened, the flour tray was removed and emptied, the bottom cavities and trays were blown out.

The trays were replaced, and the sieve was carefully put back and care was taken not to damage the screen. The mill was turned on to forward position, and the first sample was poured in, while simultaneously starting the timer. Once the last grain has fallen through the mill it was left to run for a further minute then the mill was turned into reverse position and run for 20 seconds.

The feed hopper, center shaft, perspex plate and shute was cleaned was cleaned using a painbrush and air gun.

The flour,bran trays and sieve were carefully removed, and its contents emptied into the bran tray and were then transferred into a weighing tray.

The inside cavity of the mill was blown with the air gun, and the trays were put back, the doors were closed, and the flaps were checked to ensure it was closed to avoid grain loss. The mill was now ready for the next sample.

The mill was turned on and the next sample was poured in, and the timer was restarted and while the sample was running through the mill the flour and bran weight from the previous sample was recorded. Flour was placed into a labeled, sealable plastic bag. This process was repeated for each sample.

The flour tray was put back in, and the sides of the inside cavity of the mill were brushed down making sure not to brush down any remaining bran that may reside at the end of the centre shaft at the back of the mill. The flour tray was then removed, and its contents were emptied into the other weighing tray.

Flour recovery was calculated as:

$$\text{Recovery} = \left(\frac{(Flour\ weight + Bran\ weigh\ \ )}{(50 + mls\ water\ added)}\right) \times 100$$

Flour yield was calculated as:

$$\text{Flour yield} = \left(\frac{(Flour\ weig\quad)}{((Flour\ weight + Bran\ wei\quad)}\right) \times 100$$

3.3.7.4 Flour Protein

The 2014 milled samples were then placed through the Inframatic 8100 near infrared analyser to get a flour protein reading. The 2015 milled samples were placed through the SpectraAlyzer FLOUR 110A100-5 (Zeutec, Rendsburg, Germany)for the protein reading with the value being corrected to 11%mb.

3.3.7.5 Mixograph

The mixograph measurements took place at the Tamworth DPI for the bread wheat samples following the Mixograph on Semolina: TAI-CC21 procedure. This analysis records the resistance of dough to mixing and also the optimum development time. The milled samples were left out overnight to reach room temperature before they were used on the mixograph. The mixograph was allowed to warm up for 30 mins, and a dummy sample was run before using the Manildra check. The Manildra check was then processed, and once it passed on the control chart (within 3 standard deviations of the average mean from at least 40 sample values), the samples were then run. The bowls used were allowed to warm in the water bath (25 °C) and once ready were dried, and the balance was tared with the bowl on it. 10 g of the well-mixed using a spatula milled sample was weighed into the bowl. The bowl was then placed onto the mixograph platform, and the mixing head was lowered after which trace marker pen was lowered onto the chart paper. Reverse osmosis water was added to the sample then the mixograph was triggered to run for 9 minutes. Using the mixsmart software, each sample was processed and data stored and the option 'Collect and Analyse' was selected. The software recorded the following vital elements mixograph peak time, (MPT) mixograph peak height (MPH), width at peak (WAP), width after 8 minutes mixing (Wa8) and resistance breakdown (RBD) which is calculated as follows:

$$RBD\ = \frac{\mathrm{WAP} - \mathrm{WA8}}{2aWAP} \times 100$$

The setting used for bread wheat was adding 6 mL of reverse osmosis water, and with a spring setting of 9.

3.3.8 Statistical analysis

3.3.8.1 Estimation of main effects and interactions

All statistical analysis was accomplished with the GenStat statistical package 15th edition (Payne et al.,, 2011). The output from the report was assessed at a P>0.05. The programs Linear mixed models (Residual Maximum Likelihood or REML) were used to estimate variance components and interactions. The factors included in these interactions were the year, sowing date and genotype as fixed effects and range/row coordinates within sowing dates within years were considered as random effects. A multiple regression analysis was achieved on the combined means of all traits. Interactions found among parameters were assessed using the Person’s simple correlation test option The relationships between genotypes and environments were illustrated using GGE biplots on GenStat.

3.4 Durum wheat experiments

3.4.1 Germplasm information

One hundred and twenty durum genotypes were selected from a wide genetic diversity (Appendix Table 2). Durum wheat germplasm used in this trial were found to have heat tolerance from Mexico and ICARDA and included locally adapted germplasm from locally adapted durum wheat from the national durum wheat breeding program nodes at Tamworth and Adelaide. The durum genotypes used in this experiment include widely grown popular commercial Australian varieties as benchmarks. The daily maximum temperature during the crucial growth stages of the durum trial in 2014 and 2015 is illustrated below (Figure 3.10)

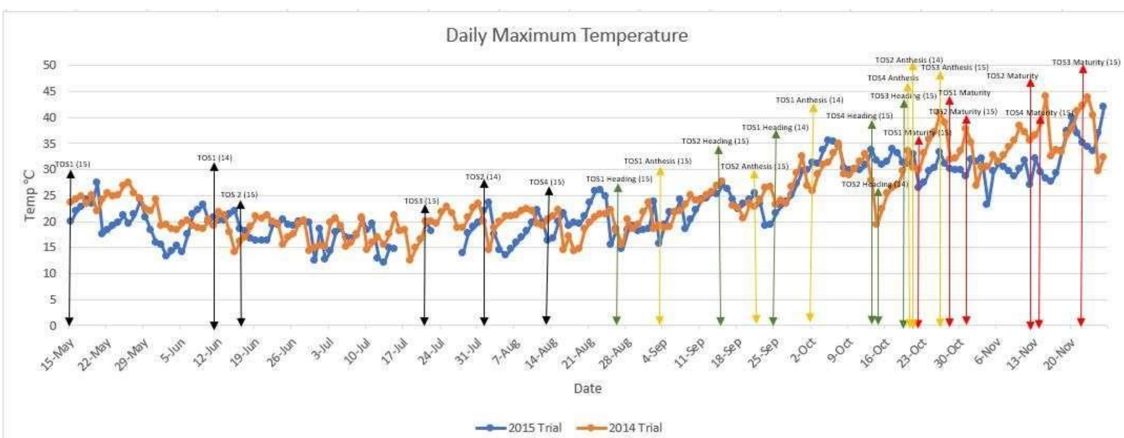


Figure 3.10; daily maximum temperature during the crucial growth stages of the durum trial in 2014 and 2015

3.4.2 Management, soil properties and irrigation

The experimental site had a black Vertosol soil type with high agricultural potential as it is rich in clay allowing for high water holding capacity and is high in chemical fertility. However, a significant amount of water must be available before water can be available to crops. Table 3.4 and Table 3.5 describe the soil analysis for the 2014 and 2015 season.

Table 3.4: Required N to reach yield 4t/ha in 2014 and 2015

Output Summary Demand	Yield		
	Low	Expected	High
Target Yield (t/ha):	3	4	5
Target Protein (%):	13	13	13
Grain Removal (kg/ha):	68	91	114
Estimated Nitrogen Transfer Efficiency %:	50	50	50
Estimated Crop N Demand (kg/ha):	137	182	228
N Required for Rest of The Crop (kg/ha)	137	182	228

Table 3.5: 2014 and 2015 Physical soil properties

2014

Depth Range(cm)	Bulk Density (t/m3)	Nitrate N (mg/kg)	Ammonium N (mg/kg)	Mineral N (kg/ha)	Organic Carbon %
0 - 10	1.3	11	2.2	14	0.47
Oct-60	1.35	2.9	0.97	20	-
60 - 90	1.4	3.7	1.1	16	-

2015

Depth Range(cm)	Bulk Density (t/m3)	Nitrate N (mg/kg)	Ammonium N (mg/kg)	Mineral N (kg/ha)	Organic Carbon %

0 - 15	1.3	17	0.6	33	0.51
15 - 60	1.35	4.1	0.6	25	-
60 - 90	1.4	11	0.6	46	-

Fertiliser application was as follows, in 2014 110 kg/ha urea or 50 kg/ha N was applied on 15/4/14 and in 2015, 150 kg/ha urea or 75 kg/ha N applied 16/4/15.

The experimental sites were irrigated using an overhead irrigator. In 2014 irrigation was applied only once on 3/8/14 with 30 mm applied. In 2015 there were two irrigation applications, one on 10/10/15 with 35mm and the other on 21/10/15 with 30 mm.

3.4.3 Chemical spray application

The chemical spray was applied according to the agronomic advice provided. Appendix Table 13 and 14 illustrate the chemical spray applied for each year.

3.4.4 Experimental design

The durum materials were sown in experiments on two dates in 2014 and four dates of sowing in 2015 . The analyses contained one hundred and twenty genotypes with two replicates. So, each trial comprised 240 plots with Sunlin as a buffer. Field layout 2014: 2 m × 6 m plots. Field layout 2015: plot sizes were 2 m × 6 m with four times of sowing

3.4.5 In-field crop measurements

3.4.5.1 Ground cover assessment

Ground cover assessments were conducted by taking photographs with a digital camera. The ground cover photos were taken from early emergence to full canopy cover which is usually Zadok's Decimal Code 12 to 30. The photographs were taken using a Samsung Galaxy S4. The camera was held at approximately 1 m above each plot. The representative area was kept free of weeds to reduce error. The photographs were processed using the CSIRO software 'Canopy Cover' (downloaded from http://www.pi.csiro.au/canopy_cover/ Canopy Cover_setup.zip.) and coverage was determined on a 01 scale (Atta, 2013). Greenness and soil were distinguishable giving a total percentage of the image that was green. The percentage of bare soil was at set at 0, and the noise threshold at 2%.

3.4.5.2 Normalised Difference Vegetation Index (NDVI)

As previously elaborated in sec on 3.3.6.1

3.4.5.3 Canopy temperature (CT)

Canopy temperature is a measure of plant ability to maintain gas exchange and transpiration which is correlated with water status under stress. In 2014, a DT-8838 high temperature non-contact infrared thermometer was used, and in 2015 an Impac M1-N15+ pyrometer due to equipment availabity. Measurements were taken at the vegetative stage (before spike emergence) and at anthesis in each plot. To avoid bias, plots needed to have full canopy cover as soil coverage will interfere results. The recordings were aimed around solar noon (12 pm) as this best describes the genotypes' ability to avoid dehydration. Cloud and wind changes can easily adjust CT readings, so records were taken at a wind speed < ~5 km/h on sunny days. Each plot was scanned in a figure of eight hand movement as this provides a more consistent reading, making sure the sun was behind and avoiding casting a shadow on the plot. Each plot was scanned twice and the readings averaged.

3.4.5.4 Days to heading (DH)

As previously elaborated in sec on 3.3.6.2

3.4.5.5 Days to physiological maturity (DM)

Detailed methodology in sec on 3.3.6.3

3.4.5.6 Plant height at maturity

Detailed methodology in sec on 3.3.6.4

3.4.5.7 Crop lodging

Crop lodging calculated by Fischer and Stapper (1987) was scored at plant physiological maturity (around DC87+). The percentage of the plot that had lodged and the angle of stem lodging was estimated.

% ×

$Lodging\ score = \underline{\hspace{10cm}}$ Whereby , % plot area lodged is the lodged area/net plot area × 100; 0° , angle from vertical is the main stem standing upright; and 90° angle from vertical is main stem laid down horizontally

3.4.5.8 Grain yield

Detailed methodology in sec on 3.3.6.5

3.4.6 post-harvest measurements

3.4.6.1 Screenings

Elaborated in sec on 3.3.7.1

3.4.6.2 Thousand Kernel Weight (TKW)

Elaborated in section 3.3.7.2

3.4.6.3 Near-Infrared spectroscopy screening (NIR)

A Foss Infratec 1241 Analyzer was used to measure grain protein content and test weight of the bread wheat experiment. The analysis was achieved by firstly, cleaning the seeds (Kimseed vacuum) then weighing out a sample of 450 g per plot. The protein content obtained was converted to a percentage and test weight was expressed as kg per hectoliter (kg/hL) at 11% moisture content.

The durum wheat was analysed at the Tamworth Department of Primary Industries (DPI) using a NIRSystems Model 6500 scanning spectrophotometer. The spectral data were recorded and processed using the WINISI software. The NIR equipment used records spectra at wavelengths at intervals of 2 nm and the software defaults to ranges of 8 nm for processing data for computation of equations.

3.4.6.4 Quadrumat Junior Milling

The durum wheat samples were analysed at the Tamworth DPI following the Quadrumat Junior Mill: TAI-CC08 procedure which produces semolina and bran fractions. Moisture of the grain samples were taken using NIR Scanning. Fifty g of gain samples were weighed into individually labeled containers and were then conditioned the afternoon before milling. The samples were conditioned to 15% moisture. The calculated water required for 15% moisture was then added to the individual sample. The samples were manually shaken for 10 seconds once the water was added and then placed into a rotary conditioning tumbler for one hour. The containers were then removed and shaken once more for 10 seconds and left overnight. The Brabender Quadrumat Junior Mill with rolls for semolina production was used to assess the samples. Flour (semolina) yield was calculated as:

Flour (semolina) yield = $\frac{(flour\ weight)}{(Total\ weigh\ \ )}\times 100$

3.4.6.5 Mixograph on semolina

Elaborated in section 3.3.7.5

3.4.7 Statistical analysis

3.4.7.1 Estimation of main effects and interactions

Elaborated in sec on 3.3.8.1

3.4.7.2 Heat Susceptibility Index (HSI)

Heat susceptibility index was assessed in both years using the formulas published by Fischer and Maurer (1978);

$$HSI = \frac{(1-\frac{Yl}{Yc})}{(1-\frac{Xl}{Xc})}$$

where Xl and Xc represent late sowing and conventional sowing individual genotype yield, respectively and Yl and Yc represent genotype mean yield of late sowing and conventional sowing, respectively.

3.4.7.3 Heritability estimates (H^2)

Broad sense heritability was estimated following Nyquist and Baker (1991) as:

$$H^2 = \frac{\quad}{(\quad)\ (\quad)}$$

where H^2 denotes broad sense heritability, σ denotes genotypic variance, σ denotes the genotype-by- environment interaction variance, σ denotes the error/ residual variance, E denotes the number of environments and r denotes the number of replicates per environment.

The mean squares (MS) obtained from the analysis of variance were used to calculate the variance components. These were calculated as:

$$\sigma = MS$$

$$\sigma = \frac{\quad}{\quad}$$

$$\sigma = \underline{\qquad\qquad}$$

Whereby MS represents the error mean square, MS represents the mean square for genotype-by-environment interaction, E represents the number of environments and MS represents the genotypic mean square.

3.5 Genome-wide association analysis of bread wheat

3.5.1 Germplasm information

The experimental lines comprised of 282 bread wheat genotypes (Appendix Table 12). The plant material was sown in 4 consecutive sowing dates each year between May and August from 2012 to 2015. Randomised complete block designs with two replications arranged in regular grids were used each year. The evaluated germplasm represented international and domestic germplasm. The international lines were supplied by the CIMMYT, Australia ICARDA Germplasm Evaluation (CAIGE) program (http://www.caigeproject.org.au/). The wheat genotypes were hexaploid, with some derived from crosses with cultivated emmer (Triticum dicoccum) and others synthetic derived lines based on crosses between durum wheat (T. durum) and the donor of the D-genome (Aegilops tauschii). The commercial durum wheat cultivar Hyperno (Triticum durum) was included in experiments in 2013. The commercial check cultivars originated from the northern NSW cropping system except for Scout and five released cultivars were maintained in all experiments over years. A complete list of the check cultivars can be found in the Appendix X.

3.5.2 Statistical analysis of phenotypic data

A pooled analysis of the genotypes across the 4 years was generated to calculate a Wald statistic for yield, screenings% and TKW (g). This calculation was achieved using the linear mixed model (REML) function in GenStat version 16.0 (Payne et al., 2011). Genotypes and environments were considered fixed effects and ranges/ rows within replicates within environments as random terms.

A heat map of kinship matrix was generated in R (R Core Team 2018) to convey the population structure. Manhattan plots to illustrate the SNPs arranged by chromosome with base pairs and their $\log_{10}$ P scores were generated using R (R Core Team 2018).

3.5.3 SNP genotyping and data analysis

DNA extraction was performed in the molecular laboratory of the Plant Breeding Institute, Cobbitty, using the CTAB method established by Doyle and Doyle (1990). The process was as follows: firstly, 4 pieces of 2 cm long young leaves were collected in an Eppendorf tube with silica gel and dried for 7 days at room temperature. The material was then ground into a fine powder by adding 2 ball bearings into the tube and placed in a mixer mill (MM300 Restch®, Haan, Germany) and mixed for 2 minutes at 20 rpm. The ball bearings were then removed from the tube and the extraction buffer was added. The process of adding the extraction buffer is as follows: 800 µL of warmed CTAB (cetyltrimethyl ammonium bromide) buffer was added into each tube and was then vortexed thoroughly. The tubes were then incubated at 65°C for 30-40 minutes, gentle swirling of the tubes every 10 minutes. This process resulted in the removal of polysaccharides which can hinder enzyme activity. Once completed, the tubes were then left at room temperature for 5 minutes. 600 µL of chloroform: phenol (24:1 v: v) was added and gently mixed by inversion for 2 minutes until two layers separated.

The samples were then centrifuged aBeckman Coulter Allegra 25R, Brea, USAkm kmm ,,) 10000 rpm at room temperature for 20 minutes. The resulting aqueous phase known as the supernatant was then removed with a wide bore pipette. The pipetted aqueous phase was transferred to a clean 1.5 mL falcon tube and 2/3 to 1 volume of cold isopropanol was added and mixed gently to precipitate the nucleic acids. The tubes were then stored in 4°C temperature and left overnight. Once this was completed the tubes were then centrifuged at 10,000 rpm for 10 minutes and the supernatant was discarded and the tube was left open for 20 minutes to dry the DNA. 500 microlitre of washing buffer of approximately 70% ethanol was added into each tube and was gently mixed by inversion. The tubes were then centrifuged at 7000 rpm for 10 minutes and left out for 2 minutes to dry. One hundred microlitre of TE (Tris-EDTA) buffer (pH 8) with RNAase (1 microlitre per 100 µL of TE) was added and left to dissolve the samples and placed in an oven at 37°C overnight to solubilise the DNA.

Dilutions of each DNA sample were prepared at a concentration of 200 ng/µL (total volume 50 µL). The material was then quantified via a Nanodrop ND-100 spectrophotometer. The quantified genomic DNA material was then sent to y AgriBio, La Trobe University, Victoria, Australia, to be genotyped using the Infinium iSelect 90K SNP Assay (Wang et al., 2014; Cavanagh et al., 2013), following the protocol set by the manufacturer.

The previously mentioned phenotypic data were pooled across 4 years (2012-2015) within each time of sowing and best linear unbiased estimators (BLUEs) were calculated for each genotype in each time of sowing. The model used for BLUEs was set out according to the description in Fikere et al.,, 2018; Fikere et al.,, 2020 and is as follows:

yijk = µ + gi + rj + ck + eijk,

where yijk is the phenotype, μ is the overall mean, gi is the fixed effect for variety i, rj is the random effect for row j, ck is the random effect for column k fit as spline, and eijk is the residual. The generated estimates were then used for the subsequent GWAS analyses. A total of 38,721 qualitycontrolled SNPs were used initially and was then formatted and filtered using the PLINK software http://pngu.mgh.harvard. edu/~purcell/plink/ to distinguish and uphold SNPs with call rates greater than 40% (Purcell et al., 2007; Anderson et al., 2010). SNPs that had no map position were included in the GWAS analysis and SNPs containing a minor allele frequency (MAF) <0.01 were omitted. Marker trait associations with a $-\log^{10}$ P value >3.3 were deemed significant and this resulted in 72 significant SNPs linked to screenings, 51 significant SNPs linked to TKW and 38 significant SNPs linked to yield. The GWAS analysis was conducted using the genome-wide complex trait analysis (GCTA) software (http://cnsgenomics.com/software/gcta/) (Yang et al., 2011). The following model was used to explain the population structure: Y = mu + SNP + random (GRM)

where, Y signifies population structure in the sample (n1 vector of phenotypes with n being the sample size), mu represents the overall mean, SNP is the fixed SNP effect and genetic relationship matrix (GRM). The SNP markers in this study only segregated within the studied population and not all markers are unique to a single position. This thesis used population sequencing (PopSeq) (Mascher et al., 2013) for the anchoring and ordering of next generation sequencing contig assemblies for the physical map positions which were defined in centimorgan (cM). Physical map positions in cM were only available for markers that had a physical position, were uniquely mapped within a chromosome, and were found to be segregating in the population. Therefore, the selected markers had $-\log^{10}$ P>3, and either had a positive or negative impact on the trait and a pleiotropic effect where relevant.

Chapter 4: Bread wheat tolerance to heat stress

Abstract

This experiment aimed to identify the impact of high temperatures on industrial quality of bread wheat using samples produced by Thistlethwaite (2017). Twenty genotypes were evaluated across two years; 2014 and 2015, in two sowing dates in field and laboratory experiments to determine their response to temperature stress. Irrigation was applied when required to avoid drought as a confounding factor. Yield, physiological traits and phenology data were provided by the earlier study and grain quality including dough rheological properties were assessed each season. Field and grain characteristics were assessed at the University of Sydney's Plant Breeding Institute, Narrabri NSW and dough rheological properties at the Tamworth Agricultural Institute, Calala NSW. Late sowing was effective in identifying genotypes with better heat tolerance. Heat stress resulted in reduced grain yield and hastened plant development that resulted in reduced biomass accumulation, smaller grain size, higher flour protein and decreased dough strength. Several genotypes had stable grain yield and quality under heat stress and could be used in future breeding to enhance heat tolerance in bread wheat.

4.1 Introduction

There has been an increase in global demand for agricultural products due to increasing human population, rising incomes and changing preferences and consumption of food (Wang et al.,, 2018). However, climate change has dramatically affected crop growth, development and distribution, and has resulted in reduced yield in some regions (Wang et al.,, 2018).

Heat stress is categorised in two forms: heat shock and chronic heat stress. Heat shock is defined as the exposure to sudden extreme high temperatures (>32℃) for a short duration (3-5 days). Chronic heat stress is defined as exposure to moderately high maximum temperatures (20-30 ℃) for a longer duration (Li et al.,, 2013). Increased night temperature was observed to accelerate crop development and shortened crop duration for both wheat and barley during the grain number determination and grain-filling periods (Garcia et al.,, 2018). These authors also found that increased night temperatures during the critical growth period resulted in a 7% reduction in yield, while higher night temperatures during the grain-filling period reduced yield by 4%. Sadras and Dreccer (2015) defined those higher temperatures in the non-stressful range shortened crop cycles, whereas high temperature in the stressful range hindered reproduction, nevertheless, crop growth was directly and indirectly impacted by both temperature ranges. Heat shock can take different forms and is characterised by timing, with reference to days before and after anthesis and by duration (Corbellini et al.,, 1997; Li et al.,, 2013).

The ideal temperature for wheat anthesis and grain-filling is 12-22°C and exposure to temperatures above this can lead to reductions in grain yield (Farooq et al.,, 2011). However, chronic high temperatures ranging between 20 and 30°C, short periods of heat shock and days over 32°C are common in Australia during grain-filling (Wardlaw et al.,, 2002). As a result, yield penalties of 10–15% are regularly observed (Wardlaw et al.,, 2002).

Heat stress during anthesis increased the incidence of floret abortion (Wardlaw and Wrigley, 1994). During the reproductive phase heat stress can lead to pollen sterility, tissue dehydration, lower CO_2 assimilation and increased photorespiration (Farooq et al.,, 2011). Exposure to temperatures above the ideal range can cause senescence-related metabolic changes in wheat, inhibition of chlorophyll biosynthesis, degradation of chlorophyll content and breakdown of thylakoid components (Ramya et al.,, 2015). Even though high temperatures accelerate crop growth (Fischer, 1980; Kase and Catsky,1984; Farooq et al.,, 2011), the time available to capture resources is reduced leading to lower grain yield (Farooq et al.,, 2011).

High temperatures during grain-filling increased grain protein content which in turn increased mixograph peak height (MPH). Heat stress can enhance dough and pasta quality, even though the heat stress has a negative impact on yield and physical grain characteristics (Sissons et al.,, 2017). Temperatures of approximately 30°C (chronic heat stress) can increase dough strength. However, temperatures above 35°C (heat shock) can decrease dough strength (Corbellini et al.,, 1997, 1998; Wrigley, 2007; Li et al.,, 2013; Sissons et al.,, 2017).

This chapter describes two field experiments grown under two different sowing conditions; normal and late sowing in two years; 2014 and 2015. The aim was to determine the impact of temperature stress on bread wheat growth, grain yield and quality.

4.2 Material and Method

4.2.1 Germplasm tested

One hundred bread wheat genotypes were evaluated in 2014 and 2015. However, the present study focused on twenty core genotypes. A complete list of germplasm evaluated can be found in Table 3.1.

4.2.2 Field location, treatment and experimental design

The field experiments were conducted at the I.A. Watson Grains Research Centre in Narrabri. The research centre is located on the north-western plains of NSW (30.3324°S,149. 7812°E and with an elevation of 212 m above sea level).

Experiments were sown at 4 consecutive sowing dates between May and August over two years (2014 and 2015). The sowing dates for 2014 were as follows: 16/05/2014, 25/06/2014, 24/07/2014 and

25/08/2014 and the sowing dates in 2025 were: 15/05/2015, 14/06/2015, 21/07/2015 and 13/08/2015. The experimental design for each year was a randomised complete block of two replications arranged in a regular grid.

The detailed method of the data captured is presented in Chapter 3, Section 3.3.

4.2.3 Post-harvest assessments

The complete method of the data assessed post-harvest is described in Chapter 3, Section 3.3.

4.2.4 Statistical design

All statistical analyses were conducted using the GenStat statistical package 15th edition (Payne et al.,, 2011). Significance was determined at $P<0.05$. Linear Mixed Models (Residual Maximum Likelihood or REML) were used to estimate variance components and interactions (Table 4.3). Year, sowing date and genotype were considered fixed effects and range/row coordinates within replicates, sowing dates and years as random effects. A multiple regression analysis was conducted using the adjusted means of all traits. Interactions found among variables were assessed using the Pearson's correlation test in GenStat (Payne et al.,, 2011). The relationships between genotypes and environments were illustrated using Genotype plus Genotype-versus-Environment (GGE) biplots in GenStat. The detailed method of the statistical analyses performed are presented in Chapter 3, Section 3.3.

4.3 Results

4.3.1 Impact of heat stress on agronomic and physiological traits

4.3.1.1 Grain yield

Year, time of sowing (environment), genotype, year by time of sowing, and year by genotype interaction had highly significant impact on grain yield at P<0. 001 (see Table 4.1). Time of sowing by genotype was significant at P<0.01 and year by time of sowing by genotype at P<0.05. In 2014, the mean minimum/maximum temperatures during anthesis were 8/21 and 16/33°C for TOS1 and TOS 3, respectively, and the mean minimum/maximum temperatures during grain filling were 8/24 and 16/34°C for TOS1 and TOS2, respectively (Figure 3.1). In 2015, the mean minimum/maximum temperatures during anthesis were 6/19 and 17/29°C in TOS1 and TOS2, respectively, and mean minimum/maximum temperatures during grain filling were 5/22 and 17/31°C for TOS1 and TOS3, respectively (Figure 3.5).

Time of sowing 1 was higher yielding in both 2014 and 2015 (Figure 4.1 a) and 2014 was the highest yielding year. Earlier sowing produced higher mean yields than late sowing in both years. In 2014, yield reduced by 54.5% and by 43.5% in 2015 There was significant genotype x year interaction at later sowing dates and the most heat tolerant genotype in 2014 (#7) was not the most tolerant in 2015, where genotype 12 produced the highest yield. The highest yielding genotypes in early sowing were not the highest yielding under late sowing due to the significant genotype x sowing date interaction observed (Table 4.1). However, some genotypes, such as #9, 11 and 20 were low yielding in both early and late sowing indicating a lack of yield potential rather than any real susceptibility to hightemperatures. The genotype-by-environment (G × E) interaction for grain yield identified three megaenvironments (Figure 4.2 a).. Principal component 1 (PC1) accounted for 86.12% of the total variation and principal component 2 (PC2) equated to 8.09% of the total variation, in total contributing to 94.21% of total variation. Genotype #17 and 18 was higher yielding in 2014 TOS1, #14, 2 and 7 were higher yielding in 2014 TOS 3. In 2015 TOS 1 and 3, gentyope #8 was higher yielding. In time of sowing 1, yield was significantly correlated with days to maturity, flour yield and TKW at P<0.001. Plant height was highly significantly negatively correlated with yield at P<0.001 (Table 4.2 a). NDVI at booting in TOS 1 had a significant positive correlation with yield at P<0.01 (Table 4.2 a). Days to heading and W8 were negatively correlated with yield at P<0.01. Flour protein and MPT were negatively correlated with yield at P<0.05. Yield also had a highly significant positive correlation at P<0.001 with flour yield, TKW and days to maturity. Plant height and yield were found to have a highly significant negative correlation at P<0.001. In time of sowing 3, yield had a highly significant positive interaction with screenings% at P<0.001 (Table 4.2 b). NDVI at booting and NDVI at heading were highly significantly negatively correlated with yield at P<0.001 (Table 4.2 b). Flour yield and plant height also had a significant positive correlation with yield at P<0.01 (Table 4.2

b) and WAP was negatively correlated with yield at $P<0.01$. MPH had a negative correlation with yield at $P<0.05$.

Table 4.1: Components of variance from the combined analysis across two years (2014, 2015) and two environments (TOS1, TOS 3)

Traits	Y	DTH	DTM	NDVI Booting	NDH	PH	Scr	TKW	FP	FY	MPH	MPT	RBD	W8	WAP
Rep	6887672***	76.52*	67.34*	NS	0.051048**	NS	109.195***	NS	NS	NS	NS	11.7174***	1878.2***	89.593***	98.545**
Year	88463827***	NS	283.2***	0.025973**	0.391568***	NS	2646.433***	360.379***	NS	1979.103***	NS	29.1008***	9264***	245.641***	236.748***
TOS	208764190***	36020.19***	79818.11***	0.464131***	1.774235***	16515.05***	12629.789***	3910.668***	83.8923***	NS	NS	9.5147***	1381.5**	302.079***	840.883***
Entry	1494305***	27.62*	NS	NS	NS	151.33***	144.334***	74.072***	3.0344***	37.365***	NS	9.59***	2705***	112.656***	42.813***
Year.TOS	22186584***	153.47**	130.47**	0.229601***	0.62775***	3169.91***	1828.096***	270.422***	18.8888***	159.821***	NS	2.7757**	5993.5***	60.675***	NS
Year.Entry	1045854***	NS	NS	NS	NS	39.95***	11.122*	NS	1.1358***	13.696*	NS	1.5016***	1233.2***	17.953***	NS
TOS.Entry	507566**	26.79*	NS	NS	NS	33.01***	103.417***	NS	NS	NS	NS	0.871*	1333.9***	45.385***	18.708*
Year.TOS.Entry	350186*	NS	NS	NS	NS	22.22**	NS	NS	NS	NS	NS	0.7257*	1611.1***	23.641***	27.486***

Y, Yield (t/ha), DTH, days to heading DTM, days to maturity; NDVI Booting; NDH, NDVI at heading; PH, plant height (cm); Scr, screening (%); TKW, thousand kernel weight (g); FP,flour protein; FY, flour yield; MPH, mean peak height; MPT, mean peat time; RBD, resistance breakdown, W8, width at 8 minutes; WAP, width at peak; NDVI, normalized difference vegetation index; TOS, time of sowing; Entry, genotype

*, **, *** indicates significance at P<0.05, P<0.01, P<0.001, respectively and NS=Not significant

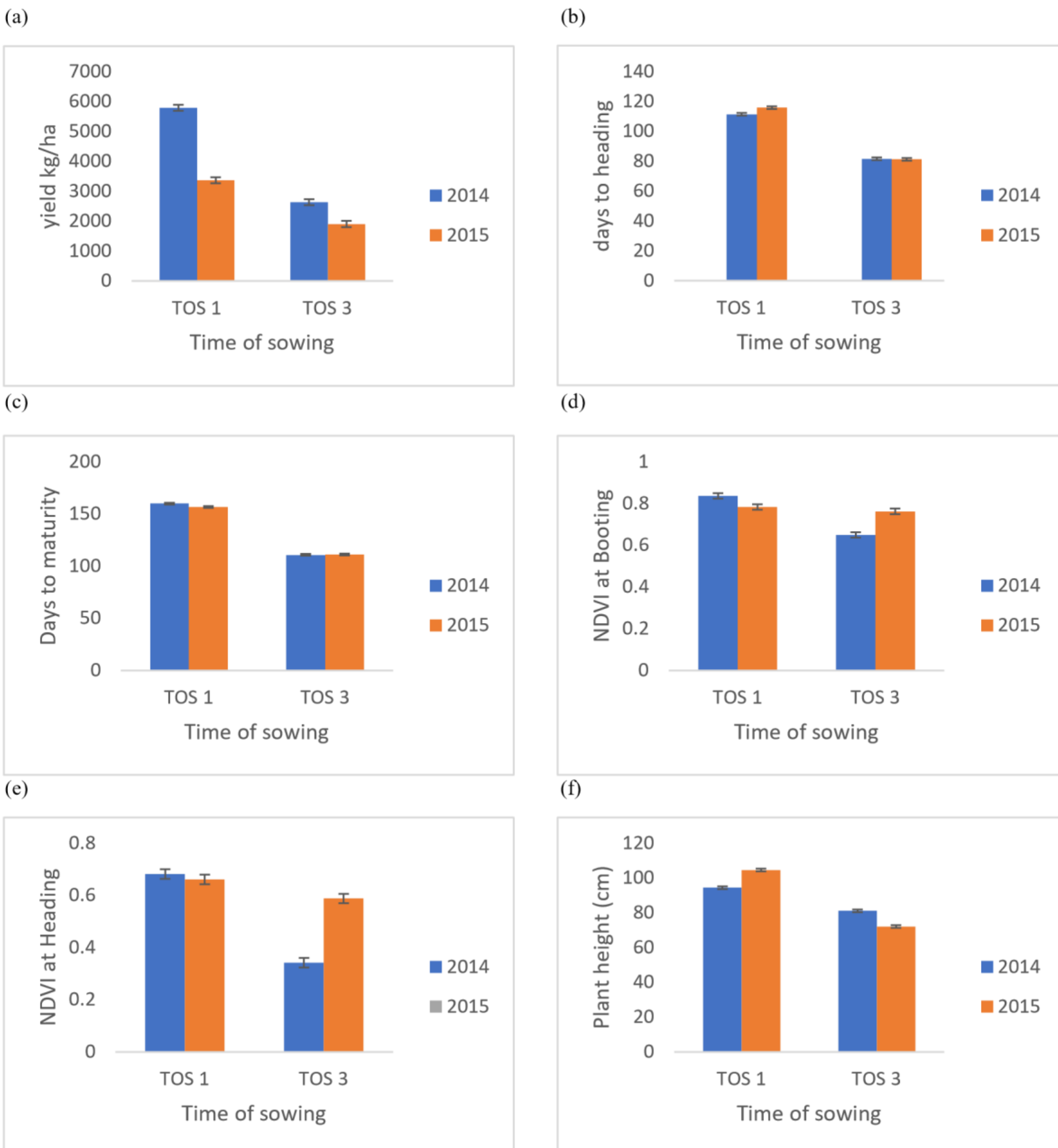
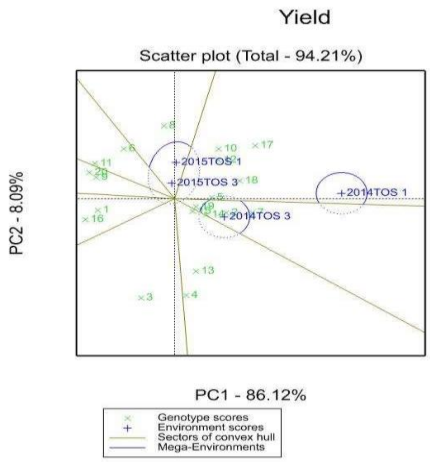
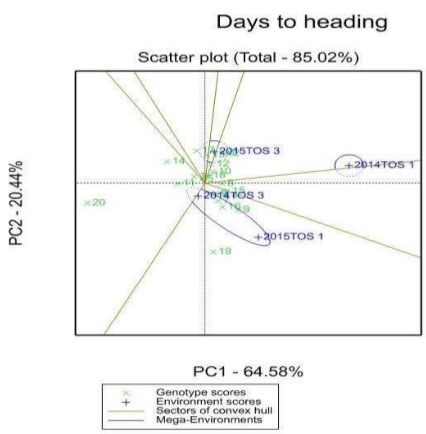


Figure 4.1: Predicted means of time of sowing (TOS) by year (2014-2015) effect of heat stress at optimal sowing (TOS 1) and late sowing (TOS 3) on (a) grain yield (GY) kg/ha, (b) days to heading (DTH), (c) days to maturity (DTM), (d) normalised vegetative index (NDVI) at booting, (e) normalised vegetative index at heading and (f) plant height (cm).

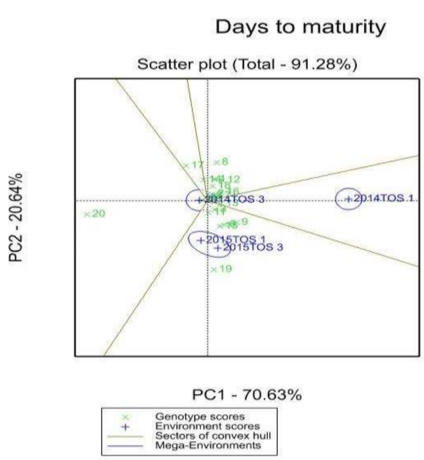
(a)


Yield
Scatter plot (Total - 94.21%)
PC2 - 8.09%
PC1 - 86.12%
+2015TOS 1
+2015TOS 3
+2014TOS 1
+2014TOS 3
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

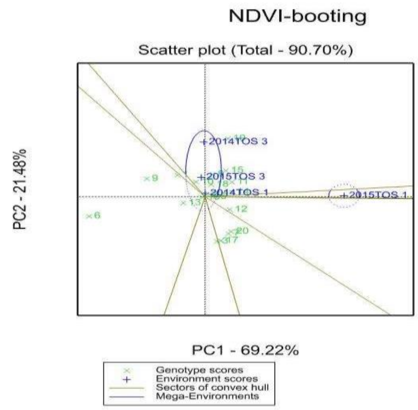
(b)


Days to heading
Scatter plot (Total - 85.02%)
PC2 - 20.44%
PC1 - 64.58%
+2015TOS 3
+2014TOS 1
+2014TOS 3
+2015TOS 1
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

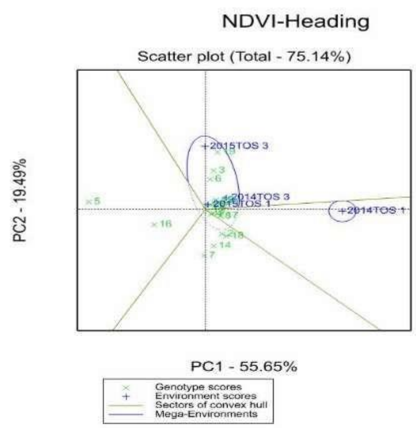
(c)


Days to maturity
Scatter plot (Total - 91.28%)
PC2 - 20.64%
PC1 - 70.63%
+2014TOS 3
+2014TOS 1
+2015TOS 1
+2015TOS 3
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

(d)



(e)



(f)

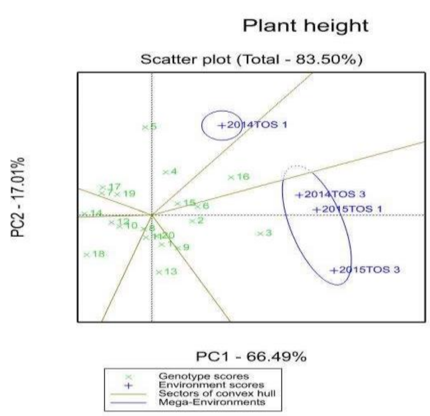


Figure 4.2: Genotype and genotype by environment (GGE) effects at optimal sowing time (TOS 1) and late sowing (TOS 3) on (a) grain yield (GY) kg/ha, (b) days to heading (DTH), (c) days to maturity (DTM), (d) normalised vegetative index (NDVI) at booting, (e) normalised vegetative index at heading and (f) plant height (cm).

Table 4.2: Bread wheat correlations among variables assessed in (a) optimal sowing (TOS 1) and (b) late sowing (TOS 3)

(a) Bread wheat correlations TOS 1

Traits	DTH	DTM	FP	FY	MPH	MPT	NDB	NDH	PH	RBD	SCR	TKW	W8	WAP	Y
DTH	-														
DTM	0.0082	-													
FP	0.1953	-0.3819	-												
FY	-0.4133*	0.5309**	-0.2577	-											
MPH	0.2075	-0.3203	0.5415**	-0.0991	-										
MPT	0.7574***	-0.0942	0.1527	-0.3809	0.0005	-									
NDB	-0.1076	0.4612*	-0.6007**	0.5339**	-0.3745	-0.0798	-								
NDH	0.0285	0.1069	-0.0594	0.2693	0.0521	-0.1841	0.0983	-							
PH	0.3173	-0.5368**	0.4623*	-0.5438	0.1824	0.3807	-0.4076*	-0.38	-						
RBD	-0.4491*	0.2096	-0.1997	0.1148	-0.1944	-0.5615**	0.0138	0.052	-0.1123	-					
SCR	-0.0805	0.1009	-0.182	0.3089	-0.0195	0.1108	0.1216	0.2595	-0.2205	0.0586	-				
TKW	-0.6767***	0.4628*	-0.3622	0.5772**	-0.4194*	-0.6893***	0.4723*	0.0104	-0.3868	0.4228*	-0.1228	-			
W8	0.6964***	-0.2971	0.3674	-0.405*	0.2009	0.8033***	-0.3167	-0.0829	0.3407	-0.5624**	0.1224	-0.8044***	-		
WAP	0.1002	-0.3427	0.4399*	-0.2671	0.3636	-0.0372	-0.412*	0.1061	0.2337	0.3878	-0.0302	-0.3326	0.322	-	

Y	-0.4963**	0.6816***	-0.4715*	0.7861***	-0.3369	-0.4079*	0.5355**	0.1988	-0.6878***	0.3565	0.3613	0.6549***	-0.5749**	-0.3011	-

(b) Bread wheat correlations TOS 3

Traits	DTH	DTM	FP	FY	MPH	MPT	NDB	NDH	PH	RBD	SCR	TKW	W8	WAP	Y
DTH	-														
DTM	-0.0348	-													
FP	0.1401	-0.1429	-												
FY	0.0729	-0.1486	0.4173*	-											
MPH	0.3937*	-0.1232	0.2687	-0.0961	-										
MPT	-0.1285	0.2591	-0.0857	-0.1699	-0.0871	-									
NDB	0.2089	0.3577	-0.196	-0.6083***	0.2579	0.3819	-								
NDH	0.2186	0.4086*	-0.3473	-0.6008**	0.283	0.2839	0.8782***	-							
PH	-0.0483	-0.0507	0.1487	0.3203	-0.3465	-0.1176	-0.6093***	-0.5343**	-						
RBD	0.215	-0.2985	0.1281	0.0853	0.1219	-0.8656***	-0.317	-0.1592	0.0563	-					
SCR	-0.026	-0.1559	0.3379	0.6483***	-0.2835	-0.1069	-0.5318**	-0.6209***	0.1984	0.0256	-				
TKW	-0.1329	-0.0314	-0.3475	-0.343	-0.012	-0.2392	-0.119	0.0684	0.3065	0.252	-0.686***	-			

W8	-0.1337	0.2525	-0.1011	-0.1088	-0.0984	0.8843***	0.3333	0.2049	-0.0447	-0.9623***	-0.1053	-0.1969	-		
WAP	0.1054	-0.0446	0.1782	-0.2422	0.4407*	0.3386	0.3003	0.3875	-0.1389	-0.1332	-0.4109	0.0653	0.3186	-	
Y	-0.2701	-0.2848	0.095	0.6008**	-0.4145*	-0.1935	-0.8498***	-0.8907***	0.5406**	0.0277	0.6207***	-0.0915	-0.1053	-0.5399**	-

DTH, days to heading DTM, days to maturity; NDH, NDVI at heading; PH, plant height (cm); TKW, thousand kernel weight (g); Scr, screening (%); FP,flour protein; FY, flour yield; MPH, mean peak height; MPT, mean peat time; RBD, resistance breakdown, W8, width at 8 minutes; WAP, width at peak; Y, Yield (t/ha); NDVI, normalized difference vegetation index; TOS, time of sowing; Entry, genotype

*, **, *** indicates significance at P<0.05, P<0.01, P<0.001, respectively and NS=Nonsignificant

4.3.1.2 Days to heading and maturity

Time of sowing (environment) had a highly significant impact on bread wheat days to heading (Table 4.4). Year by time of sowing interaction (environment) was significant for days to heading at P<0.01. Genotype and genotype by time of sowing were also significant for days to heading at P<0.05. Late sowing reduced days to heading in both years (Figure 4.1 b). In 2014 there was a 26.8% reduction and 29.8% in 2015. Genotype #9 had the longest days to heading in both years, indicating unresponsiveness to temperature stress. The significant year x sowing date and time of sowing x genotype interaction observed (Table 4.1). For days to heading in both years and times of sowing indicate the impact of temperature on days to heading. The genotype-by-environment (G × E) interaction for days to heading resulted in three mega-environments (Figure 4.2 b). Principal component 1 (PC1) accounted for 64.58% of the variation and principal component 2 (PC2) 20.44%.
Genotypes #16, 9 and 19 were higher in days to heading in 2014 TOS 3 and 2015 TOS1. In 2015 TOS 3, genotypes #17, 15 and 2 were longer in days to heading. Days to heading in TOS 1 had a highly significant positive correlation (P<0.001) with MPT and W8 (Table 4.2 a). TKW had a highly significant (P<0.001) negative correlation with days to heading (Table 4.2 a). Yield was significantly (P<0.01) negatively correlated with days to heading (Table 4.2 a). Flour yield and RBD were negatively correlated (P<0.05) with days to heading (Table 4.2 a). In time of sowing 3, days to heading was only positively correlated with MPH (P<0.05) (Table 4.2 b).

Year and time of sowing (environment) interaction was highly significant for days to maturity (P<0.001) and days to heading at P<0.01). The relative effects of year × time of sowing, genotype x year and genotype x time of sowing on days to maturity are presented in Figure 4.2. Late sowing hastened days to maturity in both years (Figure 4.1 c). In 2014, by 30.7% and 29% in 2015.Genotype #9 had the longest days to maturity in both years. The genotype-by-environment (G × E) interaction for bread wheat days to maturity showed that there are 3 mega-environments (presented in Figure 4.2 c). The genotypes evaluated within these environments are not expected to show crossover interaction. Time of sowing 1 and 3 in 2015 comprise one mega environment, which is indicative of a significant year effect. Principal component 1 (PC1) accounted for 70.63% of variation and principal component 2 (PC2) 20.64%. In 2015 TOS 1 and TOS 3, genotype #19 had higher days to maturity, #13 had longer days to maturity in 2014 TOS 1 and in 2014 TOS 3, gentyope #20 was higher in days to maturity. Days to maturity in time of sowing 1 had a highly significant positive interaction with yield (P<0.001) (Table 4.2 a). At P<0.01 days to maturity was positively correlated with flour yield and negatively correlated with plant height (Table 4.2 a). NDVI at booting and TKW were positively correlated with days to maturity (P<0.05). In time of sowing 3, days to maturity was only positively correlated with NDVI at heading (P<0.05) (Table 4.2 b).

4.3.1.3 Normalized difference vegetation index (NDVI) booting and heading

Time of sowing (environment) and year by time of sowing interaction were highly significant for NDVI at booting (P<0.001) (Table 4.1). There is also a significant year effect for NDVI at booting (P<0.01) and a highly significant time of sowing effect (P<0.001) (Table 4.1). Early sowing resulted in higher NDVI in both years compared to late sowing (Figure 4.1 d). There was 22.4% difference in 2014 and 2.6% in 2015.Higher NDVI readings were observed in 2015 (Table 4.1). No significant genotype response to heat stress was observed (Table 4.1). The genotype-by-environment (G × E) interaction for NDVI at booting produced 2 mega-environments (Figure 4.2 d). Principal component 1 (PC1) accounted for 69.22% of variation and Principal component 2 (PC2) 21.48%. Genotypes #10,
15, 8 and 11 had higher NDVI in 2014 TOS 1, TOS 3 and 2015 TOS 3. Genotype #12 had higher NDVI in 2015 TOS 1.

Year, time of sowing (environment) and year by time of sowing interactions were highly significant for NDVI at heading (P<0.001) (Table 4.1). Figure 4.1 e portrays that early sowing had higher NDVI at heading for both 2014 and 2015. In 2014, there was a 49.9% difference in NDVI at heading and 11% in 2015. This is due to lower heat stress during time of sowing 1. 2015 had higher NDVI at heading for all genotypes compared to 2014 due to the highly significant year interaction observed (Table 4.1). The G × E interaction for NDVI at heading is illustrated in Figure 4.2 e. Principle component 1 (PC1) accounted for 55.65% of variation and principal component 2 (PC2) 19.49%. In 2014 TOS 1, genotypes #17 and 8 had higher NDVI. In 2014 TOS 3 and 2015 TOS 1 and 3, genotypes #19, 3 and 6.In time of sowing 1, NDVI at booting was significantly positively correlated with flour yield and grain yield and negatively correlated with flour protein (P<0.01) (Table 4.2 a). At P<0.05, NDVI at booting was positively correlated with TKW and day to maturity and negatively correlated with WAP and plant height. In time of sowing 3, NDVI at booting had a highly significant positive correlation with NDVI at heading (P<0.001). NDVI at booting was significantly negatively correlated with flour yield, plant height, TKW and grain yield (P<0.001) (Table 4.2 b). NDVI at booting had a significant negative correlation with screenings at P<0.01

NDVI at heading in time of sowing 1 was not correlated with most traits (Table 4.2 a). In time of sowing 3, NDVI heading was highly significantly positively correlated with NDVI at booting (P<0.001) (Table 4.2 b). NDVI at heading was highly significantly correlated with screenings% and grain yield (P<0.001). NDVI at heading was negatively correlated with flour yield and plant height (P<0.01) and positively correlated with days to maturity (P<0.05).

4.3.1.4 Plant height

Time of sowing, genotype, year by time of sowing, year by genotype and time of sowing by genotype interaction were all highly significant for plant height at P<0.001 (Table 4.1). The year by time of sowing by genotype interaction was significant at P<0.05. Earlier sowing resulted in taller plants than late sowing in both years (Figure 4.1 f). There was a 14% difference in 2014 and 31% in 2015.Genotype #3 was the tallest in 2014 TOS 3 and 2015 TOS 1 and TOS 3. However, it was shorter in 2014 TOS 1. The genotype-by-environment (G × E) interaction resulted in two mega-environments (Figure 4.2 f). Principal component 1 (PC1) accounted for 66.49% of variation and principal component 2 (PC2) 17.01%In 2014 TOS 1, genotypes #5 and 4 were taller and in 2014 TOS 3, 2015 TOS 1 and 3, genotypes #3, 2, 6 and 9 were taller.

In time of sowing 1, plant height was highly significantly negatively correlated with grain yield (P<0.001) (Table 4.2 a). Plant was significantly negatively correlated with days to maturity (P<0.01). Plant height was positively correlated with flour protein and negatively with NDVI at booting (P<0.05). In time of sowing 3, plant height was highly significantly negatively correlated with NDVI Booting (Table 4.2 b). Plant height was significantly positively correlated with grain yield and negatively with NDVI heading (P<0.01).

4.3.2 Impact of heat stress on grain quality traits

4.3.2.1 Screening%

Year, genotype, time of sowing (environment) and year × time of sowing interaction were highly significant for screenings% (P<0.001) (Table 4.1). The year by genotype interaction was significant at P<0.05 (Table 4.1). Screenings% increased under heat stress in both 2014 and 2015 (Table 4.2 a). there was a 79.5% increase in 2014 and 71.5% increase in 2015. In 2014, time of sowing 3 had the largest increase in screenings% due higher heat stress. The number of days >30°C from booting till early grain filling was higher in 2014.

G × E for screenings produced two mega-environments (Figure 4.4 a). Principal component 1 (PC1) accounted for 92.14% of variation and principal component 2 a(PC2) 6.18% In 2014 TOS 3 and 2015 TOS 1 and 3, genotypes #5, 10 and 18 had higher screenings%In 2014 TOS 1 genotypes #19 and 17 had higher screenings%. Genotypes #16 had lower screenings% across all environments.

In TOS 1, screenings% was not correlated with the examined traits (Table 4.2 a). In time of sowing 3, screenings% had a highly significant positive correlation with grain yield and flour yield and negatively correlated with NDVI heading and TKW (P<0.001) (Table 4.2 b). Screenings% was also significantly negatively correlated with NDVI Booting (P<0.01).

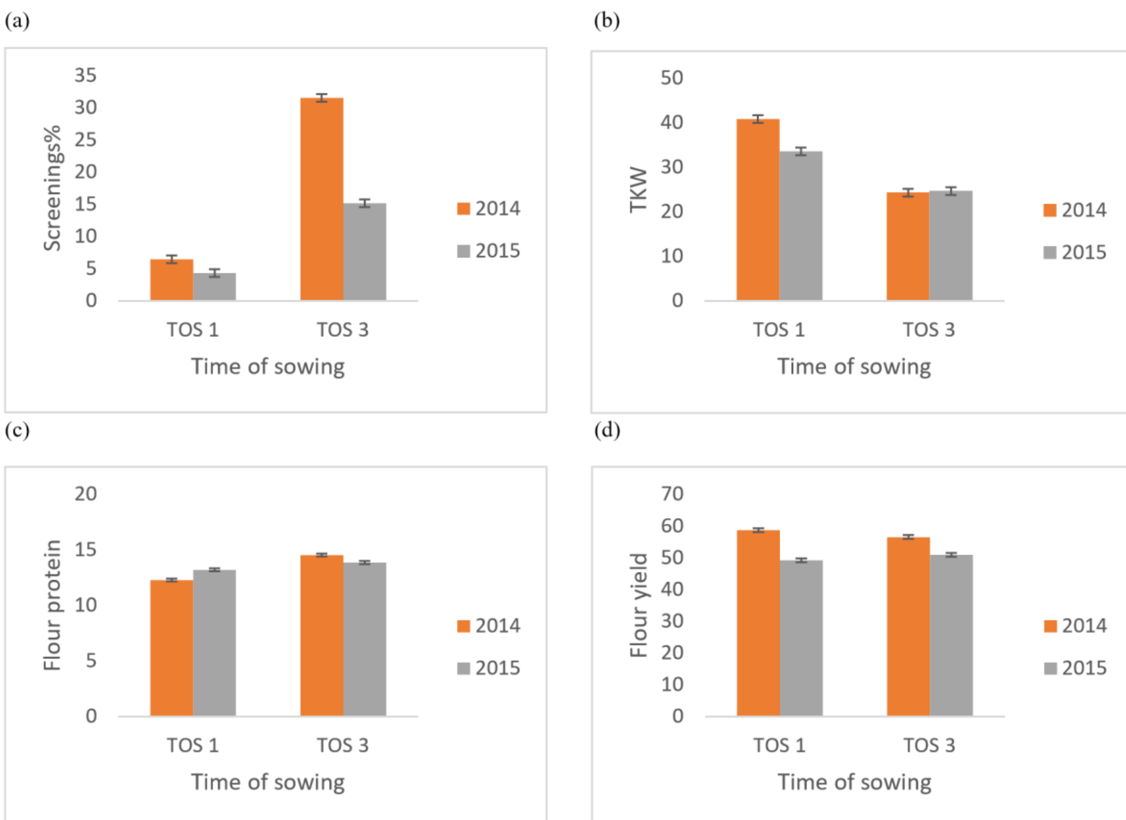
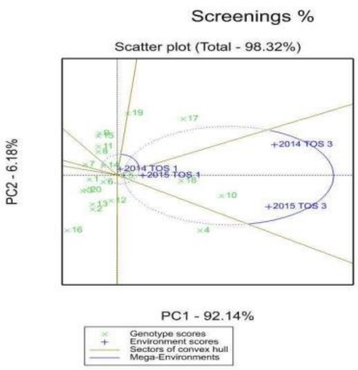


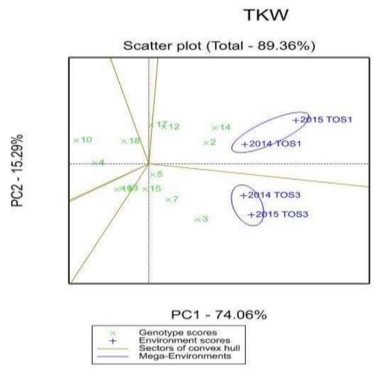
Figure 4.3: Predicted means of time of sowing (TOS) by year (2014-2015). TOS 1 was normal sown and TOS 3 late sown and the impact of heat stress presented for (a) screenings%, (b) thousand kernel weight (TKW), (c) flour protein and (d) flour yield

(a)



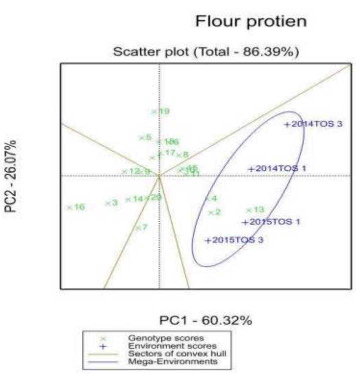
Screenings %
Scatter plot (Total - 98.32%)
PC2 - 6.18%
PC1 - 92.14%
+2014 TOS 3
+2015 TOS 3
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

(b)



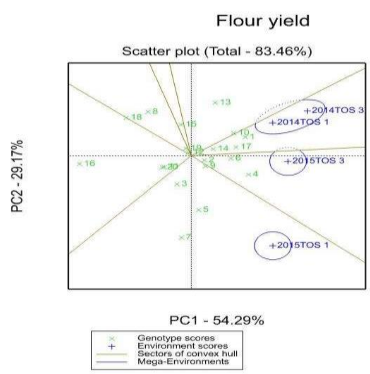
TKW
Scatter plot (Total - 89.36%)
PC2 - 15.29%
PC1 - 74.06%
+2015 TOS1
+2014 TOS1
+2014 TOS3
+2015 TOS3
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

(c)



Flour protien
Scatter plot (Total - 86.39%)
PC2 - 26.07%
PC1 - 60.32%
+2014TOS 3
+2014TOS 1
+2015TOS 1
+2015TOS 3
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

(d)



Flour yield
Scatter plot (Total - 83.46%)
PC2 - 29.17%
PC1 - 54.29%
+2014TOS 3
+2014TOS 1
+2015TOS 3
+2015TOS 1
Genotype scores
Environment scores
Sectors of convex hull
Mega-Environments

Figure 4.4: Genotype and genotype by environment (GGE) effect of heat stress at time of sowing 1(TOS 1) which was normal sown and time of sowing 3 (TOS 3) which was exposed to heat stress on (a) screenings%, (b) thousand kernel weight (TKW), (c) flour protein and (d) flour yield.

4.3.2.2 Thousand kernel weight (TKW)

Year, time of sowing (environment), genotype and year × time of sowing (environment) interaction for TKW were highly significant at $P<0.001$ (Table 4.1). The interaction effects for TKW are presented in Figure 4.3 b. TKW reduced following exposure to heat stress in both 2014 and 2015 by 40.5 and 26.5%, respectively. The predicted means in time of sowing 3 (late sowing) were similar across the two years.

Two mega-environments were observed (Figure 4.4 b). PC1 accounted for 74.06% of the variation and PC2 15.29%. Genotypes #14 and 2 were higher in TKW in TOS 2014 and 2015. Genotypes #3 and 7 were higher in TKW in TOS 3 in 2014 and 2015.

In time of sowing 1, TKW was highly correlated with grain yield and highly negatively correlated with days to heading, MPT and W8 at $P<0.001$ (Table 4.2 a). TKW was also significantly positively correlated with flour yield (at $P<0.01$) and days to maturity, NDVI Booting and RBD ($P<0.05$) and negatively correlated with MPH. In time of sowing 3, TKW was highly negatively correlated with screenings% ($P<0.001$) (Table 4.2 b).

4.3.2.3 Flour protein

Time of sowing, genotype, year × time of sowing and year x genotype effects were highly significant for flour protein content ($P<0.001$) (Table 4.1). Late sowing resulted in higher protein content in both 2014 and 2015 by 18.3 and 5%, respectively. (Figure 4.3 c). Genotype #13 produced the highest protein content in both sowing conditions in both years. Genotype #4 also had consistently higher protein content in both sowing conditions in both years.

The G × E interaction for flour protein content in presented in Figure 4.4 c and shows one megaenvironment comprised of all times of sowing in both years. Genotypes #13, 2, 4, 11, 10 and had higher flour protein across all environments.

Time of sowing 1 flour protein was significantly correlated with MPH and negatively correlated with NDVI Booting ($P<0.01$) (Table 4.2 a). Flour protein was positively correlated with plant height and WAP and negatively correlated with grain yield ($P<0.05$) (Table 5 a). In time of sowing 3, flour protein was positively correlated with flour yield ($P<0.05$) (Table 4.2 b).

4.3.2.4 Flour yield

Year, genotype and year × time of sowing interaction was significant at $P<0.001$ and year × genotype at $P<0.05$ (Table 4.1). In 2014, early sowing produced higher flour yield compared to late sowing by 3.7%, however, this was reversed in 2015 by 3.3% (Figure 4.3 d). This was not surprising given the highly significant year by time of sowing interaction observed. Genotypes varied by year for flour yield. Genotype #13 had high flour yield in 2014 but much lower in 2015, while Genotype #7 had the opposite response. However, genotype × sowing time interactions were overall not significant (Table
4.4).

The G × E interaction for flour yield is presented in Figure 4.4 d and 3 mega-environments were observed.. PC1 accounted for 54.29% of variation and PC2 29.17%. In 2014 TOS 1 and 3, genotypes #10, 1 and 17 were higher yielding. In 2015 TOS 1, genotypes #7 and 5 were higher yield and in 2015 TOS 3, genotypes #4, 6, 9, and 2 were higher yielding.

Flour yield in time of sowing 1 was significantly correlated with grain yield ($P<0.001$) (Table 4.2 a). Flour yield was also significantly correlated with TKW, NDVI Booting and days to maturity at $P<0.05$ (Table 4.2 a). However, flour yield was negatively correlated days to heading and W8 ($P<0.05$). In time of sowing 3, flour yield was significantly positively correlated with screenings% and negatively correlated with NDVI Booting ($P<0.001$) (Table 4.2 b). Flour yield was positively correlated with grain yield and negatively with NDVI Heading at $P<0.01$ (Table 4.2b). Flour yield had a positive correlation with flour protein ($P<0.05$) (Table 4.2 b).

4.3.3 Impact of heat stress on dough rheological traits

4.3.3.1 Mean peak mixograph height (MPH) and mean peak time (MPT)

Time of sowing (or environment) had a highly significant effect on MPH at $P<0.001$ (Table 4.1), whereas genotype and year × genotype interaction effects were significant at $P<0.05$.

Late sowing increased MPH in both 2014 and 2015 by 15.4 and 14.1%, respectively(Figure 4.5 a). Genotype #13 had consistently high MPH in both times of sowing over both years indicating greater stability in dough strength under heat stress. However, other genotypes such as #5 and #12, were much more unstable, producing higher peaks in different sowing times and years.

The G × E interaction for MPH is shown in Figure 4.6 a. Here, one mega- environment was observed comprising all times of sowing. PC1 accounted for 48.94% of the variation and PC2 32.75%.

Genotypes #13, 10, 17 2, 5 and 1 had higher MPH across all environments.

Year, time of sowing, genotype and year × genotype interaction were highly significant for MPT at $P<0.001$, whereas year × time of sowing interaction was significant at $P<0.01$ and time of sowing x genotype and year × time of sowing × genotype interactions were significant at $P<0.05$ (Table 4.1). Late sowing resulted in higher MPT in both 2014 and 2015 by 21.5 and 2.6%, respectively. (Figure 4.5 b). Genotype responses varied. Genotype #15 and #1 had consistently high MPT in both times of sowing over both years, whereas Genotype #14 had the lowest MPT for both times of sowing in both years.

The G × E interaction for MPT is summarized in Figure 4.6 b and 2 mega-environments were observed.. Genotype 15 was observed to have the highest MPT in all environments. PC1 accounted for 81.08% of the variation and PC2 10.75%.

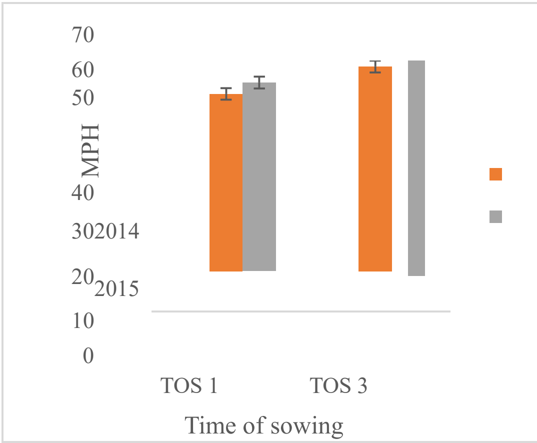
MPH in time of sowing 1 was significantly correlated with flour protein ($P<0.01$) (Table 4.2 a) and negatively with TKW ($P<0.05$). In time of sowing 3, MPH was positively correlated with days to heading and WAP and negatively correlated with grain yield ($P<0.05$) (Table 4.2 b).

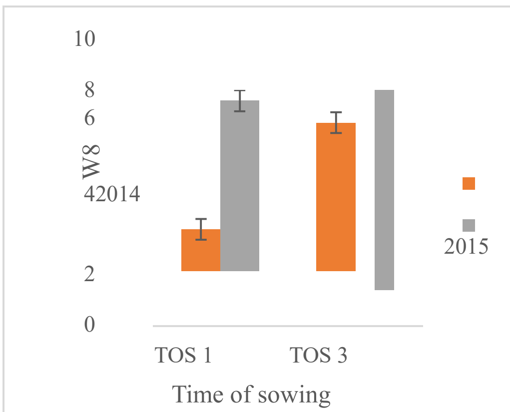
MPT in time of sowing 1 was significantly positively correlated with days to heading and W8 and negatively correlated with TKW ($P<0.001$) (Table 4.2 a). MPT was also negatively correlated with RBD ($P<0.01$) and grain yield (0.05) (Table 4.2 a). In time of sowing 3, MPT was positively correlated with W8 and RBD ($P<0.001$) (Table 4.2 b).

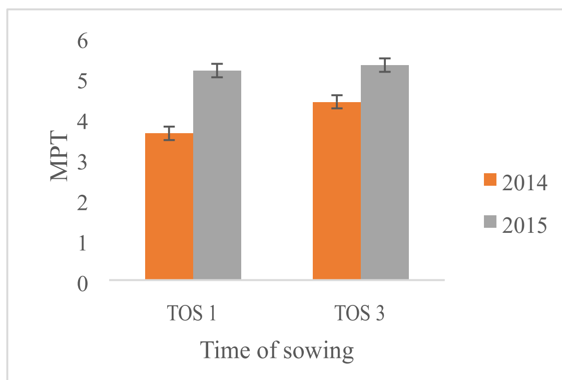
(a)

(b)

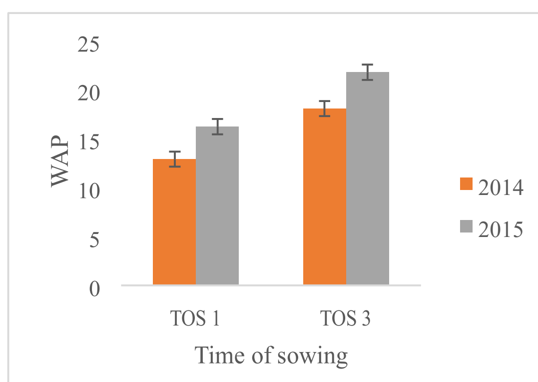
(c)


70
60
50
MPH
40
302014
20
2015
10
0
TOS 1
TOS 3
Time of sowing


10
8
6
W8
42014
2015
2
0
TOS 1
TOS 3
Time of sowing


6
5
4
MPT
3
2
1
0
2014
2015
TOS 1
TOS 3
Time of sowing

(d)


25
20
15
WAP
10
5
0
2014
2015
TOS 1
TOS 3
Time of sowing

(e)

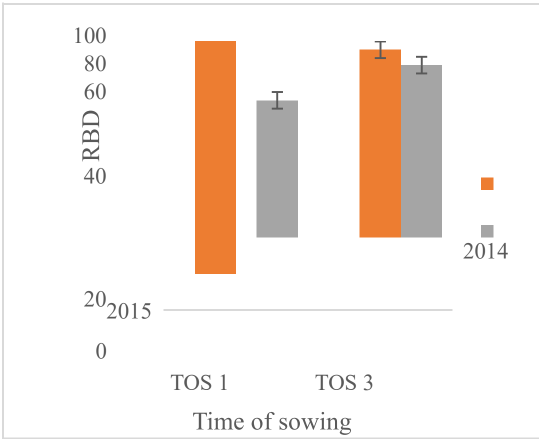
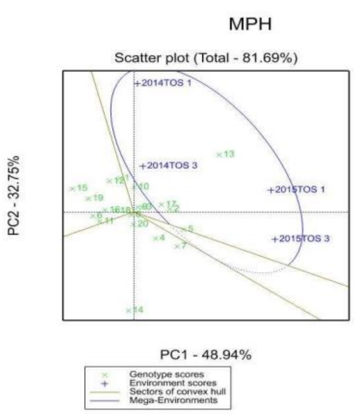
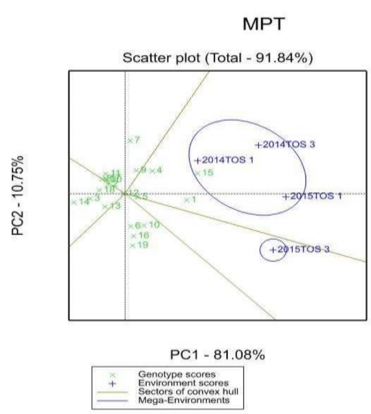


Figure 4.5: Predicted means of time of sowing (TOS) by year (2014-2015) effect of heat stress at time of sowing 1(TOS 1) which was normal sown and time of sowing 3 (TOS 3) which was exposed to heat stress on (a) mean peak height (MPH), (b) mean peak time (MPT), (c) resistance breakdown (RBD), (d) width at 8 minutes (W8) and (e) width at peak (WAP)

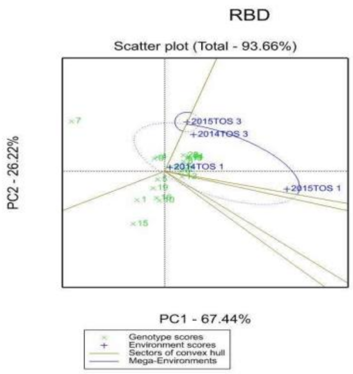
(a)

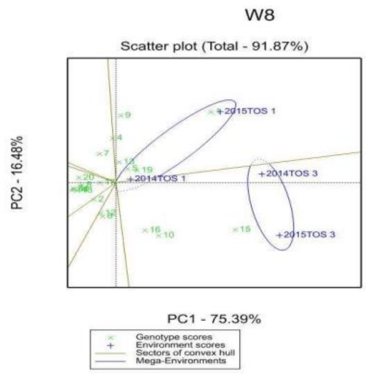


(b)



(e) (d)





(e)

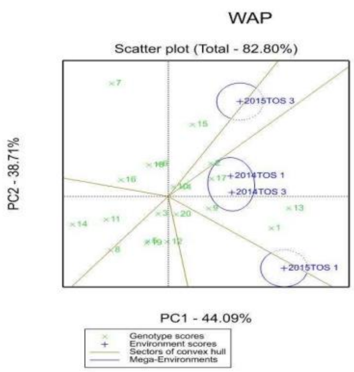


Figure 4.6: Genotype and genotype by environment (GGE) effect of heat stress at time of sowing 1(TOS 1) which was normal sown and time of sowing 3 (TOS 3) which was exposed to heat stress on (a) mean peak height (MPH), (b) mean peak time (MPT), (c) resistance breakdown (RBD), (d) width at 8 minutes (W8) and (e) width at peak (WAP)

4.3.3.2 Resistance Breakdown (RBD)

Year, genotype, and year × time of sowing, year × genotype, time of sowing × genotype and year × time of sowing x genotype interactions were all highly significant ($P<0.001$) (Table 4.1). The time of sowing main effect was significant at $P<0.01$.

In 2015, RBD increased 20.4% with heat stress, which means the dough is less stable as the width at 8 min mixing time is reduced compared to the width at peak. Whereas in 2014, RBD decreased by 19.3%, meaning more stable, which is a good quality.

Genotype #16 had lower RBD in late sowing in both years indicative of a more stable dough. Genotypes that had a higher RBD in time of sowing 3 include: Genotypes 4,7,9,12 and 20 as a result were less stable.

The G × E interaction for RBD is shown in Figure 4.6 c and resulted in two mega-environments.. Genotype #15 and 7 had the lowest RBD across all environments. PC1 explains 67.44% of the variation and PC2 26.22%.

In time of sowing 1, RBD was correlated with MPT and W8 (Table 4.2 a). RBD was also positively correlated with TKW and negatively correlated with days to heading ($P<0.05$) (Table 4.2 a). In time of sowing 3, RBD was positively correlated with MPT and W8 at $P<0.001$ (Table 4.2 b).

4.3.3.3 Width at 8 minutes (W8) and Width at peak (WAP)

Year, time of sowing, genotype, and year × time of sowing, year × genotype and time of sowing x genotype and year × time of sowing × genotype interactions were all highly significant ($P<0.001$) (Table 4.1). Later sowing resulted in higher W8 in both 2014 and 2015 by 71.9 and 14.8%, respectively (Figure 4.5 d), indicating that the trait was impacted by higher temperature. Genotype response varied greatly. Genotype #15 had consistently high RBD in both times of sowing in both years, whereas genotype #14 had consistently low RBD in both times of sowing in both years. Both genotypes appear to be little impacted by temperature. In contrast, Genotype #13 had lower RBD in later sowings in both years indicating a degree of temperature stress intolerance.

The G × E interaction for W8 is presented in Figure 4.6 d and produced two mega environments based on sowing time. . PC1 accounted for 75.39% of the variation and PC2 16.48%.

Year, time of sowing, genotype and year × time of sowing x genotype interaction were highly significant for WAP ($P<0.001$). The time of sowing x genotype interaction was also significant ($P<0.05$).

Later sowing produced higher WAP in both 2014 and 2015 by 28.6 and 25.5%, respectively (Figure 4.7 e), indicating that WAP was impacted by temperature stress. Genotype #13 had consistently high WAP in both times of sowing in both years, indicating little impact of temperature, whereas Genotype #7 produced higher WAP in the later sowing dates in both years, indicating some impact of heat stress.

The G × E interaction for WAP is presented in Figure 4.6 e, showing that there are three megaenvironments. . PC1 accounted for 44.09% of the variation and PC2 38.71%. In 2014 TOS 1 and 3, genotypes #17, 9, 1 and 13 had higher WAP; in 2015 TOS 1, genotype #20 was higher for WAP and in 2015 TOS 3, genotype #15 was found to be higher for WAP.

In time of sowing 1, W8 was positively correlated with days to heading and MPT and a highly negatively correlated with TKW (Table 4.2 a). W8 was negatively correlated with RBD ($P<0.01$), grain yield ($P<0.01$) and flour yield ($P<0.05$) (Table 5 a). In time of sowing 3, W8 was positively correlated with MPT and negatively with RBD (Table 4.2 b).

In time of sowing 1, WAP was positively correlated with flour protein and negative with NDVI Booting at $P<0.05$ (Table 4.2 a). In time of sowing 3, WAP was negatively correlated grain yield ($P<0.01$) and positively correlated with MPH ($P<0.05$) (Table 4.2 b).

4.4 Discussion

4.4.1 Consequences of heat stress during growing season

Heat stress as a result of late sowing caused a reduction in grain yield for both 2014 and 2015 as expected. Farooq et al., (2011) explained that heat stress reduces plant photosynthetic capacity and impairs metabolic functions leading to oxidative damage to chloroplasts, which in turn reduces dry matter accumulation and ultimately grain yield. In 2014, the temperature increases during anthesis could potentially cause a yield reduction of 263 kg/ha for every 1 °C rise in mean maximum temperature which equates to a 4.4% reduction for every 1 °C rise in mean maximum temperature also, temperature increases during grain filling could be expected to have a yield reduction of 315.6 kg/ha for every 1 °C rise in mean maximum temperature which equates to a 5.5% reduction for every 1 °C rise in mean maximum temperature. In 2015, the temperature increases during anthesis could cause a yield reduction of 146.3 kg/ha for every 1 °C rise in mean maximum temperature, which equates to a 4.3% reduction in yield for every 1 °C rise in mean maximum temperature and during grain filling could also result in a yield reduction of 162.4 kg/ha for every 1 °C rise in mean maximum temperature, which equates to a 4.8% reduction in yield for every 1 °C rise in mean maximum temperature. Late sowing (heat stress) also resulted in reductions in yield as seen in the study by (El
Rady, 2022)

The days to heading and maturity in the current study were reduced as a result of higher temperatures (Tewolde et al., 2006). The ideal temperature for wheat anthesis and grain filling ranges between 12 to 22°C (Farooq et al., 2011) and temperatures in this study clearly exceeded these ranges. In 2014, with increases in mean maximum temperature days to heading hastened by 26.8% and in 2015, days to heading hastened by 29.8%. Days to heading in 2014 was hastened by 30.7% and in 2015, by 29%.

Plant height was also reduced by exposure to higher temperatures as observed by others (Aziz et al., 2021; El Rady, 2022). In 2014, the study observed a 13.32% reduction in plant height and in 2015 a 31% reduction with increases in mean maximum temperature. There was also a positive correlation between plant height and grain yield and this could be correlated with increased accumulation of stem water-soluble carbohydrates in taller plants and increased biomass. Lodging can reduce yield, however, under heat stress the full potential for height is not reached and lodging generally ceases to be a constraint.

NDVI booting in 2014 was found to have a 22.4% reduction in vegetation greenness and in 2015, a 2.6% reduction. In 2014. NDVI heading was observed to result in 49.9% reduction in vegetation greenness with increase in mean maximum temperature and in 2015, resulted in a 11% reduction. The study by (Kumar et al., 2023) also confirms the findings in this experiment that plant greenness (NDVI) was reduced with heat stress.

4.4.2 Consequences of heat stress on grain quality

Overall, screenings were higher in late sowing and the variation between years related to differences in grain filling temperatures. Others observed similar results (Ullah et al., 2018), however, some genotypes produced significantly fewer screenings indicating a genetic effect that can be exploited by breeding. Screenings do influence grain quality (Nuttal et al., 2017) and impact flour milling and functional dough properties. In 2014, effects of heat stress resulted in a 388% increase in screenings percentage and in 2015, the study observed an increase of 252%.

Generally, TKW reduced with heat stress, although 2014 was an anomaly (Figure 4.3 b). The gradual increase in temperature that year may have allowed short-term acclimation of some genotypes to higher temperatures. High temperatures during grain filling reduce final grain weight mainly by shortening the period of grain filling (Wardlaw and Moncur, 1995). In 2014, increased temperatures during grain-filling resulted in a 1.7 g decrease in TKW for every 1℃ increase in temperature, which equated to a 4% reduction in weight for every 1℃ increase in temperature. During anthesis, the increased temperatures resulted in a 1.4g decrease in weight for every 1℃ increase in temperature, which equated to a 3.4% reduction in grain weight for every 1℃ increase in temperature. In 2015, increase in anthesis temperature resulted in a 0.9 g decrease in weight for every 1℃ increase in temperature which equated to a reduction of 2.6% in weight for every 1℃ increase in temperature and increases in grain filling temperature resulted in a 0.99 g decrease in weight for every 1℃ increase in temperature, equating to a reduction in weight of 2.9% for every 1℃ increase in temperature.

Flour yield generally reduced under heat stress due to impaired endosperm development confirming earlier observations (Sissons et al., 2017). However, this was not observed in 2015 where late sowing actually produced higher flour yield. The study observed an increase of 3.3% in flour yield this is most likely due the rainfall experienced during critical growth period (Figure 4.2). In 2014, flour yield reduced by 3.7% with late sowing since, TKW reduced and screenings increased under late sowing in that year, indicating reduced endosperm development.

Flour protein also increased under heat stress as observed by others (Labuschagne et al., 2009). This was a direct consequence of reduced endosperm development. Smaller seeds with reduced endosperms tend to have higher protein content as the ratio of protein to endosperm increases. In 2014, heat stress resulted in an increase of 18.3% in flour protein and 2015, resulted in an increase of 5% in flour protein.

4.4.3 Consequences of heat stress for dough rheological properties

In 2014, a 15.4% increase in MPH was observed with increase in mean maximum temperatures, the same was observed in 2015, with an increase of 14.1%. This is due to increases in flour protein as MPH is generally highly correlated with grain/flour protein.

In 2014, an increase of 21.5% in MPT was observed in late sowing and in 2015 the increase was 2.6% with late sowing. Sissons et al. (2017) found that longer mixograph to peak dough development was connected with stronger dough and that with late sowing there was an improvement of dough quality as indicated by the current results.

In 2014, a decrease of 19.3% in RBD was observed which is indicative of a more stable dough and this finding also mirrors that of Sissons et al. (2017) whereby late sowing resulted in reduced RBD. However, in 2015 there was an increase of 20.4% in RBD. This result could possibly be attributed to a less intense heat period during anthesis and grain filling compared to 2014 (Figure 4.1 and Figure 4.2). Also, the direction in which RBD responds to heat stress may also be influenced by the glutenin alleles present (Sissons et al., 2017 and Tabbita et al., 2023) which can potentially be a reference point for future studies.

Uhlen et al. (1998) found that mixogram bandwidth increased as temperature during grain filling increased which concurs with the findings in the current study. In 2014, W8 increased by 71.9% with heat stress and WAP by 28.6% and in 2015, W8 increased by 14.8% and WAP increased by 25.5%. Tahir et al. (2006) found that mixograph curve width was significantly decreased as a result of heat stress which resulted in reduced dough elasticity. This finding differs from the current study as mixograph width increased meaning increased dough elasticity. It also must be noted that the plant material examined in the Uhlen study differs from the material in the present study and the experiments in the Uhlen et al. (1998) study was grown in growth chambers whereas the material in the present study were grown in a field experiment and different environments.

4.4.4Target traits for plant breeders

The positive effect of heat stress on grain quality traits including the increased flour protein, although can result in decreases of micro-nitorents and MPH also, and reduced RBD can possibly be exploited if the negative effects of heat stress on other quality traits and grain yield can be reduced (Sissons et al.,, 2017). The positive effects of heat stress on grain protein content are offset by reduced grain weight and ultimately flour and grain yield. Hence, it could be challenging to enhance all yield and quality related traits simultaneously through breeding.

Nevertheless, significant genotypic differences for most traits under heat stress were observed, indicating that sufficient genetic variation exists to breed more heat tolerant wheats that maintain industrial quality at high temperatures. This is supported by the significant genotype x sowing time interactions observed for key traits such as grain and flour yield as observed by genotype #17 being high yielding with high flour yield when exposed to heat stress. Nevertheless, #17 had high screenings% and this would need to be improved, potentially by crossing to # 14 which produced low screenings% and high TKW across environments and years. Genotype #18 had high yield and stable dough properties producing low W8 and high RBD. Genotype # 10 had high grain and flour yield and stable dough properties with high W8 and low RBD. Genotype #15 had high flour protein content and low screenings% across environments and stable dough (low RBD and high W8). Genotype #15 could be crossed with #17 to produce a truly heat tolerant genotype. The basis for these crossing strategies is from only two environments and more GxE trials are needed to confirm genotype responses to heat stress. Clearly, there is a strong basis among these materials for a wheat improvement program targeting temperature tolerance.

Conclusion

Late sowing was effective in identifying heat tolerant wheat genotypes. Nevertheless, the selected materials should be confirmed in either controlled conditions or in genuinely hot environments at normal dates of sowing. Also, must be noted that some irrigation was used and may interfere with the responses in normal sowing under a hot environment with only rainfall It is essential that we are not selecting specifically for adaptation to late planting alone, but real heat tolerance. In addition, the metabolic and development pathways associated with heat stress tolerance and energy regulation must be further investigated to provide a fundamental basis for breeding heat tolerant cultivars.

Chapter 5: Durum wheat tolerance to heat stress exposure

Abstract

The frequency of hot weather has increased across much of Australia and these periods of high temperature are a major threat to durum wheat grain yield and grain quality. One hundred and twenty durum genotypes were evaluated in field experiments at two times of sowing in 2014 and four times of sowing in 2015 in north-western NSW (Narrabri) to assess heat tolerance during the crucial reproductive and grain-filling periods of development. Late sowing reduced grain yield between 11 and 62%, grain weight between 1 and 28% , dough strength between 0.3 abd 8% and flour milling yield between 1 and 6%, while grain protein content increased between 1 and 14%. Late sowing was effective in identifying genotypes that tolerated heat stress while maintaining industrial quality. The highest yielding genotypes were semi dwarf in stature and had longer days of grain-fill. . Overall, heat stress reduced grain and flour yield, grain size and increased protein content. The current study (at least in 2014) did find a dough strengthening effect at higher temperature with increased MPH, MPT, WA8 and WAP. However, this was not observed in 2015 as the environment was less stressed and rainfall higher thus the impact of heat stress on dough quality underlining the vagaries of the field environments and the different germplasm evaluated.

5.1 Introduction

Heat stress is known to impact the yield and processing quality of durum wheat (Sissons et al., 2017; Guzman et al., 2016; Li et al., 2013; Fois et al., 2011; Corbellini et al., 1997, Kamrani et al., 2018). However, most studies have used glasshouse experiments to assess heat tolerance (Liu et al., 2019; Cosentino et al., 2018; Corbellini et al., 1997).

Liu et al. (2019) examined post-anthesis heat stress on 10 durum wheat varieties in the glasshouse and found that the effect of heat stress on grain straits such as protein content differed significantly among the genotypes examined. Cosentino et al. (2018) also investigated the effects of post-anthesis heat stress on durum wheat with in two contrasting environments. Heat stress was applied by placing pots in growth chambers and applying temperature stress at 5, 15, 25, 35- and 45days post anthesis. They reported that heat stress in the range 35–40°C during grain filling significantly increases protein accumulation. The Corbellini et al. (1997) glasshouse study also found that heat shock during late grain filling did not impact grain yield or protein concentration, however a dough weakening effect was found.

Kamrani et al. (2018) examined heat stress on 45 durum wheat varieties in field trials over two growing seasons with normal sowing and late sowing used to induce contrasting temperatures. This study only focused on yield and did not measure other crucial traits. They reported a strong positive correlation between sowing dates for yield. Sall et al. (2018) also examined heat tolerance of 24 durum wheat genotypes and found exposure to heat stress during grain filing resulted in a reduced grain size and weight. However, these authors did not examine the effect of heat stress on dough rheological properties linked to pasta quality.

This chapter describes two field experiments grown under two different sowing conditions; normal and late sowing in two years; 2014 and 2015. The aim was to determine the impacts of temperature stress on durum wheat growth, grain yield and quality. Temperature tolerance and yield improvement can be enhanced by exploiting genetic diversity the evolution of new phenotypes through hybrisation and incorportation of TaHSP90A transcripts (Ammar et al., 2023,2024).

5.2 Materials and method

5.2.1 Germplasm

One hundred and twenty durum wheat genotypes were evaluated, including 22 landraces, 97 semi dwarf genotypes and 1 Triticum dicoccum. The full list of the germplasm tested can be found in section 3.4.

5.2.2 Field location, treatments and experimental design

The field experiments were conducted at the I.A. Watson Grains Research Centre in Narrabri. The research centre is located on the north-western slopes of NSW (30.3324°S,149. 7812°E at an elevation of 212 m above sea level).

Experiments at each time of sowing were arranged in randomized complete block designs of 120 genotypes and 2 replicates. Each trial comprised 240 6m plots of 2m in in width. In 2014, time of time of sowing 1 and 2 were sown on 11/06/2014 and 01/08/2014, respectively. The experiments were adjacent to each other. In 2015, the four time of sowing experiments were sown adjacent to each other in plots of similar size. Times of sowing were 15/05/15, 14/06/2015, 21/07/15 and time 13/08/15 for dates 1, 2, 3 and 4, respectively.

5.2.3 Data captured in season

The data captured in season and post season is summarised on Table 5.1. Detailed methods of data capture are found in section 3.4. From this point onwards, time of sowing 1 in 2014 is renamed early sowing 2014, time of sowing 2 2014 as late sowing 2014, time of sowing 1 2015 as very early sowing 2015, time of sowing 2 as early sowing 2015, time of sowing 3 2015 as late sowing 2015 and time of sowing 4 2015 as very late sowing 2015. This was done to improve connectivity between years for data analysis. Some NDVI and CT measurements were not captured in all sowing dates due to unfavourable weather conditions and timing issues.

Table 5.1: Traits assessed in all environments in both years

5.2.4 Post-harvest assessments

Quality data assessed post-harvest is summarised in Table 5.2 and complete methods if capture is described in Section 3.5. The dough rheological data was only captured on early sowing 2014, late sowing 2014, early sowing 2015 and late sowing 2015. This was done to provide connectivity across environments and to reduce the samples for testing.

Table 5.2: Post-harvest data measurements for all environments over both years.

5.2.5 Statistical analysis

All statistical analyses were conducted using the GenStat statistical package 15th edition (Payne et al., 2011). Significance was assessed at a P>0.05. Linear Mixed Models (Residual Maximum Likelihood or REML) were used to estimate variance components and interactions. The factors included in these interactions were the year, sowing date and genotype as fixed effects and range/row coordinates within replicates, sowing dates and years were considered as random effects. A multiple regression analysis was conducted using the combined means of all traits. Interactions observed among parameters were assessed using the Pearson's correlation test on GenStat (Payne et al., 2011). The relationships between genotypes and environments were illustrated using Genotype plus Genotype by-Environment (GGE) biplots in GenStat. The statistical analyses performed are presented in Table
5.3 and the detailed method is described in Section 3.4.

Table 5.3: Statistical analysis performed on captured data on all environments over both years.

5.3 Results

5.3.1 Impacts of heat stress on agronomic and physiological traits

5.3.1.1 Impact of heat stress on grain yield

Increased temperatures during late sowing reduced grain yield (Figure 3.12, 3.1 and 3.5). For both 2014 and 2015, yields were reduced by late sowing between 11-62%, and this was associated with increased temperatures at critical growth phases (Figure 3.12) and reduced rainfall (Figure 3.1 and 3.5). In 2014, average temperature during anthesis in the optimally sown experiment was 26.4°C (1 day ≥ 30°C), whereas the average temperature during grainfill was higher at 30.6°C (17 days ≥ 30°C).

Late sowing in 2014 resulted in an average temperature was 26.7°C (3 days ≥30°C) at heading and 34°C (22 days ≥30°C) at maturity. In 2015, the very early sown trial recorded an average temperature of 18.3°C at anthesis and 26.9°C (22 days ≥ 30°C) during grainfilling. In contrast, the latest sowing date recorded an average temperature of 31.2°C (12 days ≥ 30°C) during anthesis and 30°C (21 days ≥ 30°C) during grainfilling. The higher yield in the latest sown experiment compared to the penultimate sowing date was likely due to increased rainfall during grainfilling and associated lower temperatures.

The GGE biplot explained 89% of the total variation in grain yield (Figure 5.2 a). However, there was some differentiation between environments for yield, with very late sowing in 2015 being the most different. Genotypes #4 and 11 produced the lowest grain yield and performed poorly in all environments. Genotpe #35 was higher yielding in early sowing 2015, #18 was higher yielding in very early sowing 2015. Genotype #63 was higher yielding in late sowing 2015 and very early sowing 2015 and #120 was higher yielding in very late sowing 2015 The early sowing environments accounted for most of the G × E interaction for yield compared to the late sowing environments which had the shortest vectors.

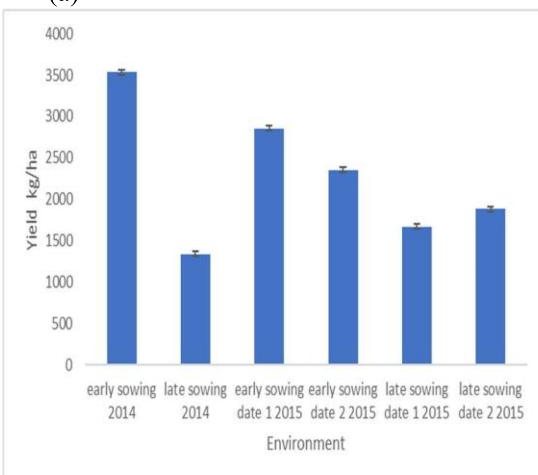
Genotype, environment and G × E effects were all significant for yield ($P<0.001$) (Table 5.1 a). In 2014, broad-sense heritability ranged from 0.9 (very early and early sowing) to 0.7 (late sowing) (Table 5.2). Heritability was also high in very early and early sowing in 2015 ($h^2 = 0.9$) and selection will be fruitful and lowest for very late sowing ($h^2 = 0.6$) (Table 5.2). The highest yielding genotypes in early sowing in 2014 were #80 which was 77.8% higher than average yield, 79 which was 78.9% higher than average yield, 67 which was 78.95% higher average yield, 86 which was 79% higher than average yield, and 78 which was 79% higher than average yield, and in late sowing were 35 74% higher than average yield,80 which was 74% higher than average yield,106 which was 75% higher than average yield,89 which was 76% higher than average yield and 101 which was 76% higher than average yield. Genotype 80 produced exceptionally high yield in 2014 for both

environments. In 2015, the highest yielding genotypes from very early sowing were 57 which was 66.8% higher than average yield, 35 which was 67.8% higher than average yield, 108 which was 68% higher than average yield, 94 which was 68.2% higher than average yield and 61 which was 68.9% higher than average yield, compared to high yielding lines in early sowing (35 higher than average yield by
64.3%, 81 which was 70.9% higher than average yield, 80 which was 71% higher than average yield, 117 which was 74% higher than average yield and 101 which was 74.1% higher than average yield), late sowing (61 which was 66.7% higher than average yield, 82 which was 68.7% higher than average yield, 103 which was 68.7% higher than average yield, 106 which was 72.2% higher than average yield and 116 which was 73% higher than average yield) and very late sowing (120 which was 60% higher than average yield, 114 which was 66.9% higher than average yield, 118 which was 67.2% higher than average yield, 110 which was 72.2% higher than average yield and 111 which was 73.9% higher than average yield). These changes in rank are indicative of the high G ×E observed.

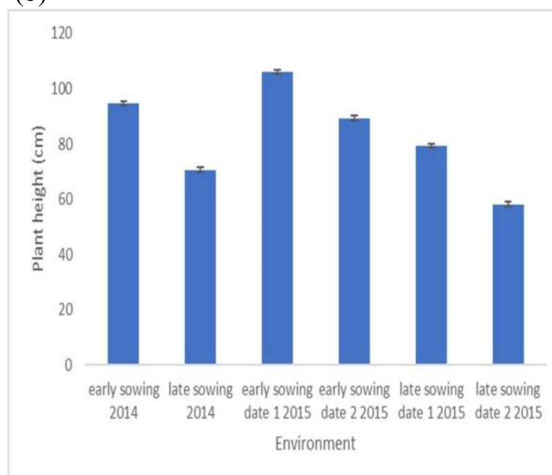
Yield in early sowing was highly negatively correlated with HLW, , RBD and WG ($P<0.001$) (Table 5.3 a). However, yield was positively correlated with WA8, WAP, y-pig and DTGF which indicates that these traits increased with increasing yield. In the late sown environment, yield was negatively correlated with DTH, plant height and RBD (Table 5.3 b). Highly significant positive correlations with yield in the late sowing environment included WA8, WAP, y-pig and DTGF. Yield in early sowing was negatively correlated with grain protein ($P = 0.01$).

Yield in early and late sowing was positively correlated with MPT. However, early sowing yield was negatively correlated with NDVI at heading and DTM, but positively correlated with CT heading ($P<0.05$). Late sowing yield was negatively correlated with SY but positively correlated with grain protein ($P< 0.05$).

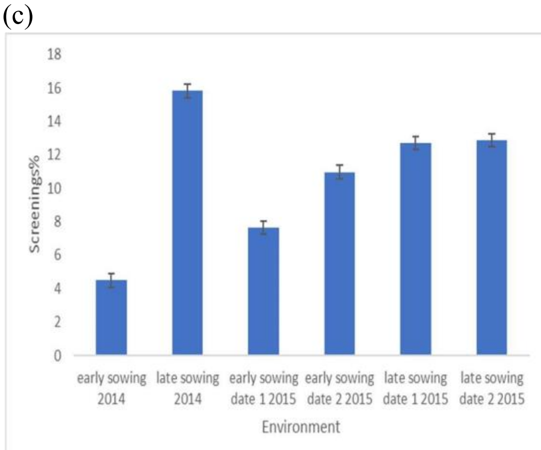
(a)


4000
3500
3000
2500
2000
1500
1000
500
0
Yield kg/ha
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment

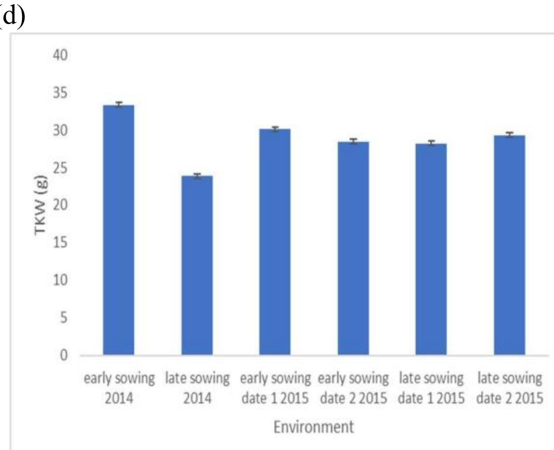
(b)


120
100
80
60
40
20
0
Plant height (cm)
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment

(c)


18
16
14
12
10
8
6
4
2
0
Screenings%
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment

(d)


40
35
30
25
20
15
10
5
0
TKW (g)
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment

(e)

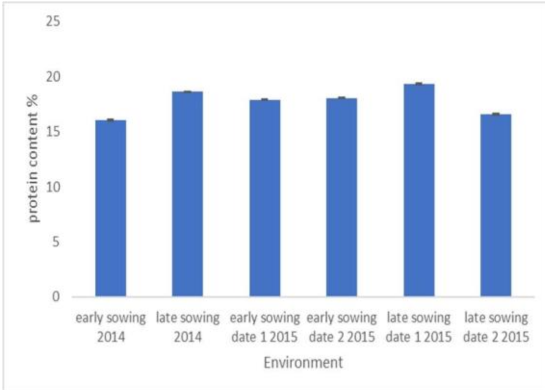
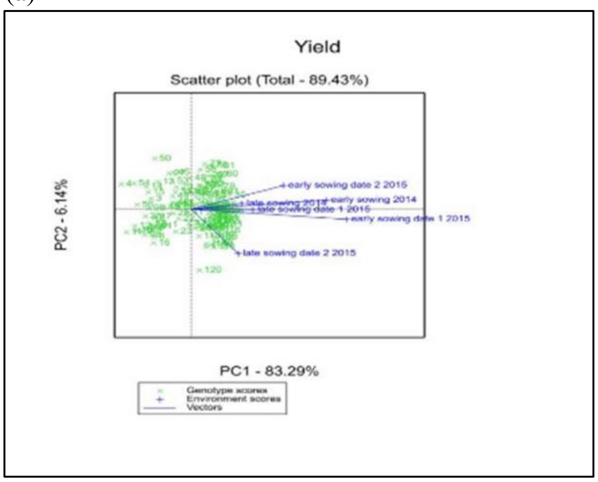
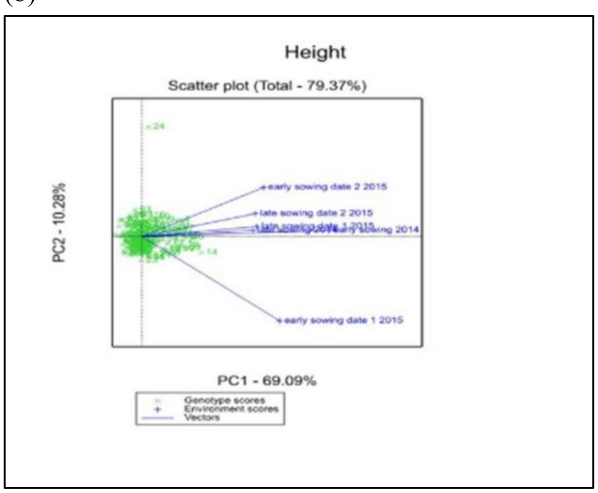


Figure 5.1: Predicted means for durum yield (kg/ha), plant height (cm), screenings%, TKW (g) and protein content % in six contrasting environments over two years. (a) yield (kg/ha), (b) plant height (cm), (c) %, (d) TKW (Thousand kernel weight) and (e) protein content

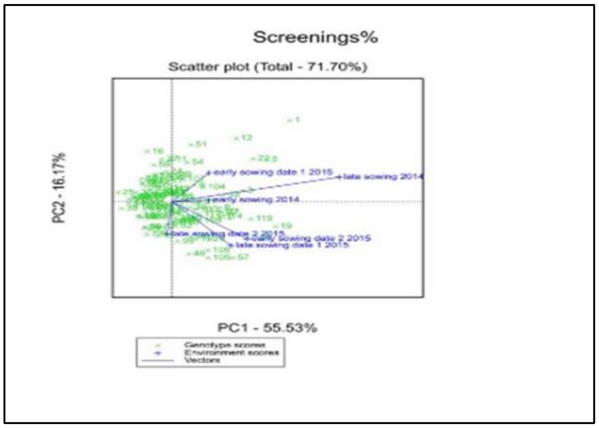
(a)



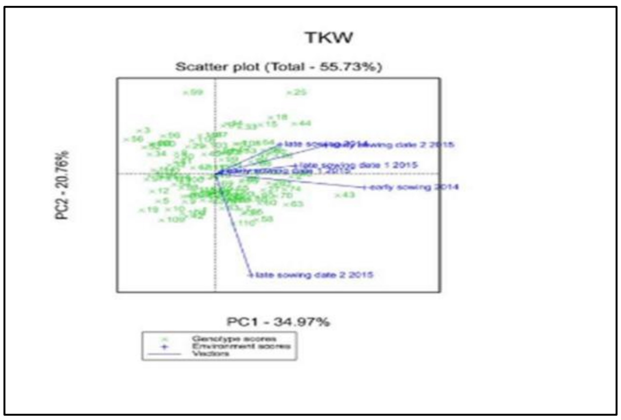
(b)



(c)



(d)



(e)

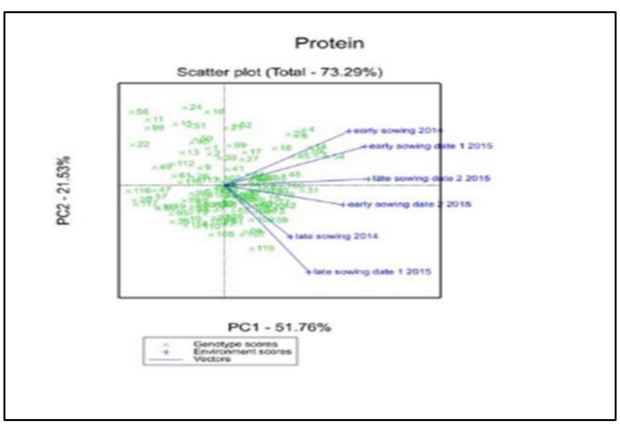


Figure 5.2: Genotype and genotype by environment (GGE) interaction biplot for durum (a) yield (kg/ha),(b) plant height (cm), (c) screenings%,(d) TKW (g) and (e) protein content % in six contrasting environments over two years.

Table 5.1: Wald statistics and components of variance for all measures traits in all environments across both years (2014 and 2015)

(a) Wald statistics for all agronomic traits captured in all environments across both years (2014 and 2015)

Trait	Yield	Days to heading	Days to maturity	Days of grain-fill	GC% 1	GC% 2	GC Rate	Plant height	Screenings	TKW	NDVI heading	2015 NDVI jointing	CT heading	2015 CT early grain-fill	2015 CT mid boot
Environment	7764.48***	33338.***	75718.3***	6992.65 ***	2235.74***	2481.92***	1810.98***	3721.04 ***	1058.78***	992.21***	5330.49***	199.31***	13066.5***	34.47***	3083.22***
Genotype	4120.59***	630.23***	555.63***	231.27***	100.62	103.16	123.58	2356.28***	831.79***	482.25***	218.44***	123.73	94.84	26.82	129.46
Environment .Genotype	1836.78***	1382.98***	1203.24***	1409.38***	546.96	495.26	694.46*	1187.25***	1424.82***	1158.73***	633.77***	109.76	273.92	26.82	252.52

(b) Wald statistics for grain quality traits measured in all environments across both years (2014 and 2015)

Trait	Protein content	SKHI	HLW	SY	WG	Y-pig
Environment	5070.19***	8238.22***	4095.73***	3615.28***	4547.56***	11610.64***
Genotype	1967.48***	2784.49***	1377.64***	3519.39***	2004.72***	9844.11***
Environment.Genotype	1996.35***	2765.2***	1204.91***	2808.47***	1965.22***	1708.23***

(c) Means square for dough rheological properties measured in all environments across both years (2014 and 2015)

Trait	Flour yield	MPH	MPT	RBD	WA8	WAP
Rep	0.78	153.1	0.0591	112.7	0.072	23.85
year	366.94***	1.9	0.02	28.6	0.901	26.99
sowing	192.22***	0.4	0.0552	3268.3***	196.046***	199.65**
Genotype	66.02***	156.1*	2.667***	2168.3***	126.679***	157.4***
year.sowing	371.73***	1666.1***	0.1414	3769.8***	300.604***	628.04***
year.genotype	27.31***	91.7	0.3004	179.4	3.798	40.74*
sowing.genotype	23.93**	110.7	0.1848	137.3	5.806**	33.21
year.sowing.genotype	26.6***	124	0.4108	182.2*	9.207***	33.62

yield, Screenings% (src%), Thousand kernel weight (TKW), days to heading, days to maturity, days to grain-fill, early ground cover (GC%1), late ground cover (GC%2), ground cover rate (GC rate), plant height, Normalized Differential Vegetation Index (NDVI) at heading, (j) Normalized

Differential Vegetation Index (NDVI) at jointing, canopy temperature (CT) at heading, (l) canopy temperature (CT) at early grain-fill, canopy temperature (CT) at mid boot, protein content, single kernel hardness index (SKHI), hectolitre weight (HLW), semolina yield (SY), wet gluten (WG), yellow-pigment (y-pig), flour yield, mean peak height (MPH), mixograph time to peak dough development (MPT), resistance breakdown (RBD), width of curve after 8 mins mixing (WA8) and width at peak mixing time (WAP)

*, **, *** indicates significance at P<0.05, P<0.01, P<0.001, respectively

Table 5.2: Differences in trait values of materials classified as heat tolerant, moderately tolerant or heat susceptible based on the heat susceptibility index (HSI) and heritability (H) of each trait across all environments in both years (2014 and 2015)

(a) Early sowing 2014 agronomic traits

Traits	TKW	Scr%	CTH	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIH	NDVIEGF	PH	Y
heat tolerant	3. 39 a	4.82 a	19.91 a	31.73 a	107.2 a	138.9 ab	0.149 a	0.67 a	499.3 a	0.72 b	0.62 a	109.92 b	2560 b
moderately tolerant	3.37 a	3.99 a	20.04 a	33.26 a	105.4 a	138.6 b	0.146 a	0.96 a	506.5 a	0.75 a	0.63 a	93.77 a	3700 a
heat susceptible	3.27 a	4.96 a	20.27 a	33.11 a	106.8 a	139.9 a	0.145 a	0.68 a	516.7 a	0.75 a	0.63 a	91.8 a	3602 a
Heritability	0.8	0.8	-0.1	0.7	0.9	0.9	0.0	-0.1	-0.1	0.5	-0.1	0.9	0.9

(b) Late sowing 2014 agronomic traits

Traits	TKW	Scr%	CTH	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIH	PH	Y
heat tolerant	2.52 b	14.89 a	26.3 ab	27.5 ab	75.65 ab	103.2 a	0.1 a	0.41 a	447.9 a	0.58 b	82.46 b	1217 a
moderately tolerant	2.4 ab	14.99 a	26.44 b	29.05 b	74.49 b	103.5 a	0.09 a	0.43a	514.6 a	0.60 c	70.05 a	1494 b
heat susceptible	2.33 a	16.99 a	26.82 a	27.44 a	76.24 a	103.7 a	0.09 a	0.43a	542.2 a	0.62 a	68.3 a	1206 a
Heritability	0.5	0.8	-0.1	0.9	0.9	0.4	0.0	0.0	0.2	0.6	0.8	0.7

(c) Early sowing date 1 2015 agronomic traits

Traits	TKW	Scr%	CTJ	CTH	CTEGF	CTMGF	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIJ	NDVIEB	NDVIH	NDVIMGF	PH	Y
Heat tolerant	2.97 a	7.82 a	11.52 a	12.83 ab	19.46 a	23.6 a	55.74 a	103.4 a	159.2 a	0.339 a	0.82 a	250.7 a	0.794 a	0.273 a	0.7851 a	0.702 a	110.4 b	2063 b
moderately tolerant	3.01 a	7.49 a	11.8 a	12.35 b	20.04 a	22.98 a	54.59 a	102.9 a	157.5 a	0.337 a	0.81 a	244.3 a	0.792 a	0.210 a	0.7822 a	0.686 a	104.6 ab	2995 a
Heat susceptible	3.04 a	7.54 a	11.51 a	12.86 a	19.8 a	22.9 a	54.53 a	103.8 a	158.3 a	0.3395 a	0.83 a	252.2 a	0.796 a	0.290 a	0.7852 a	1.308 a	103.3 a	3381 a
Heritability	0.0	0.5	0.0	-0.1	-0.5	0.0	0.4	0.0	0.5	0.1	-0.1	0.1	0.0	0.2	-0.1	0.0	0.7	0.9

(d) Early sowing date 2 2015 agronomic traits

Traits	TKW	Scr%	CTMB	CTH	CTEGF	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIJ	NDVIH	NDVIEGF	NDVIMGF	PH	Y
Heat tolerant	2.896a	9.51 a	12.85 a	15 a	17.87 a	46.67 a	94 a	140.7 a	0.235 a	0.593 a	259.5 a	0.638 a	0.805 a	1.539 a	0.547 a	93.48 b	2058 b
moderately tolerant	2.783 a	12.9 b	12.95 a	15.29 a	17.8 a	48.31 a	92.28 a	140.6 a	0.232 a	0.564 a	246 a	0.630 a	0.814 b	0.771 a	0.58 a	87.12 ab	2401 a
Heat susceptible	2.83 a	11.44 ab	13.06 a	15.08 a	17.83 a	46.83 a	93.43 a	140.3 a	0.236 a	0.559 a	243.7 a	0.657 a	0.809 ab	0.769 a	0.542 a	86.89 a	2573 a
Heritability	0.7	0.6	0.1	-0.2	0.0	0.2	0.2	0.3	-0.1	-0.1	-0.1	0.0	1.0	0.0	0.3	0.7	0.9

(e) Late sowing date 1 2015 agronomic traits

Traits	TKW	Scr%	CTMB	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIMB	NDVILB	PH	Y
Heat tolerant	2.85 a	11.21 a	20.27 a	33.5 a	91.37 a	124.9 a	0.233 a	0.807 a	356.4 ab	0.797 a	0.710 a	84.24 b	1572 a
moderately tolerant	2.84 a	15 b	19.77 a	32.28 a	92.06 b	124.3 a	0.228 a	0.835 a	372.4 b	0.804 a	0.709 a	77.5 ab	1809 a
Heat susceptible	2.80 a	13.12 ab	20.21 a	32.44 a	90.63 a	123.1 a	0.240 a	0.814 a	346.5 a	0.803 a	0.706 a	76.17 a	1706 a
Heritability	0.2	0.3	0.1	0.5	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.2	0.8

(f) Late sowing date 2 2015 agronomic traits

Traits	TKW	Scr%	CTMB	DOFGF	DTH	DTM	GC% 1	GC% 2	GCR	NDVIH	NDVILGF	PH	Y
Heat tolerant	2.96 a	10.76 a	24.17 a	31.64 a	62.51 a	94.15 a	0.115 a	0.686 ab	617.7 a	0.670 a	0.377 a	62.43 b	1702 b
moderately tolerant	2.85 a	13.52 b	23.47 a	30.97 a	62.25 a	93.22 a	0.112 a	0.705 b	651.8 a	0.672 a	0.361 a	56.25 ab	2043 a
Heat susceptible	2.93 a	14.16 b	23.88 a	32.31 a	61.89 a	94.2 a	0.110 a	0.679 a	632.7 a	0.665 a	0.379 a	55.47 a	1964 a
Heritability	0.6	0.1	0.1	0.2	0.4	-0.1	0.0	-0.2	0.1	0.0	0.1	0.7	0.6

(g) Early sowing 2014 grain quality traits

Traits	HLW	Pro	SKHI	SY	WG	Y-pig	FY	MPH	MPT	RBD	WA8	WAP
heat tolerant	80.96 ab	16.78 b	84.49 a	71.11 a	40.59 b	6.66	58 a	54.09 a	2.40 a	81.54 a	3.50 a	18.22 a
moderately tolerant	81 b	15.79 a	84.95 a	71.52 a	37.17 a	8.24	58.42 a	58.16 a	2.94 a	68.59 a	6.31 a	19.14 a
heat susceptible	80.46 a	15.91 a	85.4 a	71.28 a	37.63 a	8.56	58.03 a	57.49 a	2. 67 a	76.05 a	4.80 a	18.26 a
Heritability	0.6	0.8	0.9	0.6	0.8	0.9	0.5	0.1	0.3	0.6	0.9	0.4

(h) Late sowing 2014 grain quality traits

Traits	HLW	Pro	SKHI	SY	WG	Y-pig	FY	MPH	MPT	RBD	WA8	WAP
heat tolerant	76.97 b	18.38 a	78.33 a	70.16 a	44.45 a	7.189 b	58.41 a	61.01 a	2.38 a	77.01 a	4.83 a	19.71 a
moderately tolerant	75.9 a	18.55 a	77.4 a	69.87 a	44.08 a	8.423 a	55.63 a	61.73 a	3.08 b	71.03 a	6.32 a	20.46 a
heat susceptible	75.38 a	18.58 a	77.86 a	69.67 a	44.58 a	8.513 a	59.03 a	61.95 a	2.71 ab	74.56 a	5.14 a	19.43 a
Heritability	0.7	0.8	0.8	0.7	0.7	0.9	0.6	-0.1	0.6	0.6	0.8	0.4

(i) Early sowing date 1 2015 grain quality traits

Traits	HLW	Pro	SKHI	SY	WG	Y-pig	FY	MPH	MPT	RBD	WA8	WAP
Heat tolerant	76.07 a	18.36 b	84.58 b	67.54 b	43.56 b	4.37 b	58.1 a	63.25 a	2.41 b	75.77 b	5.08 b	20.08 a
moderately tolerant	76.32 a	17.82 ab	86.34 a	68.48 a	41.75 a	4.96 ab	58.36 a	61.84 a	2.77 ab	62 ab	10.20 a	25.17 a
Heat susceptible	76.75 a	17.57 a	87.47 a	69.27 a	40.88 a	5.35 a	58.17 a	60.4 a	3.18 a	58.24 a	8.53 a	20.3 a
Heritability	0.6	0.6	0.8	0.8	0.7	0.9	0.0	0.1	0.6	0.8	0.9	0.5

(j) Early sowing date 2 2015 grain quality traits

Traits	HLW	protein	SKHI	SY	WG	Y-pig
Heat tolerant	74.51 a	17.93 a	81.86 b	67.99 b	43.39 a	4.99 b
moderately tolerant	74.99 a	18.22 a	83.69 a	68.92 a	44.08 a	5.42 ab
Heat susceptible	75.01 a	18.09 a	84.25 a	69.58 a	43.15 a	5.72 a
Heritability	0.4	0.6	0.7	0.9	0.6	0.8

(k) Late sowing date 1 2015 grain quality traits

Traits	HLW	Pro	SKHI	SY	WG	Y-pig
Heat tolerant	75.21 a	18.86 b	75.55 a	67.59 b	45.02 b	4.55 b
moderately tolerant	75.48 a	19.18 ab	74.61 a	68.56 a	45.56 ab	5.04 ab
Heat susceptible	75.38 a	19.63 a	74.53 a	69.07 a	46.33 a	5.22 a
Heritability	0.5	0.7	0.8	0.8	0.6	0.9

(l) Late sowing date 2 2015 grain quality traits

Traits	HLW	Pro	SKHI	SY	WG	Y-pig	FY	MPH	MPT	RBD	WA8	WAP
Heat tolerant	76.71 a	16.75 a	78.35 a	69.18 b	39.33 a	5.02	61.32 a	58.04 a	2.65 a	87.06 b	1.822 b	14.16 a
moderately tolerant	76.95 a	16.28 a	78.17 a	70.36 a	38.2 a	5.57	63.27 a	58.63 a	2.77 a	79.55 ab	4.49 ab	19.44 b
Heat susceptible	77.19 a	16.49 a	77.83 a	70.71 a	38.13 a	5.69	62.24 a	55.58 a	2.90 a	72.78 a	5.366 a	17.9 b
Heritability	0.6	0.8	0.7	0.8	0.7	0.8	0.7	0.2	0.6	0.7	0.8	0.5

yield, Thousand kernel weight (TKW), screenings% (scr%), days to heading, days to maturity, days to grain-fill, early ground cover (GC%1), late ground cover (GC%2), ground cover rate (GC rate), plant height, Normalized Differential Vegetation Index (NDVI) at heading, Normalized Differential Vegetation Index (NDVI) at jointing, canopy temperature (CT) at heading, (l) canopy temperature (CT) at early grain-fill and (m) canopy temperature (CT) at mid boot, protein content, single kernel hardness index (SKHI), hectolitre weight (HLW), semolina yield (SY), wet gluten (WG), yellow-pigment (y-pig), flour yield, mean peak height (MPH), mixograph time to peak dough development (MPT), resistance breakdown (RBD), width of curve after 8 mins mixing (WA8) and width at peak mixing time (WAP)

Note: means in columns followed by the same letter are not significantly different at P≤0.05Table 5.3: Two sided correlations different from zero (a) early sowing environment (b) late sowing environment

Table 5.3: Two sided correlations different from zero (a) early sowing environment (b) late sowing environment

(a)

Traits	CTH	DTH	FY	GC%1	GC%2	GCR	HLW	H	MPH	MPT	NDVIEGF	NDVIH	Pro	RBD	SKHI	SY	Scr%	TKW	WA8	WAP	WG	Y-pig	Y	DTGF	DTM
CTH	-																								
DTH	-0.3001	-																							
FY	0.1744	-0.2709	-																						

GC%1	0.0154	-0.0563	0.0706	-																			
GC%2	0.1117	-0.256	0.074	-0.2147	-																		
GCR	0.0618	0.0239	-0.0077	-0.846***	0.5193***	-																	
HLW	-0.1007	-0.2477	0.127	0.0585	0.3805*	0.164	-																
H	-0.582***	0.544***	-0.2704	0.0253	0.0478	0.0526	0.3514*	-															
MPH	-0.3709*	-0.0392	0.2179	0.1042	0.1911	-0.0654	0.2553	0.0293	-														
MPT	0.1702	-0.3899*	0.091	0.1243	0.0033	-0.1108	-0.2238	-0.3945*	0.0225	-													
NDVIEGF	-0.0848	0.1488	0.1403	-0.0378	-0.0756	0.0973	-0.0268	0.0814	0.14	-0.1449	-												
NDVIH	0.3982*	-0.09	0.2839	0.1901	-0.1385	-0.2533	-0.4036*	-0.5842***	0.0785	0.3507*	-0.1056	-											
Pro	-0.4243**	0.6318***	-0.0478	0.0073	-0.2265	-0.0679	-0.2055	0.3763*	0.2238	-0.4548**	0.0245	0.0815	-										
RBD	-0.2553	0.4734**	-0.2689	-0.1498	-0.1108	0.0637	0.1621	0.4976**	-0.2424	-0.7706***	0.0099	-0.3746*	0.3724*	-									
SKHI	0.3158	0.0694	-0.017	0.0934	-0.102	-0.0986	-0.2161	-0.2027	-0.144	-0.0922	-0.1139	0.335*	-0.0296	-0.1924	-								
SY	-0.0238	-0.1645	-0.0283	-0.1941	0.4475**	0.4279**	0.6089***	0.0848	-0.023	-0.1758	0.0624	-0.3242	-0.2746	0.168	-0.0994	-							
Scr%	0.1171	0.3459*	-0.0486	-0.0398	-0.309	-0.0048	-0.5014**	-0.1757	-0.0763	0.2624	0.282	0.2954	0.0378	-0.1002	0.1436	-0.1467	-						
TKW	-0.0101	-0.2165	0.1144	0.0238	0.2789	0.0527	0.583***	0.2386	0.0717	-0.3332*	-0.2133	-0.3642*	-0.1046	0.1208	0.0757	0.2345	-0.7846***	-					
WA8	0.2773	-0.4438**	0.3179	0.1203	0.1047	-0.0455	-0.1132	-0.5291***	0.3298*	0.6089***	0.0129	0.4131*	-0.3518*	-0.9322***	0.3431*	-0.0944	0.1287	-0.0738	-				
WAP	0.1195	-0.2765	0.2722	0.043	0.0328	-0.082	-0.0343	-0.4001*	0.3716	0.1723	-0.0195	0.2215	-0.1882	-0.4946**	0.3429*	-0.081	0.1178	0.0646	0.7276***	-			
WG	-0.3401*	0.6575***	-0.1345	-0.0311	-0.2243	-0.0542	-0.2147	0.3812*	0.0728	-0.5906***	-0.0016	0.0028	0.922***	0.587***	-0.0181	-0.2059	-0.0018	-0.0294	-0.5788***	-0.3696*	-		
Y-pig	0.3403*	-0.468**	0.2865	0.0224	0.0295	-0.0872	-0.3667*	-0.6227***	0.0764	0.2891	0.0359	0.4933**	-0.2372	-0.5677***	0.3938*	-0.2589	0.0917	-0.1712	0.6715***	0.533***	-0.3552*	-	
Y	0.3898*	-0.6308***	0.0358	0.1705	0.1995	-0.1292	-0.0044	-0.6105***	0.2258	0.4789**	-0.0076	0.368*	-0.4946**	-0.7025***	0.2312	0.0465	0.0214	-0.0479	0.7408***	0.5203***	-0.608***	0.6409***	-

DTGF	0.4075*	-0.7924***	0.3485*	0.1839	0.0495	-0.1307	0.0094	-0.5781***	0.0675	0.3861*	0.0961	0.3823*	-0.3585*	-0.5645***	0.0896	-0.105	-0.1443	0.0302	0.5249***	0.2462	-0.4684**	0.5556***	0.609***	-	
DTM	-0.0808	0.8113***	-0.0915	0.0878	-0.3547*	-0.0877	-0.3802*	0.3004	0.0031	-0.2425	0.3258*	0.2251	0.6489***	0.2026	0.1949	-0.359*	0.4051*	-0.3111	-0.194	-0.1983	0.5839***	-0.2026	-0.4072*	-0.2864	-

Canopy temperature heading (CTH), Days to heading (DTH), Flour yield (FY), early ground cover (GC%1), late ground cover (GC%2), ground cover rate (GCR), Hectolitre weight (HLW), height (H), mean peak height (MPH), mean peak time (MPT), NDVI early grain-fill (NDVIEGF),NDVI heading (NDVIH),protein (Pro), resistance breakdown (RBD), single-kernel harness index (SKHI), semolina yield (SY), screenings% (scr%), thousand kernel weight (TKW), width at 8minutes (WA8), width at peak (WAP), wet gluten (WG), yellow pigment (y-pig), yield (Y), days to grain-fill (DTGF) and days to maturity (DTM) *, **, *** indicates significance at P<0.05, P<0.01, P<0.001, respectively

(b)

Traits	CTH	DTH	FY	GC%1	GC%2	GCR	HLW	H	MPH	MPT	NDVIH	Pro	RBD	SKHI	SY	Scr%	TKW	WA8	WAP	WG	Y-pig	Y	DTGF	DTM
CTH	-																							
DTH	-0.067	-																						
FY	0.2425	-0.114	-																					
GC%1	-0.2308	0.2418	-0.022	-																				
GC%2	0.0973	0.0865	0.0962	0.018	-																			
GCR	-0.1501	0.1916	0.049	0.1505	0.674***	-																		
HLW	-0.1904	-0.0435	-0.225	-0.0297	-0.3489*	-0.094	-																	
H	-0.3641*	0.513**	-0.4117*	0.3892*	-0.1426	0.1155	0.3489*	-																
MPH	-0.1445	-0.2533	-0.001	-0.208	-0.0885	-0.196	0.154	-0.1018	-															
MPT	0.1627	-0.3208	0.215	-0.1701	0.2148	-0.002	-0.3909*	-0.5069**	-0.025	-														
NDVIH	0.2048	0.2552	0.2629	-0.0472	0.2952	0.1806	-0.6668***	-0.4887**	-0.135	0.2436	-													
Pro	0.4114*	-0.1482	0.2987	-0.1593	0.2224	-0.014	-0.3894*	-0.4624**	-0.027	0.3282*	0.3553*	-												
RBD	-0.197	0.4621**	-0.3553*	0.2267	-0.2712	-0.067	0.3837*	0.6583***	-0.071	-0.837***	-0.2948	-0.4514**	-											
SKHI	0.0346	0.338*	0.3488*	-0.0467	0.0315	0.0741	0.0229	-0.0294	-0.064	-0.0083	0.1955	0.0031	-0.2327	-										
SY	-0.1144	0.1176	0.0053	0.0103	-0.2717	-0.045	0.7352***	0.2645	-0.032	-0.4715**	-0.3794*	-0.2114	0.5012**	0.0061	-									
Scr%	-0.1407	-0.1452	-0.3323*	-0.1692	0.0011	-0.09	-0.1877	0.0502	0.31	0.2396	-0.0095	-0.0276	0.0238	-0.61***	-0.1621	-								

TKW	-0.0669	0.2252	-0.036	0.2161	-0.1305	0.0477	0.41*	0.3468*	-0.197	-0.2734	-0.2952	0.026	0.1159	0.4591**	0.2913	-0.6956***	-							
WA8	0.1431	-0.5343***	0.2953	-0.2512	0.2018	0.0449	-0.3746*	-0.6766***	0.1455	0.6815***	0.2924	0.3779*	-0.9323***	0.1914	-0.5291***	-0.0485	-0.1709	-						
WAP	0.1146	-0.5834***	0.0142	-0.3369*	0.0667	0.0728	-0.2264	-0.4852**	0.3091	0.1957	0.1764	0.1696	-0.4514**	-0.0807	-0.421**	0.066	-0.2206	0.6813***	-					
WG	0.3217	0.0594	0.3723*	-0.0163	0.2483	0.1668	-0.2579	-0.357*	-0.191	-0.0102	0.3422*	0.7792***	-0.109	0.0772	0.1184	-0.175	0.0789	0.0363	-0.0508	-				
Y-pig	0.381*	-0.5642***	0.2938	-0.3005	0.0926	-0.183	-0.4584**	-0.7008***	0.0079	0.4514**	0.3655*	0.4078*	-0.6251***	0.0368	-0.4923**	-0.0213	-0.2293	0.7113***	0.6145***	0.1768	-			
Y	0.1185	-0.7868***	0.1712	-0.2251	-0.0511	-0.235	-0.2136	-0.554***	0.1725	0.4997**	-0.0005	0.3402*	-0.7035***	-0.0826	-0.401*	-0.0389	-0.0636	0.7763***	0.6538***	-0.0199	0.6825***	-		
DTGF	0.1063	-0.9249***	0.2407	-0.3087	-0.0151	-0.102	-0.0812	-0.6248***	0.1909	0.4464**	-0.0588	0.1997	-0.6061***	-0.1851	-0.2132	0.0366	-0.2357	0.6664***	0.6265***	-0.0213	0.6568***	0.8343***	-	
DTM	0.0691	0.4862**	0.2554	-0.0779	0.1913	0.2649	-0.3004	-0.0961	-0.223	0.1882	0.5315***	0.072	-0.186	0.4573**	-0.1829	-0.2952	0.0465	0.1362	-0.0839	0.106	0.036	-0.1375	-0.1174	-

Canopy temperature heading (CTH), Days to heading (DTH), Flour yield (FY), early ground cover (GC%1), late ground cover (GC%2), ground cover rate (GCR), Hectolitre weight (HLW), height (H), mean peak height (MPH), mean peak time (MPT), NDVI heading (NDVIH),protein (Pro), resistance breakdown (RBD), single-kernel harness index (SKHI), semolina yield (SY), screenings% (scr%), thousand kernel weight (TKW), width at 8minutes (WA8), width at peak (WAP), wet gluten (WG), yellow pigment (y-pig), yield (Y), days to grain-fill (DTGF) and days to maturity (DTM)

*, **, *** indicates significance at P<0.05, P<0.01, P<0.001, respectively

5.3.1.2 Impact of heat stress on plant height

Plant height was reduced with increasing temperatures for both 2014 and 2015 by 25% and between 16-45%, repectively (Figure 5.1 b). The GGE biplot explained 79% of total variation in plant height (Figure 5.2 b). Early sowing in 2014 and very early and early sowing in 2015 were the most different environments. Genotype #14 was taller across all environments and genotype #93 and 23 were shorter across all environments.

Genotype, environment and G × E effects were all significant for plant height ($P < 0.001$) (Table 5.1). In 2014, heat tolerant material (based on the heat susceptibility index) was generally taller. Heritability ranged from 0.9 (early sowing) to 0.8 (late sowing) (Table 5.2) fruitful for selection. The 2015, taller genotypes were also more heat tolerant, and heritability ranged from 0.7 fruitful for selection (all sowing environments except late sowing) to 0.2 (late sowing) (Table 5.2). In 2014, taller genotypes in early sowing were #15, 14, 5, 16 and 59, which was higher than average height by 65.97, 69.86, 70.9 and 71.2% , respectively compared to ate sowing (5, 14, 5, 3,22 and 24) which was higher than average height by 68.6%, 69.2%, 72.4%, 72.8%, and 73.6%, repectively. In 2015, the taller genotypes in very early sowing were (14, 5, 3, 16 and 59)which was higher than average yield by
64.4, 73.6, 74.1, 74.7 and 74.9% , respctively and in early sowing the taller genotypes were 110, 17, 3, 14 and 88 and where higher than average height by 68.4, 96.7, 70.6, 72.6 and 73.5% In late sowing the taller gentoypes were 5, 2, 44, 18 and 21 and where taller than average heigh by 69.2, 70.1, 71.7, 73 and 73% and very late sowing 14, 59, 4, 5 and 3 and where taller than average by 51.6,
54.8, 59.3, 62.1 and 64.9%showed some G ×E for plant height.

Plant height in early sowing was highly negatively correlated with CTH, NDVI at heading, WA8, ypig, DTGF and yield (Table 5.3 a). DTH had a highly significant positive correlation with plant height
($P<0.001$). Plant height was negatively correlated with WAP and MPT and positively correlated with WG, protein and HLW ($P<0.05$).

In late sowing, plant height was negatively correlated with WA8, y-pig, yield and DTGF and a positively with RBD ($P<0.001$) (Table 5.3 b). Plant height was negatively correlated with WAP, protein, NDVI at heading and MPT and positively correlated with DTH in late sowing ($P<0.01$). Plant height was also negatively correlated with CTH, FY and WG and positively correlated with GC%1, HLW and TKW ($P<0.05$).

5.3.1.3 Impact of heat stress on screenings%

Screenings increased with increasing temperatures for both 2014 by 72% and between 1.4-41% in

2015 (Figure 5.1 c). Genotype, environment and G × E effects were all significant for screenings (Table 5.1 a). The GGE biplot explained 71.70% of the total variation in screenings% (Figure 5.2 c).. Genotypes #25 and #39 had the lowest screenings% across all environments. In 2014 TOS 1 and TOS In 2014, broad-sense heritability for screenings% was 0.8 which is fruitful for selection in both early and late sown environments (Table 5.2). However, heritability in 2015 tended to be lower and ranged from 0.5 (very early sowing) to 0.07 (very late sowing) (Table 5.2). Heat tolerant genotypes, classified as such based on their HSI, tended to have low screenings% in early, late and very late sowing in 2015 (Table 5.2).

In 2014, genotypes with low screenings% in early sowing were #43, 70, 74 ,97 and 55, which were lower than average screenings% by 26.7, 27.2, 27.8, 31.2 and 31.6%, respectively which was different to late sowing with gentoypers25, 39, 18, 44 and 2 and were lower than average screenings% by 23.4, 24. 25.9, 34.9 and 35.1% indicating significant G×E. Similarly in 2015, there was very little genotype commonality among the four environments for low screenings%.

Screening% in early sowing was highly significantly negatively correlated with TKW and HLW ($P<0.01$) (Table 5.3 a). However, screenings% was positively correlated with DTM and DTH ($P<0.05$). In late sowing, screenings% was negatively correlated with TKW and SKHI ($P<0.001$) and with FY ($P<0.05$).

5.3.1.4 Impact of heat stress on thousand kernel weight

Thousand kernel weight (TKW) decreased with late sowing in 2014 by 28% but less so in 2015 between 0.24-1.87% (Figure 5.1 d). Nevertheless, very late sowing had higher TKW relative to late sowing in 2015 – a consequence of late rainfall in that year. Genotype, environment and G × E effects were all significant for TKW ($P<0.001$) (Table 5.1 a). The GGE biplot explained 55.73% of the total variation in TKW (Figure 5.2 d) Genotype #26 had high TKW for early sowing 2014, #64 had high TKW for late sowing 2014, #48 had high TKW for very early sowing 2015, #26 was high in TKW for early sowing 2015, #2 was high in TKW in late sowing 2015 and genotype #110 had high TKW for very late sowing 2015, Early sowing and late sowing in 2014 had broad-sense heritabilities of 0.8 which is fruitful for selection and 0.5, respectively (Table 5.2). The heat tolerant genotypes, classified using hsi, had higher TKW and therefore heavier grain.

In 2015, heritability in early, late and very late sowing was 0.7 which is fruitful, 0.2 and 0.6, respectively (Table 5.2). The heat tolerant genotypes based on HSI in these environments also had high TKW which was as expected. However, very early sowing had a heritability of 0 and low TKW (Table 5.2) due to rainfall during maturity (Figure 5.1) and was discarded from further TKW analysis.

Those genotypes with the highest TKW in 2014 were 43,70,97,55 and 2 with 74.9, 77.5, 79.8. 80.8 and 81.3% above average TKW and 25,39,64,2 and 18, for early and late sowing,with 75.7, 76.9, 79.5, 80.8 and 80.8% above average, respectively. For very early sowing in 2015, the highest TKW was observed for genotypes were 60, 38, 76, 72 and 88 with increase of 79.7. 80.8, 81.3. 81.9 and 82.5%, respectively and for early sowing 2015 the highest TKW genotypes were 43,39,15,40 and 4 with increases of 79.1, 80.2, 81.3, 81.3 and 82.5%Whereas genotypes with high TKW in late and very late sowing were 38,18,25,75,78 and 55,80,110,17 and 31, respectively. With increases of 79.5, 81.8, 81.8, 83.0 , 83.0 and 82.5, 82.5, 82.5, 83.7 , 83.7, respectively. Again, significant G ×E was observed across sowing times.

In early sowing, TKW was positively correlated with HLW and negatively correlated with screenings% ($P<0.001$) (Table 5.3 a). MPT and NDVI at heading had a negative correlation with TKW in early sowing ($P<0.05$). In late sowing, TKW was highly significantly negatively correlated with screenings% (Table 5.3 b). TKW correlated positively with SKHI ($P<0.01$) and HLW ($P<0.05$).

5.3.1.5 Impact of heat stress on protein content

Protein content increased with increasing temperatures in 2014 by 14% and between 1-14% in 2015 (Figure 5.1 e). However, in 2015 protein content reduced in very late sowing due to late rainfall and reduced heat stress during late grainfill (Figure 5.1 a). Genotype, environment and G × E effects were all significant for protein content ($P<0.001$) (Table 5.1 b). The common genotypes across both years with high protein content were genotypes #3,4,5,12,14,31,54 and 59. The GGE biplot (Figure 5.2.e) explained 73.29% of the variation for protein content. Genotype #99 was high for protein content in early sowing 2014, #45 was high for protein content in very late sowing 2015 and late spwing 2014 and #15 was high in protein content for very early sowing 2015.

Heritability for protein content was 0.8 very fruitful in regards to selection for both early and late sowing in 2014, and heat tolerant genotypes based on HSI had higher protein content in early sowing and a lower content in late sowing (Table 5.2).

In 2015, heritability ranged from 0.8 very fruitful for selection (very late sowing) to 0.6 (very early and early sowing) (Table 5.2). However, the protein contents of the heat tolerant lines varied by environment. Heat tolerant materials in very early sowing had higher protein content, this was lower in early and late sowing but higher in very late sowing.

In the early sown environment, protein content was positively correlated with DTM, WG and DTH ($P<0.001$) (Table 5.3 a). Protein content was negatively correlated with CTH, MPT and yield ($P<0.01$). At p-value 0.05 Protein content was positively correlated with height and RBD, and negatively with WA8 and DTGF.

In late sowing, protein was significantly correlated with WG ($P<0.001$), and negatively with RBD and height ($P<0.01$). Protein content was negatively correlated with HLW and positively correlated with CTH, MPT, NDVI at heading, WA8, y-pig and yield ($P<0.05$).

5.3.2 Impact of heat stress on phenology

5.3.2.1 Impact of heat stress on days to heading, maturity and grain-fill

Days to heading and the grainfilling period reduced with late sowing (Figure 5.3 a b,and c). IN 2014 days to heading reduced by 29% and in 2015 between 3-34%. Days to grainfill reduced by 15% in 2014 and between 3-43% in 2015. Days to maturity reduced by 26% in 2014 and between 11-41% in 2014.

GGE biplot explained 72% of the total variation in days to heading Figure 5.4 a). Genotype #15 had longer days to heading in early and late sowing 2014. Genotype 11 and 4 had longer days to heading in very late sowing 2015, #64, 12 and 8 had longer days to heading in very early sowing 2015 and late sowing 2015, genotypes #97 had longer days to heading. The GGE biplot for days to maturity explains 67.38% of the total variation (Figure 5.4 b). Genotype #16 and 5 had longer days to maturity in 2014 TOS 1 and 2. Genotype #36 and 24 had longer days to maturity in very early sowing 2015, genotype 56 had longer days to maturity in early sowing 2015. Genotypes #4 and 50 had longer days to maturity in 2015 very late and late sowing. GGE biplot for days to grainfill explains 63.48% of the total variation. (Figure 5.4 c). Genotype #101 and 61 had longer days to grainfill in 2014 TOS 1 and 2, respectively. Genotypes #96, 47, 25 and 18 had longer days to grainfill, 2015 very early sowing. Genotype #99 had longer days to grainfill in 2015 early sowing. Genotypes #16, 14, 21, 52 and 24 had longer days to grainfill in 2015 late sowing. Genotype 48 had longer days to grainfill in 2015 very late sowing. (Figure L

Genotype, environment and G × E effects were all significant for days to heading, maturity and grainfill (Table 5.1 a). All phenological traits reduced with heat stress as expected due to acceleration in plant growth rates.

In 2014, the broad-sense heritability was high for days to heading, days to maturity and days of grainfill, ranging from 0.7 - 0.9 very fruitful for selection (Table 5.2a and 5.5b). The exception was days to maturity in late sowing in 2014 (0.4) (Table 5.2 b). However, heritability was relatively low in all 2015 environments for phenological traits which could be a result of increased rainfall in 2015 compared to 2014 (Figure 3.1 and 3.5 b) (Table 5.2 c, d, e and f).

In early sowing in 2014, heat tolerant varieties (based on HSI) had reduced days of grain-fill (31.73 dayst), longest days to heading (107.2 days) and average days to maturity (138.9 days)(Table 5.2 a). In late sowing 2014, heat tolerant genotypes have average days of grain-filling (27.5 days) and days to heading (75.65 days), but the shortest days to maturity (103.2 days) (Table 5.2 b). In very early sowing in 2015, heat tolerant genotypes had the longest grain-fill (55.74 days), average days to heading (103.4 days) and longest days to maturity(159.2 days) (Table 5.2 c). In early sowing in the same year, heat tolerant materials had the shortest grain-filling (46.67 days) and longest days to heading (94days) (Table 5.2 d). In late sowing in 2015, the most heat tolerant materials had average grain-fill period, days to heading and days to maturity (Table 5.2 e). In the very late sowing, heat tolerance was associated with average grain-filling (33.5 days) length but longer days to heading (91.37 days) and average days to maturity (124.9 days) (Table 5.2 f).

Days to heading in early sowing was positively correlated with height, protein, wet gluten and days to maturity ($P<0.001$), thus as days to heading lengthen so do these trait values (Table 5.3 a). Days to heading in early sowing was negatively correlated with yield and grain-filling period (Table 5.3 a). In late sowing, days to heading was negatively correlated with WA8, WAP, y-pig, yield and days of grain-fill (Table 5.3 b). However, early sowing, days to heading was negatively correlated with WA8 and y-pig ($P<0.01$) (Table 5.3 a). Days to heading was also correlated with RBD ($P< 0.01$) in very early sowing (Table 5.3 a). In late sowing, days to heading had a positive correlation with height, RBD and days to maturity ($P<0.01$) (Table 5.3 b). Days to heading in early sowing was positively correlated with screening % ($P<0.05$) (Table 5.3 a) and negatively correlated with MPT in the same environment. In late sowing, days to heading was positively correlated with SKHI ($P<0.05$) (Table 5.3 b).

In early sowing, days to maturity was positively correlated with days to heading, protein and wet gluten ($P<0.001$) (Table 5.3 a). In late sowing, days to maturity was positively correlated with NDVI at heading ($P<0.001$) (Table 6 b). However, in early sowing days to maturity was negatively correlated with GC%2, HLW, NDVI early grain-fill, SY and yield ($P<0.05$) (Table 5.3 a). There was also a positive correlation with screenings, thus as days to maturity increased screenings also increased. Days to maturity in the late sowing environment was positively correlation with days to heading and SKHI ($P<0.01$) (Table 5.3 b).

Grain-fill duration in early sowing was negatively correlated with days to heading, height and RBD ($P <0.001$) (Table 5.3 a) and positively correlated with WA8, y-pig and yield. In late sowing, grain-fill duration was negatively correlated with days to heading, height and RBD ($P<0.001$) (Table 5.3 b). There was also a positive correlation with WA8, WAP, y-pig and yield. In early sowing, grain-fill length was negatively correlated WG ($P<0.01$) (Table 5.3 a), whereas in late sowing grain-fill duration was positively correlated with MPT ($P<0.01$) (Table 5.3 b). In early sowing, grain-fill length was positively correlated with CT at heading, FY, MPT and NDVI at heading ($P<0.05$) (Table 5.3 a). Days of grain-fill also had a negative correlation with protein ($P<0.05$).

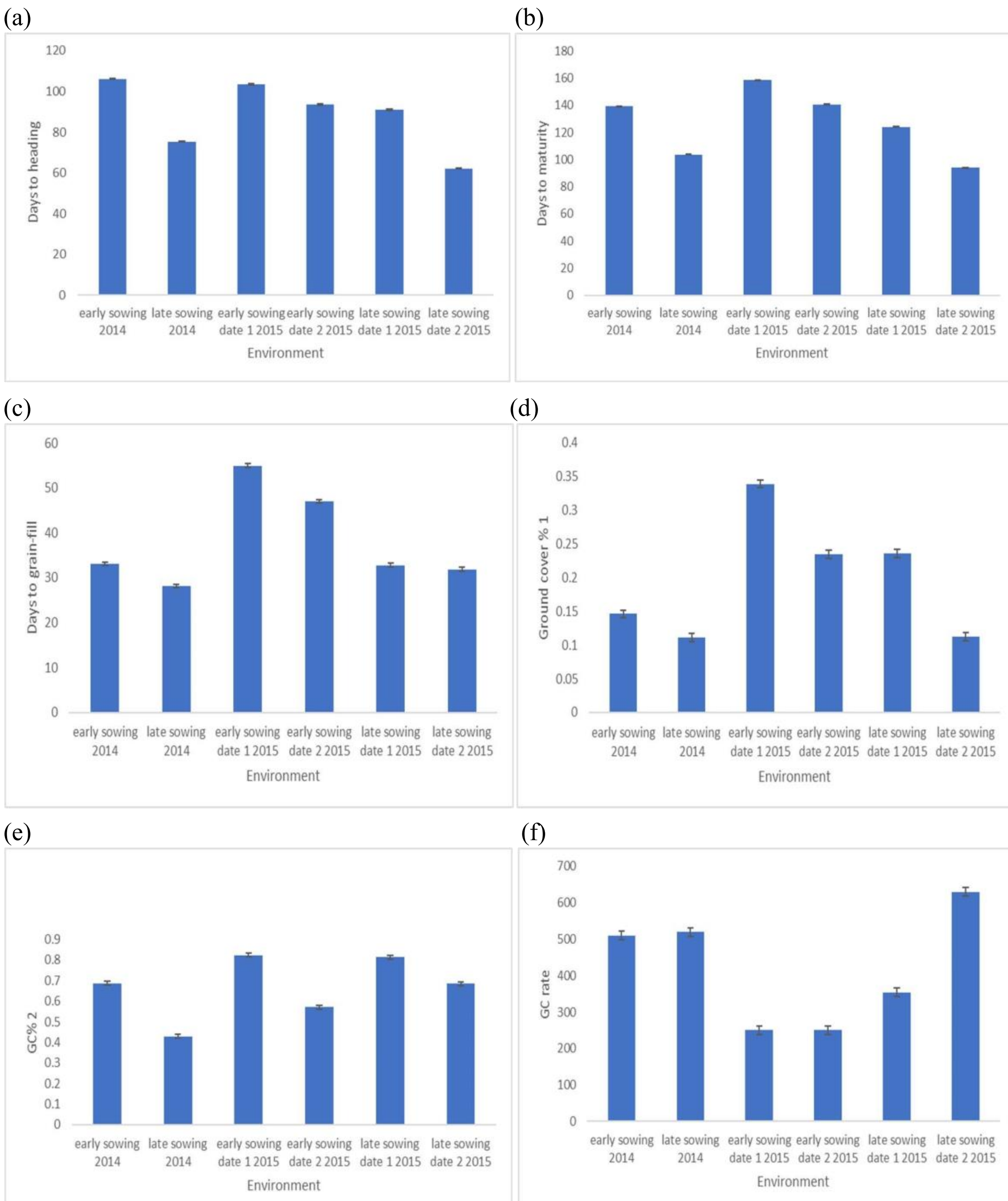
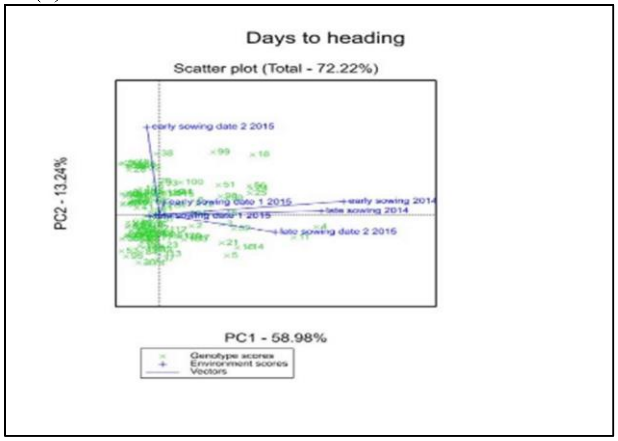
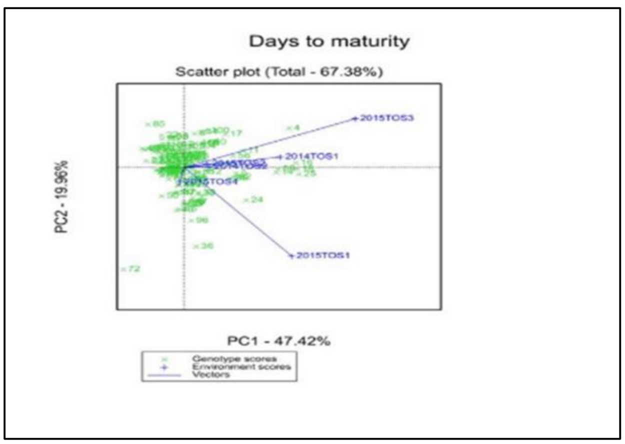

(a)
Days to heading
120
100
80
60
40
20
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment
(b)
Days to maturity
180
160
140
120
100
80
60
40
20
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment
(c)
Days to grain-fill
60
50
40
30
20
10
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment
(d)
Ground cover % 1
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment
(e)
GC% 2
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment
(f)
GC rate
700
600
500
400
300
200
100
0
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
Environment

Figure 5.3: Predicted means graph for durum phenology for six contrasting environments over two years. (a) days to heading, (b) days to maturity, (c) days to grain-fill, (d) early ground cover (ground cover% 1), (e) late ground cover (GC% 2) and (f) ground cover rate (GC rate)

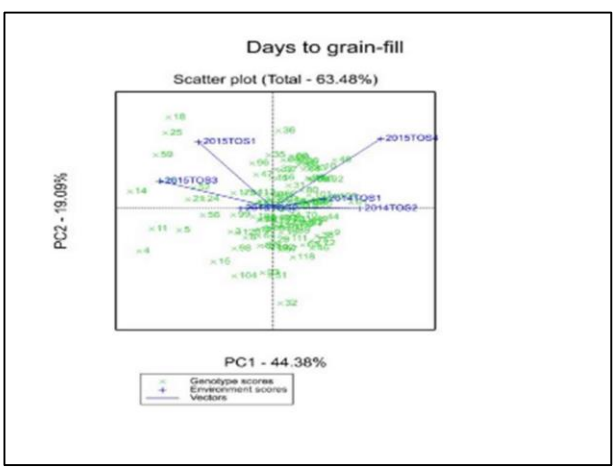
(a)



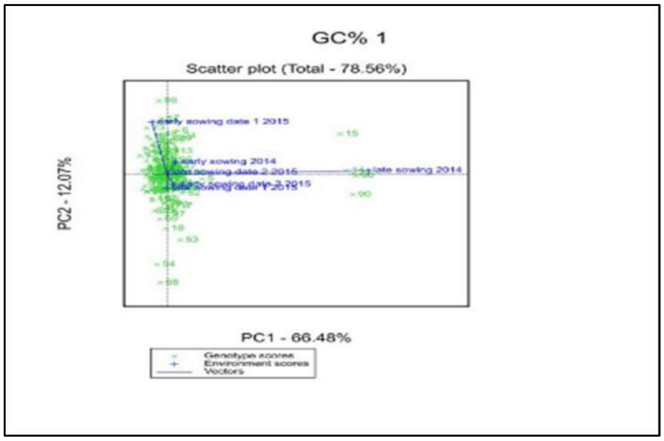
(b)



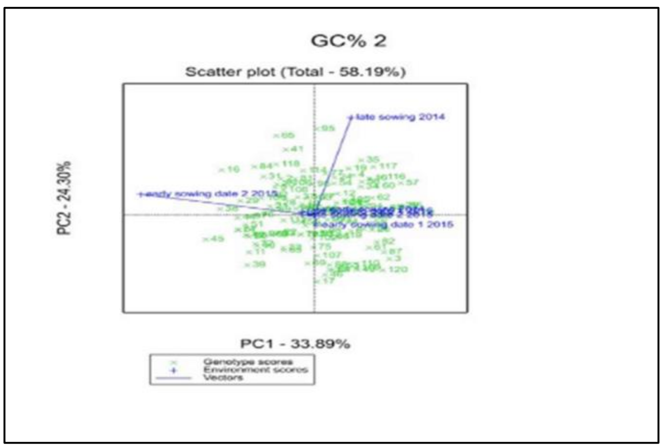
(c)



(d)



(e)



(f)

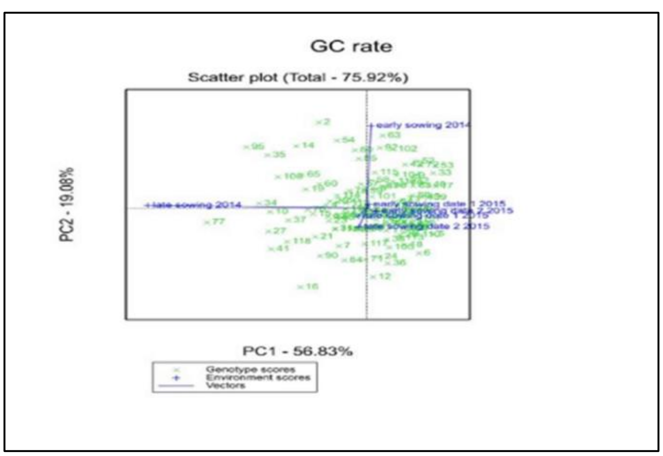


Figure 5.4: Genotype and genotype by environment (GGE) interaction biplot graph for durum phenology for six contrasting environments over two years. (a) days to heading, (b) days to maturity, (c) days to grain-fill, (d) early ground cover (ground cover% 1), (e) late ground cover (GC% 2) and (f) ground cover rate (GC rate)

5.3.2.2 Impact of heat stress on ground cover

Early ground cover (GC%1) and late ground cover (GC%2) decreased with increasing temperatures (Figure 5.3 d, Figure 5.3 e) GC%1, by 3.52% in 2014 and between 0.13-22.67% in 2015Exception was late sowing date 1, which had higher ground cover %1 and 2 by 0.13 and 24.3% ,respectively compared to early sowing date 2 which could be attributed to opportunistic rainfall during growth period (Figure 5.1 b). GC% 2 in 2014 decreased by 25.79% and between 0.95-25.25%.Ground cover rate increased with increasing temperatures (Figure 5.3 f), In 2014 by 1.75% and between 0.36-60.4% exception was 2015 early sowing date 2 by 29%, which could be attributed to increased temperatures during growth period (Figure 5.1 a). Late sowing 2014 and early sowing date 1 accounted for the majority of variation in early ground cover (Figure 5.4 d). A total of 78.56% and 58.19% of the total variation in early ground cover and late ground cover respectively, was explained (Figure 5.4 d,
Figure 5.4 e). Genotype #96 had high GC1% in 2014 TOS 1 and genotypes # 30 and 14 had high GC1% in 2014 TOS2. Genotypes #23 and 17 had high GC1% in vey early sowing 2015, genotype 5 was high in early sowing 2015, late sowing had genotype #52 with high GC1% and very late sowing had genotype #47.Genotype #50 and 95 had high GC2% in early and late sowing 2014, respectively. Very early and early sowing 2015 had gentyopes #55 and 36 with high GC2%, respectively. Late and very late sowing 2015 had genotypes #11 and 55 with high GC2%76% of the total variation in ground cover rate was accounted for (Figure 5.4 f). Genotype #63 had high GC rate in early sowing 2014 and in late sowing 2014, genotype #77 and 34 had high GC rate. Genotype #119 and 42 had high GC rate in very early and early sowing 2015, respectively. late sowing and very late sowing had genotypes #23 and 31 with high GC rate.

Genotype, environment and G × E effects were all significant for early ground cover (GC%1), late ground cover (GC%2) and ground cover rate (GC rate) ($P <0.001$) (Table 5.1 a). Ground cover increased with heat stress as expected due to acceleration in plant growth rates.

Broad sense heritability (H) was low for early ground cover, late ground cover and ground cover rate in all examined environments (Table 5.2 a-f).

In the early sowing 2014, heat tolerant varieties (based on HSI) had highest vigour for early ground cover, lowest vigour for late ground cover and ground cover rate 0.149%, 0.67% and 499.3 rate, respectively(Table 5.2 a) . Late sowing 2014, the heat tolerant varieties (basedon HSI) behaved the same as early sowing 2014 (Table 5.2 b). In very early sowing date 2015, heat tolerance (hised on HSI) was associated with average vigour for early ground cover (0.339 %), late ground cover (0.82%) and ground cover rate (250.7) (Table 5.2 c). In early sowing date 2015, the heat tolerant varieties based on HSI) had average vigour for early ground cover (0.235%)(Table 5.2 d). However, the heat tolerant varieties (HSI) had the most vigour in late ground cover and ground cover rate

0.593%, and 259.5, respectively . Late sowing date 2015, the heat tolerant varieties had average vigour for early ground cover (0.233%) and ground cover rate (356.4) (Table 5.2 e). For late ground cover (0.807%), the heat tolerant varieties (HSI) had the lowest vigour. In the very late sowing date, the heat tolerantvarities(based on HSI) was associated with high vigour in early ground cover, average vigour in late ground cover and lowest vigour for ground cover rate as follows; 0.115% 0.686% 617.7 (Table 5.2 f).

Early ground cover % (GC%1) in the early sowing environment had a highly significant negative correlation with ground cover rate (GC rate) ($P<0.001$) (Table 5.3 a). In the late sowing environment early ground cover had a significant positive correlation with plant height at $P = 0.05$ (Table 5.3 b). However, early ground cover also had a negative correlation with WAP at p-value 0.05. Late ground cover (GC%2) in the early sowing environment had a highly significant negative correlation with ground cover rate (GC rate) at $P<0.001$ (Table 5.3 a). GC%2 had a significant positive correlation with SY at p-value 0.01. GC%2 had a negative correlation with days to maturity and a positive correlation with HLW ($P<0.05$). In the late sowing environment GC%2 had a highly significant positive correlation with GC rate however, this correlation was negative in the early sowing environment (Table 5.3 b). GC%2 also had a negative correlation with HLW ($P<0.05$) which was also negative in the early sowing environment. In the early sowing environment ground cover rate (GC rate) had a highly significantly negative correlation with GC%1 and GC%2 at p-value <0.001 (Table
5.6 a). SY was also positively correlated with GC rate at p-value 0.01. In the late sowing environment GC rate had a highly significant positive correlation with GC%2 at $P <0.001$ which was negative in the early sowing environment (Table 5.3 b).

5.3.2.3 Impact of heat stress on normalised vegetation index

NDVI heading included the environments early sowing 2014, late sowing 2014, very early sowing date 2015, early sowing date 2015 and very late sowing date 2015. NDVI jointing was only taken for very early sowing date 2015 and early sowing date 2015. NDVI at heading period decreased with heat stress in 2014 by 18.4% and in 2015 by 2.9% (Figure 5.5 a). Exception to this there was an increase in NDVI in the 2015 trial during very early sowing to early sowing (by 17.4%). This could be attributed rainfall and heat stress during critical growth stages in early sowing date 2015 and very late sowing date 2015 (Figure 5.1 a and Figure 5.1 b). NDVI at jointing decreased with heat stress by 18.7% (5.6 b). A total of 77.48% and 100% of the total variation in NDVI heading and jointing respectively, was explained (Figure 5.6 a, Figure 5.6 b). Genotypes #2 and 49 had the lowest NDVI heading across all environments. Genotypes #46, 75 and 15 had high NDVI at heading in 2014 early and late sowing. Genotypes #23, 99 and 83 had high NDVI at heading in environments very early and early sowing 2015. Genotype# 96 and 40 had high NDVI at heading for very late sowing 2015.

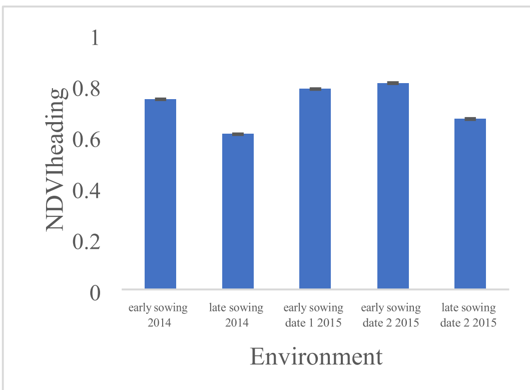
Genotype #55 had low NDVI at jointing across all environments. Genotype #115, 29, 36 had high NDVI at jointing for very early sowing 2015. Genotype #22 and 12 had high NDVI at jointing for early sowing 2015.Genotype, environment and G × E effects were all significant for NDVI at heading and jointing ($P<0.001$) (Table 5.1 a). NDVI decreased with heat stress as expected due to acceleration in plant growth rates.

In early sowing 2014, the heat tolerant varieties (based on HSI) for NDVI at heading and NDVI at early grain-fill had low NDVI values 0.72 0.62, respectively with broad sense heritability 0.5 and 0, respectively (Table 5.2 a). In Late sowing 2014, NDVI at heading was also low (0.58) for the heat tolerant varieties (based on HSI) with HSI of 0.6 (Table 5.2 b). Very early sowing date 2015 had a broad-sense heritability for NDVI ranging from 0-0.2 (Table 5.2 c). The heat tolerant material based on HSI had average NDVI readings (0.273, 0.7851, and 0.702). In early sowing 2015, NDVI measurements for the early sowing date 2015 environments were taken at jointing, heading, early grainfill and mid grainfill with heritabilities of 0, 1, 0 and 0.3, respectively. Also, the heat tolerant material based on NDVI HSI were observed to be 0.638, 0.805, 1.539 and 0.547 , respectively(Table 5.2 d). In late sowing 2015, NDVI mid boot and late boot had a heritability of 0.1 and the heat tolerant material based on HSI had low and high NDVI measurements, 0.797 and 0.710, respectively (Table 5.2 e). In late sowing date 2 2015, NDVI heading and NDVI late grainfill had H values of 0.0 and
o.07, respectively. the heat tolerant material based on HSI were found to have average NDVI measurements 0.670 and 0.377, respectively.

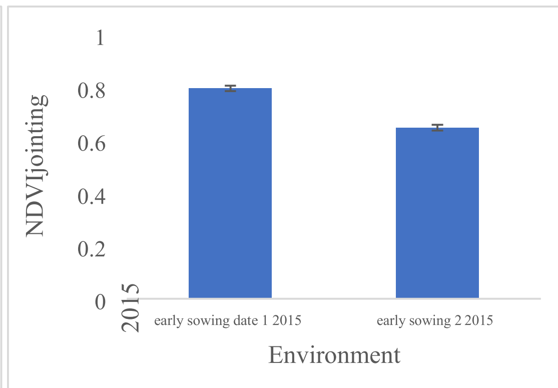
NDVI in the early sowing environment was positively correlated at early grain-fill with NDVI at heading (Table 5.3 a). NDVI early grain-fill was positively correlated with days to maturity ($P<0.05$).

NDVI heading was found to have a highly significant negative correlation with height ($P<0.001$). NDVI heading was also correlated with y-pig ($P<0.01$). NDVI heading was negatively correlated with
HLW, RBD and TKW ($P<0.05$). NDVI heading was also positively correlated with MPT, SKHI, WA8, yield and days of grain-fill ($P<0.05$). Late sowing also showed correlations for NDVI heading (Table 5.3 b). NDVI heading at a negative correlation with HLW and a positive correlation with days to maturity ($P<0.001$). At p-value 0.01 NDVI heading had a negative correlation with height ($P<0.01$). Protein, WG and y-pig were negatively correlated with NDVI heading and as was SY ($P<0.05$).

(a)

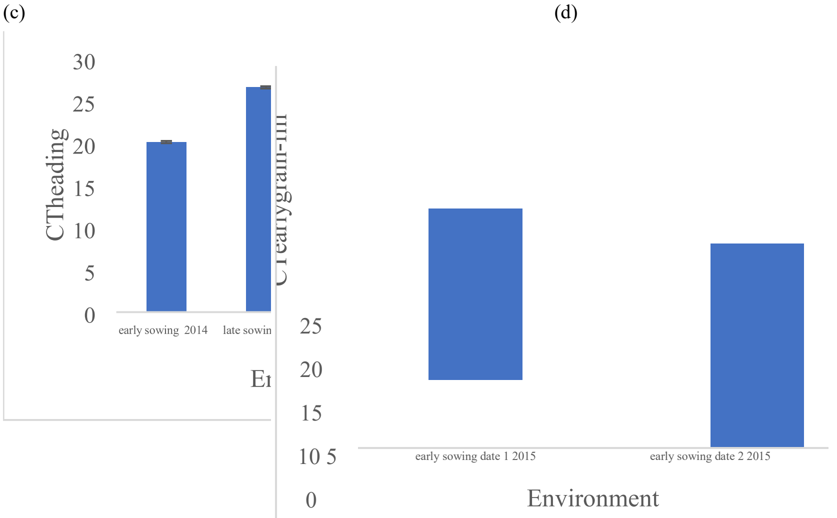

1
0.8
0.6
0.4
0.2
0
NDVIheading
early sowing 2014
late sowing 2014
early sowing date 1 2015
early sowing date 2 2015
late sowing date 2 2015
Environment

(b)

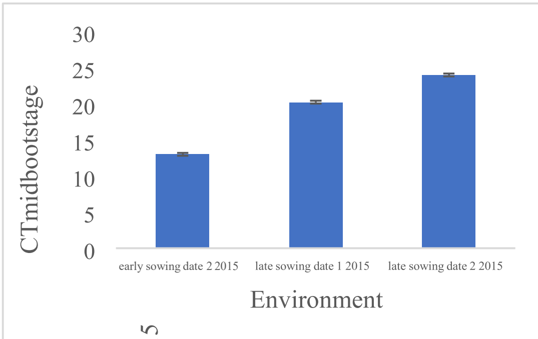

1
0.8
0.6
0.4
0.2
0
NDVIjointing
2015
early sowing date 1 2015
early sowing 2 2015
Environment

(c)

(d)


30
25
20
15
10
5
0
CTheading
early sowing 2014
late sowin
25
20
15
10 5
0
early sowing date 1 2015
early sowing date 2 2015
Environment

(e)



2015

Figure 5.5: Predicted means for Durum normalised vegetation index (NDVI) and canopy temperature (CT) measurements which were taken in various contrasting environments. (a) NDVI at heading for five environments over two years, (b) NDVI jointing for early sowing date 1 2015 and early sowing date 2 2015, (c) CT at heading for four contrasting environments over two years, (d) CT early grain-fill for early sowing date 1 2015 and early sowing date 2 2015 and (e) CT mid-boot stage for early sowing date 1 2015, late sowing date 1 2015 and late sowing date 2 2015.

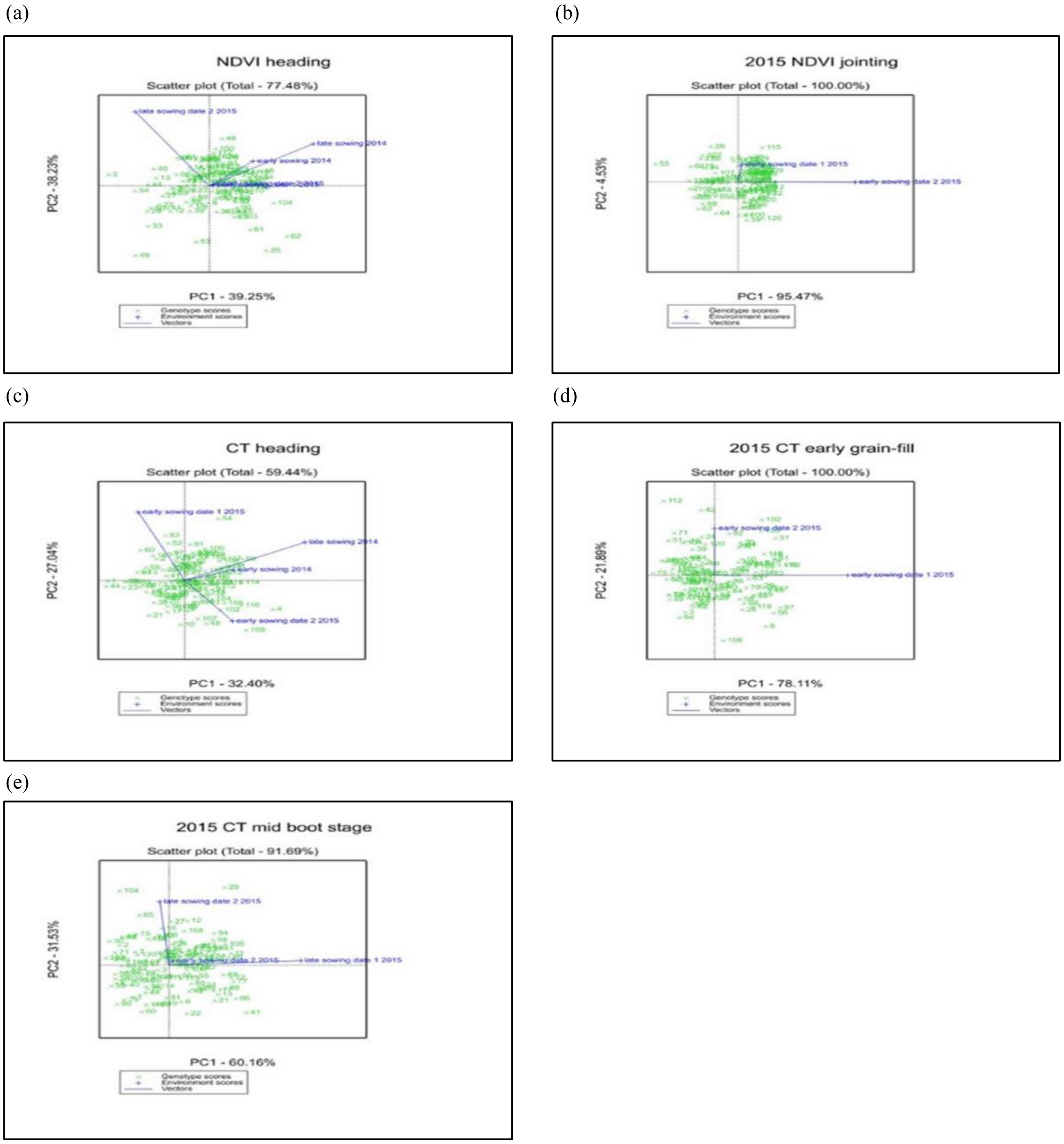


Figure 5.6: Genotype and Genotype by environment (GGE) biplot of Durum normalised vegetation index (NDVI) and canopy temperature (CT) measurements which were taken in various contrasting environments. (a) NDVI at heading for five environments over two years, (b) NDVI jointing of early sowing date 1 2015 and early sowing date 2 2015, (c) CT at heading for four contrasting environments over two years, (d) CT early grain-fill for early sowing date 1 2015 and early sowing date 2 2015 and (e) CT mid-boot stage for early sowing date 1 2015, late sowing date 1 2015 and late sowing date 2 2015.

5.3.2.4 Impact of heat stress on canopy temperature

Canopy temperature at heading (Figure 5.5 c) was taken for early sowing 2014, late sowing 2014, very early sowing date 2015 and early sowing date 2015. CT early grain-fill was taken for very early sowing date 2015 and early sowing date 2015 (Figure 5.5 d). CT mid boot stage was taken for early sowing date 2015, late sowing date 2015 and very late sowing date 2015(Figure 5.5). A total of 59%, 100% and 91.69% of the total variation in CT heading, early grainfill and mid boot, respectively was explained (Figure 5.6 c – Figure 5.6 e). Early sowing 2014,had genotypes #42, 12 and 11 with high CT at heading, very early sowing had genotypes #83, 52 and 64 with high CT at heading and genotpyes #109, 48,107 and 102 with high CT at heading for early sowing 2015. Genotype #66 was high in CT at heading for environment late sowing. Genotypes #42, 24, 120 and 92 were found to have high CT at early grainfill in early sowing 2015. Genotypes #83 and 180 had high CT early grainfill for very early sowing 2015. Genotypes #66 and 11 were found to have high CT at mid boot stage during late sowing 2015 and very late sowing 2015 found genotypes # 85 and 104 to be high in CT during mid boot stage.

CT heading, early grainfill and mid boot all found to have a highly significant relationship with environment interaction with a p-value <0.001 (Table 5.1 a). CT measurements reveal that with temperature increase CT also increases. CT heading for 2014 and 2015 had increases of 24.3 and 15.3%, respectively and fpr CT mid boot there was increases between 15.7-45.8%Exception was CT at early grainfill was found to reduce with heat stress by 9.5%, this result could be attributed to the level of low heat stress during the early grainfill period of very early sowing and early sowing (Table 5.1 a)

In early sowing 2014, CT at heading depicted that the heat tolerant material (based on HSI) had low CT (19.91) and had a H value of 0.06 (Table 5.2 a). Late sowing 2014, had a H value 0.1 (Table 5.2 b) and he heat tolerant varieties based on HSI also, had the low CT (26.3). CT measurements for very early sowing date 2015, were taken at jointing, heading, early grain-fill and mid grain-fill. CT at jointing and heading had average CT (11.52 and 12.83) for heat tolerant material (based on HSI) (Table 5.2 c). At early grain-fill the heat tolerant material based on HSI had low CT (19.46) and mid grain-fill had the highest CT (23.6) for heat tolerant varieties. CT heritability was low for early sowing date 1 2015. Early sowing date 2015 had CT measurements taken at mid boot, heading and early grain-fill with values of 12.85, 15 and 17.87, respectively (Table 5.2 d). Heat tolerant genotypes (based on HSI) had low CT for mid boot and heading and the highest for early grain-fill. The heritability of CT trait in early sowing date 2015 was low. Late sowing date 2015 and very late sowing date 2015 had CT measurements taken at mid boot with values of 20.27 and 24.17, respectively (Table 5.2 e and 5.5f). The heat tolerant genotypes (based on HSI) had the highest CT for both late sowing date 2015 and very late sowing date 2015, the heritability of the trait was low for both as well.

In the early sowing environment CT at heading had a highly significant negative correlation with HLW (Table 5.3 a). There was also a negative correlation with protein at p-value 0.01. At p-value 0.05 CT heading was negatively correlated with MPH and WG. There was positive correlation as pvalue 0.05 with NDVI at heading, y-pig, yield and days of grain-fill. In the late sowing environment CT heading had correlations at p-value 0.05 with height which was negative and a positive correlation with protein and y-pig (Table 5.3 b).

5.3.3 Impacts of heat stress on grainquality traits

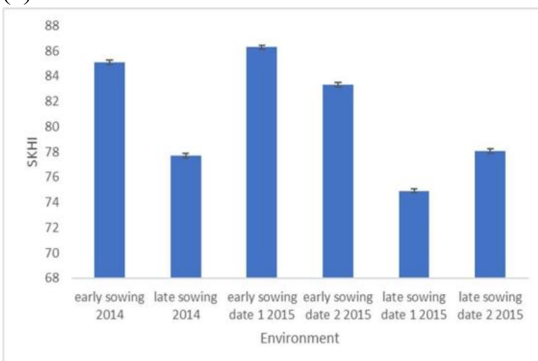
5.3.3.1 Impact of heat stress on single kernel hardness index

Single-kernel hardness index (SKHI) reduced with increasing temperatures for both 2014 and 2015 by 8.7% and between 3.4-13.2%, respectively (Figure 5.7 a). Exception to this was 2015 very late sowing, whereby SKHI was higher (4%) than late sowing but still lower than early sowing. This could be attributed to reduced heat stress during critical growth periods resulting from sowing from August associated with weather conditions (Figure 5.1 a). Genotype, environment and G × E effects were all significant for SKHI ($P < 0.001$) (Table 5.1 b). The GGE biplot explained 79% of the total variation (Figure 5.8 a). Genotype #60 and 97 has SKHI in early sowing 2014 and for late sowing 2014, genotype # 78 and 118 had high SKHI. Very early and early 2015 had genotype 77 with high SKHI and for very late and late sowing 2015, genotypes #56 and 17 has high SKHI, respectively.

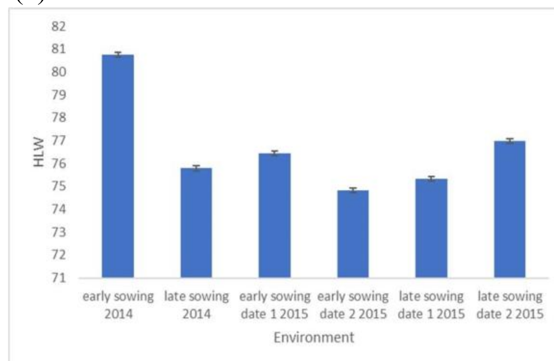
In the early sowing environment SKHI had a positive correlation at p-value with 0.05 with WA8, WAP and y-pig (Table 5.3 a). In the late sowing environment SKHI had a highly significant inverse correlation at p-value <0.001 with screenings% (Table 5.3 b). At p-value 0.01 SKHI was correlated with TKW and DTM. At p-value 0.05 SKHI was correlated with FY.

SKHI in the early sowing environment 2014 had a high H value of 0.9 and the heat tolerant varieties, classed using HSI had low SKHI (84.49 g)(Table 5.2 g). The late sowing environment 2014 also had a high H value of 0.8. However, the heat tolerant varieties, based on HSI had high SKHI
(78.33g)value (Table 5.2 h). The heat tolerant varieties, based on HSI in very early sowing date 2015 had low SKHI (84.58g) and a high H value of 0.8 (Table 5.2 i). Early sowing date 2015 also had a high H value of 0.7 and the heat tolerant varieties, classified using HSI had low SKHI (81.86) as well (Table 5.2 j). The late sowing environment 2015 had a high H value of 0.8 and the heat tolerant varieties, based on HSI had high SKHI (75.55 g)(Table 5.2 k). Very Late sowing date 2015 also had a high H value of 0.7 and the heat tolerant varieties based on HSI had high SKHI (78.35g) as well (Table 5.2 l).

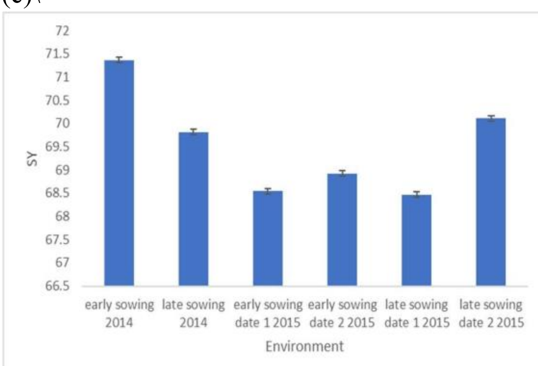
(a)



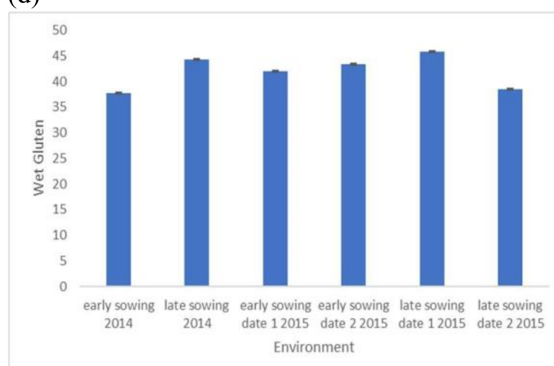
(b)



(c)\



(d)



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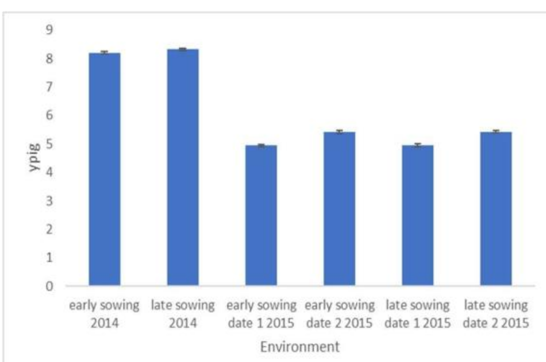
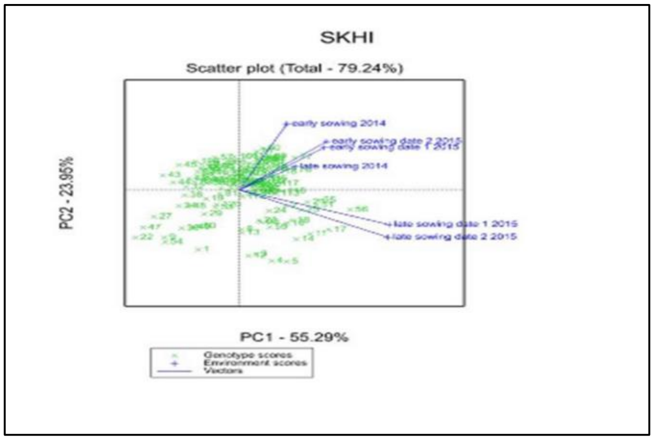
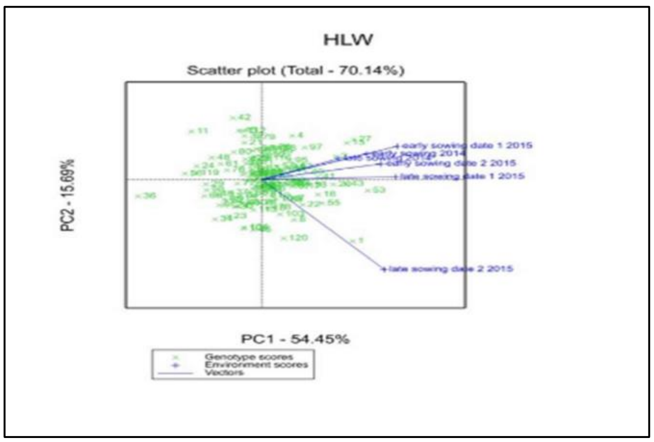


Figure 5.7: Predicted means graph for durum grain quality traits for six contrasting environments over two years. (a) single kernel hardness index (SKHI) , (b) hectolitre weight (HLW), (c) semolina yield (SY), (d) wet gluten (WG) and (e) yellow-pigment (ypig)

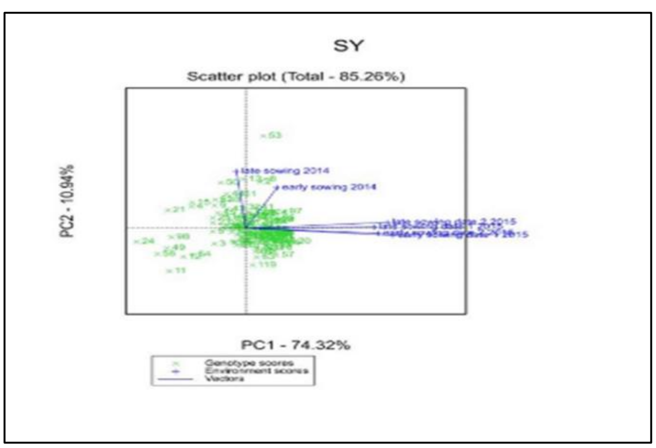
(a)


SKHI
Scatter plot (Total - 79.24%)
early sowing 2014
late sowing 2014
late sowing date 1 2015
late sowing date 2 2015
PC2 - 23.95%
PC1 - 55.29%
Genotype scores
Environment scores
Vectors

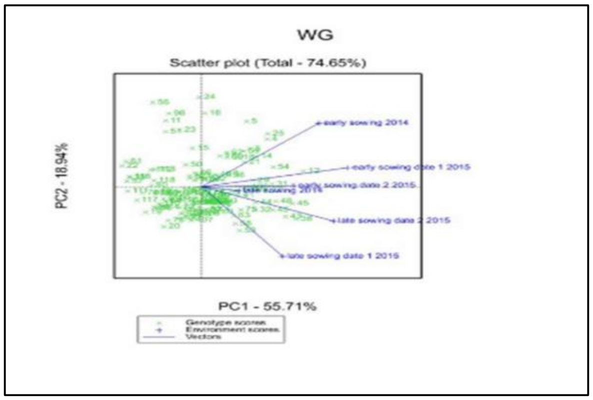
(b)


HLW
Scatter plot (Total - 70.14%)
early sowing date 1 2015
early sowing date 2 2015
late sowing date 1 2015
late sowing date 2 2015
PC2 - 15.69%
PC1 - 54.45%
Genotype scores
Environment scores
Vectors

(c)


SY
Scatter plot (Total - 85.26%)
late sowing 2014
early sowing 2014
PC2 - 10.94%
PC1 - 74.32%
Genotype scores
Environment scores
Vectors

(d)



(e)

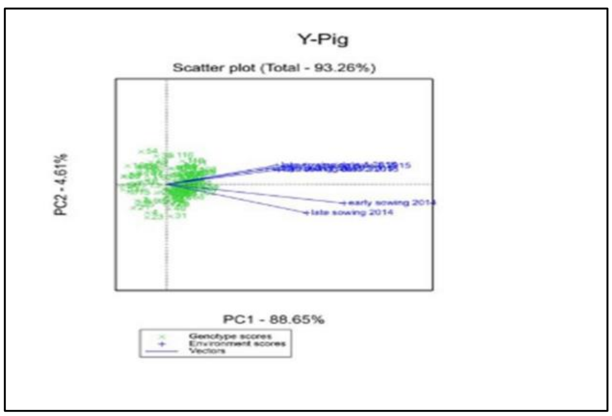


Figure 5.8: Genotype and Genotype by environment biplot graph of durum grain quality traits for six contrasting environments over two years. (a) single kernel hardness index (SKHI), (b) hectolitre weight (HLW), (c) semolina yield (SY), (d) wet gluten (WG) and (e) -pigment

(ypig)

5.3.3.2 Impact of heat stress on hectolitre weight

Hectolitre weight reduced with heat stress in 2015 by 6.2% and between 1.5-2.1% in 2015 (Figure 5.7
b). Exception to this was the late sowing dates of 2015 resulted in an increase in HLW compared to early sowing dates of 2015 between 0.7-2.8%. This result is due to the increased rainfall experienced during the critical growth periods for the late sowing date trials (Figure 5.1 b). Genotype, environment and G × E effects were all significant for HLW ($P<0.001$) (Table 5.1 b). The GGE biplot for HLW (Figure 5.8 b) explains 70.14% of the total variation for HLW. Genotype #36 had low HLW across all environments. Genotype #2 had high HLW in 2015 early and late sowing. Genotype #27 and 13 had high SKHI in very early sowing 2015, genotype #40 had high SKHI in early sowing 2015, Very late and late sowing 2015 had genotypes #53 and 1 with high SKHI, respectively.

HLW in the early sowing environment 2014 had an H value of 0.6 and the heat tolerant genotypes, classified using HSI had average weights(80.96) (Table 5.2 g). In the late sowing environment 2014 HLW had an H value of 0.7 and the heat tolerant varieties, based on HSI had high weights (76.97) (Table 5.2 h). HLW in the very early sowing date 2015 environment HLW had a H value of 0.6 and the heat tolerant varieties, classified HSI had low weights (84.58) (Table 5.2 i). In the early sowing date 2015 environment HLW had a H value of 0.4 and the heat tolerant varieties, based on HSI had low weights (74.51) (Table 5.2 j). In the late sowing date 2015 environment the heat tolerant varieties, based on HSI had low weights (75.21)and a H value of 0.5 (Table 5.2 k). In the very late sowing date 2015 environment the heat tolerant genotypes, classified using HSI had low weights (76.71) and a H value of 0.6 (Table 5.2 l).

In the early sowing environment HLW had a highly significant positive correlation at p-value <0.001 with SY and TKW (Table 5.3 a). At p-value 0.01 HLW had a negative correlation with screenings%. At p-value 0.05 HLW was correlated with height and GC% 2 and inversely correlated with DTM, ypig and NDVI at heading. In the late sowing environment HLW had a highly significant positive correlation at p-value <0.001 with SY negative correlation with NDVI at heading (Table 6 b). At pvalue 0.01 HLW had a negative correlation with y-pig. At p-value 0.05 HLW was correlated with height, RBD and TKW and inversely correlated with GC%2, MPT, protein and WA8.

5.3.3.3 Impact of heat stress on semolina yield

Semolina yield (SY) decreased with late sowing by 2.2% in 2014 (Figure 5.6 c). However, in 2015 SY increased in very late vs. early sowing date by 1,7%, and was not changed between late sowing date and very early sowing date. The fluctuations in SY in 2015 could be attributed to rainfall and heat stress during critical growth periods during September-October (Figure 5.1 a and Figure 5.1 b).

Genotype, environment and G × E effects were all significant for SY (P <0.001). GGE biplot for SY (Figure 5.8 c) explains 85.26% of total variation. Genotypes #2 and 8 had high SY in early sowing 2014 and genotypes #13 and 50 had high SY in late sowing 2014. Genotype #24 had low SY across all environments.

SY in the early sowing environment 2014 had H value of 0.5 and the heat tolerant genotypes, based on HSI had low SY (Table 5.2 g). However, in the late sowing environment 2014 the heat tolerant genotypes, classified using HSI had high SY and high H value of 0.7 (Table 5.2 h). All the environments examined in 2015 had high H values between 0.8 and 0.9 and the heat tolerant varieties based on HSI all low SY (Table 5.2 i-l).

In the early sowing environment Sy had a highly significant correlation with HLW at p-value <0.001 (Table 5.3 a). At p-value 0.01 SY was correlated with GCR and GC%2. At p-value 0.05 SY had a negative correlation with DTM. In the late sowing environment SY had a highly significant positive correlation at p-value <0.001 with HLW and negative correlation with WA8 (Table 5.3 b). At p-value 0.01 SY was negatively correlated with y-pig and WAP and positively correlated with RBD. At pvalue 0.05 SY was negatively correlated with yield and NDVI at heading.

5.3.3.4 Impact of heat stress on wet gluten

Wet gluten increased with heat stress in 2014 by 14.9% and between 3.2-8.3 in 22015 (Figure 58 d). Exception to this is environment very late sowing date 2015 which has reduced WG levels between 8.1-15.7% compared to early sowing date 2015. This result could be attributed to rainfall and heat stress (Figure 5.1 a and Figure 5.1 b) which could have affected WG levels during critical growth stages August-October. Genotype, environment and G × E effects were all significant for WG (P<0.001) (Table 5.1 b). The GGE biplot for WG (Figure 5.8 d) explains 74.65% of the total variation for wet gluten. Genotypes #25 and 4 had high WG in early sowing 2014 and in late sowing 2015, genotypes #41 and 28 had high WG. Very late and late sowing had genotypes #53 and 38 with high WG, respectively. Very early and early sowing 2015, had genotypes #12 and 31 with high WG.

WG in early sowing 2014 had a H value of 0.8 and the heat tolerant genotypes, based on HSI also had high WG (40.59) (Table 5.2 g). The heat tolerant genotypes, classified using HSI in late sowing 2014 environment had average WG (44.45)and a H value of 0.7 (Table 5.2 h). Very early sowing

date 2015 also had a H value of 0.7 and the heat tolerant genotypes, based on HSI had high WG (43.56) (Table 5
i). The heat tolerant varieties classified using HSI in early sowing date 2015 had average WG (43.39)and a H value 0.6 (Table 5 j). The environment late sowing date 2015 also had a H value of 0.6 and the heat tolerant genotypes, based on HSI also had low WG (45.02)(Table 5.2 k). The heat tolerant genotypes, based on HSI in very late sowing date 2015 had a high WG (39.33) and a high H value of 0.7 (Table 5.2 l).

In the early sowing environment WG had a highly significant positive correlation at p-value <0.001 with DTH, protein content, RBD and DTM and negative correlation with MPT, WA8 and yield (Table 5.3 a). At p-value 0.01 WG was negatively correlated with DTGF. At p-value 0.05 WG was correlated with height and inversely correlated with y-pig, WAP and CTH. In the late sowing environment WG was positively correlated at p-value 0.05 with FY and NDVI at heading and negatively correlated with height (Table 5.3 b). WG had a highly significant correlation with protein at p-value <0.001.

5.3.3.5 Impact of heat stress on yellow pigment

Yellow pigment (Y-pig) increased with increasing temperatures in 2014 by 1.4% and between 0.3-9% in 2015 (Figure 5.7 e). Exception to this was late sowing 2015 where there was a decrease in rate (8.5-8.8%) due to rainfall and heat stress (Figure 5.1 a and Figure 5.1 b) which could have affected YG levels during critical growth stages August-October.

Yellow pigment (Y-pig) had a highly significant relationship with genotype, environment and genotype by environment interaction at p-value <0.001 (Table 5.1 b). The GGE biplot for yellow pigment (Figure 5.8 e) explains 93.26% of the total variation. Genotpes #16,53,75,21,4,23 and 54 had low YP across all environments. Genotype #108 and 102 had high YP across all environments.

Y-pig for all the examined environments in both years had high H value between 0.8 and 0.9 and the heat tolerant genotypes, based on HSI had low y-pig (Table 5.2 g-l).

In the early sowing environment Y-pig had a highly significant positive correlation with at p-value <0.001 with DTGF, yield, WA8, WAP and negatively correlated with RBD and height (Table 5.3 a). At p-value 0.01 Y-pig was positively correlated with NDVI at heading and negatively correlated with DTH. At p-value 0.05 Y-pig was positively correlated with SKHI and CTH and negatively correlated with HLW and WG. In the late sowing environment Y-pig had a highly significant positive correlation with DTGF, yield, WAP and WA8 and inversely correlated with RBD, height and DTH (Table 5.3 b). At p-value 0.01 Y-pig was positively correlated with MPT and negatively correlated with HLW and SY. At p-value 0.05 Y-pig was positively correlated with NDVI at heading and CTH.

5.3.4 Impacts of heat stress on flour yield and dough rheological properties

5.3.4.1 Impact of heat stress on flour yield %

Flour yield % reduced under heat stress (Late sowing) in 2014 by 1%and by 6% in 2015 (Figure 5.9 a). Nevertheless, late sowing had increased flour yield %, a consequence of the opportunistic effects of rainfall during critical growth periods (Figure 5.1 a and Figure 5.1 b). Flour yield had a highly significant relationship with year, sowing, genotype, year by sowing, year by genotype, sowing by genotype and year by sowing by genotype interaction with a ($P < 0.001$). Sowing by genotype was significant with a p-vale 0.002 (Table 5.1 c). The GGE biplot explained 79.25% of the total variation in flour yield% (Figure 5.10 a). Early and late sowing 22014 had genotypes # 57 and 53 with high flour yield. Very early sowing and very late sowing 2015 had genotypes # 6 and 1 with high flour yield. Genotypes #21 and 22 had low flour yield across all environments. Genotype #31 was high yielding across all environments

In 2014, the broad-sense heritability for flour yield% was 0.5 and 0.6 for early sowing and late sowing, respectively (Table 5.2 g and Table 5.2 h). Heritability in 2015 ranged from 0 to 0.7 for very early sowing and late sowing, respectively (Table 5.2 i and l).In 2014 heat tolerant genotypes, classified as such based on their HSI, ranged from low flour yield% (58) to average flour yield (58.41)% for early sowing and late sowing, respectively. In 2015, the heat tolerant genotypes, based on HSI, were lower in flour yield% 58.1 and 61.32 for very early sowing and very late sowing, respectively.

In the early sowing environment flour yield had a significant correlation at p-value 0.05 with DTGF (Table 5.3 a). In the late sowing environment flour yield was inversely correlated with height, RBD and screenings% and positively correlated with SKHI and WG (Table 5.3 b).

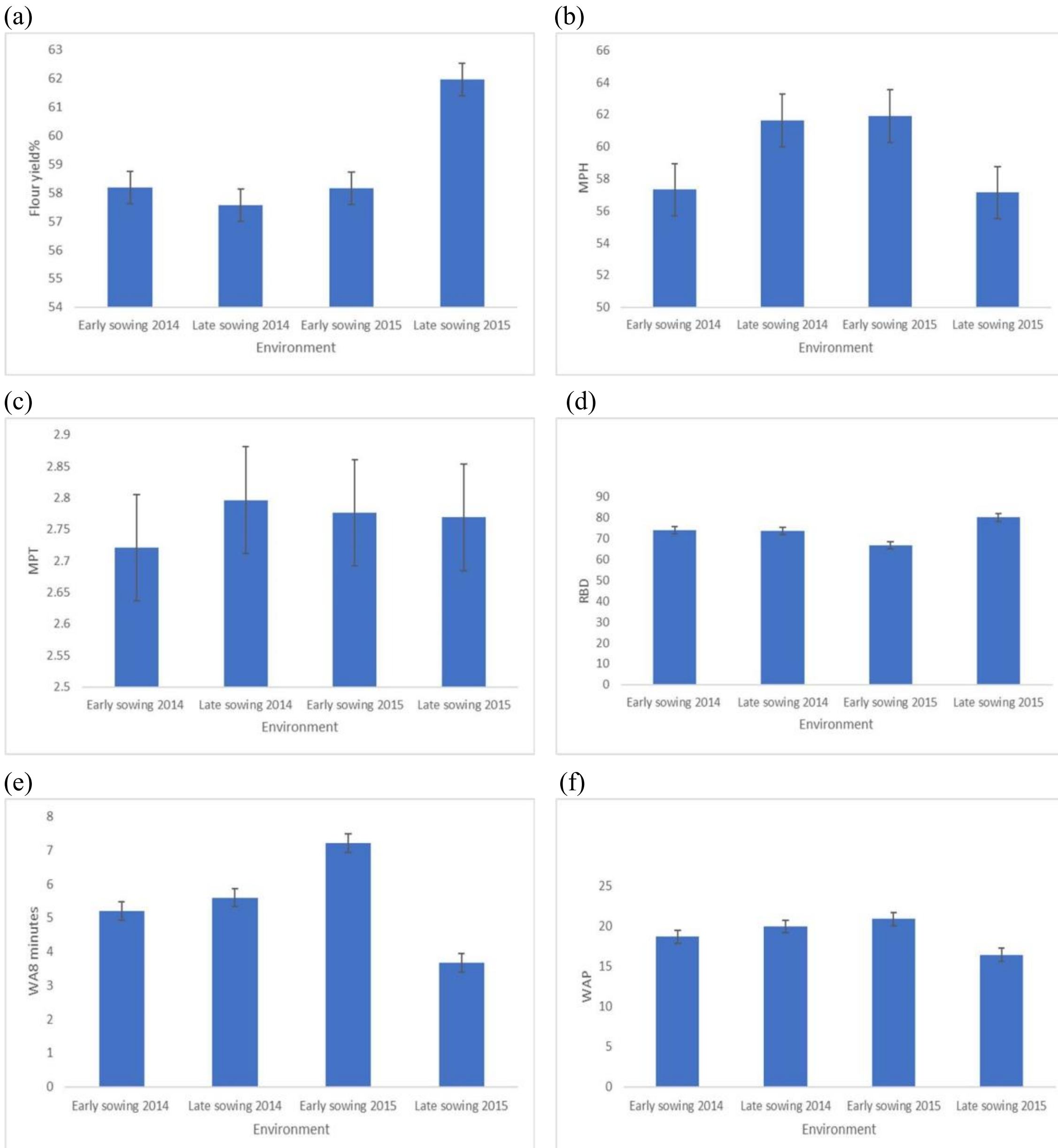
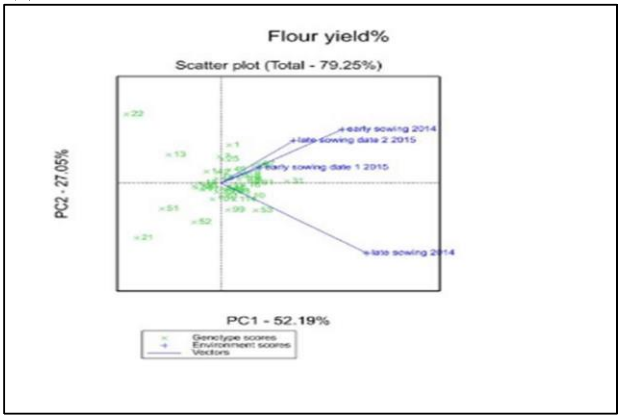


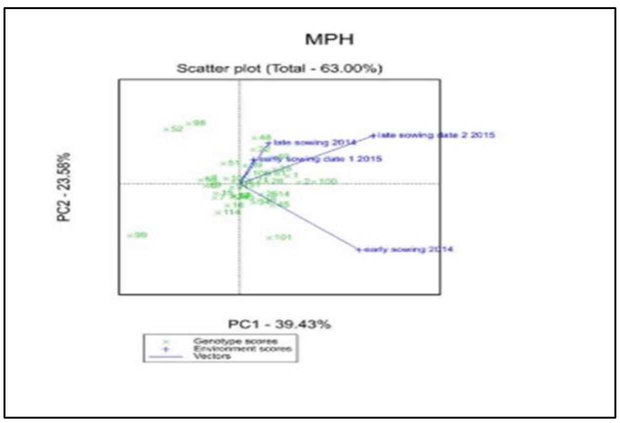
Figure 5.9: Predicted means graph for durum grain quality traits for six contrasting environments over two years. (a) flour yield %, (b) mean peak height (MPH), (c) mean peak time (MPT), (d) breakdown (RBD), (e) width at 8 minutes (WA8) and (f) width at peak (WAP)

(a)



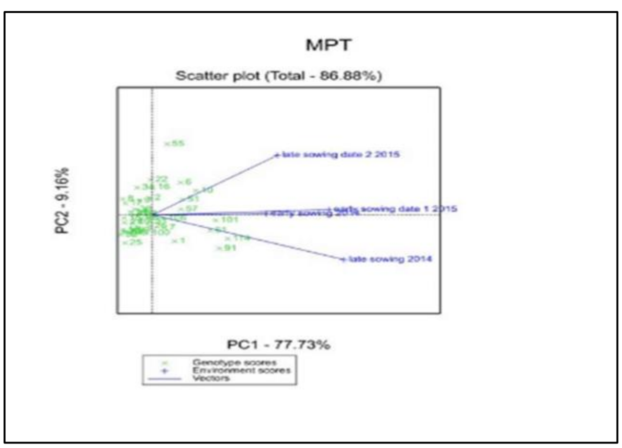
Flour yield%
Scatter plot (Total - 79.25%)
early sowing 2014
late sowing date 2 2015
early sowing date 1 2015
late sowing 2014
PC2 - 27.05%
PC1 - 52.19%
Genotype scores
Environment scores
Vectors

(b)



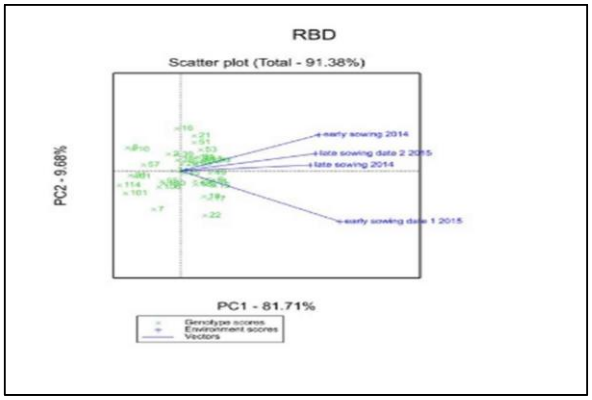
MPH
Scatter plot (Total - 63.00%)
late sowing 2014
late sowing date 2 2015
early sowing date 1 2015
early sowing 2014
PC2 - 23.58%
PC1 - 39.43%
Genotype scores
Environment scores
Vectors

(c)

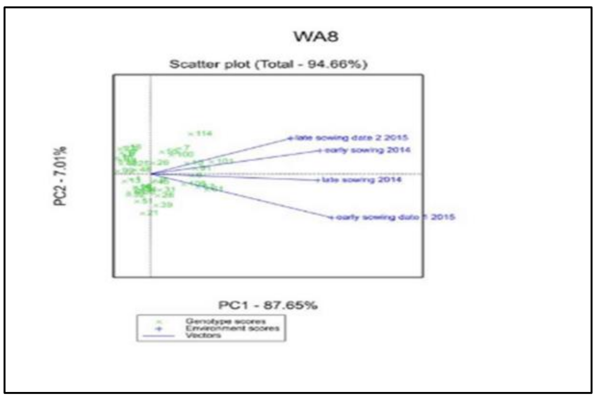


MPT
Scatter plot (Total - 86.88%)
late sowing date 2 2015
early sowing date 1 2015
early sowing 2014
late sowing 2014
PC2 - 9.16%
PC1 - 77.73%
Genotype scores
Environment scores
Vectors

(d)



(e)



(f)

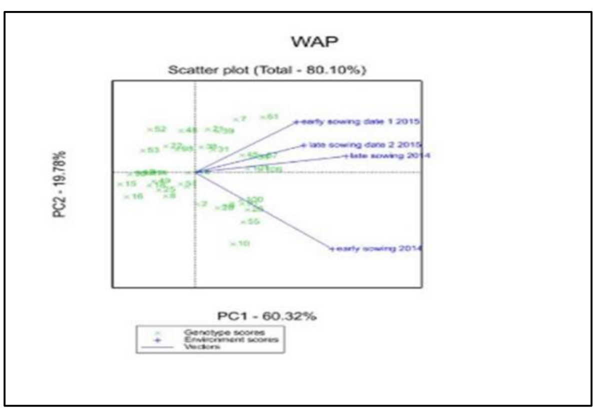


Figure 5.10: Genotype and genotype by environment (GGE) biplot of durum dough rheological properties for four contrasting over two years. (a) flour yield %, (b) mean peak height (MPH), (c) GGE bmean peak time (MPT), (d) resistance breakdown (RBD), (e) width at 8 minutes (WA8) and (f) width at peak (WAP)

5.3.4.2 Impact of heat stress on mean peak height and time to peak dough development

In 2014 MPH increased with heat in late sowing by 7%(see Figure 5.9 b). However, in 2015 MPH decreased by 8%with heat stress with early sowing having higher MPH. The GGE biplot explained 63% of the total variation for MPH (Figure 5.10 b). Early sowing 2015 had genotypes #45 and 101 with high MPH, late sowing 2014, had genotypes #22 and 48 with high MPH. Very early sowing 2015 had genotypes # 39 and 106 with high MPH and very late sowing 2015, had genotypes #26 and 61 with high MPH. genotypes #99, 52 and 98 had low MPH across all environments, while genotype 100 had high MPH across all environments.. Mean peak height has a highly significant relationship with year by sowing interaction and a significant relationship with genotype interaction (Table 5.1 c).

In 2014, early sowing date had lower MPT by 3% compared to the heat stress trial late sowing, however, in 2015 the early sowing date trial had a higher MPT by 0.3% compared to late sowing (Figure 5.9 c). The GGE biplot explains 86.88% of the total variation for MPT (Figure 5.10 c).Genotype #101 had high MPT in early sowing 2014 and genotypes # 114, 91 and 61 had high MPT in late sowing 2014. Genotype #57 had high MPT in very early sowing 2015 and genotypes # 10, 51 had high MPT in very late sowing 2015.Same as MPH, genotype 101 had high MPT across all environments.MPT has a highly significant relationship with genotype interaction with a p-value <0.001 (Table 5.1 c).

In 2014, the heat tolerant genotypes, classified based on their HSI, had low MPh and MPT, 54.09 and 2.40 for early sowing and 61.01, 2.38 for late sowing (Table 5.2 g and h), with heritability for MPH ranging between 0 and 0.2 for early sowing and late sowing with MPT ranging between 0.3 and 0.6 for early and late sowing, respectively. The 2015 trial, MPH was ranging between 0.06 and 0.2 for very earlt sowing and very late sowing, respectively with H value of 0.6 for both sowing environments (Table 5.2 i and l)

In the early sowing environment MPH was positively correlated with WA8 and negatively correlated with CT at heading at p-value 0.05 (Table 5.3 a). MPH had no significant correlation in the late sowing environment (Table 5.3 b). In the early sowing environment MPT was positively correlated with DTGF and inverse correlation with DTH, height, NDVI at heading and TKW at p-value 0.05 (Table 5.3 a). At p-value 0.01 MPT was correlated with yield. MPT had a highly significant inverse correlation with RBD and WG and a positive correlation with WA8. In the late sowing environment MPT had a positive correlation with protein and a negative correlation with HLW at p-value 0.05 (Table 5.3 b). At p-value 0.01 MPT was positively correlated with DTGF, yield and y-pig and negatively correlated with height and SY. At p-value <0.001 which is a highly significant correlation MPT was inversely correlated with RBD and positively correlated with WA8.

5.3.4.3 Impact of heat stress on resistance breakdown

In 2014 late sowing (heat stress trial) reduced resistance breakdown (RBD) by 0.7%. However, in 2015 the late sown trial had increased RBD by 17% (Figure 5.9 d). The GGE biplot explains 91.38% of the total variation in RBD (Figure 5.10 d) with very early sowing 2015 being the most different environment. Genotype #98 had high RBD in early sowing 2014 and genotype #49 had high RBD in late sowing 2014. Genotype 45, 15, 9, and 14 was high for RBD in very early sowing 2015 and genotype #98 was high in RBD in very late sowing 2015, Genotypes #114,6,10,101 and 7 had low RBD across all environments. Resistance breakdown (RBD) had a highly significant relationship with sowing, genotype and year by sowing interaction with a p-value <0.001. RBD also had a significant relationship with year by sowing by genotype interaction with a p-value 0.046 (Table 5.1 c).

The heat tolerant genotypes classified based on their HSI in all the examined environments had high RBD value and H value was between 0.6 and 0.8 indicative of a heritable trait (Table 5.2 g-l).

In the early sowing environment RBD had a negative correlation a p-value 0.05 with NDVI at heading and protein. At p-value 0.01 RBD was correlated with DTH and height and inversely correlated with WAP. At p-value <0.001 RBD had a highly significant correlation with WG and an inverse correlation with WA8, y-pig, yield and DTGF. In the late sowing environment at p-value 0.05 was correlated HLW and negatively correlated with FY (Table 5.3 b). At p-value 0.01 RBD was correlated with SY and DTH and inversely correlated with WAP and protein. At p-value <0.001 RBD had a highly significant correlation with plant height and inversely correlated with MPT, WA8, y-pig, yield and DTGF.

5.3.4.4 Impact of heat stress on width of the curve after 8 min mixing and Width of the curve at peak mixing time

In 2014 late sown trial (heat stressed) had a higher WA8 and WAP by 7 and 6%, respectively as depicted in Figure 5.9 e and Figure 5.9 f However, in 2015 the late sown trial had lower WA8 and WAP by 49 and 21%, respectively. These results could be attributed to the rainfall and temperature stress during critical growth periods (Figure 5.1 a). The GGE biplot explains 95% of the total variation in WA8(Figure 11 e). Genotypes # 91 and 101 had high WA8 for early sowing 2014 and for late sowing 2014, genotype #6 had high WA8. Genotypes #106, 57 and 61 had high WA8 for very early sowing 2015 and for very late sowing, genotype #10 had high WA8. The WAP GGE biplot explained 80.10% of the total variation(Figure 5.10 f). Genotypes #26,91,100 had high WAP for early sowing 2014 and for late sowing 2014, genotypes #14, 101 and 106 had high WAP. Genotypes #31 and 45 had high WAP for very early sowing 2015 and for very late sowing, genotypes #34 and 57 had high WAP.

WA8 had a highly significant relationship with sowing, genotype, year by sowing, sowing by genotype and year by sowing by genotype interaction with a p-value <0.001 (Table 5.1 c). WA8 also had a significant relationship with sowing by genotype interaction with a p-value of 0.001. WAP was found to have a highly significant relationship with genotype and year by sowing interaction with a pvalue <0.001 (Table 5.1 c). WAP also had a significant relationship with sowing interaction with a pvalue 0.005 and year by genotype interaction with a p-value of 0.015.

The heat tolerant genotypes, based on their HSI all had low WA8 and WAP values in all the examined environments the only exception was in late sowing 2014 whereby the heat tolerant varieties (HSI) and average WAP values (Table 5.2 g, h, i and l). WA8 and WAP HSI values for early and late sowing are as follows; 3.50, 18.22 and 4.83, 19.71, respectively. WA8 and WAP for very early sowing and very late sowing are as Follow; 5.08, 20.08 and 1.822, 14.16, respectively.WA8 had high H values between 0.8 and 0.9 in all the examined environments. WAP had H value between 0.4 and
0.5.

In the early sowing environment WA8 at p-value 0.05 was positively correlated with MPH, NDVI at heading and SKHI and inversely correlated with protein (Table 5.3 a). At p-value 0.01 WA8 had a negative correlation with DTH. WA8 had a highly significant positive correlation at p-value <0.001 with DTGF, yield, y-pig, WAP and MPT and negatively correlated with height, RBD and WG. In the late sowing environment WA8 at p-value was positively correlated with protein and negatively correlated with DTH (Table 5.3 b). WA8 had a highly significant positive correlation at p-value <0.001 with DTGF, yield, y-pig, WAP and MPT and negatively correlated with DTH, height, RBD and SY.

In the early sowing environment WAP at p-value 0.05 was positively correlated with SKHI and negatively correlated with height and WG (Table 5.3 a). At p-value 0.01 WAP was negatively correlated with RBD. WAP had a highly significant positive correlation with yield, y-pig and yield. In the late sowing environment at p-value 0.05 WAP was negatively correlated with GC%1 (Table 5.3
b). At p-value 0.01 WAP was negatively correlated with height, RBD and SY. WAP had a highly significant positive correlation at p-value <0.001 with DTGF, yield, y-pig and WA8 and negatively correlated with DTH.

5.4 Discussion

5.4.1 Consequences of growing season heat stress

Post-anthesis heat stress, from delayed sowing had a negative impact on grain yield and yield components and temperatures above 25°C during the grain-filling period drastically reduced grain yield (Tian et al., 2018). The optimum temperature for anthesis and grain-filling in wheat lies between 12 to 22°C and temperatures above this range detrimentally impact grain yield (Farooq et al.,2011). The 2014 trial in this study found a 62% reduction in grain yield with exposure to heat stress. The 2015 trial produced an 18% reduction in grain yield between very early sowing and early sowing environments. However, yield reduced by 41% between very early sowing and late sowing and by 34% between very early sowing and very late sowing. Yield reduced by 29% between early sowing and late sowing and by 20% between early sowing and very late sowing. However, yield reduction was just 11% between late sowing and very late sowing, largely because rainfall of 97mm was received during late grain fill in the very late sowing which reduced heat stress.

The highly significant G × E interaction observed for grain yield was similar to most reports (Ullah et al., 2020; Thistlethwaite et al., 2020). The genotypes with longer days to grain-fill resulted in higher grain yield as they had more time to capture resources (Cosentino et al., 2018; Modarresi et al., 2010). It is likely that heat stress reduced photosynthetic capacity by restricting metabolic functions, resulting in oxidative damage to chloroplasts and ultimately reduced accumulation of dry matter and grain yield (Farooq et al., 2011). However, taller plants under heat stress had reduced grain yield, most likely a consequence of carbon partitioning to biomass rather than grain as also observed by Modarresi et al. (2010).

No significant correlation between grain yield and grain weight or grain yield and screenings percentage was observed. Typically, a positive relationship between grain yield and kernel weight is observed (Cosentino et al., 2018; Zheng et al., 2011; Lopes et al., 2012; Aisawi et al., 2015; Tshikunde et al., 2019) but not always (Xiao et al., 2012; Sharma et al., 2012; Lopes et al., 2012; Tshikunde et al., 2019; Ullah et al., 2020). Generally, yield is negatively correlated with screenings percentage (Ullah et al., 2020; Maphosa et al., 2014), however, this was not observed even though temperature stress did occur in both years (Figure 3.12, 3.1 and 3.5)). Most previous studies focussed on bread wheat and less was reported on durum wheat which may have influenced this finding. However, screenings were significantly higher under late sowing in this study, so an environmental and genotypic effect was noted suggesting that genotypes varied in their tendency towards higher screenings at higher temperature.

Days to heading, maturity and grain-fill duration reduced with heat stress as expected from previous work (Farooq et al., 2011; Sangwan et al., 2019). Heat stress also reduced NDVI or greenness as observed by Hazratkulova et al. (2012). The increased leaf senescence due to heat stress in late sowing was most likely the reason for this decline in NDVI, as reported by Ramya et al. (2015) in bread wheat. Canopy temperature also increased under heat stress, most likely due to stomatal closure leading to reduced transpiration which in turn causes canopy temperatures to rise (Li et al., 2019). Plants with cooler canopy temperatures tend to have higher yield under heat stress (Gupta et al., 2020). However, there was no significant correlation between yield and CT observed in this study, even under late sowing where temperatures were higher.

In 2014, days to heading, days to maturity, grain fill duration and plant height reduced under heat stress by 29, 26, 15 and 24%, respectively. Similar reductions were observed in 2015, where comparisons of very early sowing with early sowing, late sowing and very late sowing recorded respective reductions of 10, 12 and 40% for days to heading, 1, 22 and 41% for days to maturity, 15, 40 and 42% for grain fill duration and 16, 25 and 45% for reduction in plant height. Comparisons of early sowing with late and very late sowing produced respective reductions of 3 and 34% for days to heading, 12 and 33% for days to maturity, 30 and 23% for grain fill duration and 11 and 35% for plant height. Late sowing compared to very late sowing produced reductions of 32, 24, 3 and 27% for days to heading, days to maturity, grain fill duration and plant height, respectively. As expected, the greater the difference in sowing dates, the greater the reduction in yield, phenological traits and plant height.

5.4.2 Consequences of heat stress on grain quality

The current study showed that as temperature stress rose screenings also increased, a trend observed previously (Sissons et al., 2017; Ullah et al., 2020). High temperatures also impacted seed size and this increased screenings percentage (Li et al., 2013). Clearly, environmental factors strongly influence kernel weight (Guzman et al., 2016; Fleitas et al., 2020). In the 2014 trial, screenings%, TKW, protein content and flour yield changed by 72, 28, 14 and 1%, respectively, was following exposure to heat stress. In the 2015 trial, early sowing produced a 30% increase in screenings over very early sowing. Screenings increased by 40, 41, 14, 15 and 1% in comparisons of very early versus late, very early versus very late, early versus late, early versus very early and late versus very late sowing, respectively. The anomaly in the latter comparison was attributed to the high rainfall during anthesis and heading as stated earlier.

In 2015, heat stress reduced TKW except for comparisons of very late and late sowing due to the late rainfall mentioned earlier. However, reductions in TKW were relatively small, ranging from 6% for comparisons of very early and late sowing to just 1% for comparisons of early and late sowing.

Protein content increased under heat stress in both years to varying degrees. This trend is commonly observed (Cosentino et al., 2018) under high temperatures, largely a function of reduced carbohydrate accumulation. A review by Farooq et al. (2011) also concluded that heat stress can decrease protein functionality by altering protein aggregation and the glutenin to gliadin ratio (Corbellini et al., 1997). In 2015, protein content increased with heat stress (and sowing date) and ranged from increases of 14% for comparisons of very early and late sowing to just 1% when comparing very early and early sowing.

Flour yield under heat stress was relatively unchanged in 2015, probably a consequence of relatively small changes in kernel weight. This was more a consequence of timely rainfall than heat stress. The result is consistent with previous findings that heat stress reduces flour yield by reducing kernel diameter and size (Gibson et al., 1998).

The observation that kernel hardness decreased with increasing temperatures in both years except for very late sowing which can be attributed to the increased rainfall during maturity. Sissons et al.(2017) explained that heat stress increased protein concentration and altered the interaction between the protein matrix and starch granules thus impacting hardness.

Hectolitre weight reduced under heat stress indicating changes in the size, compactness and density of the seed (Khan et al., 1997). Generally, values above 76 kg/hL are sought as they are indicative of high semolina yield. Others reported reduced hectolitre weight under heat stress but not at a level that would reduce flour yield (Gibson et al., 1998). Nevertheless, semolina yield (SY) decreased with increasing temperatures in 2014. A similar observation was made by Sissons et al., (2017) and they concluded that the reduction in hectolitre weight and grain weight was a consequence of reduced endosperm which in turn reduced flour yield.

Wet gluten increased with heat stress in both years. Wet gluten is defined as the protein from grain that can configure a functional gluten polymer (Sissons et al., 2017) and is highly correlated to grain protein, as observed in Table 5.3. Wet gluten increased with heat stress because grain protein content also increased and most grain protein is gluten (AbuHammad et al., 2012).

Yellow pigment (Y-pig) increased slightly with increasing temperatures in both 2014 and 2015 as observed by Sissons et al., (2017) and Li et al., (2013). This increase in flour yellowness as a result of heat stress and could be attributed to a “concentration effect” of the carotenoid pigment (Guzman et al., 2016). Nevertheless, Guzman et al., (2016) also reported that flour yellowness reduced as a result of severe heat stress. They attributed this to different levels of heat tolerance in the genotypes tested and/or environmental changes. In the current study, semolina yield was lower under heat stress as pigment increased, supporting the concentration effect observed by Guzman et al., (2016).

5.4.3 Consequences of heat stress on dough rheological properties

Mixograph mean peak height (MPH) and mixograph time to peak dough development (MPT) are a measurements of dough strength. High peak MPH and long MPT are associated with cultivars that have strong dough (AbuHammad et al., 2012). In 2014, dough strength increased slightly with heat stress, as there was a 7% increase in MPH and a 3% increase in MPT which is consistent with increased grain protein as they both are highly correlated. Tahir et al. (2006) also observed that dough strength increased under heat stress. The associated increase in protein under heat stress was linked to increased gluten and therefore stronger dough (Tahir et al., 2006). In 2015, an 8% reduction in MPH and a 0.3% reduction in MPT was observed. Sissons et al. (2017) concluded that late sowing did not have a consistent effect on dough strength. Clearly, the late sown environment with many confounding factors other than temperature can influence dough strength and did not have a significant impact on dough strength. The higher rainfall in 2015 and reduced exposure to heat stress and may explain the reduction in MPH and MPT with late sowing (Figure 3.1 and 3.5).

In 2014, heat stress marginally reduced RBD by 0.7% while in 2015 RBD increased by 17%, possibly due the mentioned reduced heat stress and increased rainfall in 2015. Sissons et al., (2017) also found that late sowing decreased dough breakdown, leading to a more stable dough, resistant to overmixing (time beyond the peak mixing time) and therefore indicative of a stronger dough.

In 2014, a 7 and 8% increase in WA8 and WAP, respectively was observed, whereas in 2015, the same traits reduced by 49 and 21%. A study by Blumenthal et al. (1995) did not find a general dough weakening effect from heat stress as observed here in 2015. These differences possibly relate to the degree of heat stress (temperature, duration and timing) and genotype x environment interactions. The current study (at least in 2014) did find a dough strengthening effect at higher temperature, highlighting the vagaries of the field environments and the different germplasm evaluated.

5.4.4 Can high yield and acceptable quality be achieved under heat stress?

The positive response of durum quality traits to heat stress could possibly be exploited if the negative impacts of heat stress on grain yield and physical traits can be reduced (Sissons et al., 2017). Under heat stress, grain protein content increases, although this is a function of grain number, grain weight and yield. Hence, it is unlikely that all traits can be simultaneously improved through breeding.

Genotypes varied considerably for all traits indicating significant genetic variation in the materials evaluated. Those with high yield and reduced screenings under heat stress could be crossed to high protein achievers with stronger, more stable dough properties at higher temperatures. However, breeders would be wise to concentrate on maintenance of grain weight and reduced screenings under heat stress to avoid selecting materials with higher protein and therefore dough strength linked to shrivelled or poorly formed grain.

5.4.4 Target traits for plant breeders

Farooq et al., (2011) showed that the traits targeted by plant breeders for heat tolerance needs to be: (a) highly correlated with grain yield under heat stress; (b) rapid, stable and easy to measure; and (c) highly heritable. The heritability for yield in the current study was relatively high (ranging between 0.6-0.8) and a number of traits, including grain weights and screenings were correlated under the stress. However, while these characters are easy to measure, physical dough properties are not. While protein is an indicator of dough strength (and hence gluten content), the stability of the dough cannot be easily assessed. The late sowing experiments are also open to interpretation as truncated vegetative growth resulting from late sowing may give a false picture of true heat tolerance.

5.5 Conclusion

In this study of 120 durum wheat cultivars, the late sown experiments exposed genotypes to high heat temperature stress during the grain-filling period, which impaired grain morphology (weight and screenings%) and ultimately reduced grain yield. The study revealed that late sowing was an effective method for screening for heat tolerance potential of durum wheat by creating temperature stress during grain filling. Late sowing increased dough strength and to a lesser extent, dough balance. This was a result of higher protein and associated gluten content. However, milling yield and hectolitre weight reduced under higher temperatures due to reduced endosperm formation. Advice for breeders is to select for higher yield, reduced screenings, stable grain weights and higher grain protein under heat stress before assessing dough properties. This will avoid selecting materials with stronger dough but poorer milling characteristics.

Chapter 6: Bread wheat genome-wide association analysis of heat tolerance in bread wheat

Abstract

Heat stress adversely affects wheat growth, development and yield. The aims of this study were to identify the genetic basis of heat stress tolerance among the bread wheat materials evaluated. Based on the multi-year, multi-environment assessments of diverse genotypes in Chapter 4, a genome-wide association study (GWAS) was conducted to identify marker trait associations (MTAs) or quantitative trait loci (QTLs) linked to high temperature tolerance. The field study phenotyped 282 genotypes under heat stress tolerance for traits such as grain yield, thousand kernel weight (TKW) and screenings percentage. The materials were genotyped using a 90 K SNP Infinium assay identify single nucleotide polymorphisms (SNPs) and QTL subsequently identified. Significant heat tolerant QTLs were found on chromosomes 4A and 6B (2) for yield, chromosomes 3B and 4A for screenings and chromosomes 2B, 3B (2) and 5A for TKW. The QTL on chromosome 4A was common for both yield and screenings%. Once validated, these QTLS could be used for fine mapping and marker assisted selection to improve heat tolerance in wheat.

6.1 Introduction

Heat stress tolerance in wheat is a complex trait governed by numerous genes of minor effect which are highly influenced by the environment, thus breeding for heat tolerance is difficult (Howarth 2005; Bohnert et al., 2006; Ullah et al., 2021). Enhancement of wheat yield through direct selection poses challenges as it is polygenic and greatly influenced by environment. This is particularly evident at high temperatures. However, combining selection for heat tolerance with yield and physiological traits with higher heritability then yield itself can improve genetic gain. The selection process requires careful attention to the relationship between traits, identifying trade-offs, especially negative correlations between related traits (Ward et al., 2019). In crop plants, resistance to stress is an energy spending process which often means that resistance to heat stress and yield potential are negatively correlated (Xia et al., 2019; Paliwal et al., 2012). Hence, breeding requires an improved understanding of the relationships among traits linked to high temperature tolerance (El Hassouni et al., 2019).

The introgression of promising alleles from close relatives of wheat into modern varieties is a method that can enhance tolerance to abiotic stress (Ullah et al., 2018; Ullah et al., 2021). This can

be done by targeting unique alleles of value without losing agronomically fundamental traits (Trethowan.
2014).

Mapping QTL of bi-parental populations is commonly used to identify chromosome segments governing traits of agronomic interest that segregate between the two parents (Pinto et al., 2010).

These detected regions (either QTLs or genes) can then be used in marker-assisted selection to increase the efficiency of selection.

Genome wide association studies (GWAS) or linkage disequilibrium mapping is a method that can be used to identify links between traits of interest and genetic markers using large numbers of genotypes
(Crossa et al., 2007; Van Eeuwijk et al., 2010; Maarup, 2016). This procedure leads to the identification of MTAs or QTL associated with heat tolerance (Huang and Han, 2014; Mwadzingeni et al., 2017). GWAS experiments have extensively been used to locate allelic variation in hexaploid and tetraploid wheat under various climatic conditions (Wang et al., 2014; Sukumaran et al., 2018). There is however inadequate information on allelic diversity found in wild relatives which could potentially be used to enhance abiotic stress tolerance in modern wheat cultivars (Sehgal et al., 2015; Gupta et al., 2019). GWAS can explore more ancestral gene recombination than is possible with biparental populations (Ward et al., 2019). However, allele frequency is a major limiting factor in GWAS studies since marker-trait associations are often impossible to detect if casual variants are scarce in the testing panel. Linear mixed models can alleviate this to some extent by accounting for false positives through estimation of population structure or kinship among genotypes (Ward et al.,, 2019).

The use of bi-parental populations in QTL mapping describes only a fragment of the genetic makeup of a trait as a result of only two alleles per locus being evaluated at a time. Bi-parental populations are also limited by reduced mapping resolution, population specificity of detected QTL and is time consuming when developing mapping populations. As a result of these limitations the turnover of knowledge from bi-parental QTLs to practical application for use in plant breeding has been a lengthy process (Edae et al., 2014). Association mapping overcomes several of the shortcomings of biparental mapping populations. Association mapping uses diverse germplasm and as a result, QTL for a variety of traits can be detected with high resolution in a single study. However, the resolution and power of the association method relies on the degree of linkage disequilibrium (LD) across the genome. LD is affected by population history, recombination frequency and mating system, and as a result needs to be determined in each study. LD is anticipated to decline as a function of the nucleotide or linkage distance, since recombination reduces LD (Edae et al., 2014).

The aims of the study were to identify the genetic basis of heat stress tolerance in bread wheat based on important productivity traits.

6.2 Materials and Methods

6.2.1 Plant materials

A total of 282 bread wheat genotypes were sown at 4 consecutive sowing dates each year between May and August between 2012 and 2015. The experimental design for each year was a randomised complete block with two replications arranged in a regular grid. A complete list of germplasm evaluated can be found in Appendix Table 12.

6.2.2 Phenotypic data assessment

All traits common across years were used for genome-wide association analysis,detailed method is presented in Section 3.4.

6.2.3 Statistical analysis of phenotypic data

Detailed method is presented in section 3.5.2

6.2.4 SNP genotyping and data analysis

Detailed method is presented in section 3.5.3

6.3 Results

6.3.1 Population structure and association analysis

Figure 6.1 illustrates the genetic relatedness of the mapping population panel. Relatedness among the testing panel lines ranged from low to high due as the population had key parents represented across families, in the figure, red depicts low levels of relatedness and blue represents a high level of relatedness.

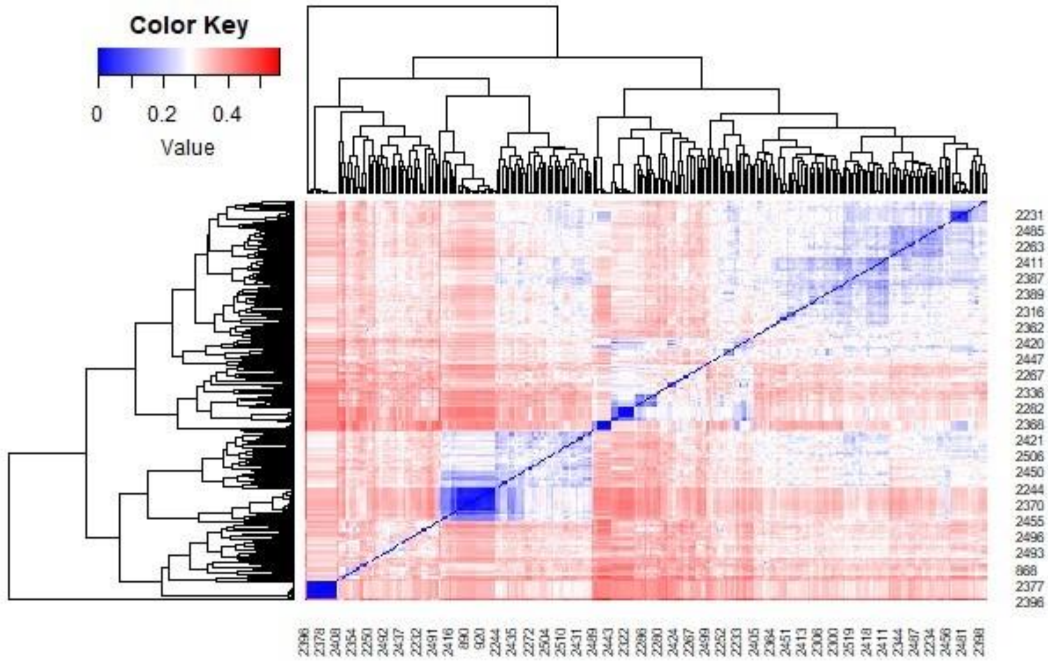


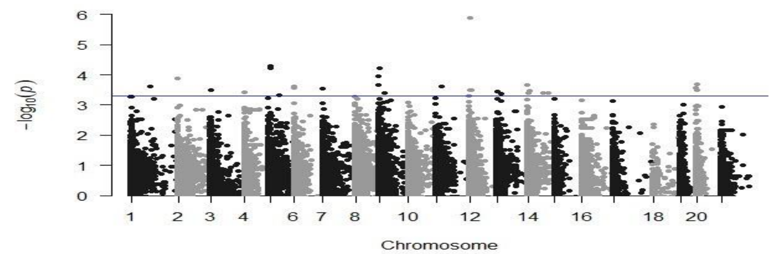
Figure 6.1: Population structure analysis represented in a heat map of kinship matrix with dendrogram, where blue represent more and red represents less related individuals.

A total of 38 significant MTAs for yield were found at -log10 P>3.3 (Figure 6.2). The highest number of MTAs were found on the B genome (19) followed by the A genome (17) and D genome (2). For
TOS 1, 8 significant MTAs were observed (Figure 6.2 a), 10 for TOS 2 (Figure 6.2 b), 16 for TOS 3 (Figure 6.3 c) and 14 for TOS 4 (Figure 6.2 d). The marker 28159, co-located on chromosome 3B in TOS 4 and TOS 2, had a negative effect on yield in both times of sowing. No marker with a positive effect on yield was observed in all sowing dates.

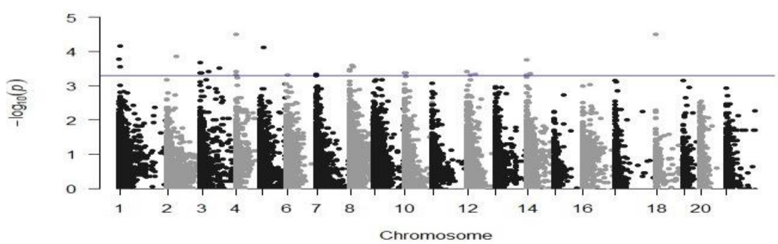
A total of 51 significant MTAs for TKW were identified at -log10 P>3.3 (Figure 6.3). The highest number of MTAs were found on the B genome (28) followed by A genome (16) and D genome (7). For TOS 1, 18 significant MTAs were observed (Figure 6.3 a), 10 for TOS 3 (Figure 3 b) and 23 for TOS 4 (Figure 6.3 c). The marker 37030, co-located on chromosome 3A in TOS 3 and TOS 4, had a positive effect on TKW. No marker with a positive effect on TKW was observed in all sowing dates.

A total of 72 significant MTAs were observed for screenings% at -log10 P>3.3 (Figure 6.4). The highest number of MTAs were found on the B genome (42) followed by the A genome (18) and D genome (12). Twenty were observed in TOS 1 (Figure 6.4 a), 13 in TOS 2 (Figure 6.4 b), 16 in TOS 3 (Figure 6.4 c) and 23 in TOS4 (Figure 6.4 d).

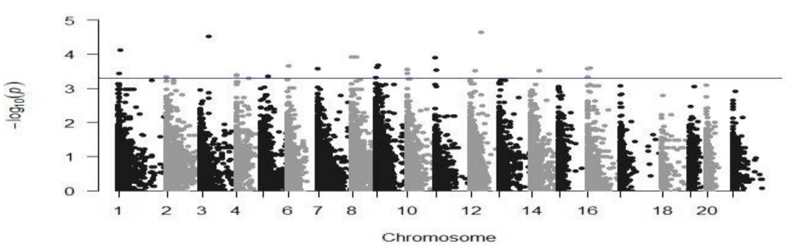
(a)



(b)



(c)



(d)

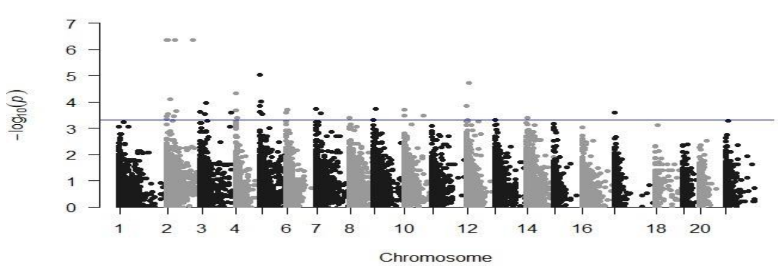
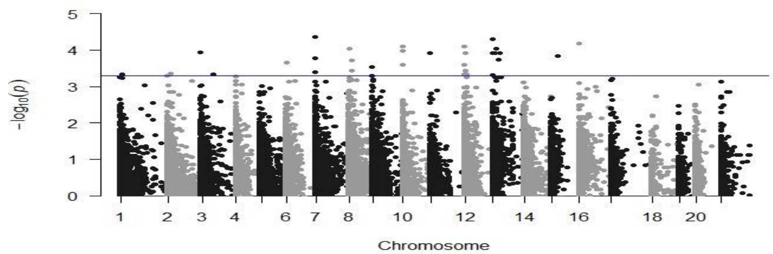
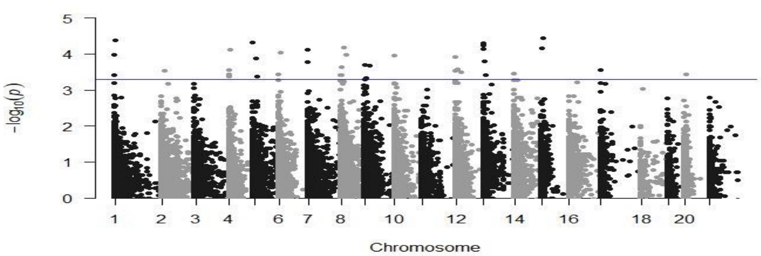


Figure 6.2: Manhattan Plot of single nucleotide polymorphisms (SNPs) arranged by chromosome, base pairs and their -$\log_{10}$ P scores for Yield in (a) Time of sowing 1, (b) Time of sowing 2, (c) Time of sowing 3 and (d) Time of sowing 4. SNPs were considered significant at -$\log_{10}$ P>3.3

(a)



(b)



(c)

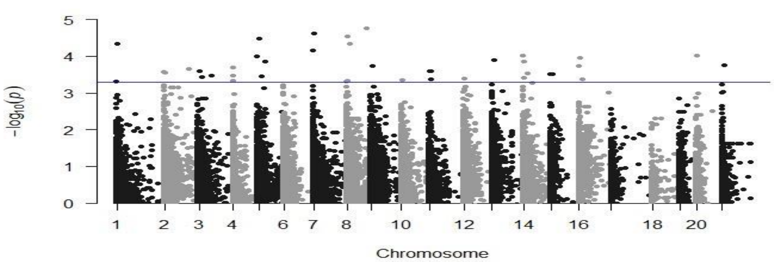
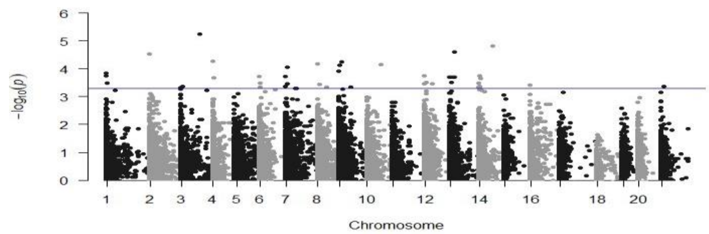
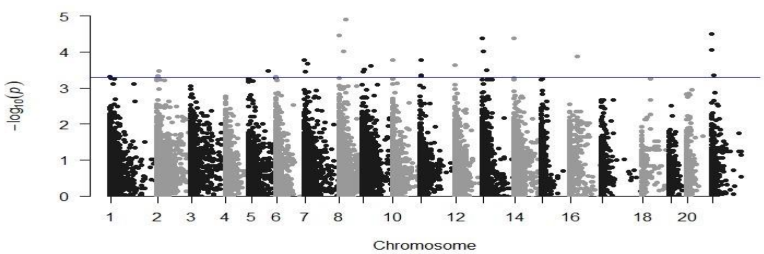


Figure 6.3: Manhattan plot of SNPs arranged by chromosome, base pairs and their -$\log_{10}$ P scores for Thousand Kernel Weight (TKW) in (a) Time of sowing 1, (b) Time of sowing 3 and (c) Time of sowing 4. SNPs were considered significant at -$\log_{10}$ P>3.3

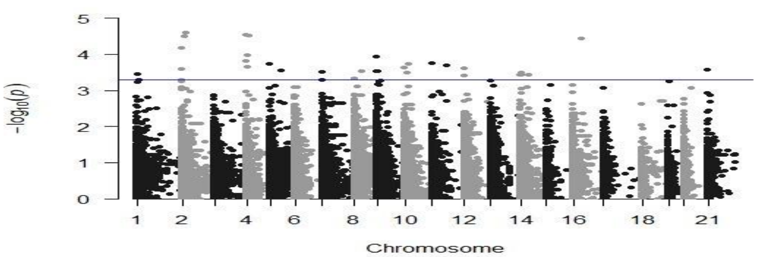
(a)



(b)



(c)



(d)

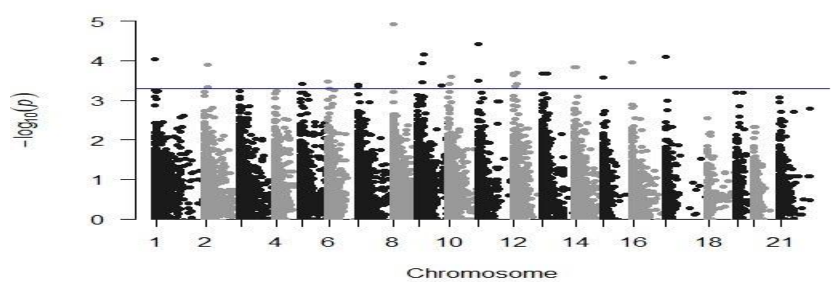


Figure 6.4: Manhattan Plot of SNPs arranged by chromosome, base pairs and their $-\log_{10}$ P scores for Screenings% in (a) Time of sowing 1, (b) Time of sowing 2, (c) Time of sowing 3 and (d) Time of sowing 4. SNPs were considered significant at $-\log_{10} P>3.3$

6.3.2 Yield

A summary of the significant MTAs for yield including the effects of each significant probe for each sowing date is given in Table 6.1. Most MTAs were negative, however positive effects were observed in TOS 2 (on chromosomes 1B, 2A and 7A), TOS 3 (on 4A and 6B) and TOS 4 (6B). Of the significant MTAs, only probe 12180 located on 4A had a physical map position, located at 110.995 cM. No significant positive MTAs were observed on TOS 1.

Table 6.1: Significant marker trait associations (MTAs) for yield (-Log10 >3.4) for each sowing date.

Calculated using best linear unbiased estimators (BLUEs) estimated across years.

TOS	Chromosome	GWAS_Order	SNP 90K Probe	Position (bp)	A1	A2	Freq	Effect	-LOG10	Position (cM)
1	2B	15487	7307	0	1	2	0.021	-	3.607	
1	3A	17670	34980	4114879	1	2	0.330	-	3.726	
1	4B	24846	73234	26507	2	1	0.053	-	3.845	
1	4B	24961	7350	6082552	2	1	0.025	-	3.921	65.573
1	5A	26020	74955	2938356	1	2	0.021	-	4.031	
1	6B	34150	46216	217935	1	2	0.255	-	4.019	
1	7A	37996	15364	0	2	1	0.057	-	4.287	30.755
1	7A	37515	57921	1291499	1	2	0.018	-	3.796	
2	1B	4292	80419	10204795	2	1	0.209	+	3.576	
2	2A	8970	61745	671737	1	2	0.383	+	3.540	
2	3A	18280	64060	1987436	1	2	0.011	-	3.519	

2	3A	18347	33347	3545332	2	1	0.043	-	3.547	
2	3A	18094	80566	9544729	2	1	0.011	-	4.567	
2	3A	18106	1698	21184897	1	2	0.011	-	4.567	67.119
2	3B	20731	28159	691351	1	2	0.110	-	4.177	
2	5B	29776	19533	0	2	1	0.362	-	3.986	63.731
2	6B	35074	46910	0	2	1	0.025	-	4.914	

1

2	7A	37273	56298	10875921	2	1	0.01	+	6.746	
3	1B	2495	15723	1205905	1	2	0.191	-	3.334	
3	2D	16577	11731	607778	1	2	0.018	-	3.891	84.316
3	4A	23182	12180	221055	1	2	0.379	+	3.487	110.995
3	6B	34788	14375	0	1	2	0.482	-	3.409	
3	6B	34648	74811	549999	2	1	0.450	-	3.579	
3	6B	34592	71379	913993	1	2	0.489	+	3.736	
4	1B	5469	29320	0	2	1	0.206	-	3.435	
4	2D	16577	11731	607778	1	2	0.018	-	3.568	84.316
4	3A	18911	61135	0	2	1	0.028	-	3.655	
4	3A	17295	79053	619865	2	1	0.348	-	4.065	
4	3A	17654	61370	1946697	1	2	0.124	-	3.760	
4	3A	17659	6870	2805901	1	2	0.110	-	4.470	55.868
4	3A	18123	7655	5077423	2	1	0.028	-	3.655	
4	3B	20938	11439	0	2	1	0.167	-	3.441	
4	3B	21278	44641	0	1	2	0.039	-	3.473	
4	3B	21387	55459	0	1	2	0.160	-	3.628	
4	3B	20731	28159	691351	1	2	0.110	-	5.521	
4	3B	20700	57094	1889175	2	1	0.170	-	3.792	

TOS	Chromosome	GWAS_Order	SNP 90K Probe	Position (bp)	A1	A2	Freq	Effect	-LOG10	Position (cM)
					1	2				
					1	2				
4	6B	35281	64923	0	1	2	0.387	+	3.759	
4	7A	36343	22779	334061	2	1	0.241	-	3.420	1.387

6.3.3 TKW

A summary of the significant MTAs for TKW including the effects of each significant probe for each sowing date is given in Table 6.2. Most MTAs were negative, however positive effects were observed in TOS 1 (on chromosomes 2B and 2D), TOS 3 (2B, 3B and 5A) and TOS 4 (3B). Of the significant MTAs, only probe 11383 on 2B in TOS 3 had a physical map position, located at 59.148 cM. TKW was not assessed on TOS 2.

Table 6.2: Significant marker trait associations (MTAs) for thousand kernel weight (TKW) (-Log10 >3.5) for each sowing date. Calculated using best linear unbiased estimators (BLUEs) estimated across years.

TOS	Chromosome	GWAS_Order	SNP 90K Probe	Position (bp)	A1	A2	Freq	Effect	-LOG10	Position (cM)
1	1B	5321	21820	0	1	2	0.018	-	3.483	67.202
1	2B	14623	2961	0	2	1	0.011	+	3.485	
1	2D	16724	2961	0	2	1	0.011	+	3.485	
1	3A	18913	6177	0	1	2	0.028	-	3.502	57.903
1	3A	18070	76934	3515864	1	2	0.028	-	3.502	
1	3B	20249	80530	631227	2	1	0.177	-	4.393	
1	3B	20252	80630	911426	1	2	0.174	-	4.393	
1	3B	20258	77488	1261439	1	2	0.163	-	3.740	
1	3B	20232	54260	1695413	2	1	0.188	-	3.698	
1	3B	20234	77015	2177232	2	1	0.188	-	3.698	
1	3B	20104	73083	2661391	1	2	0.191	-	4.002	
1	3B	20243	76387	3735127	2	1	0.188	-	3.698	
1	3B	20288	11679	7671149	1	2	0.181	-	3.483	59.177
1	3B	20296	50898	8123543	1	2	0.174	-	4.231	

1	4A	23891	48243	0	1	2	0.025	-	4.063	
1	5A	27409	66978	0	1	2	0.011	-	3.795	
1	5A	26856	61923	836252	2	1	0.401	-	3.696	
1	6B	35074	46910	0	2	1	0.025	-	3.863	
3	2B	11383	8834	1106845	1	2	0.089	+	3.521	59.148
3	3A	18913	6177	0	1	2	0.028	-	4.792	57.903
3	3A	18621	37030	51070	2	1	0.035	-	4.774	
3	3A	18070	76934	3515864	1	2	0.028	-	4.792	
3	3A	18101	72995	18922969	2	1	0.025	-	3.891	
3	3B	19949	44228	386255	2	1	0.046	+	3.573	
3	4A	23716	26452	0	2	1	0.099	-	3.590	
3	5A	26857	9808	836276	2	1	0.379	-	3.895	49.534
3	5A	26801	43525	3136212	2	1	0.387	+	4.046	
3	5A	26828	61908	5898401	1	2	0.241	-	3.515	
4	1B	5321	21820	0	1	2	0.018	-	4.810	
4	1B	6298	68552	0	1	2	0.241	-	3.673	
4	1B	6084	57678	0	1	2	0.025	-	3.629	
4	1B	2793	7249	1539312	1	2	0.252	-	3.871	43.363
4	1D	7427	14480	0	2	1	0.018	-	4.299	
4	1D	7447	2175	0	1	2	0.021	-	3.530	
4	1D	6892	10764	72237			0.021	-	3.711	39.406
4	1D	6996	65654	2562458			0.014	-	5.488	
4	1D	6939	10598	3557661	1	2	0.021	-	3.530	44.999
4	1D	6954	13348	10825323	1	2	0.021	-	3.530	46.847
4	3A	18621	37030	51070	2	1	0.035	-	3.522	
4	3B	21281	45059	0	1	2	0.014	-	5.488	
4	3B	20771	22806	52032	2	1	0.021	+	4.015	
4	3B	19949	44228	386255	2	1	0.046	-	3.604	
4	3B	19307	55771	1420894	2	1	0.018	-	4.177	
4	3B	20104	73083	2661391	1	2	0.191	-	3.723	
4	5A	27010	39604	2048405	1	2	0.050	-	4.024	

					1	2				
					1	2				
4	5B	29547	43191	312819	2	1	0.021	-	4.107	
4	6A	31535	77981	2023724	1	2	0.043	-	3.586	
4	6B	35074	46910	0	2	1	0.025	-	5.376	
4	6B	35059	45189	0	1	2	0.064	-	3.941	
4	6B	33252	2600	270762	1	2	0.043	-	3.586	
4	6B	33269	56376	1206416	1	2	0.043	-	3.586	

6.3.4 Screenings%

A summary of the significant MTAs for screenings% including the effects of each significant probe for each sowing date is given in Table 6.3. Most MTAs were positive, that is associated with an increase in screening which is not favourable, however, negative effects were observed in TOS 2 (on chromosome 2B at two locations, although close proximity suggests they are the same effect) and TOS 4 (3B and 4A). Of the significant MTAs, only probe 10434 on 2B in TOS2 had a physical map position, located at 16.44 cM. No significant negative MTAs were observed in TOS1 and 3.

Table 6.3: Significant marker trait associations (MTAS) for Screenings% (-Log10 >3.5) for each sowing date. Calculated using best linear unbiased estimators (BLUEs) estimated across years.

TOS	Chromosome	GWAS_Order	SNP 90K Probe	Position (bp)	A1	A2	Freq	Effect	-LOG10	Position (cM)
1	1A	1339	12579	1520371	1	2	0.280	+	4.164	72.49
1	1B	4534	60140	315330	2	1	0.305	+	3.520	
1	1B	5535	31771	0	1	2	0.301	+	3.508	
1	1D	7390	41123	348410	1	2	0.018	+	3.918	
1	3A	18057	1051	1399948	2	1	0.092	+	4.775	61.35
1	3B	20833	64375	1542779	1	2	0.018	+	5.284	
1	3B	21530	6624	0	1	2	0.014	+	4.041	
1	3B	19257	76983	619552	1	2	0.011	+	3.765	
1	3B	19785	236	4852565	1	2	0.039	+	3.630	52.43
1	3D	22067	64375	422011	1	2	0.018	+	5.284	

					1	2				
					1	2				
1	3D	21928	34348	24470969			0.011	+	3.837	
1	4A	23086	12088	257160			0.028	+	3.795	92.28
1	6B	34376	27834	1251121	2	1	0.032	+	3.923	
1	6B	35235	60655	0	1	2	0.014	+	3.623	
1	7A	37625	43244	981570	1	2	0.018	+	5.352	
1	7B	39305	56634	842018	1	2	0.014	+	5.696	
1	7B	39307	74934	1460938	2	1	0.014	+	5.696	
1	7B	39314	40981	3742450	1	2	0.011	+	4.351	
1	7B	39618	45142	7978815	1	2	0.046	+	3.854	
1	7D	41385	9578	5452959	2	1	0.046	+	3.838	115.73
2	1A	192	11203	1466254	1	2	0.064	+	4.229	
2	1B	5224	13832	0	2	1	0.021	+	3.448	79.25
2	2A	9375	1315	0	1	2	0.018	+	4.434	
2	2B	14718	32843	0	2	1	0.014	+	4.628	
2	2B	15069	54174	0	1	2	0.057	+	4.435	
2	2B	10145	10434	571385	2	1	0.149	-	3.818	16.44
2	2B	15114	55953	0	1	2	0.025	+	3.663	
2	2B	12515	30976	3827691	1	2	0.032	-	3.520	
2	2D	15897	13678	3524560	2	1	0.046	+	3.614	64.70
2	3B	19080	57554	771671	1	2	0.025	+	4.837	
2	3D	22266	27441	0	1	2	0.057	+	3.882	
2	4A	23789	34224	0	2	1	0.191	+	3.489	
2	5D	30872	2651	254560	1	2	0.039	+	3.489	170.24
3	2B	15114	55953	0	1	2	0.025	+	4.301	
3	2B	14378	16321	0	2	1	0.011	+	3.888	11.03
3	2D	16981	63286	0	1	2	0.096	+	3.676	
3	3B	21530	6624	0	1	2	0.014	+	5.065	
3	3B	21357	52089	0	1	2	0.021	+	4.149	
3	3B	20664	66835	1900656	1	2	0.018	+	4.070	
3	3B	19080	57554	771671	1	2	0.025	+	3.801	
3	5B	29474	27862	5070891	1	2	0.011	+	6.183	

					1	2				
					1	2				
3	5B	29376	71749	158478	1	2	0.018	+	4.287	
3	5B	29413	73180	1831611	1	2	0.018	+	4.287	
3	5B	29425	71820	3313072	1	2	0.018	+	4.287	
3	5B	29902	29239	0	1	2	0.018	+	3.803	
3	5B	29979	34702	0	2	1	0.014	+	3.769	
3	5D	30720	4718	1380277	2	1	0.011	+	6.230	112.95
3	6D	35982	5708	0	1	2	0.011	+	7.527	
3	7B	38893	45667	1366898	1	2	0.018	+	5.557	
4	1A	2190	62300	0	1	2	0.043	+	5.257	
4	3B	19141	38606	1413726	2	1	0.011	+	9.385	
4	3B	21530	6624	0	1	2	0.014	+	6.007	
4	3B	21249	42793	0	2	1	0.106	-	3.519	
4	4A	23693	23634	0	2	1	0.014	+	3.794	
4	4A	23839	42009	0	2	1	0.348	-	3.599	
4	5A	26981	7528	5413707	2	1	0.046	+	4.246	86.17
4	5D	30997	77924	0			0.011	+	4.649	
4	5D	30998	77925	0			0.011	+	4.649	
4	6A	32537	12244	0	1	2	0.043	+	5.257	
4	6A	32589	23734	0	2	1	0.025	+	4.919	42.69
4	6A	33018	76021	0	1	2	0.071	+	4.773	
4	6A	32665	33626	0	1	2	0.074	+	4.338	
4	6A	32553	13914	0	2	1	0.078	+	4.002	
4	6A	31390	69687	1475701	2	1	0.032	+	6.822	
4	6A	31432	6752	8316499	1	2	0.071	+	4.773	45.47
4	6B	33345	23734	61407	2	1	0.025	+	4.919	42.69
4	6B	33387	39117	1787295	2	1	0.021	+	4.874	
4	6B	34481	6854	810453	1	2	0.039	+	4.377	76.83
4	6B	35444	81017	0	2	1	0.025	+	3.964	
4	7B	39876	51642	102865	1	2	0.113	+	3.684	
4	7B	39957	12357	224708	1	2	0.113	+	3.684	

4	7B	38779	73048	11327870	2	1	0.025	+	3.677

6.3.5 Co-located MTAs

Some MTAs were linked with two or more traits, both across and within times of sowing. However, most were associated with an undesirable effect on phenotype.

Several markers had a negative effect on TKW across different times of sowing including the probes 76934 (3A) in TOS 1 and 3, 73083 (3B) in TOS 1 and 4, 21820 (1B) in TOS 1 and 4 and 6177 (3A) in TOS 1 and 3. One probe, 44228 (3B) did, however, have a positive effect on TKW in TOS 3 and 4.

There were no markers with positive effect on yield across sowing dates, and only one probe, 11731 (2D) had a negative effect on yield across TOS 3 and 4.

Two markers were linked to an increase in screenings across times of sowing. These were 57554 (3B) and 55953 (2B), both had a positive effect across TOS 2 and 3. Only one probe, 6624 (3B was linked to decreased screenings across TOS 1, 3 and 4.

One probe, 46910 (6B) was associated with decreases in TKW (TOS 1 and 4), yield (TOS 2).

6.3.6 Significant MTAs with the desired effect

Sixteen highly significant MTAs with the desired effect on the trait were found (Table 6.4). Of the six yield effects, 5 were reported previously except for the unmapped effect on 6B in TOS 4. There was another significant effect on 6B (TOS 3 at 98,771 cM) and these two probes could be located in the same region and thus the same effect.

None of the 4 significant MTAs for reduced screenings were reported earlier and their map positions are unknown. It is therefore unclear if these MTAs are unique.

Three of the 6 MTAs for increased TKW, 4 were reported earlier (those on 2B, 3B and 5A), all in either TOS 3 and/or 4, therefore likely linked to reduce screenings under higher temperatures. In fact, the effect on 3B is found in both TOS 3 and 4, indicating a reliable effect on seed size under stress.

Table 6.4 Significant MTAs (-Log>3.3) with the desired effect on the traits examined

Trait	TOS	Chromosome	SNP 90K Probe	Position (bp)	-LOG10	Position (cM)	Effect	Source
Yield	2	1B	80419	10204795	3.576363	47.814	+	Tura et al.,, 2020 ; Tahmasebi et al.,, 2017 ; Pinto et al.,, 2016
Yield	2	2A	61745	671737	3.53986	11.03	+	Tura et al.,, 2020 ; Bhusal et al.,, 2017 ; Sukumaran et al.,, 2018
Yield	2	7A	56298	10875921	6.746301	65.694	+	Tura et al.,, 2020 ; Sukumaran et al.,, 2018 ; Pinto et al.,, 2016
Yield	3	4A	12180	221055	3.486882	110.9947171	+	Guan et al.,,2018 ; Tadesse et al.,, 2018 ; Cook et al.,, 2020., Tura et al 2020 ; Sukumaran et al.,, 2018
Yield	3	6B	71379	913993	3.735697	98.771	+	Pinto et al.,, 2016
Yield	4	6B	64923	0	3.758638	uncharacterised	+	
screenings	2	2B	32843	0	4.62835	uncharacterised	-	
screenings	2	2B	55953	0	3.663098	uncharacterised	-	
screenings	4	3B	6624	0	6.006889	uncharacterised	-	
screenings	4	4A	42009	0	3.598693	uncharacterised	-	
TKW	1	2B	2961	0	3.485092	uncharacterised	+	
TKW	1	2D	2961	0	3.485092	uncharacterised	+	
TKW	3	2B	8834	1106845	3.520661	59.14824838	+	Guan et al.,,2018 ; Ullah et al.,, 2018 ; Tura et al 2020 ; Bhusal et al.,, 2017
TKW	3	3B	44228	386255	3.572915	42.207	+	Tahmasebi et al.,, 2017 ; Pinto et al.,, 2016

TKW	3	5A	61908	5898401	3.51532 7	46.882	+	Tura et al.,, 2020 ; Sunil et al.,, 2020 ; Sukumaran et al.,, 2018
TKW	4	3B	44228	386255	3.60446 7	42.207	+	Tahmasebi et al.,, 2017 ; Pinto et al.,, 2016

6.4 Discussion

This multi-year, multi-environment GWAS study identified genomic regions connected to heat stress tolerance. More MTAs were located on the A and B genomes than the D genome which was like other reports (Quarrie et al., 2005; Ogbonnaya et al., 2017). AB genomes have been found to have a larger contribution to heat stress tolerance in this study which is caused by reduced marker coverage on the D genome (Ullah et al.,, 2021).

Positive MTAs for grain yield were distributed across the genome with the most important located on chromosomes 1B, 2A, 4A, 6B (2) and 7A.

The MTA for increased yield at 110.994717cM on chromosome 4A was also observed by Guan et al (2018) for grain number per spike and by Cook et al. (2020) for TKW. Yield is a function of grain number and grain weight so it is not surprising that this was a yield enhancing region. Others reported QTL on the same chromosome for yield but at slightly different positions, including Tadesse et al.
(2018) (at 66.3cM) and Tura et al. (2020) (at 60.2-66.1 cM).

Grain yield is an integrative trait encompassing the complete effect of physiological processes throughout the crop lifecycle. The significant interactions of QTL effects for grain yield with environment simply reflect the significant G ×E observed, and complicate the selection for increased heat tolerance based on QTL associated with yield under selection. However, dissection of yield into component traits, each with higher heritability, may be beneficial and could increase rates of genetic gain (Pinto et al.,, 2010).

TKW is one such yield component and significant favourable MTAs were observed on chromosomes 2B (2), 2D and 5A. A significant MTA mapped to 59.14824838 cM on 2B, and others found similar effects for grain number per spike between 111.6-131 cM (Guan et al.,, 2018; Liu et al.,, 2014). This is an interesting relationship, as grain number and grain weight can be inversely correlated, as more grains tend to lead to reduced grain weight through compensatory effects. However, Ullah et al. (2018) also found a similar MTA at 108.31cM for higher yield and this indicates that in these materials, higher grain weights lead to higher yield. TKW is a target trait for selection of higher yielding cultivars under stress as its heritability is higher than yield alone, particularly if accompanied by information on grain number (Pinto et al.,, 2010).

Significant MTAs for screenings% with the desired effect of reduced screenings were observed on chromosomes 2B (2), 3B and 4A. The regions on 2B and 3B were also linked to increased grain size or TKW and the region on 4A also was correlated with increasing yield. However, none of these MTAs were mapped and it was not possible to compare these MTAs to previous findings.

A large number of significant MTAs with an undesirable effect on traits were observed including 32 for yield, 45 for TKW and 68 for % screenings. These are difficult to interpret as no undesirable associations could be explained by a desirable association for another correlated trait based on markers in common. For example, it might be expected that high screenings could be associated with lower yield under stress or reduced grain weights, however, these associations were not obvious.

A correlation between known photoperiod genes and the QTLs found in the current study was observed. The photoperiod gene ppd-A1 with a map position of 62.2 cM (Guedira et al.,, 2016) was likely associated with the positive yield QTL on chromosome 2A (map position 11.03 cM). The photoperiod gene Ppd-B1, mapped at 94.6 cM (Guedira et al.,, 2016) was also likely responsible for the significant positive effect on TKW on 2B at 59.14824838 cM. Similarly, the photoperiod gene Ppd-D1 located at 9.6 cM (Guedira et al.,, 2016) was likely associated with the unmapped QTL on chromosome 2D responsible for higher TKW. The vernalisation gene Vrn-B1, mapped at 142.8cM (Guedira et al.,, 2016) could also have been responsible for the negative effect on yield on chromosome 5B (63.73126094). Although this significant negative effect on yield was observed in TOS 2, the slightly later sowing may still have reduced the vernalisation period sufficiently to impacting flowering time and subsequently yield. No associations with semi-dwarfing genes were observed.

Conclusions

The data presented in this study identified potentially new QTLs linked to thousand grain weight, screenings percentage and yield. However, there is a probability that some of the positive MTAs may be artifactual and these need to be validated in unrelated materials. Nevertheless, other published QTLs were detected, and these can be used in breeding with more confidence and can also be used in the development of new phenotypes through hybrisisation and incorporation TaHSP90A transcripts(Ammar et al., 2023,2024).

Chapter 7: General discussion

The ever-prevalent issue of global climate change is increasing in severity and causing constraints to wheat production (Ni et al.,, 2018; Wang et al.,, 2017). The ambient temperature for daytime growth and reproductive development of wheat is 15°C and every degree Celsius above the ambient temperature results in a 3-4% reduction in grain yield (Ni et al.,, 2018; Morgounov et al.,, 2018). Climate models project that the average global temperature is increasing at a rate of 0.18°C every decade (Ni et al.,, 2018). Heat stress on wheat results in damage to cellular structures which affects various metabolic pathways such as membrane thermostability, photosynthesis and starch synthesis (Ni et al.,, 2018; Farooq et al.,, 2011). An increased concentration of unsaturated fatty acids is also a result of exposure to heat stress which results in the disruption of water, ion and organic solute movement across membranes which in turn leads to increased cell membrane permeability, leading to inhibition of cellular function (Ni et al.,, 2018). Heat stress also effects agronomic traits of wheat such as grain number per spike and yield (Ni et al.,, 2018). To address this issue, mechanisms of inheritance of heat tolerance in wheat needs to be well understood. Progress is restrained due to the lack of information in the genetic mechanisms of heat tolerance.

This thesis investigated the mechanisms and inheritance of heat tolerance in durum and bread wheat (Table 7.1). Field experiments have enhanced our understanding of the effect of temperature stress on grain quality, dough rheological properties, agronomic and physiological traits of bread wheat (Chapter 4) and durum wheat (Chapter 5). The genome-wide association study on bread wheat (Chapter 6) identified significant heat tolerant QTLs which can be used in marker assisted selection.

Table 7.1: Relative contribution of each chapter of the thesis towards science

Chapter	Objectives	Key findings	Outcomes	Future directions
4	To determine the effect of heat stress on agronomic, physiological and dough rheological traits of bread wheat	1. Heat stress accelerates plant development and growth 2. Heat stress results in shorter plant height 3. Heat stress results in reduced yield and TKW but increased protein content	Likely inheritance of heat tolerance in hexaploid wheat through association mapping	The metabolic and development pathways associated with heat stress and energy regulation must be investigated and further research is needed into the knowledge of molecular response and tolerance mechanism to obtain sustainable grain yields
5	To determine the effect of heat agronomic, physiological and dough rheological traits of durum wheat. Heritability and heat susceptibility of measured traits	1. Heat stress resulted in reduced grain and milling yield 2. Yield was found to be highly heritable with H value ranging between 0.6-0.9. Late sowing is an effective method for screening for heat tolerance potential of durum wheat and bread wheat	Likely inheritance of heat tolerance in the wild tetraploids through association mapping	Enhancements in the molecular knowledge of the response and tolerance mechanisms used by wheat crops will allow for harvesting higher grain yields while exposed to heat stress
6	To identify links between traits of interest and genetic markers in bread wheat	1. Identified significant MTAs 2. Identified significant heat tolerant QTLs	Identify the genetic basis of heat tolerance	Conduct fine mapping with the identified QTLs could be used in marker assisted selection programs which could lead to the improvement in the effectiveness of breeding and selection programs

7.1 Heat stress on bread wheat

The effects of heat stress on growth, physiology and dough rheological properties of bread were studied in two years of field experiments (Chapter 4). Reduction in grain yield was a general response of bread wheat to heat stress which was applied through late sowing. Other studies have implemented artificially warmed environments in screening wheat varieties for heat tolerance, and the main focus of those studies was to assess physiological traits rather than genetic variation (Ottman, Kimball, White, & Wall, 2011; Tian et al.,, 2014). The in-field screening methodologies used in this study allowed for season-long warming and exposure to typical field situations that cannot be achieved with controlled chamber experiments (Russel and Van Sanford, 2018). Studies have found that the ambient temperature for anthesis and grain-filling is between 12 to 22°C (Farooq et al.,, 2011) with temperatures above this range as experienced by the current study and other work result in a substantial reduction in grain yield between 6 and 16% (McDonald et al.,, 1983; Macas et al.,,1999,2000; Mullarkey and Jones, 2000; Tewolde et al.,, 2006). These mentioned studies indicated that heat stress results in hastening of the wheat life cycle leading to reductions in grain yields which concurs with previous studies (Sangwan et al.,, 2019; Bala and Sikder., 2018; Lopes and Reynolds. 2012). Consistent with previous reports, this study found that heat stress resulted in increased protein concentration between 12.3-14.1% (Uhlen et al.,, 1998; Labuschagne et al.,, 2008). However, Sissons et al (2017) found that protein concentration can be affected by temperature duration and temperature achieved during the late sowing. The Blumenthal study et al (1995) found that heat stress results in overall weakening of dough quality and supports the findings in the present study. This study found that Livingston (Genotype #17) was high yielding with high flour yield across both normal sowing date and late time of sowing date which implies that the genotype is stable for high yield even under exposure to heat stress. Genotype # 10 also had high grain yield and flour yield in all times of sowing in both years and maintained the dough rheological properties W8 and RBD under heat stress.

High grain yield and acceptable quality can be achieved under heat stress with the use of functional genomic methods. This will allow for the enhancement in knowledge of the molecular basis of heat tolerance in wheat crops. with the identification of allelic sources that are known to be controlling heat tolerance and the introgression of those sources into elite breeding lines to achieve the desired outcome.

7.2 Heat stress on durum wheat

This field and laboratory experiment explored the effects of heat stress on the physiology, grain quality and dough rheological traits of durum wheat (Chapter 5). Heat stress induced grain yield losses in wheat associated with reductions in the plants photosynthetic capacity caused by metabolic restrictions and oxidative damage to chloroplasts leading to decreases in the accretion of dry matter and grain yield (Farooq et al.,, 2011). Minimal research has gone into the varieties studied in this experiment by other studies (Magallanes-Lopez et al.,, 2017; Aberkane et al.,, 2021; Liu et al.,, 2019).

This experiment confirmed that there was significant environment (E), genotype (G) and environment by genotype (G) x (E) interaction imposed on grain yield in line with other studies (Sissons et al.,, 2017; Thistlethwaite et al.,, 2020; Ullah et al.,, 2019;). Characteristically, studies have discovered a positive relationship between grain yield and kernel weight (Cosentino et al.,, 2018). Usually, yield is negatively correlated with screenings percentage (Ullah et al.,, 2019;

Maphosa et al.,, 2014). This study confirmed that heat stress resulted in increased screenings percentage and reduced thousand kernel weight since seed size is strongly dependent on temperature (Nuttall et al.,, 2017). Protein content increased with heat stress. While protein concentration increased, the functionality of the protein is reduced (Farooq et al.,, 2011; Corbellini et al.,, 1997. The genotypes in the present study can be used for further research for potential improvements in molecular knowledge of the response and tolerance mechanism of these genotypes and could then be used in breeding programs. Yield was a highly heritable trait with H value between 0.6-0.9. The traits; RBD, WA8, MPT, yellow-pigment, SY and protein content were highly heritable. This study found that as heat increased protein content increased but negative effects were reduced dough strength as in higher RBD lower MPT, reduced grain size and reduced flour yield. The finding indicates that the positive responses of heat stress on durum quality can be exploited while reducing the negative effects of heat stress on grain yield.

7.3 GWAS of the effects of heat stress on bread wheat

This experiment detected the links between traits of interest and genetic markers and was able to identify QTLs associated with heat tolerance (Chapter 6). The multi-year, multi environment GWAS study confirmed that the AB genome has a larger contribution to heat stress tolerance and also confirmed that the D genome has reduced marker coverage in line with Ullah et al. (2021). This experiment discovered MTAs for grain yield had positive effects over the whole genome. The significant MTAs with grain yield increasing effect were discovered on chromosome 1B, 2A, 4A, 6B (2) and 7A. The experiments found highly significant MTAs for screenings percentage on chromosome 2B (2), 3B and 4A and for TKW, highly significant MTAs were found on chromosome 2B, 2D, 3B (2) and 4A. There was a correlation between photoperiod genes and the QTLs discovered in the current study. The QTL on chromosome 2A, map position 11.03 cM was associated with significant effect of an increase in grain yield was discovered to be associated with the photoperiod gene ppd-A1 with a position of 62.2 cM (Guedira et al.,, 2016). The QTL discovered on chromosome 2B, map position 59.14824838 cM was responsible for a significant positive effect on TKW and was found to be correlated with the photoperiod gene Ppd-B1 with a map position of 94.6 cM (Guedira et al.,, 2016). The unmapped QTL on chromosome 2D responsible for significant positive effect on TKW could potentially be correlated with the photoperiod gene Ppd-D1 with a map position of 9.6 cM (Guedira et al.,, 2016). The experiment was unable to find any correlations between semi-dwarf gene and QTLs from the experiment. The experiment discovered a correlation between vernalisation gene Vrn-B1 with a map position of 142.8 cM (Guedira et al.,, 2016) and the QTL on chromosome 5B responsible for having a negative effect on yield with map position (63.73126094) and the QTL found in this experiment on chromosome 5B, map position 63.73126094 cM which was found to cause reductions in yields. This association could be due to the mentioned QTL being found in TOS 2 meaning that the vegetative state will be longer since TOS 2 has cooler conditions and as a result vernalisation genes will have a negative effect on yield.

7.4 Major hypothesis of the thesis and recommendations

The major hypothesis of the thesis was “there is adequate genetic diversity for tolerance to high temperature stresses in both bread wheat and durum wheat? Was field-based phenotyping alongside genome-wide association study (GWAS) successful in identifying and selecting superior genotypes for genetic enhancement?” Field experiments suggested that heat stress negatively affected physical grain quality and grain yield in both durum and bread wheat. The hypothesis “there is adequate genetic diversity for tolerance to high temperature stresses in both bread wheat and durum wheat” was supported by the fact that the genotypes evaluated in this thesis presented a range of genetic diversity for tolerance to heat stress >30°C and identified genotypes of bread and durum wheat with better heat tolerance. The GWAS experiment was successful in identifying QTLs with tolerance to heat stress which can be used in selecting genotypes for genetic enhancement.

The data from the bread wheat experiment confirmed the hypothesis that there was adequate genetic diversity for high stress tolerance in adapted bread wheat as genotypes stable for high yield and grain quality under heat stress were identified. Genotype 17# was high yielding with high flour yield across both times of sowing in both years which is indicative of high stable yield and heat stress tolerance. Genotype # 14 was stable in producing low screenings% in both times of sowing in both years and the genotype was also high yielding except in 2015 time of sowing 1, which could be explained by the reduced rainfall during critical growth stages (Figure 5.1 b). Genotype #18 was high yielding, except in 2015 TOS 3, and stable, producing low W8 and high RBD. Genotype # 10 was stable for high grain yield and flour yield in all times of sowing in both years and stable for high W8 and low RBD. Genotype #15 was stable for high flour protein content and low screenings% in all times of sowing in both environments and had low RBD and high W8. The genetic diversity for heat tolerance in these genotypes can be exploited by crossing among them on the basis of complementary traits.

The field and dough rheological experiments on durum wheat also confirmed that adequate genetic diversity for high stress tolerance exists in durum wheat. The experiments identified various genotypes that were high yielding under higher temperatures. However, there was little consistency between years with only # 106 showing high yield in both conditions. Nevertheless, genotypes with complementary quality and yield traits under stress were identified and could be used to breed more climate ready durum wheats. The high broad sense heritabilities observed for most traits will assist with the selection process and it should be possible to develop a high yielding genotype with excellent seed and dough properties under high temperatures.

The multi-year, multi-environment GWAS study confirmed that field-based phenotyping and GWAS was successful in identifying and selecting superior genotypes for genetic enhancement of heat tolerance. The study confirmed previously published QTL and identified potential new QTL. These new QTL can be used in marker-assisted selection for heat tolerance once validated in other materials.

Following validation, fine mapping will provide plant breeders with the tools needed to integrate heat tolerance in to their breeding pipelines.

7.5 Future research

This study provided insights into physiological and genetic mechanisms of heat tolerance, and suggested methods for enhancing wheat performance under heat stress. Various sources of genetic variability for tolerance in bread and durum wheat were identified. Limitations to this study include the use of sowing dates to induce heat stress. Flowering time differences may have contributed to less accuracy. Later sowing also reduced the vegetative period and this may have influenced the heat response compared to materials were sown optimally and then exposed to heat stress during grainfilling. Clearly, fmore environments are needed to better understand the influence of G ×E on heat tolerance. Thus, future research should focus on this issue.

- Detailed studies are required to uncover the expression pattern of genes regulating heat tolerance
- The dough rheological experiments and field experiments provided supporting evidence of effects of heat stress on wheat physiology, quality and yield. These experiments need to be repeated, and germplasm validated in more environments.
- The QTLs identified in the GWAS study should be validated before use in breeding programs
- Crosses should be made among genotypes carrying complementary yield and quality traits under heat stress.
- The number of genotypes tested and isogenic lines should be increased.
- Changing experiment design from randomised complete block design to alpha lattice due to only have two replicates, or increasing the number of replicates.

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Appendix

Table 1: Bread wheat predicted means for examined traits

Entry	2014 TOS 1	Yield Kg/ha	Screenings %	TKW g	Days to heading	Days to Maturity	NDVI Booting	NDVI Heading	Plant height cm	Flour protein	Flour yield	MPH	MPT	RBD	W8	WAP
1	2014 TOS 1	4332	6.69		110	161	0.8455	0.703	89.97	12.54	61.37	55.12	4.665	88.27	2.153	17.39
2	2014 TOS 1	6815	4.87	43.88	116	161	0.8436	0.72	97.47	13.59	59.85	51.44	3.185	92.53	1.448	18.1
3	2014 TOS 1	5021	5.11	40.88	115	161	0.8257	0.6966	94.97	11.69	58.63	52.71	2.65	94.45	0.783	13.23
4	2014 TOS 1	6038	6.17	37.38	113.5	159.5	0.8146	0.6923	99.97	12.84	59.11	48.36	5.105	87.43	1.483	11.19
5	2014 TOS 1	6570	6.47	43.88	111	160.5	0.8457	0.4045	102.47	11.89	57.9	48.12	3.925	88.11	1.118	9.3
6	2014 TOS 1	4891	7.76		114	163	0.8306	0.6919	99.97	12.34	62.21	51.18	2.65	98.2	0.243	10.72
7	2014 TOS 1	7334	4.72	41.88	114	162	0.837	0.6877	94.97	11.04	54.75	43.45	4.49	83.67	1.933	11.58
8	2014 TOS 1	5829	9.87		114	162	0.8284	0.7153	94.97	12.74	58.7	49.29	3.065	93.26	0.558	7.69
9	2014 TOS 1	4287	4.77		116	165	0.8475	0.7061	92.47	11.99	59.14	50.98	4.45	78.58	3.263	14.25
10	2014 TOS 1	6690	5.61	35.88	113.5	159	0.8409	0.683	92.47	12.49	60.63	55	3.9	80.42	2.953	14.96
11	2014 TOS 1	4312	7.67		106.5	160	0.8211	0.6851	92.47	12.59	58.2	49.33	3.21	90.49	0.953	9.57
12	2014 TOS 1	6554	7.34	41.38	114.5	162.5	0.8377	0.7018	92.47	11.99	56.62	55.55	5.03	58.62	1.148	6.82
13	2014 TOS 1	6227	4.75	39.38	113	162	0.8265	0.6839	84.97	13.64	61.99	62.53	2.97	84.83	2.628	17.13
14	2014 TOS 1	6391	5.47	49.88	106	159.5	0.8257	0.7046	92.47	12.39	60.29	29.37	1.815	97.43	0.358	12.12
15	2014 TOS 1	6112	6.75	38.88	114.5	162	0.8452	0.7144	97.47	13.09	58.74	56.42	5.385	76.55	3.543	15
16	2014 TOS 1	3938	5.57		114	162.5	0.8317	0.5647	104.97	10.64	52.32	52.04	2.95	91.14	1.278	13.64
17	2014 TOS 1	7470	6.87	39.38	111.5	156.5	0.857	0.7223	92.47	12.22	61.4	53.72	3.365	87.97	2.098	17.6
18	2014 TOS 1	7149	7.55	40.88	112.5	161	0.8153	0.7204	84.97	12.14	56.55	51.3	2.87	94.62	0.693	11.36
19	2014 TOS 1	6285	7.3	38.88	110.5	161	0.864	0.7094	97.47	12.29	60.18	52.96	3.295	85.6	2.013	13.49
20	2014 TOS 1	4120	6.92		92	139.5	0.8399	0.7302	92.47	11.74	56.06	46.56	3.52	89.46	2.067	12.87
1	2014 TOS 3	2120	25.72		83	110.5	0.6712	0.3298	84.97	14.34	60.61	59.88	7.605	8.18	23.088	25.17
2	2014 TOS 3	3012	24.77	27.88	81	110	0.6591	0.3619	82.47	14.84	57.59	57.31	4.48	69.98	4.798	15.76

Entry	2014 TOS 1	Yield Kg/ha	Screenings %	TKW g	Days to heading	Days to Maturity	NDVI Booting	NDVI Heading	Plant height cm	Flour protein	Flour yield	MPH	MPT	RBD	W8	WAP
3	2014 TOS 3	2913	23.81	32.38	79	109	0.5875	0.3791	94.97	12.59	53.07	54.73	2.555	92.81	1.558	19.78
4	2014 TOS 3	2751	44.01	22.38	80	110	0.6595	0.3605	82.47	15.49	57.41	49.56	5.505	83.68	2.528	15.35
5	2014 TOS 3	2813	32.69	25.88	79.5	110.5	0.6412	0.3165	87.47	14.89	55.14	61.84	4.605	72.26	5.833	20.73
6	2014 TOS 3	2104	28.14		83	111	0.6287	0.3473	82.47	15.29	58.52	59.23	4.27	86.2	2.593	18.22
7	2014 TOS 3	3143	26	25.88	81.5	110.5	0.6158	0.2814	77.47	13.79	52.07	57.55	5.645	75.89	4.633	19.03
8	2014 TOS 3	1848	28.94		83	111.5	0.6829	0.3521	74.97	15.14	53.78	59.68	4.02	85.17	2.573	16.73
9	2014 TOS 3	2121	30.8		83	111.5	0.6738	0.3313	84.97	14.17	57	60.95	5.005	69.25	6.358	20
10	2014 TOS 3	2898	50.66	19.38	81	110	0.6715	0.4046	74.97	14.99	62.12	61.45	4.695	64.1	5.863	16.19
11	2014 TOS 3	1952	29.62		81	110	0.6713	0.3293	79.97	15.14	54.15	60.11	4.245	89.39	1.863	16.63
12	2014 TOS 3	3321	28.55	24.38	81.5	110	0.6205	0.3843	79.97	13.74	59.44	61.54	4.065	86.83	2.628	19.3
13	2014 TOS 3	2823	24.82	23.38	81.5	110	0.6345	0.365	84.97	16.12	61.66	65.1	3.26	79.15	4.908	23.64
14	2014 TOS 3	3026	29.6	26.88	80.5	111	0.6669	0.3231	72.47	13.19	58.83	52.76	2.24	91.23	1.078	10.62
15	2014 TOS 3	2968	30.24	24.38	79.5	109	0.6813	0.3035	82.47	14.94	56.63	60	8.555	-29.41	27.768	21.58
16	2014 TOS 3	2516	18.3		83	112.5	0.6508	0.2982	89.97	11.99	48.64	56.03	3.91	59.73	6.298	16.61
17	2014 TOS 3	2913	47.77	22.88	82	112	0.5897	0.3173	77.47	14.99	59.23	58.5	3.935	73.93	3.823	15.72
18	2014 TOS 3	2866	43.56	21.88	81	111	0.665	0.4189	72.47	15.34	53.21	58.48	3.29	88.13	2.098	17.19
19	2014 TOS 3	2629	37.29	21.38	83	112	0.7201	0.3576	79.97	15.44	55.58	58.22	2.625	66.9	4.483	13.45
20	2014 TOS 3	2176	24.37		83	112	0.5933	0.2751	79.97	14.14	54.9	58.99	3.55	92.61	1.518	19.53
1	2015 TOS 1	3035	3.69		115	153	0.7409	0.6716	104.97	13.14	49.78	60.11	8.04	7.65	23.18	25.1
2	2015 TOS 1	3245	2.08	42	115	158	0.7937	0.62	110	14.5	50.98	61.97	3.33	93.5	1.15	17.7
3	2015 TOS 1	2745	4.13	37	115	156	0.8135	0.66	120	13.3	51.32	57.16	3.52	96.3	0.58	15.66
4	2015 TOS 1	2565	8.45	28	121	155	0.8157	0.7	110	13.9	51.81	56.44	7.31	28.36	13.21	18.44
5	2015 TOS 1	3225	5.03	32	116	156	0.8116	0.65	105	12.1	55.41	55.97	6.37	39.16	10.47	17.21
6	2015 TOS 1	3480	4.46		116	160	0.5743	0.7016	110.97	13.09	51.95	42.09	5.51	85.32	1.99	13.56
7	2015 TOS 1	3325	4.43	34	117	156	0.8336	0.67	98	13.3	56.11	60.54	5.88	-174.2	7.76	2.83
8	2015 TOS 1	3478	2.74		118	156	0.8064	0.6816	104.97	13.49	42.49	54.64	3.58	87.36	2.01	15.9
9	2015 TOS 1	3475	4.12		121	158.5	0.6833	0.6416	104.47	12.74	51.09	54.95	6.35	24	15.26	20.08

Entry	2014 TOS 1	Yield Kg/ha	Screenings %	TKW g	Days to heading	Days to Maturity	NDVI Booting	NDVI Heading	Plant height cm	Flour protein	Flour yield	MPH	MPT	RBD	W8	WAP
10	2015 TOS 1	3698	6.76	27.88	115	155.5	0.7751	0.6516	102.47	13.99	49.97	55.78	5.64	52.01	7.76	16.17
11	2015 TOS 1	3483	2.25		116	156.5	0.8424	0.6966	102.47	13.89	49.64	43.95	3.93	96.35	0.47	12.89
12	2015 TOS 1	3870	4.02	38.38	112	155	0.8384	0.6366	94.97	12.24	49.85	53.51	4	90.85	1.87	20.43
13	2015 TOS 1	2753	5.21	29.38	113	155	0.7515	0.6316	105.97	14.94	46.49	68.63	3.91	61.38	10.1	26.15
14	2015 TOS 1	3225	3.2	41	112	156	0.8413	0.66	97	12.6	50.27	52.77	2.19	96.17	0.43	11.23
15	2015 TOS 1	3310	3.6	33	119	159	0.8315	0.56	110	13.4	45.45	41.08	8.85	11.92	10.57	12
16	2015 TOS 1	3375	2.4		119	156	0.7866	0.66	112	12.4	44.56	48.95	5.73	44.96	5.84	10.61
17	2015 TOS 1	3670	7.42	38	112	154	0.82	0.69	105	12.8	50.42	55.96	3.99	74.86	4.77	18.97
18	2015 TOS 1	3415	5.1	32	115	156	0.8035	0.67	101	12.1	42.28	50.02	3.96	94.33	0.73	12.87
19	2015 TOS 1	3140	5.27	29	124	162	0.8363	0.69	95	12.1	48.59	48.66	6.87	32.51	12.6	18.67
20	2015 TOS 1	3678	3.82		111	159	0.8404	0.6566	106.47	13.04	49.23	56.81	4.51	84.36	2.77	17.71
1	2015 TOS 3	2165	9.83		83	111	0.79	0.58	75	13.1	55.72	50.96	8.87	29.01	15.71	22.13
2	2015 TOS 3	1805	12.38	28	85	109	0.74	0.54	80	14.9	50.59	65.69	4.69	83.79	4.4	27.14
3	2015 TOS 3	1630	9.13	31	85	113	0.75	0.65	85	13.4	50.77	61.54	3.53	97.99	0.37	18.44
4	2015 TOS 3	1560	33.75	20	85	112	0.75	0.57	70	15.2	60.47	67.01	5.71	78.75	5.39	25.36
5	2015 TOS 3	2038	16.04	25.38	82	111	0.7803	0.5966	62.47	13.39	50.2	75.91	5.78	40	9.6	16
6	2015 TOS 3	2248	12.67		78	112	0.7503	0.6366	79.97	13.24	52.56	59.69	6.46	64.18	9.11	25.43
7	2015 TOS 3	1595	7.83	30	77	111	0.7	0.51	65	15.3	52.14	69.72	3.83	92.54	2.24	30.01
8	2015 TOS 3	2125	10.03		84	106	0.76	0.57	75	13.4	50.88	60.12	3.9	88.2	1.66	14.07
9	2015 TOS 3	1870	8.48		81	113	0.77	0.6	80	13.8	52.09	61.87	4.92	84.68	3.43	22.39
10	2015 TOS 3	2050	35.65	17.88	81.5	112	0.7603	0.5816	69.97	13.54	51.85	59.63	7.5	3.36	22.14	22.91
11	2015 TOS 3	1945	9.61		84	113	0.7603	0.5916	74.97	13.89	48.41	60.2	3.87	96.87	0.51	16.29
12	2015 TOS 3	1948	15.37	23.88	78	109.5	0.7853	0.5966	69.97	13.79	48.56	53.77	5.9	56.29	8.27	18.92
13	2015 TOS 3	1665	11.73	25	83	113	0.78	0.58	75	15.5	50.08	74.61	4.75	71.64	7.44	26.23
14	2015 TOS 3	1975	11.57	27.88	83	108.5	0.7303	0.5216	64.97	14.29	51.29	61.97	3.05	96.77	0.45	13.94
15	2015 TOS 3	1880	8.67	27.38	82	113	0.7753	0.6166	74.97	13.89	52.2	53.79	8.54	5.12	28.01	29.52
16	2015 TOS 3	1773	8.97		79.5	110.5	0.7553	0.5616	82.47	13.64	45.54	57.24	6.87	8.78	18.29	20.05

Entry	2014 TOS 1	Yield Kg/ha	Screenings %	TKW g	Days to heading	Days to Maturity	NDVI Booting	NDVI Heading	Plant height cm	Flour protein	Flour yield	MPH	MPT	RBD	W8	WAP
17	2015 TOS 3	1935	23.32	23.38	83.5	108	0.7403	0.5766	59.97	13.64	54.78	68.65	3.94	80.36	5.06	25.77
18	2015 TOS 3	1818	27.29	21.88	81	109.5	0.7703	0.5216	64.97	13.94	48.75	59.55	3.79	95.33	1.15	24.63
19	2015 TOS 3	1918	12.64	25.88	78	117	0.7953	0.6866	69.97	12.79	50.7	51.86	6.45	21.76	12.69	16.22
20	2015 TOS 3	1625	9.92		79	110.5	0.7703	0.6116	74.97	14.59	49.26	58.76	3.78	95.79	0.84	19.97

Table:2 Durum wheat germplasm including entry number, pedigree, source and type.

ENTRY	NAME	PEDIGREE	SOURCE	TYPE
1	AUS10105	AUS10105	13INDBRZ 130485	LANDRACE
2	AUS10110	AUS10110	13INDBRZ 130629	LANDRACE
3	AUS10191	AUS10191	13INDBRZ 130480	LANDRACE
4	AUS11706	AUS11706	13INDBRZ 130694	LANDRACE
5	AUS14211	AUS14211	13INDBRZ 130535	LANDRACE
6	CAPAROI		13INDBRZ 130559	SEMI DWARF
7	DWL5002	AUS21132	13INDBRZ 130656	SEMIDWARF
8	GHODIBANSI	AUS8629	13INDBRZ 130624	LANDRACE
9	GUARANI	AUS8634	13INDBRZ 130575	LANDRACE
10	HYPERNO		13INDBRZ 130645	SEMI DWARF
11	IG130969	AUS32610	13INDBRZ 130574	LANDRACE
12	IG130971	AUS32612	13INDBRZ 130515	LANDRACE
13	IG130973	AUS32614	13INDBRZ 130584	LANDRACE
14	IG130978	AUS32619	13INDBRZ 130704	LANDRACE
15	IG130979	AUS32620	13INDBRZ 130477	LANDRACE
16	IG130980	AUS32621	13INDBRZ 130498	LANDRACE
17	IG130995	AUS32636	13INDBRZ 130679	LANDRACE
18	IG130998	AUS32639	13INDBRZ 130696	LANDRACE
19	IG98794	AUS31877	13INDBRZ 130534	SEMIDWARF

20	IG98808	AUS31891	13INDBRZ 130483	SEMIDWARF
21	INDIA32	AUS4668	13INDBRZ 130632	LANDRACE
22	INDIAN6	AUS4647	13INDBRZ 130682	LANDRACE
23	KHAPLI	AUS378	13INDBRZ 130605	T dicoccum
24	KHIBRI	AUS8624	13INDBRZ 130502	LANDRACE
25	LALKASARWALI	AUS2840	13INDBRZ 130667	LANDRACE
26	NIPHAD81	AUS19427	13INDBRZ 130549	SEMIDWARF
27	PH*003	Sunco/230604	13INDBRZ 130506	SEMIDWARF

ENTRY	NAME	PEDIGREE	SOURCE	TYPE
28	PH*009	Sunco/230604	13INDBRZ 130674	SEMIDWARF
29	PH*013	Sunco/230604	13INDBRZ 130571	SEMIDWARF
30	PH*018	Sunco/230604	13INDBRZ 130657	SEMIDWARF
31	PH*020	Sunco/230604	13INDBRZ 130499	SEMIDWARF
32	PH*068	Sunco/230604	13INDBRZ 130533	SEMIDWARF
33	PH*070	Sunco/230604	13INDBRZ 130618	SEMIDWARF
34	PH*077	Sunco/230604	13INDBRZ 130616	SEMIDWARF
35	PH*078	Sunco/230604	13INDBRZ 130689	SEMIDWARF
36	PH*086	Sunco/230604	13INDBRZ 130708	SEMIDWARF
37	PI*001	Sunco/230616	13INDBRZ 130551	SEMIDWARF
38	PI*002	Sunco/230616	13INDBRZ 130536	SEMIDWARF
39	PI*003	Sunco/230616	13INDBRZ 130583	SEMIDWARF
40	PI*005	Sunco/230616	13INDBRZ 130565	SEMIDWARF
41	PI*012	Sunco/230616	13INDBRZ 130596	SEMIDWARF
42	PI*016	Sunco/230616	13INDBRZ 130475	SEMIDWARF
43	PI*017	Sunco/230616	13INDBRZ 130488	SEMIDWARF
44	PI*021	Sunco/230616	13INDBRZ 130487	SEMIDWARF

45	PI*023	Sunco/230616	13INDBRZ 130554	SEMIDWARF
46	PI*027	Sunco/230616	13INDBRZ 130479	SEMIDWARF
47	PI*029	Sunco/230616	13INDBRZ 130501	SEMIDWARF
48	PI*053	Sunco/230616	13INDBRZ 130562	SEMIDWARF
49	POONA168	AUS12086	13INDBRZ 130597	SEMIDWARF
50	POONA805	AUS834	13INDBRZ 130510	SEMIDWARF
51	POONA806	AUS835	13INDBRZ 130589	SEMIDWARF
52	POONA809	AUS837	13INDBRZ 130665	SEMIDWARF
53	POONA810	AUS836	13INDBRZ 130513	SEMIDWARF
54	PUSA20	AUS909	13INDBRZ 130591	SEMIDWARF
55	RAJ1555	AUS22132	13INDBRZ 130491	SEMIDWARF

ENTRY	NAME	PEDIGREE	SOURCE	TYPE
56	ROSCHANUM	AUS11773	13INDBRZ 130662	LANDRACE
57	UAD951096		13INDBRZ 130520	SEMI DWARF
58	V121182	920777/Kronos	13INDBRZ 130626	SEMIDWARF
59	V121183	920777/Kronos	13INDBRZ 130619	SEMIDWARF
60	V121184	920777/Kronos	13INDBRZ 130504	SEMIDWARF
61	V121186	920777/Kronos	13INDBRZ 130617	SEMIDWARF
62	V121187	920777/Kronos	13INDBRZ 130540	SEMIDWARF
63	V121188	920777/Kronos	13INDBRZ 130620	SEMIDWARF
64	V121189	920777/Kronos	13INDBRZ 130507	SEMIDWARF
65	V121190	920777/Kronos	13INDBRZ 130593	SEMIDWARF
66	V121192	920777/Kronos	13INDBRZ 130647	SEMIDWARF
67	V121194	920777/Kronos	13INDBRZ 130580	SEMIDWARF
68	V121195	920777/Kronos	13INDBRZ 130604	SEMIDWARF
69	V121197	920777/Kronos	13INDBRZ 130474	SEMIDWARF

ENTRY	NAME	PEDIGREE	SOURCE	TYPE
70	V121200	920777/Kronos	13INDBRZ 130528	SEMIDWARF
71	V121201	920777/Kronos	13INDBRZ 130511	SEMIDWARF
72	V121203	920777/Kronos	13INDBRZ 130484	SEMIDWARF
73	V121204	920777/Kronos	13INDBRZ 130590	SEMIDWARF
74	V121205	920777/Kronos	13INDBRZ 130529	SEMIDWARF
75	V121208	920777/Kronos	13INDBRZ 130525	SEMIDWARF
76	V121269	920777/Kronos	13INDBRZ 130503	SEMIDWARF
77	V121270	920777/Kronos	13INDBRZ 130602	SEMIDWARF
78	V121272	920777/Kronos	13INDBRZ 130641	SEMIDWARF
79	V121276	920777/Kronos	13INDBRZ 130615	SEMIDWARF
80	V121277	920777/Kronos	13INDBRZ 130560	SEMIDWARF
81	V121279	920777/Kronos	13INDBRZ 130625	SEMI DWARF
82	V121281	920777/Kronos	13INDBRZ 130472	SEMI DWARF
83	V121283	920777/Kronos	13INDBRZ 130652	SEMI DWARF
84	V121288	920777/Kronos	13INDBRZ 130648	SEMI DWARF
85	V121290	920777/Kronos	13INDBRZ 130555	SEMI DWARF
86	V121291	920777/Kronos	13INDBRZ 130712	SEMI DWARF
87	V121292	920777/Kronos	13INDBRZ 130660	SEMI DWARF
88	V121293	920777/Kronos	13INDBRZ 130563	SEMI DWARF
89	V121294	920777/Kronos	13INDBRZ 130639	SEMI DWARF
90	V121296	920777/Kronos	13INDBRZ 130606	SEMI DWARF
91	V121299	920777/Kronos	13INDBRZ 130489	SEMI DWARF
92	V121300	920777/Kronos	13INDBRZ 130621	SEMI DWARF
93	V126491	920318/Kronos	13INDBRZ 130473	SEMI DWARF
94	V126492	920318/Kronos	13INDBRZ 130476	SEMI DWARF
95	V126505	920334/Kronos	13INDBRZ 130658	SEMI DWARF
96	V126506	920334/Kronos	13INDBRZ 130486	SEMI DWARF

97	V126535	920325/Kronos	13INDBRZ 130599	SEMI DWARF
98	WKOELZ8814	AUS7947	13INDBRZ 130684	LANDRACE
99	WKOELZ9182	AUS7951	13INDBRZ 130646	LANDRACE
100	BELLAROI			SEMI DWARF
101	JANDAROI			SEMI DWARF
102	V190873	CAPAROI/261102.		SEMI DWARF
103	V190886	CAPAROI/261102.		SEMI DWARF
104	V192482	230349/260233.		SEMI DWARF
105	V195498	B1071C/Haz//09 - 1107		SEMI DWARF
106	V241046	960273/980596		SEMI DWARF
107	V280913	200856/980990		SEMI DWARF
108	V290491	230616/230800		SEMI DWARF
109	V290564	230616/230800		SEMI DWARF
110	V114912	2/49 A 3 - 3		SEMI DWARF
111	V114918	2/49 B 1 - 1		SEMI DWARF

ENTRY	NAME	PEDIGREE	SOURCE	TYPE
112	V114922	2/49 B 1 - 1		SEMI DWARF
113	V114926	2/49 B 1 - 6		SEMI DWARF
114	V114973	951-51149		SEMI DWARF
115	V114985	A - 2_Sunco/Bellaroi		SEMI DWARF
116	V114992	A - 27_Sunco/Bellaroi		SEMI DWARF
117	V115005	A - 42_Sunco/Bellaroi		SEMI DWARF
118	V115306	D - 58_Sunco/200468		SEMI DWARF
119	V190150	200641/PO7518.		SEMI DWARF
120	V195321	CFR/51//302 - 76		SEMI DWARF

Table 3: Durum wheat predicted means for traits days to heading, days to maturity, days to grain-fill, plant height, ground cover 1, ground cover 2, ground cover rate, yield, protein, SKHI, HLW, SY, WG, Y-pig for 2014 and 2015 all times of sowing

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
1	early sowing 2014	112	139	27	121.5	0.14	0.61	432.1	2590	16.63	79.05	82.28	71.95	39.4	4.655	2590
2	early sowing 2014	112	140	28	132.5	0.1	0.8	795	2595	16.03	84.82	84.05	73.16	38.14	3.969	2595
3	early sowing 2014	115	142	27	132.5	0.13	0.62	467.9	2335	18.17	78.84	79.88	70.57	43.71	4.965	2335
4	early sowing 2014	123	149	26	131.5	0.15	0.78	536.9	1533	17.98	79.75	80.1	70.71	43.45	6.644	1533
5	early sowing 2014	112	142	30	133.5	0.13	0.56	440.1	2162	18.66	77.64	80.51	70.88	45.08	4.85	2162
6	early sowing 2014	106.5	141	34.5	84	0.2	0.59	378.3	4244	15.29	85.56	80.39	71.31	35.3	9.672	4244
7	early sowing 2014	104	138.5	34.5	75	0.2	0.67	352.1	3776	15.58	84.4	80.91	72.07	37.62	5.857	3776
8	early sowing 2014	112	138.5	26.5	116.5	0.13	0.73	582.1	2619	16.85	82.06	81.1	73.22	40.08	6.366	2619
9	early sowing 2014	103	137	34	87.5	0.11	0.68	624.2	2334	15.4	76.81	80.97	71.85	37.96	7.933	2334

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
10	early sowing 2014	104	139	35	90	0.14	0.69	493.1	4184	15.1	86.49	79.9	71.55	34.67	10.26	4184
11	early sowing 2014	122	148	26	124.5	0.18	0.65	450.9	1383	16.17	84.85	78.25	69.16	40.99	5.714	1383
12	early sowing 2014	116	139	23	116	0.25	0.66	299.1	1577	19.27	80.43	79.94	69.62	46.39	5.725	1577
13	early sowing 2014	103	135.5	32.5	117.5	0.15	0.72	489.4	2626	15.2	82.11	84.02	72.61	36.2	6.115	2626
14	early sowing 2014	115.5	142.5	27	135.5	0.11	0.75	716.7	2176	18.28	79.4	81.68	71.5	43.97	4.303	2176
15	early sowing 2014	112	140	28	143.5	0.16	0.74	488.3	2338	15.48	90.68	81.33	72.46	39.27	5.361	2338
16	early sowing 2014	113	146	33	133.5	0.25	0.58	262.3	2284	17.47	85.01	82	70.94	40.97	3.982	2284
17	early sowing 2014	109.5	145	35.5	132	0.13	0.68	557.8	2301	17.36	84.24	80.17	71.41	41.04	5.07	2301
18	early sowing 2014	119.5	147	27.5	126	0.16	0.61	381.3	1911	17.95	82.74	80.46	70.39	42.17	5.685	1911
19	early sowing 2014	103	137	34	93	0.14	0.69	542.8	3842	14.35	81.19	80.8	71.26	32.37	8.85	3842
20	early sowing 2014	105	140	35	84.5	0.16	0.71	498.3	4159	14.2	86.54	82.53	71.76	32.17	6.123	4159
21	early sowing 2014	115	142.5	27.5	126	0.15	0.64	424.1	4243	17.15	86.86	80.61	71.52	42.86	6.28	4243
22	early sowing 2014	103	134	31	123	0.15	0.7	479.3	3049	14.95	70.42	81	70.96	35.32	3.84	3049
23	early sowing 2014	105	133.5	28.5	95	0.15	0.68	464.7	3180	16.62	88.15	76.28	70.86	40.72	6.358	3180
24	early sowing 2014	121	149	28	123.5	0.14	0.46	354	1912	17.27	85.42	78.05	69.5	44.45	5.479	1912
25	early sowing 2014	119.5	149	29.5	128	0.13	0.66	507.7	2019	18.44	83.95	80.43	70.53	44.28	6.089	2019
26	early sowing 2014	103	136.5	33.5	104.5	0.15	0.71	487.5	3519	15.83	87.18	82.95	71.18	37.52	9.14	3519
27	early sowing 2014	103	135	32	110.5	0.17	0.71	426.3	3466	16.53	80.11	83.53	71.5	39.48	8.979	3466
28	early sowing 2014	103	135.5	32.5	118.5	0.13	0.59	455.4	2786	16.94	85.37	79.86	71.03	39.7	9.505	2786
29	early sowing 2014	103	141	38	77.5	0.11	0.57	513.6	3108	16.94	81.67	80.73	70.87	41.77	6.929	3108
30	early sowing 2014	103	138.5	35.5	76	0.19	0.65	429.6	3419	15.74	84.07	79.2	70.97	37.2	9.022	3419
31	early sowing 2014	103	139.5	36.5	84	0.17	0.75	449.6	3581	17.94	84.52	81.25	71.17	42.65	9.533	3581
32	early sowing 2014	104	136.5	32.5	82	0.12	0.72	615.7	3613	16.7	86.07	80.8	72.4	39.79	9.194	3613
33	early sowing 2014	103	136.5	33.5	110.5	0.11	0.64	633.9	3450	16.36	84.08	80.73	71.24	38.39	7.986	3450
34	early sowing 2014	110	141	31	67.5	0.15	0.73	505.5	3054	16.3	81.28	78.36	71.01	40.28	7.295	3054
35	early sowing 2014	103	136	33	80.5	0.13	0.81	658.8	4376	14.68	85.46	81.66	70.96	34.8	8.428	4376

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
36	early sowing 2014	103	136	33	112.5	0.18	0.61	350.7	3151	16.22	79.37	76.5	70.9	40.56	6.358	3151
37	early sowing 2014	104	139.5	35.5	78	0.13	0.6	460.7	4323	14.98	84.5	81.46	71.37	36.62	8.2	4323
38	early sowing 2014	107.5	137.5	30	120.5	0.19	0.69	387.9	3281	16.54	83.4	82.05	72.04	40.33	7.942	3281
39	early sowing 2014	103	137	34	115.5	0.14	0.76	541.7	3530	16.31	85.51	81.51	70.91	37.92	8.838	3530
40	early sowing 2014	104	137	33	103.5	0.12	0.66	574.2	3744	16.42	85.53	82.75	71.24	38.93	9.607	3744
41	early sowing 2014	103	137	34	110.5	0.17	0.66	394.4	2984	16.78	84.35	82.1	71.37	39.38	8.965	2984
42	early sowing 2014	105.5	138.5	33	70.5	0.12	0.78	679.6	3452	16.39	86.27	81.45	71.81	39.91	8.756	3452
43	early sowing 2014	103	138	35	100.5	0.14	0.63	494.1	3075	17.11	85.43	83.92	71.73	41	7.414	3075
44	early sowing 2014	103	138	35	118.5	0.25	0.8	465.4	2989	16.38	86.25	81.64	72.27	39.07	7.827	2989
45	early sowing 2014	103	136.5	33.5	73.5	0.15	0.64	447.5	2999	16.8	85.01	80.62	71.16	41.22	8.233	2999
46	early sowing 2014	103	139.5	36.5	61.5	0.13	0.68	543.3	3771	16.11	86.05	79.14	72.44	37.64	8.889	3771
47	early sowing 2014	103	138.5	35.5	85.5	0.16	0.74	467.5	3169	14.55	79.89	80.43	72.02	35.67	7.947	3169
48	early sowing 2014	103	141	38	74	0.11	0.61	544.2	3584	16.37	84.34	80	71.25	40.03	8.313	3584
49	early sowing 2014	103	134	31	106.5	0.12	0.63	562.5	2803	15.02	79.37	80.34	70.73	37.85	5.691	2803
50	early sowing 2014	103	134	31	96.5	0.14	0.65	538	2544	15.2	78.57	80.55	72.89	38.09	3.502	2544
51	early sowing 2014	115	140	25	121	0.14	0.71	517.7	2171	16.75	82.95	80.62	72.31	39.84	5.678	2171
52	early sowing 2014	115.5	145	29.5	103	0.11	0.6	651.9	2071	17.25	88.33	78.88	71.84	41.3	7.218	2071
53	early sowing 2014	103	135.5	32.5	100	0.12	0.77	658	3336	15.37	81.79	84.42	75.27	37.03	3.923	3336
54	early sowing 2014	107.5	140	32.5	109	0.11	0.76	719.1	1579	18.41	81.44	81.01	69.31	43.25	4.57	1579
55	early sowing 2014	103	136.5	33.5	90	0.15	0.66	463	3785	15.14	86.9	82.13	71.24	35	5.026	3785
56	early sowing 2014	120	146.5	26.5	117.5	0.13	0.57	438.5	1702	16.02	88.79	78.37	68.95	40.76	6.544	1702
57	early sowing 2014	106.5	140.5	34	88.5	0.13	0.74	584.3	4209	14.95	86.03	80.94	71.4	33.72	10.774	4209
58	early sowing 2014	103	137.5	34.5	84	0.13	0.77	600.6	4056	16.09	86.2	82.3	71.49	36.74	8.821	4056
59	early sowing 2014	115	141	26	133	0.11	0.6	560	1933	18.19	81.53	80.1	71.56	42.73	4.407	1933
60	early sowing 2014	103	141.5	38.5	81	0.17	0.74	564.8	3713	15.94	89.83	80.77	70.92	36.6	8.825	3713
61	early sowing 2014	103	137	34	82.5	0.14	0.71	521.1	4179	15.39	87.47	79.89	70.87	35.8	8.967	4179

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
62	early sowing 2014	103	137	34	80.5	0.15	0.63	463.2	4253	15.91	86.5	81.36	71.59	36.39	9.152	4253
63	early sowing 2014	103	138.5	35.5	86	0.11	0.81	736.4	4144	16.01	86.3	81.91	71.22	36.81	8.615	4144
64	early sowing 2014	104	140	36	84	0.15	0.74	512.1	3872	16.13	88.52	80.28	70.42	36.09	9.875	3872
65	early sowing 2014	103	138.5	35.5	82.5	0.12	0.75	649.2	3798	16.22	86.76	78.77	70.82	36.95	10.03	3798
66	early sowing 2014	103	137.5	34.5	92	0.16	0.8	497.8	4243	15.98	86.87	80.68	70.49	36.64	10.456	4243
67	early sowing 2014	103	138	35	78.5	0.15	0.58	407.9	4476	15.33	86.75	82.47	71.28	34.83	9.628	4476
68	early sowing 2014	103	138.5	35.5	81.5	0.14	0.65	462.3	4178	15.68	87.48	79.34	70.51	35.71	10.489	4178
69	early sowing 2014	103	137.5	34.5	86	0.14	0.65	459.7	4269	15.22	85.48	81.24	72.13	34.41	9.876	4269
70	early sowing 2014	103	141	38	77.5	0.14	0.61	466.6	4022	16.04	88.93	81.93	71.59	36.19	9.112	4022
71	early sowing 2014	103	140	37	82.5	0.26	0.74	368.7	4150	15.87	84.59	80.67	71.06	36.1	9.389	4150
72	early sowing 2014	103	136.5	33.5	82.5	0.11	0.73	689.3	4122	16.32	85.17	81.13	71.01	38.13	8.423	4122
73	early sowing 2014	103	137	34	86.5	0.14	0.74	528.6	4170	16.39	84.39	80.56	70.84	38.45	8.247	4170
74	early sowing 2014	103	137.5	34.5	80.5	0.15	0.59	470	4023	15.4	89.66	81.78	71.97	35.18	9.206	4023
75	early sowing 2014	103	138.5	35.5	81.5	0.14	0.66	467.9	3917	16.53	85.05	81.67	71.82	38.77	8.84	3917
76	early sowing 2014	103	138.5	35.5	85.5	0.14	0.7	509.4	4028	16.03	88.41	80.28	71.76	37.01	9.093	4028
77	early sowing 2014	103	139.5	36.5	88	0.17	0.7	428.9	4072	16.33	88.58	80.81	71.83	37.79	8.82	4072
78	early sowing 2014	103	138.5	35.5	83	0.13	0.74	573.2	4460	14.91	85.93	81.27	71.68	33.79	9.469	4460
79	early sowing 2014	103	137	34	89	0.2	0.72	581.3	4477	14.81	86.47	81.57	70.83	34.4	9.729	4477
80	early sowing 2014	103	139.5	36.5	80.5	0.1	0.68	709.4	4541	15.1	88.46	81.18	71.56	35.68	8.386	4541
81	early sowing 2014	103	139.5	36.5	87	0.13	0.7	533.3	3681	15.67	83.65	80.39	71	36.24	9.71	3681
82	early sowing 2014	103	139.5	36.5	80	0.16	0.65	482.4	4399	15.5	86.18	81.35	71.19	36.57	9.058	4399
83	early sowing 2014	103	138.5	35.5	73.5	0.15	0.77	555.8	4357	15.31	84.75	81.93	71.18	35.8	8.88	4357
84	early sowing 2014	103	139.5	36.5	83	0.22	0.61	305.8	4294	16.22	88.63	81.55	71.46	37.11	8.619	4294
85	early sowing 2014	108	140.5	32.5	89.5	0.12	0.78	678.4	4272	16.53	86.46	80.36	70.5	38.11	9.34	4272
86	early sowing 2014	104	139.5	35.5	89	0.16	0.74	475	4466	15.79	88.51	81.11	71.63	36.49	9.732	4466
87	early sowing 2014	103	136	33	81	0.14	0.76	563.5	3911	16.42	85.02	80.07	70.69	37.81	9.371	3911

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
88	early sowing 2014	103	140	37	79	0.12	0.71	591.7	4223	15.62	86.19	82.07	71.13	36.59	9.402	4223
89	early sowing 2014	103	142	39	87.5	0.19	0.64	416.5	4281	15.91	86.7	80.86	72.24	36.64	9.477	4281
90	early sowing 2014	103	139	36	87	0.21	0.58	333.3	3932	16.48	84.67	80.63	71.7	38.69	8.575	3932
91	early sowing 2014	103	138.5	35.5	87	0.15	0.65	484.9	4082	15.32	87.03	82.06	72.29	35.15	9.576	4082
92	early sowing 2014	103	137	34	79.5	0.12	0.84	702.4	4234	15.21	88.78	81.71	71.58	35.15	9.048	4234
93	early sowing 2014	103	137.5	34.5	87.5	0.14	0.66	489	4162	15.15	86.66	79.5	71.18	33.09	10.586	4162
94	early sowing 2014	103	137	34	78	0.14	0.68	499.2	4404	15.23	88.02	81.19	71.78	34.14	10.058	4404
95	early sowing 2014	103	136.5	33.5	82	0.12	0.88	726.2	4193	14.94	87.04	80.89	72.47	34.49	10.286	4193
96	early sowing 2014	103	135.5	32.5	84.5	0.12	0.62	542.7	3970	16.16	85.24	79.65	71.38	36.59	10.624	3970
97	early sowing 2014	103	137.5	34.5	86	0.17	0.63	402.1	4118	15.05	90.38	83.27	72.39	34.78	9.881	4118
98	early sowing 2014	115	141	26	91	0.12	0.6	495.8	1819	15.97	92.71	78.93	70.51	40.77	6.271	1819
99	early sowing 2014	113.5	143	29.5	132.5	0.16	0.7	456.4	2179	16.61	83.8	80.7	71.12	40	6.046	2179
100	early sowing 2014	112.5	143	30.5	75.5	0.13	0.64	492.3	3984	17.14	86.84	79.17	71.35	39.79	9.309	3984
101	early sowing 2014	103	137	34	85.5	0.14	0.72	533.2	4260	16.38	86.95	81.1	71.83	37.35	8.813	4260
102	early sowing 2014	105.5	140	34.5	72	0.12	0.81	703.8	4166	15.24	86.16	81.21	71.32	34.63	11.085	4166
103	early sowing 2014	110	139.5	29.5	80.5	0.17	0.75	454.2	3890	16.12	87.58	81.07	72.52	37.25	10.544	3890
104	early sowing 2014	108.5	141	32.5	82.5	0.11	0.66	628.6	3884	15.73	87.17	79.06	72.09	36.27	11.376	3884
105	early sowing 2014	104	137.5	33.5	89	0.26	0.81	357.4	3946	15.46	85.78	79.38	71.33	35.18	8.925	3946
106	early sowing 2014	103	137.5	34.5	87	0.17	0.84	513.2	4134	15.91	87.46	80.97	72.36	37.49	9.902	4134
107	early sowing 2014	103	136.5	33.5	71.5	0.16	0.75	470.2	4317	15.57	86.82	79.88	71.47	35.3	11.716	4317
108	early sowing 2014	104	139	35	88	0.12	0.78	653.1	4217	15.75	85.91	79.47	71.63	36.69	10.643	4217
109	early sowing 2014	104	142	38	80.5	0.14	0.59	439	3950	16.42	86.15	78.81	71.16	37.53	10.678	3950
110	early sowing 2014	106.5	141	34.5	82.5	0.17	0.63	396.7	4295	14.76	87.46	80.79	71.78	34.29	9.55	4295
111	early sowing 2014	105.5	136.5	31	92	0.17	0.82	497.2	4226	14.71	86.37	80.21	71.73	33.45	10.028	4226
112	early sowing 2014	106	140	34	88.5	0.12	0.67	597.3	3934	15.06	84.98	79.99	71.22	34.21	9.04	3934
113	early sowing 2014	107.5	141	33.5	84	0.17	0.65	392	4091	15.1	85.7	80.59	70.46	34.77	9.748	4091

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
114	early sowing 2014	105.5	140	34.5	89.5	0.14	0.72	557.7	4244	14.79	85.82	80.13	71.27	33.39	9.714	4244
115	early sowing 2014	111	141	30	86	0.12	0.74	616.7	4085	15.16	87.35	80.31	71.42	34.9	9.193	4085
116	early sowing 2014	103	137.5	34.5	87.5	0.15	0.78	546.6	4318	14.64	85.26	80.84	71.68	34.16	8.034	4318
117	early sowing 2014	103	137.5	34.5	96.5	0.16	0.59	379.1	4266	14.38	85.29	81.11	71.15	33.46	9.02	4266
118	early sowing 2014	110	140.5	30.5	81.5	0.17	0.63	374.7	4207	15.36	87.48	80.75	70.82	35.25	9.037	4207
119	early sowing 2014	103	140	37	83	0.15	0.69	501	3940	15.61	82.45	78.88	69.5	36.37	9.613	3940
120	early sowing 2014	107.5	137.5	30	90	0.16	0.67	473.6	3640	16.1	83.58	80.05	71.63	36.65	10.203	3640
1	late sowing 2014	76.5	101	24.5	85.5	0.12	0.41	441.1	1000	17.92	71.6	77.76	70.33	41.96	5.819	1000
2	late sowing 2014	78	104.5	26.5	93.5	0.08	0.51	715	1022	17.88	80.93	80.93	72.01	42.96	4.666	1022
3	late sowing 2014	82.5	105	22.5	97.5	0.08	0.36	438.9	1027	19.57	73.82	76.57	68.87	47.19	4.815	1027
4	late sowing 2014	97	106	9	76	0.09	0.54	675	44	18.49	81.21	77.89	71.24	44.48	8.173	44
5	late sowing 2014	81.5	104	22.5	103	0.19	0.5	258.6	1117	19.5	75.97	77.23	69.61	47.25	4.794	1117
6	late sowing 2014	76.5	106	29.5	65.5	0.14	0.42	306.6	1724	18.71	77.98	74.8	69.17	43.74	10.061	1724
7	late sowing 2014	74.5	103.5	29	56.5	0.09	0.48	621.4	1578	19.36	77.02	75.87	70.56	46.63	6.579	1578
8	late sowing 2014	79	103.5	24.5	88.5	0.08	0.36	486.6	1103	19.67	74.65	76.45	72	47.2	6.563	1103
9	late sowing 2014	73	103	30	65	0.11	0.36	340.4	1105	18.05	75.32	76.56	70.93	44.6	8.479	1105
10	late sowing 2014	73.5	105.5	32	69	0.06	0.55	894.3	1559	18.63	78.76	74.86	70.14	44.21	9.144	1559
11	late sowing 2014	91	105.5	14.5	85	0.09	0.31	400	297	16.66	78.76	74.16	68.22	42.38	6.832	297
12	late sowing 2014	76	101	25	92	0.11	0.5	483.2	709	19.31	77.63	76.13	68.56	46.82	5.465	709
13	late sowing 2014	72	103	31	81.5	0.08	0.46	606.2	1124	17.39	75.29	79.38	72.41	42.33	6.546	1124
14	late sowing 2014	84	103	19	102	0.52	0.42	800	601	18.44	75.03	76.43	70.35	44.39	4.243	601
15	late sowing 2014	80	104.5	24.5	96	0.5	0.47	725	1074	17.04	80.65	76.61	70.59	43.34	5.893	1074
16	late sowing 2014	85.5	106.5	21	85	0.07	0.5	772.6	704	17.6	81.87	76.53	70.24	42.56	4.644	704
17	late sowing 2014	82	105	23	88.5	0.11	0.26	252.8	1019	18.44	82.63	77.52	70.72	43.82	5.311	1019
18	late sowing 2014	86	105	19	83.5	0.1	0.36	368.8	635	18.33	81.47	77.7	71.18	43.59	6.173	635
19	late sowing 2014	72.5	101.5	29	66.5	0.08	0.57	759.8	1386	19.07	74.65	74.06	69.77	44.54	7.438	1386

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
20	late sowing 2014	73.5	103.5	30	63.5	0.09	0.35	411.1	1601	17.91	78.1	76.14	68.88	41.16	6.252	1601
21	late sowing 2014	79.5	103.5	24	83	0.06	0.43	716.7	789	17.57	81.82	76.45	70.54	44.85	5.837	789
22	late sowing 2014	75.5	100.5	25	97	0.1	0.37	366.7	1219	17.37	67.34	76.29	69.59	41.27	6.918	1219
23	late sowing 2014	77.5	100	22.5	71.5	0.07	0.47	664.3	1199	18.99	80.4	72.11	70.42	47.38	8.646	1199
24	late sowing 2014	83.5	105.5	22	96	0.14	0.55	463.8	656	16.8	78.26	75.37	69.54	43.95	5.831	656
25	late sowing 2014	88.5	105.5	17	83	0.08	0.49	667.9	825	18.53	82.06	77.21	70.6	45.62	6.538	825
26	late sowing 2014	73	101.5	28.5	79.5	0.07	0.42	629.2	1265	17.72	79.26	76.38	68.69	42.38	9.557	1265
27	late sowing 2014	71	101	30	83	0.53	0.47	900	1404	18.12	76.69	77.18	69.96	42.56	9.522	1404
28	late sowing 2014	71	100	29	88.5	0.12	0.46	383.5	1451	18.94	79.34	76.49	70.13	44.52	9.035	1451
29	late sowing 2014	73	103	30	62	0.13	0.44	384.3	1296	18.45	71.62	74.69	70.44	45.46	8.334	1296
30	late sowing 2014	72	103	31	56.5	0.53	0.46	520	1109	18.66	77.58	74.57	69.51	44.28	8.693	1109
31	late sowing 2014	73.5	105.5	32	60	0.09	0.5	643.9	1293	19.42	75.7	76.1	70.4	47.11	9.517	1293
32	late sowing 2014	72	101	29	61.5	0.1	0.33	348.1	1116	19.03	76.51	75.41	70.5	46.25	8.981	1116
33	late sowing 2014	72	103	31	86.5	0.12	0.3	258.3	1330	19.23	76.96	75.65	70.69	45.67	8.489	1330
34	late sowing 2014	76.5	104	27.5	62	0.06	0.51	941.7	1034	18.45	75.92	75.55	70.61	45.04	8.664	1034
35	late sowing 2014	72	102	30	61	0.08	0.59	913.6	1811	18.64	76.7	75.62	70.14	44.57	9.32	1811
36	late sowing 2014	70	101.5	31.5	71	0.1	0.41	429.8	1240	18.5	73.39	73.06	69.26	45.55	6.693	1240
37	late sowing 2014	75	104.5	29.5	62.5	0.07	0.48	826.2	1681	18.06	78.31	76.13	70.24	44.43	8.489	1681
38	late sowing 2014	75	103	28	77	0.09	0.38	440.2	1296	18.37	78.74	78.02	71.4	44.93	8.406	1296
39	late sowing 2014	72	103	31	79.5	0.1	0.27	279.2	1701	18.03	79.92	77.46	70.15	42.28	8.997	1701
40	late sowing 2014	72.5	102	29.5	74.5	0.12	0.33	286.6	1303	17.45	79.64	75.86	68.97	41.58	9.429	1303
41	late sowing 2014	73	102.5	29.5	76.5	0.07	0.58	886.3	1277	18.22	77.5	76.67	71.21	43.21	8.714	1277
42	late sowing 2014	76.5	104	27.5	55	0.11	0.35	375	1081	19.1	78.22	75.71	70.1	46.22	9.525	1081
43	late sowing 2014	73.5	103.5	30	78	0.08	0.45	601.8	1378	18.53	77.6	78.55	70.71	45.13	8.154	1378
44	late sowing 2014	71	102.5	31.5	91	0.08	0.39	511.1	1468	17.96	77.26	77.37	71.74	43.54	8.228	1468
45	late sowing 2014	73.5	104.5	31	65.5	0.08	0.32	433	1351	17.85	79.48	77.77	71.29	43.9	9.526	1351

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
46	late sowing 2014	72	103.5	31.5	50	0.09	0.28	337.9	1411	19.16	76.36	74.72	69.99	45.1	9.56	1411
47	late sowing 2014	75	103	28	73.5	0.14	0.45	332.1	1014	17.11	72.07	75.54	70.02	41.96	8.626	1014
48	late sowing 2014	75	103	28	56.5	0.1	0.44	427.8	1241	18.53	73.97	76.74	69.83	44.98	8.663	1241
49	late sowing 2014	72	100.5	28.5	73.5	0.11	0.32	300	1047	18.25	74.97	74.7	68.74	46.23	6.819	1047
50	late sowing 2014	75	101	26	75	0.08	0.44	619.4	1042	17.38	79.74	76.42	71.92	43.73	5.098	1042
51	late sowing 2014	81.5	107	25.5	91	0.09	0.38	439.6	849	17.23	79.53	76.98	71.48	41.27	5.977	849
52	late sowing 2014	85	103	18	77	0.15	0.46	330.1	652	17.9	81.77	75.54	71.37	43.84	7.145	652
53	late sowing 2014	70	99	29	65	0.14	0.31	251	1159	17.73	74.5	79.57	73.69	43.89	5.278	1159
54	late sowing 2014	78.5	102	23.5	82	0.08	0.52	643.7	731	19.47	73.89	77.87	69.19	46.11	5.615	731
55	late sowing 2014	72	102.5	30.5	75	0.1	0.42	441.2	1682	18.06	77.63	76.09	68.92	42.15	5.772	1682
56	late sowing 2014	85.5	104	18.5	82.5	0.09	0.54	639.6	498	16.24	83.66	74.51	69.24	41.92	6.033	498
57	late sowing 2014	74.5	104	29.5	64	0.11	0.55	540.3	1361	18.33	75.94	75.07	68.3	42.61	9.419	1361
58	late sowing 2014	72	103.5	31.5	63	0.1	0.43	501.9	1704	19.04	76.32	75.72	69.49	43.88	8.971	1704
59	late sowing 2014	83.5	104.5	21	95.5	0.09	0.45	527.1	757	18.92	75.39	76.64	69.8	45.57	4.678	757
60	late sowing 2014	74	106.5	32.5	65.5	0.08	0.53	710.7	1509	19.1	80.91	75.41	69.69	45.43	8.934	1509
61	late sowing 2014	72.5	105	32.5	55	0.08	0.37	502.7	1611	17.77	79.91	76.25	69.59	42.08	9.824	1611
62	late sowing 2014	73	103.5	30.5	65.5	0.08	0.5	667.9	1744	19.07	76.94	76.63	69.25	44.54	9.658	1744
63	late sowing 2014	72	102.5	30.5	65	0.1	0.35	468.6	1555	19.53	76.01	76	68.04	45.7	9.441	1555
64	late sowing 2014	79	104	25	72	0.08	0.31	413.4	1051	18.12	80.91	75.95	69.54	44.43	7.985	1051
65	late sowing 2014	73.5	104	30.5	66	0.08	0.62	775	1588	19.07	78.01	73.95	69.39	44.22	9.652	1588
66	late sowing 2014	72.5	103	30.5	69	0.11	0.43	406.4	1754	18.57	78.23	76.46	69.69	43.18	9.64	1754
67	late sowing 2014	74.5	104	29.5	63.5	0.07	0.37	586.9	1512	19.03	80.23	75.87	69.41	44.27	9.432	1512
68	late sowing 2014	72.5	103	30.5	57	0.09	0.48	558.3	1741	18.57	77.23	74.31	68.71	43.43	10.561	1741
69	late sowing 2014	74.5	103.5	29	63	0.09	0.31	351.3	1548	19.94	76.05	74.5	69.22	46.29	9.54	1548
70	late sowing 2014	76	104.5	28.5	67.5	0.07	0.49	748.8	1488	19.18	78.65	75.7	68.35	44.36	8.912	1488
71	late sowing 2014	76	106	30	65	0.08	0.37	516.7	1438	19.18	77.91	75.39	69.45	45.06	8.215	1438

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
72	late sowing 2014	73	104.5	31.5	63	0.11	0.33	306.9	1615	19.95	76.23	75.74	69.39	46.7	9.15	1615
73	late sowing 2014	74	103.5	29.5	61	0.12	0.42	381.9	1464	19.84	77.5	75.64	68.88	46.68	8.924	1464
74	late sowing 2014	75.5	104.5	29	67	0.08	0.37	484.8	1429	18.96	80.84	75.44	69.88	44.88	9.299	1429
75	late sowing 2014	74	104	30	64	0.11	0.35	343.1	1699	19.12	77.92	76.3	70.8	45.72	8.975	1699
76	late sowing 2014	75	104	29	67.5	0.09	0.41	508.4	1532	19.47	80.49	74.39	69.36	45.47	9.677	1532
77	late sowing 2014	76.5	105.5	29	62	0.05	0.55	1145.8	1323	19.41	80.26	73.99	69.36	45.67	8.978	1323
78	late sowing 2014	72	102.5	30.5	60.5	0.09	0.49	583.8	1749	18.49	76.18	75.22	69.4	42.69	8.639	1749
79	late sowing 2014	72.5	104.5	32	63.5	0.13	0.44	368.3	1539	18.53	77.22	76.17	70.19	44.16	9.136	1539
80	late sowing 2014	71	103	32	62	0.11	0.48	570.8	1810	18.44	78.15	75.82	69.32	43.57	9.164	1810
81	late sowing 2014	74.5	104	29.5	63.5	0.1	0.52	548.9	1464	18.82	74.77	75.38	69.01	44.38	8.802	1464
82	late sowing 2014	73	105.5	32.5	64	0.1	0.39	516.7	1579	18.86	75.9	75.83	69.02	44.97	9.272	1579
83	late sowing 2014	74	103	29	65	0.1	0.32	343.9	1707	19.15	75.28	76.08	69.45	45.22	9.265	1707
84	late sowing 2014	72	103.5	31.5	66	0.09	0.53	606.9	1584	19.15	77.68	76.25	68.93	44.59	8.74	1584
85	late sowing 2014	74.5	103.5	29	67.5	0.1	0.49	551.2	1562	19.41	78.51	75.28	68.84	45.57	9.241	1562
86	late sowing 2014	73.5	104	30.5	65.5	0.1	0.38	375	1746	19.12	79.27	75.31	69.46	45.53	9.65	1746
87	late sowing 2014	72.5	104	31.5	68.5	0.08	0.36	463.9	1653	18.89	78.97	75.73	69.79	43.91	9.86	1653
88	late sowing 2014	72.5	105	32.5	63	0.12	0.31	335.8	1714	18.89	79.11	76.47	69.77	44.58	8.935	1714
89	late sowing 2014	73.5	104	30.5	67.5	0.08	0.43	562.5	1761	18.65	78.48	76.42	69.78	44.19	9.708	1761
90	late sowing 2014	72	104	32	59.5	0.52	0.45	700	1383	19.57	75.46	75.33	69.08	46.7	8.654	1383
91	late sowing 2014	75	106	31	60	0.12	0.39	359.4	1698	18.83	78.13	75.3	69.15	44.29	9.439	1698
92	late sowing 2014	74	105.5	31.5	65.5	0.1	0.45	475.6	1613	18.88	78.23	75.53	69.53	44.25	9.334	1613
93	late sowing 2014	72	104.5	32.5	61.5	0.07	0.37	561.1	1559	18.42	78.12	75.34	69.61	42.16	9.862	1559
94	late sowing 2014	72	105	33	63.5	0.1	0.48	479.2	1711	18.68	80.66	76.06	70.37	42.73	9.989	1711
95	late sowing 2014	72	103.5	31.5	70.5	0.07	0.64	994	1573	18.28	78.46	75.23	69.95	42.84	9.99	1573
96	late sowing 2014	71	100.5	29.5	65.5	0.13	0.51	441.7	1536	18.79	77.16	74.86	69.45	43.4	10.123	1536
97	late sowing 2014	72	102.5	30.5	70	0.11	0.41	380.9	1738	17.67	80.94	77.02	70.51	41.31	9.544	1738

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
98	late sowing 2014	79.5	105.5	26	68	0.09	0.4	469.4	1037	18.2	80.96	74.97	69.51	44.42	8.191	1037
99	late sowing 2014	82	105.5	23.5	92.5	0.12	0.42	431.2	903	17.51	74.31	74.85	69.75	43.2	6.1	903
100	late sowing 2014	76.5	104.5	28	58	0.13	0.45	346.2	1092	19.14	79.74	75.29	69.48	45.67	9.464	1092
101	late sowing 2014	72	103.5	31.5	63.5	0.08	0.37	501.8	1759	18.72	78.86	76.22	69.36	43.08	9.971	1759
102	late sowing 2014	74	103	29	61	0.1	0.36	425	1526	19.05	75.72	75.38	69.02	44.51	10.641	1526
103	late sowing 2014	75	103.5	28.5	56.5	0.09	0.47	554.2	1549	19.29	77.52	74.91	69.71	45.16	9.805	1549
104	late sowing 2014	76	105	29	69	0.12	0.47	401.9	1403	19.21	79.3	74.25	70.36	44.99	10.421	1403
105	late sowing 2014	74	103	29	68.5	0.11	0.48	430.3	1596	19.55	78.09	74.71	69.69	46.06	8.061	1596
106	late sowing 2014	72.5	102	29.5	64	0.14	0.49	359.4	1778	18.84	80.36	75.91	69.96	44.49	10.487	1778
107	late sowing 2014	72	102.5	30.5	59.5	0.1	0.33	324.4	1606	19.67	77.17	74.04	69.33	45.58	10.479	1606
108	late sowing 2014	75	104	29	72.5	0.06	0.48	863.3	1517	18.76	76.25	74.41	69.51	44.79	9.85	1517
109	late sowing 2014	73.5	103.5	30	60.5	0.09	0.32	370.1	1564	19.52	76.67	74.01	68.36	45.77	9.915	1564
110	late sowing 2014	76	104	28	64.5	0.11	0.33	319.5	1717	18.65	78.48	74.93	68.53	43.62	8.924	1717
111	late sowing 2014	73	102	29	66.5	0.07	0.39	633.3	1677	18.45	77.45	73.81	69.02	43.66	8.734	1677
112	late sowing 2014	76.5	105.5	29	64	0.1	0.4	426.1	1481	18.85	78.13	74.94	69.62	44.1	9.435	1481
113	late sowing 2014	73.5	103.5	30	58	0.12	0.42	384.2	1643	18.78	77.69	75.03	69.19	43.91	8.824	1643
114	late sowing 2014	76	104.5	28.5	63.5	0.09	0.54	637.5	1242	19.36	78.09	73.39	68.9	45.72	8.606	1242
115	late sowing 2014	75	105.5	30.5	63	0.09	0.42	494.2	1509	18.48	79.24	75.16	69.63	43.88	8.96	1509
116	late sowing 2014	72	101	29	68.5	0.1	0.55	595.5	1663	18.02	77.9	75.15	69.17	41.95	7.642	1663
117	late sowing 2014	72	101	29	69	0.11	0.58	522.7	797	18.36	77.11	75.46	69.92	42.64	8.423	797
118	late sowing 2014	76.5	104.5	28	61	0.07	0.55	832.1	1723	17.98	79.02	76.06	68.84	41.98	8.837	1723
119	late sowing 2014	75	103	28	56	0.07	0.39	602.4	1184	20.03	74.1	73.58	68.46	47.71	8.909	1184
120	late sowing 2014	75.5	103	27.5	69	0.1	0.32	335.2	1326	19.18	76.03	74.61	69.49	44.6	8.998	1326
1	early sowing date 1 2015	108.5	157	48.5	130.5	0.38	0.84	219.6	2141	18.27	79.28	77.72	68.88	41.51	3.97	2141
2	early sowing date 1 2015	105	164	59	137.5	0.36	0.87	240.3	1747	18.47	87.43	78.44	69.2	44.23	2.343	1747
3	early sowing date 1 2015	105	158	53	143	0.34	0.85	254.2	1525	19.86	84.78	75.48	66.12	44.95	2.314	1525

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
4	early sowing date 1 2015	108.5	161.5	53	123	0.36	0.79	222.6	919	19.66	81.57	78.47	64.74	48.6	1.932	919
5	early sowing date 1 2015	105	164	59	144	0.33	0.83	251.8	1559	19.5	86.9	73.22	66.73	44.3	2.597	1559
6	early sowing date 1 2015	105	164	59	102.5	0.39	0.86	224	3284	17.57	89.16	75.09	68.08	39.33	6.066	3284
7	early sowing date 1 2015	105	155	50	83.5	0.36	0.82	231.5	3122	16.79	89.79	79.16	68.83	42.1	3.033	3122
8	early sowing date 1 2015	108.5	155	46.5	117	0.34	0.83	248.6	1588	19.45	83.78	76.09	69.09	43.74	3.156	1588
9	early sowing date 1 2015	105	156	51	89.5	0.31	0.78	257.2	816	18.66	79.31	71.61	66.91	41.88	5.669	816
10	early sowing date 1 2015	105	160.5	55.5	103.5	0.32	0.86	268.8	3634	16.75	90.33	76.98	69.84	38.74	6.158	3634
11	early sowing date 1 2015	101	160.5	59.5	123.5	0.3	0.85	289.4	841	17.62	85.56	77.02	66.31	41.77	3.973	841
12	early sowing date 1 2015	105	157	52	130.5	0.31	0.85	274.1	1219	20.52	79.59	73.54	64.43	46.59	3.292	1219
13	early sowing date 1 2015	105	157	52	118	0.32	0.87	274.6	1534	17.47	84.04	79.02	68.25	42.44	4.114	1534
14	early sowing date 1 2015	101	167.5	66.5	164.5	0.35	0.85	247	1616	19.15	89.35	76.14	67.09	43.87	1.874	1616
15	early sowing date 1 2015	101	155	54	129	0.36	0.79	218.5	1541	18.18	85.07	73.18	65.37	43.21	3.031	1541
16	early sowing date 1 2015	101	167.5	66.5	142	0.37	0.7	192.3	1531	18.83	85.83	78.65	68.55	46.22	2.411	1531
17	early sowing date 1 2015	101	157	56	129	0.42	0.8	191.6	1694	17.97	88.05	79.11	68.41	43.32	2.268	1694
18	early sowing date 1 2015	101	167.5	66.5	122.5	0.26	0.85	341.2	1141	19.07	86.9	77.59	67.85	44.04	3.138	1141
19	early sowing date 1 2015	101	155	54	107	0.3	0.84	286.8	2884	16.15	85.62	76.45	70.25	35.98	6.095	2884
20	early sowing date 1 2015	101	157	56	90.5	0.33	0.84	258.5	3775	15.8	90.65	79.28	71.04	39.58	4.599	3775
21	early sowing date 1 2015	101	164	63	131	0.34	0.75	222.9	1475	18.83	86.52	74.45	63.95	44.57	1.914	1475
22	early sowing date 1 2015	101	153	52	124.5	0.37	0.87	235.2	2309	15.93	83.92	77.43	69.3	35.89	4.372	2309
23	early sowing date 1 2015	101	155	54	121	0.4	0.87	219.5	2200	18.55	81.86	76.15	67.14	40.96	3.682	2200
24	early sowing date 1 2015	105	167.5	62.5	24.5	0.38	0.78	213.4	1403	18.11	85.08	74.49	62.3	44.63	3.332	1403
25	early sowing date 1 2015	101	169	68	132	0.35	0.8	234.3	1284	19	87.18	77.86	65.54	46.94	1.583	1284
26	early sowing date 1 2015	101	153	52	105	0.39	0.83	216.8	3078	17.37	84.62	77.39	67.48	43.46	5.49	3078
27	early sowing date 1 2015	101	153	52	106.5	0.31	0.78	256	1194	18.72	77.62	82.06	67.97	48.77	4.173	1194
28	early sowing date 1 2015	101	157	56	122.5	0.34	0.86	256.5	2275	19.28	85.85	75.71	67.79	43.71	4.865	2275
29	early sowing date 1 2015	101	155	54	92.5	0.33	0.8	244.5	2141	18.89	83.98	73.94	67.89	46.4	4.305	2141

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
30	early sowing date 1 2015	101	164	63	118.5	0.31	0.85	284	3128	18.23	87.29	74.39	69.54	41.88	5.507	3128
31	early sowing date 1 2015	101	157	56	98.5	0.34	0.81	241.8	2566	19.49	86.27	76.11	68.41	46.59	4.565	2566
32	early sowing date 1 2015	112.5	155	42.5	118	0.37	0.85	228.5	2837	18.67	81.83	77.67	67.47	46.18	5.07	2837
33	early sowing date 1 2015	105	164	59	107	0.34	0.86	253.2	1412	19.92	85.58	76.73	68.57	48.15	3.951	1412
34	early sowing date 1 2015	101	155	54	123.5	0.35	0.73	209.5	2650	18.78	82.28	73.92	67.86	45.5	4.093	2650
35	early sowing date 1 2015	101	164	63	105	0.3	0.85	296.4	4216	16.12	90.64	76.99	69.07	37.48	5.759	4216
36	early sowing date 1 2015	105	171	66	122.5	0.34	0.8	235.1	2659	19.11	81.45	72.82	68.43	45.25	4.596	2659
37	early sowing date 1 2015	101	160.5	59.5	81.5	0.33	0.84	258.4	3194	17.6	86.96	74.6	68.42	41.55	4.844	3194
38	early sowing date 1 2015	109	153	44	121.5	0.33	0.83	262.8	2150	19.09	81.9	76.99	67.94	48.41	4.453	2150
39	early sowing date 1 2015	101	157	56	109	0.3	0.82	279.4	2788	17.41	86.22	76.85	68.17	42.38	5.722	2788
40	early sowing date 1 2015	105	157	52	104.5	0.36	0.85	240.5	2866	17.45	83.65	78.15	67.9	44.04	5.447	2866
41	early sowing date 1 2015	101	157	56	119.5	0.36	0.76	210.5	2919	18.41	85.16	77.26	68.32	45.49	5.09	2919
42	early sowing date 1 2015	101	157	56	85	0.35	0.84	240.2	3069	18.54	82.1	77.11	68.18	46.32	5.905	3069
43	early sowing date 1 2015	101.5	164	62.5	100	0.34	0.84	250.3	1659	19.01	79.72	77.54	66.72	48.54	4.417	1659
44	early sowing date 1 2015	109	157	48	120	0.37	0.91	248.5	1694	18.81	81.19	77.45	67.97	47.25	4.845	1694
45	early sowing date 1 2015	109	164	55	100.5	0.34	0.81	240.4	2159	19.67	82.74	76.01	68.15	48.31	4.547	2159
46	early sowing date 1 2015	109	155	46	87	0.34	0.83	248.5	3428	17.53	87.88	76.44	68.92	41.05	4.73	3428
47	early sowing date 1 2015	101	164	63	113.5	0.34	0.8	240.7	2394	16.59	80.63	75.31	68.2	41.03	5.402	2394
48	early sowing date 1 2015	101	155	54	81.5	0.4	0.7	180.9	2866	18.73	83.5	75.08	67.81	45.89	4.567	2866
49	early sowing date 1 2015	101	153	52	99	0.33	0.83	259.5	1969	16.18	80.75	74.06	64.83	39.81	4.446	1969
50	early sowing date 1 2015	105	160.5	55.5	109	0.32	0.79	255.1	1491	17.52	83.06	76.63	67.94	40.15	3.004	1491
51	early sowing date 1 2015	112.5	157	44.5	123.5	0.33	0.84	254.7	1659	18.01	90.35	74.84	67.77	40.77	3.105	1659
52	early sowing date 1 2015	101	164	63	108.5	0.34	0.85	256.7	1691	18.53	87.93	75.33	66.75	43.94	4.495	1691
53	early sowing date 1 2015	101	153	52	101.5	0.26	0.86	365	1931	18.3	83.83	78.9	68.85	44.66	2.341	1931
54	early sowing date 1 2015	101	157	56	123	0.22	0.83	496.4	809	20.27	77.45	73.84	66.74	46.13	4.155	809
55	early sowing date 1 2015	101	153	52	109	0.35	0.9	262	3094	16.45	87.34	78.06	68.52	40.51	3.9	3094

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
56	early sowing date 1 2015	105	160.5	55.5	114.5	0.33	0.8	242.4	1256	16.84	88.82	73.36	64.24	41.48	3.966	1256
57	early sowing date 1 2015	109	157	48	104	0.32	0.89	277	4278	16.4	88.19	77.83	71.02	37.71	6.424	4278
58	early sowing date 1 2015	101	157	56	101.5	0.36	0.8	227.3	2991	18.34	85.94	79.77	69.47	44.5	4.607	2991
59	early sowing date 1 2015	101	167.5	66.5	141.5	0.35	0.79	229	1862	19.59	88	76.13	67.77	43.95	1.433	1862
60	early sowing date 1 2015	101	157	56	98.5	0.33	0.83	250	3359	18	89.72	77.74	70.1	42.51	4.949	3359
61	early sowing date 1 2015	109	157	48	101	0.35	0.86	249.6	4150	16.5	88.71	75.08	69.46	36	5.802	4150
62	early sowing date 1 2015	101	155	54	95.5	0.35	0.82	236	3419	17.61	84.71	78.62	68.59	41.71	5.555	3419
63	early sowing date 1 2015	101	163.5	62.5	104.5	0.31	0.8	257.3	3016	18.63	84.64	79.4	69.82	44.92	4.811	3016
64	early sowing date 1 2015	106	157	51	94	0.35	0.89	252.7	3450	17.82	89.87	75.45	70.38	40.2	5.976	3450
65	early sowing date 1 2015	108.5	155	46.5	98.5	0.41	0.88	217.7	3884	17.35	90.49	74.9	70.03	38.43	6.127	3884
66	early sowing date 1 2015	105	157	52	111	0.34	0.84	249.1	4031	17.58	87.34	76.1	69.8	39.62	5.74	4031
67	early sowing date 1 2015	101	157	56	104.5	0.34	0.88	257.6	3372	17.62	85.41	76.6	69.03	41.06	6.097	3372
68	early sowing date 1 2015	101	158.5	57.5	112	0.18	0.77	483.3	3822	17.99	88.01	72.37	68.75	39.75	5.947	3822
69	early sowing date 1 2015	101	157	56	93	0.28	0.82	309.4	3394	18.34	85.1	75.52	69.92	41.88	5.615	3394
70	early sowing date 1 2015	108.5	161.5	53	93.5	0.34	0.85	266.1	2806	18.88	87.85	75.96	68.86	44.97	6.087	2806
71	early sowing date 1 2015	105	160.5	55.5	96	0.36	0.78	217.2	3425	18.31	87.25	77.29	68.85	42.68	4.839	3425
72	early sowing date 1 2015	108.5	167.5	59	97.5	0.37	0.86	237.5	3416	17.88	87.4	76.8	68.35	41.34	4.973	3416
73	early sowing date 1 2015	105	157	52	100	0.32	0.83	266.7	3278	18.3	89.16	76.74	67.84	41.78	4.563	3278
74	early sowing date 1 2015	101	157	56	97.5	0.37	0.84	230.2	3653	18.45	87.43	75.99	69.08	43.62	4.674	3653
75	early sowing date 1 2015	105	153	48	117	0.35	0.86	247.9	3106	17.65	87.36	75.52	69.66	42.35	5.359	3106
76	early sowing date 1 2015	101	157	56	101	0.35	0.83	236.6	2956	19.05	89.38	73.78	69.52	42.41	5.16	2956
77	early sowing date 1 2015	105	164	59	92.5	0.38	0.87	233	3334	18.68	90.38	74.5	68.51	41.74	4.747	3334
78	early sowing date 1 2015	101	161.5	60.5	109	0.3	0.81	286.7	3562	16.64	86.99	77.23	70.01	38.21	6.35	3562
79	early sowing date 1 2015	101	153	52	99	0.37	0.81	220.1	3984	16.17	89.23	77.92	68.45	36.15	5.375	3984
80	early sowing date 1 2015	101	157	56	92.5	0.35	0.86	250	3791	17.16	88.47	75.78	68.24	38.39	4.84	3791
81	early sowing date 1 2015	105	158	53	91.5	0.34	0.83	249.4	3822	17.91	84.27	76.31	69.39	39.3	5.546	3822

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
82	early sowing date 1 2015	105	157	52	96	0.36	0.79	217.9	3900	17.76	87.67	75.35	69.38	40.86	5.196	3900
83	early sowing date 1 2015	105	157	52	99.5	0.4	0.82	207.1	3031	18.75	82.81	76.04	68.74	42.79	5.647	3031
84	early sowing date 1 2015	101	164	63	94.5	0.35	0.76	217.1	3272	17.82	90.9	77.33	69.24	40.12	4.712	3272
85	early sowing date 1 2015	101	148.5	47.5	111.5	0.37	0.81	219	3278	17.66	86.16	75.48	69.23	40.4	5.91	3278
86	early sowing date 1 2015	105	160.5	55.5	81.5	0.44	0.8	182.1	2959	18.01	88.28	75.93	68.56	40.83	5.598	2959
87	early sowing date 1 2015	101	157	56	103	0.35	0.8	227.1	2872	16.91	85.65	76.34	69.8	39.28	5.956	2872
88	early sowing date 1 2015	105	156	51	107	0.36	0.82	231	3706	18.23	83.85	76.61	68.53	43.18	5.67	3706
89	early sowing date 1 2015	101	160.5	59.5	98	0.38	0.85	224	4128	16.16	89.41	77.94	69.9	36.38	6.368	4128
90	early sowing date 1 2015	101	155	54	109	0.26	0.81	317.3	3312	17.91	86.83	76.21	68.05	42.65	4.491	3312
91	early sowing date 1 2015	109	160.5	51.5	106	0.31	0.82	266.5	3697	17.94	86.84	76.15	68.89	40.86	5.761	3697
92	early sowing date 1 2015	105	157	52	93	0.38	0.84	219.9	3803	16.99	88.08	77.79	69.79	38.76	5.214	3803
93	early sowing date 1 2015	105	157	52	85	0.34	0.82	245.1	3794	16.6	88.59	77.66	71.54	38.93	6.662	3794
94	early sowing date 1 2015	105	157	52	92	0.34	0.86	257.3	4188	16.71	90.01	78.47	71.08	39.05	6.318	4188
95	early sowing date 1 2015	101	155	54	101.5	0.33	0.83	253.9	4019	16.63	87.04	79.05	71.08	38.66	6.29	4019
96	early sowing date 1 2015	101	167.5	66.5	94.5	0.37	0.82	224.9	3869	16.83	86.48	79.09	70.99	40.02	5.884	3869
97	early sowing date 1 2015	105	155	50	92	0.27	0.88	362.5	3669	17.56	88.42	78.19	70.67	41.07	5.694	3669
98	early sowing date 1 2015	101	155	54	101.5	0.33	0.85	256.1	1156	17.61	82.72	73.45	64.35	41.82	4.386	1156
99	early sowing date 1 2015	108.5	164	55.5	137	0.38	0.79	210	1816	18.16	87.14	76.14	66.73	45.16	2.997	1816
100	early sowing date 1 2015	105	155	50	101.5	0.32	0.81	257.3	3641	17.89	87.01	76.12	69.35	42.34	6.214	3641
101	early sowing date 1 2015	105	157	52	101.5	0.32	0.82	283	3491	17.94	87.1	76.12	69.97	39.91	5.811	3491
102	early sowing date 1 2015	105	157	52	92	0.33	0.83	251.5	3797	16.61	88.04	78.48	69.75	38.33	6.923	3797
103	early sowing date 1 2015	101	155	54	95	0.42	0.85	206.6	4097	18.05	87.59	75.98	69.97	42.08	6.893	4097
104	early sowing date 1 2015	101	157	56	95	0.35	0.83	236.2	2888	18.04	85.29	75.03	69.3	42.37	6.738	2888
105	early sowing date 1 2015	101	157	56	105.5	0.3	0.85	282.8	3916	17.34	88.11	77.95	70.73	40.26	5.839	3916
106	early sowing date 1 2015	101	157	56	99.5	0.32	0.78	242.2	3950	17.74	83.45	76.13	67.66	43.12	6.076	3950
107	early sowing date 1 2015	105	157	52	85.5	0.34	0.86	257.2	3944	17.04	90.53	78.22	70.9	38.86	6.801	3944

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
108	early sowing date 1 2015	101	154	53	99.5	0.33	0.84	258.9	4200	16.46	87.96	77.13	71.18	38.23	7.451	4200
109	early sowing date 1 2015	109	157	48	96.5	0.36	0.86	242.4	3959	17.35	86.98	75.17	68.9	40.04	6.966	3959
110	early sowing date 1 2015	105	157	52	107.5	0.32	0.83	263.4	3731	17.15	90.25	76.5	68.81	38.42	5.858	3731
111	early sowing date 1 2015	105	155	50	102	0.34	0.81	241.3	3941	16.55	88.24	77.51	70.2	37.03	6.814	3941
112	early sowing date 1 2015	101	160.5	59.5	110	0.35	0.79	226.8	3250	17.48	88.17	75.75	69.58	40.76	6.588	3250
113	early sowing date 1 2015	105	160.5	55.5	96.5	0.37	0.87	250.9	3531	18.05	90.12	75.02	68.85	40.25	5.996	3531
114	early sowing date 1 2015	105	160.5	55.5	109	0.35	0.82	236.7	3122	17.01	88.99	76.65	69.21	39.96	5.997	3122
115	early sowing date 1 2015	105	156	51	109.5	0.35	0.78	227.5	2966	18.35	87.84	75.25	68.09	41.71	5.779	2966
116	early sowing date 1 2015	101	160.5	59.5	105	0.35	0.84	246	3862	15.37	91.06	78.88	70.17	35.84	6.236	3862
117	early sowing date 1 2015	101	161.5	60.5	100	0.29	0.74	254.5	3947	15.81	90.24	77.07	70.34	37.21	6.318	3947
118	early sowing date 1 2015	105	153	48	86	0.37	0.81	224.1	3572	17.13	90.51	76.83	69.38	38.88	6.619	3572
119	early sowing date 1 2015	105	160.5	55.5	82.5	0.4	0.82	210.6	3319	18.36	88.32	74.32	68.84	41.88	5.864	3319
120	early sowing date 1 2015	101	157	56	98.5	0.33	0.86	263.2	3109	17.8	84.22	76.85	69.49	41.21	6.643	3109
1	early sowing date 2 2015	94.5	140	45.5	110.5	0.23	0.61	263	2094	17.56	79.11	77.13	69.54	42.61	4.465	2094
2	early sowing date 2 2015	91	125	34	116.5	0.24	0.66	280.4	1288	17.68	84.25	74.84	69.9	44.33	4.015	1288
3	early sowing date 2 2015	91	142	51	126.5	0.21	0.4	191.1	1547	19.59	80.84	74.75	66.9	45.63	3.34	1547
4	early sowing date 2 2015	90	144.5	54.5	117.5	0.2	0.52	242.7	738	19.01	79.58	76.92	64.89	45.8	3.686	738
5	early sowing date 2 2015	89	140	51	121	0.23	0.67	297.3	1512	20.09	82.21	73.59	66.45	47.66	3.401	1512
6	early sowing date 2 2015	91	144.5	53.5	67	0.22	0.49	241	2541	17.33	84.2	74.48	69.53	40.36	5.775	2541
7	early sowing date 2 2015	91	140	49	88.5	0.29	0.42	151.2	2312	18.13	87.17	74.27	69.68	43.74	4.008	2312
8	early sowing date 2 2015	93.5	140	46.5	101.5	0.27	0.65	244.3	1128	19.45	81.56	75.78	69.68	47.08	3.969	1128
9	early sowing date 2 2015	96	140	44	92	0.22	0.66	297.7	963	17.21	77.08	72.47	66.91	41.12	6.22	963
10	early sowing date 2 2015	96	140	44	79.5	0.24	0.47	205	2509	18.54	84.11	75.94	69.59	44	6.125	2509
11	early sowing date 2 2015	90	141	51	72.5	0.3	0.69	228.3	937	16.78	84.13	70.35	64.95	40.59	4.649	937
12	early sowing date 2 2015	93	140	47	105.5	0.27	0.54	200	1006	20.86	80.21	71.56	66.11	49.29	4.438	1006
13	early sowing date 2 2015	90	141	51	110.5	0.19	0.6	316.5	2003	16.42	80.36	77.49	68.5	41.97	3.632	2003

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
14	early sowing date 2 2015	90	147	57	123	0.26	0.52	202.2	1456	19.13	85	76.05	66.81	46.05	2.375	1456
15	early sowing date 2 2015	95	141	46	108.5	0.24	0.51	209.6	1288	16.71	80.48	73.13	66.42	40.81	3.727	1288
16	early sowing date 2 2015	90	140	50	114.5	0.23	0.78	346.7	1388	17.92	80.87	76.17	69.18	44.75	3.144	1388
17	early sowing date 2 2015	90	140	50	128	0.23	0.53	235.4	1550	18.89	84.27	75.03	68.31	44.55	2.94	1550
18	early sowing date 2 2015	100	141	41	87.5	0.27	0.7	268.5	900	19.03	83.59	71.54	67.86	46.04	3.605	900
19	early sowing date 2 2015	96	141	45	82.5	0.25	0.53	211.3	2469	17.75	82.54	74.68	69.43	42.27	5.774	2469
20	early sowing date 2 2015	91	141	50	84.5	0.19	0.69	375.4	2587	16.78	87.36	77.31	71.61	42.95	4.55	2587
21	early sowing date 2 2015	90	141	51	119.5	0.23	0.65	282.6	1556	17.8	86.82	75.35	65.02	44.25	2.407	1556
22	early sowing date 2 2015	100	140	40	85	0.28	0.63	228.2	2175	15.73	79.38	76.14	70.32	36.43	4.791	2175
23	early sowing date 2 2015	90	141	51	80	0.21	0.51	242.2	1719	19.66	77.69	75.33	66.86	41.33	3.658	1719
24	early sowing date 2 2015	95	147	52	109	0.19	0.55	299	1463	17.48	83.15	72.8	63.5	41.37	4.007	1463
25	early sowing date 2 2015	94	142	48	102	0.23	0.67	302.5	1322	19.36	85.59	73.62	66.54	49.46	2.846	1322
26	early sowing date 2 2015	88	140	52	96.5	0.19	0.46	252.8	2472	16.69	82.44	75.1	69.18	41.25	6.096	2472
27	early sowing date 2 2015	100	140	40	89.5	0.27	0.57	215	2381	17.62	77.65	78.42	68.91	45.7	6.319	2381
28	early sowing date 2 2015	100	140	40	109.5	0.24	0.65	281	1919	17.99	85.52	75.2	69.34	42.63	5.921	1919
29	early sowing date 2 2015	100	140	40	81	0.27	0.72	274.9	2600	18.29	81.17	72.11	69.11	44.1	5.016	2600
30	early sowing date 2 2015	100	140	40	90	0.26	0.45	182.1	2312	18.09	82.65	74.52	70.32	43.2	5.824	2312
31	early sowing date 2 2015	91	140	49	85	0.23	0.69	314.3	2484	19.81	82.55	75	69.14	48.36	4.637	2484
32	early sowing date 2 2015	90	140	50	95	0.23	0.62	272.7	2269	19.3	79.74	73.36	69.76	46.67	6.572	2269
33	early sowing date 2 2015	90	140	50	97	0.22	0.51	235	2612	18.17	84.92	73.16	69.7	42.77	5.792	2612
34	early sowing date 2 2015	96	140	44	101	0.25	0.5	205.6	1909	18.58	79.14	73.42	69.28	45.36	4.793	1909
35	early sowing date 2 2015	91	142	51	69	0.26	0.51	195.8	3659	17.42	89.91	74.84	68.83	38.62	5.007	3659
36	early sowing date 2 2015	90	141	51	84.5	0.23	0.76	335.7	2834	17.87	78.42	70.06	68.88	41.33	5.75	2834
37	early sowing date 2 2015	89	141	52	88	0.25	0.61	248.2	2622	17.99	82.18	73.07	69.15	43.55	5.72	2622
38	early sowing date 2 2015	100	141	41	114.5	0.2	0.57	276	2334	18.23	78.81	74.43	67.97	47.61	5.378	2334
39	early sowing date 2 2015	100	140	40	115.5	0.25	0.69	278.2	2872	17.01	80.48	74.5	67.95	40.76	6.657	2872

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
40	early sowing date 2 2015	100	140	40	117	0.22	0.67	314.3	2825	16.55	81.27	76.75	68.45	42.18	6.123	2825
41	early sowing date 2 2015	95	141	46	81	0.25	0.66	279.6	2472	17.42	82.81	77.97	69.65	44.55	5.79	2472
42	early sowing date 2 2015	91	140	49	88.5	0.21	0.7	340.7	2544	18.6	81.05	74.05	68.54	47.2	5.382	2544
43	early sowing date 2 2015	92	140	48	102.5	0.22	0.6	275	2356	17.58	80.77	77.21	68.33	45.11	5.145	2356
44	early sowing date 2 2015	95	140	45	100.5	0.27	0.74	278.6	2512	17.4	78.77	76.57	68.42	43.57	5.92	2512
45	early sowing date 2 2015	95	140	45	87.5	0.24	0.78	322.9	2141	18.28	82.21	73.88	68.19	45.63	4.943	2141
46	early sowing date 2 2015	92	140	48	90.5	0.25	0.51	203.4	2597	19.29	83.29	72.03	68.56	46.4	5.631	2597
47	early sowing date 2 2015	95	140	45	91	0.23	0.47	199.2	1988	17.14	73.38	73.45	68.45	42.63	6.143	1988
48	early sowing date 2 2015	100	140	40	60.5	0.19	0.59	311.1	2300	19.04	76.81	72.79	68.2	48.56	5.638	2300
49	early sowing date 2 2015	95	140	45	88	0.23	0.46	201.7	1478	16.2	79.74	73.58	66.22	40.64	4.986	1478
50	early sowing date 2 2015	96	140	44	102.5	0.2	0.56	273.2	1816	16.81	77.51	75.6	66.91	38.77	3.291	1816
51	early sowing date 2 2015	95	140	45	117.5	0.24	0.7	309.2	1716	18.04	89.04	75.48	68.62	42.66	3.629	1716
52	early sowing date 2 2015	91	140	49	85.5	0.26	0.56	215.4	1147	18.06	82.31	72.87	67.34	44.15	5.08	1147
53	early sowing date 2 2015	89	140	51	102.5	0.25	0.49	198	2409	17.28	82.81	78.67	69.49	43.3	2.919	2409
54	early sowing date 2 2015	96	140	44	101.5	0.26	0.56	214.1	1847	19.81	72.84	73.78	65.48	47.13	4.769	1847
55	early sowing date 2 2015	91	140	49	82	0.24	0.59	254.4	2431	16.6	89.23	76.92	69.06	39.33	4.176	2431
56	early sowing date 2 2015	95	147	52	64.5	0.26	0.49	188.5	1306	16.56	86.32	72.36	64.42	41.91	4.277	1306
57	early sowing date 2 2015	92	140	48	73.5	0.25	0.42	185.8	2631	17.35	85.53	75.58	71.06	41.47	6.937	2631
58	early sowing date 2 2015	91	140	49	89.5	0.2	0.46	225	2872	19.18	83.49	75.66	69.55	44.18	5.619	2872
59	early sowing date 2 2015	95	140	45	98	0.24	0.52	211.4	1466	19.71	82.16	74.9	67.66	46.63	2.693	1466
60	early sowing date 2 2015	91	140	49	78.5	0.22	0.48	227.1	2694	17.95	86.9	74.34	70.36	43.24	6.043	2694
61	early sowing date 2 2015	95	140	45	84	0.29	0.44	154.6	3159	17.39	86.59	74.11	69.37	39.61	6.069	3159
62	early sowing date 2 2015	100	141	41	77.5	0.26	0.47	183	2763	17.48	83.29	74.45	69.61	40.76	7.015	2763
63	early sowing date 2 2015	92	142	50	70.5	0.23	0.66	310.2	2594	17.62	82.39	74.41	69.64	43.59	6.154	2594
64	early sowing date 2 2015	95	142	47	82	0.24	0.54	230.6	2903	17.12	86.5	74.65	70.89	40.84	6.425	2903
65	early sowing date 2 2015	90	140	50	83	0.23	0.69	301.9	2747	18.09	88.13	74.36	70.64	41.74	6.137	2747

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
66	early sowing date 2 2015	90	140	50	96.5	0.2	0.63	312.5	3000	18.08	85.22	75.09	70.72	43.73	6.595	3000
67	early sowing date 2 2015	91	140	49	78.5	0.23	0.72	310.6	3091	17.6	84.75	76.56	70.55	41.44	6.975	3091
68	early sowing date 2 2015	100	140	40	81.5	0.22	0.44	207	2669	17.82	85.75	75.37	69.98	40.88	5.84	2669
69	early sowing date 2 2015	92	140	48	107.5	0.23	0.56	248.7	2809	18.94	81.59	76.01	69.63	44.41	5.812	2809
70	early sowing date 2 2015	92	140	48	71.5	0.25	0.37	149	2781	18.2	83.24	76.71	69.77	44.37	6.116	2781
71	early sowing date 2 2015	95	140	45	90	0.22	0.59	282.5	2903	17.87	86.27	76.24	70	43.02	5.383	2903
72	early sowing date 2 2015	96	140	44	81	0.25	0.68	275.3	2953	18.55	85.85	74.87	70.07	42.31	5.272	2953
73	early sowing date 2 2015	91	140	49	69	0.3	0.53	182.2	2791	19.06	86.54	74.4	69.17	44.49	5.057	2791
74	early sowing date 2 2015	88	140	52	82	0.22	0.71	349.5	2600	18.66	85.7	74.22	70.59	45.24	5.799	2600
75	early sowing date 2 2015	100	140	40	83	0.22	0.56	267.9	3134	18.59	84.28	75.27	69.99	45.51	5.584	3134
76	early sowing date 2 2015	92	140	48	88	0.25	0.69	275.8	2497	18.82	88.52	74.06	70.27	43.7	5.398	2497
77	early sowing date 2 2015	91	140	49	87	0.28	0.58	207.7	3066	18.3	90.77	75.47	71.23	42.24	5.267	3066
78	early sowing date 2 2015	96	140	44	76.5	0.27	0.41	151.2	2750	17.17	81.73	74.35	70.44	40.21	6.945	2750
79	early sowing date 2 2015	95	140	45	73	0.24	0.53	214.5	2809	18.15	89.73	75.12	70.09	41.64	4.987	2809
80	early sowing date 2 2015	95	140	45	94	0.22	0.52	250.7	3313	17.44	89.72	73.81	70.41	39.87	5.762	3313
81	early sowing date 2 2015	91	140	49	87.5	0.24	0.64	265.3	3319	17.06	84.46	75.43	70.62	39.56	6.082	3319
82	early sowing date 2 2015	96	140	44	73.5	0.21	0.43	206.3	2825	18.32	85.18	74.53	69.3	43.94	5.941	2825
83	early sowing date 2 2015	90	140	50	76.5	0.25	0.62	271.7	3022	17.86	83.47	75.43	68.78	41.72	6.295	3022
84	early sowing date 2 2015	90	140	50	76	0.24	0.72	297	3012	17.03	86.24	76.33	70.88	40	5.678	3012
85	early sowing date 2 2015	91	142	51	79	0.26	0.41	155.5	2884	18	83.42	75.5	69.64	42.97	6.149	2884
86	early sowing date 2 2015	92	141	49	88.5	0.21	0.53	287.3	2622	18.13	84.85	75.19	69.35	43.45	5.902	2622
87	early sowing date 2 2015	92	141	49	68.5	0.22	0.41	194.2	2675	17.87	83.71	76.8	69.63	42.23	5.752	2675
88	early sowing date 2 2015	92	144.5	52.5	121.5	0.33	0.51	194.3	2444	17.8	80.24	74.67	67.99	43.39	5.687	2444
89	early sowing date 2 2015	91	141	50	67.5	0.29	0.66	226.3	2097	17.91	80.74	75.16	69.72	42.77	6.444	2097
90	early sowing date 2 2015	96	140	44	84	0.23	0.56	240	2875	17.94	86.08	74.83	68.83	43.28	5.425	2875
91	early sowing date 2 2015	96	140	44	80	0.24	0.55	236.1	2875	18.49	83.96	75.68	69.3	43.32	6.006	2875

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
92	early sowing date 2 2015	92	140	48	84.5	0.25	0.68	285.1	2997	18.1	89.54	75.88	70.4	42.38	5.494	2997
93	early sowing date 2 2015	100	140	40	90.5	0.23	0.64	285.2	2778	17.92	82.62	75.58	69.42	42.24	6.569	2778
94	early sowing date 2 2015	90	140	50	92	0.19	0.48	256	2788	17.91	84.53	76.12	69.76	43.63	6.689	2788
95	early sowing date 2 2015	88	140	52	74	0.27	0.63	232.1	3141	17.35	82.34	76.39	69.69	41.85	6.692	3141
96	early sowing date 2 2015	96	140	44	80.5	0.23	0.6	259.3	2341	19.03	83.03	74.89	68.93	44.63	6.25	2341
97	early sowing date 2 2015	92	140	48	78	0.24	0.71	307.6	2834	17.25	85.65	76.59	70.92	41.56	6.381	2834
98	early sowing date 2 2015	96	140	44	92	0.23	0.54	243.5	1419	16.22	79.69	74.1	65.92	41.06	3.743	1419
99	early sowing date 2 2015	100	140	40	102	0.17	0.55	318.8	1175	18.78	81.35	73.27	67.64	46.03	4.38	1175
100	early sowing date 2 2015	96	140	44	66	0.21	0.68	332	1887	20.6	81.19	75.13	68.29	50.79	5.623	1887
101	early sowing date 2 2015	91	140	49	80.5	0.26	0.59	240.2	3175	17.74	86.68	76.08	70.94	40.67	6.941	3175
102	early sowing date 2 2015	91	140	49	77.5	0.21	0.57	275.6	2603	18.21	85.7	76.36	69.43	44.29	6.244	2603
103	early sowing date 2 2015	91	140	49	83.5	0.25	0.6	240	2872	17.35	85.31	75.9	69.69	42.47	7.121	2872
104	early sowing date 2 2015	95	140	45	78.5	0.24	0.54	234.7	2278	18.27	83.16	73.93	69.2	43.76	6.567	2278
105	early sowing date 2 2015	96	140	44	78	0.24	0.53	224.5	2563	18.21	82.24	75.66	69.71	43.78	6.078	2563
106	early sowing date 2 2015	91	140	49	70	0.22	0.64	285.1	3172	16.95	82.05	74.54	70.03	41.76	7.023	3172
107	early sowing date 2 2015	95	140	45	69	0.19	0.55	282.2	2162	19.08	82.39	74.82	69.15	44.44	6.59	2162
108	early sowing date 2 2015	96	140	44	77.5	0.26	0.65	248.4	2672	19.11	82.15	73.4	68.45	46.05	7.24	2672
109	early sowing date 2 2015	96	140	44	72	0.27	0.45	168.1	2584	19.49	82.06	74.24	68.55	46.42	6.924	2584
110	early sowing date 2 2015	96	140	44	130.5	0.25	0.47	199.4	2222	18.79	85.9	73.62	69.08	44.02	6.037	2222
111	early sowing date 2 2015	91	140	49	77	0.24	0.59	249	3097	17.83	86.09	74.62	69.47	42.91	6.423	3097
112	early sowing date 2 2015	92	140	48	85.5	0.19	0.64	337.1	2659	16.95	84.21	76.65	69.91	40.06	6.166	2659
113	early sowing date 2 2015	88	147	59	73.5	0.25	0.47	202.4	2000	18.29	83.59	74.22	69.77	42.1	5.697	2000
114	early sowing date 2 2015	96	140	44	86.5	0.22	0.62	280.4	2522	17.69	83.76	74.42	69.68	42.26	6.095	2522
115	early sowing date 2 2015	95	140	45	75.5	0.22	0.63	281.7	2513	18.06	85.16	75.72	68.77	43.28	6.389	2513
116	early sowing date 2 2015	92	140	48	94.5	0.22	0.46	211.4	2647	17.55	85.1	73.31	68.85	43.42	5.909	2647
117	early sowing date 2 2015	95	140	45	96	0.25	0.48	197.9	3178	16.49	86.96	75.47	68.85	40.55	6.252	3178

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
118	early sowing date 2 2015	90	140	50	82.5	0.25	0.68	281.1	2466	18.1	85.76	74.35	69.94	43.61	6.302	2466
119	early sowing date 2 2015	92	140	48	76	0.24	0.51	216.1	2181	19.44	85.27	72.14	69.2	44.92	5.614	2181
120	early sowing date 2 2015	92	140	48	80	0.21	0.4	190.8	2225	19.48	80.87	74.35	69.22	46.31	6.481	2225
1	late sowing date 1 2015	90	121	31	88.5	0.25	0.78	310	962	18.35	72.82	79.01	69.55	45.46	3.58	962
2	late sowing date 1 2015	91.5	124	32.5	113	0.21	0.85	402.4	784	18.38	79.08	78.89	69.15	45.39	2.017	784
3	late sowing date 1 2015	90	125.5	35.5	88.5	0.26	0.8	318.7	994	19.12	78.75	75.61	67.49	45.28	3.027	994
4	late sowing date 1 2015	95	140	45	102	0.23	0.82	367	544	18.41	80.89	77.3	67.64	43.66	4.071	544
5	late sowing date 1 2015	89.5	131	41.5	114.5	0.24	0.71	303.3	1397	18.11	80.55	75.5	67.08	42.57	2.653	1397
6	late sowing date 1 2015	89.5	121	31.5	59.5	0.22	0.79	365	1787	19.56	75.61	75.06	69.21	45.61	5.715	1787
7	late sowing date 1 2015	94	121	27	56	0.23	0.88	411.9	1606	20.17	76.54	76.02	67.89	47.79	2.736	1606
8	late sowing date 1 2015	88.5	129	40.5	90.5	0.23	0.79	341.5	953	19.58	76.13	76.68	69.13	46.97	2.513	953
9	late sowing date 1 2015	99	121	22	60	0.26	0.85	354.4	1084	18.79	69.82	74.83	67.49	45.03	5.32	1084
10	late sowing date 1 2015	90	121	31	66.5	0.22	0.9	421	2062	19.75	75.1	76.28	69.23	45.48	6.149	2062
11	late sowing date 1 2015	89	131	42	96	0.25	0.81	328.3	756	17.08	83	74.67	64.16	41.4	3.286	756
12	late sowing date 1 2015	90	122.5	32.5	81	0.22	0.73	359.3	775	21.22	78.57	75.38	66.02	50.02	3.656	775
13	late sowing date 1 2015	90	121	31	92	0.23	0.82	356.5	1066	18.01	75.23	79.24	68.67	44.65	3.241	1066
14	late sowing date 1 2015	90.5	137	46.5	104.5	0.3	0.86	290	841	19.29	82.86	78	69.33	45.08	2.287	841
15	late sowing date 1 2015	88	489.5	401.5	105.5	0.19	0.83	434.2	866	17.06	76.86	75.29	65.86	41.59	2.455	866
16	late sowing date 1 2015	95	140	45	100.5	0.19	0.83	437.8	1491	17.26	81.24	77.39	69.64	40.3	3.37	1491
17	late sowing date 1 2015	91	131	40	96.5	0.21	0.84	409.7	1256	18.36	84.63	77.11	69.05	44.14	2.306	1256
18	late sowing date 1 2015	87.5	140	52.5	108.5	0.23	0.82	373.5	775	19.05	83.77	75.17	68.63	45.05	3.005	775
19	late sowing date 1 2015	92	121	29	69	0.21	0.84	401.9	1803	18.37	72.14	77.45	69.38	43.29	5.456	1803
20	late sowing date 1 2015	88	121	33	60	0.25	0.85	360.8	1912	18.61	76.81	78.26	70.74	47.19	3.968	1912
21	late sowing date 1 2015	89	129	40	108.5	0.21	0.84	403.7	906	18.04	80.29	76.64	65	46.18	2.313	906
22	late sowing date 1 2015	89.5	125.5	36	92	0.24	0.94	393.9	1681	16.86	67.94	77.06	70.58	39.08	4.297	1681
23	late sowing date 1 2015	95	121	26	73.5	0.21	0.81	394.9	1684	19.03	82.35	74.93	67.19	40.6	2.967	1684

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
24	late sowing date 1 2015	90	126	36	89.5	0.19	0.78	422.2	1134	17.15	79.54	73.43	63.92	40.89	4.055	1134
25	late sowing date 1 2015	91	138	47	72	0.2	0.83	420.1	1378	18.44	84.35	73.66	67.53	44	3.347	1378
26	late sowing date 1 2015	91	121	30	89	0.28	0.79	280	1612	19.3	73.68	75.5	68.28	47.39	6.265	1612
27	late sowing date 1 2015	90.5	121	30.5	101.5	0.21	0.86	409.8	1450	19.06	68.48	77.81	68.21	47.69	5.325	1450
28	late sowing date 1 2015	90.5	121	30.5	103	0.24	0.82	339.6	1562	20.66	72.7	74.38	66.69	48.83	4.761	1562
29	late sowing date 1 2015	88.5	121	32.5	80	0.23	0.79	351.7	1128	19.98	73.7	73.01	66.64	48.89	3.786	1128
30	late sowing date 1 2015	90.5	121	30.5	73	0.25	0.81	332.4	1775	19.71	72.48	74.89	69.05	46.27	4.884	1775
31	late sowing date 1 2015	95	129	34	58.5	0.28	0.88	328.6	1556	20.62	73.81	74.94	67.84	50.75	4.194	1556
32	late sowing date 1 2015	91	121	30	68.5	0.26	0.87	338.5	1203	20.76	68.74	74.64	67.59	52.59	5.022	1203
33	late sowing date 1 2015	91	125.5	34.5	75	0.22	0.84	393.6	1672	20.33	73.75	74.47	68.36	47.49	4.489	1672
34	late sowing date 1 2015	90	129	39	59.5	0.24	0.79	336.1	1478	19.82	69.08	72.68	69.13	48.55	4.72	1478
35	late sowing date 1 2015	92.5	125.5	33	73.5	0.25	0.82	344	2150	19.66	76.83	74.99	68.55	42.76	4.701	2150
36	late sowing date 1 2015	89	121	32	72	0.23	0.89	427	1669	19.87	69.96	70.39	67	46.94	4.781	1669
37	late sowing date 1 2015	89	121	32	65	0.25	0.84	335.3	1903	20.12	69.87	72.8	67.53	47.73	4.934	1903
38	late sowing date 1 2015	94.5	125.5	31	89	0.24	0.79	327.1	1403	20.01	70.89	76.66	66.53	51.49	4.198	1403
39	late sowing date 1 2015	91	121	30	76	0.23	0.82	364.9	2000	18.51	71.53	73.11	67.5	42.92	6.676	2000
40	late sowing date 1 2015	95	122.5	27.5	95.5	0.27	0.8	300.4	2147	18.11	72.72	76.66	67.72	44.34	5.902	2147
41	late sowing date 1 2015	89.5	121	31.5	83.5	0.24	0.84	394.9	1825	19.5	70.89	78.24	68.94	49.21	5.633	1825
42	late sowing date 1 2015	89.5	124	34.5	64	0.25	0.81	322	1491	20.62	67.23	73.92	66.37	50.16	5.572	1491
43	late sowing date 1 2015	96.5	119.5	23	80.5	0.24	0.86	363.9	1678	20.29	67.25	79.49	67.39	52.94	3.963	1678
44	late sowing date 1 2015	90.5	121	30.5	110.5	0.2	0.81	409.3	1522	19.96	67.6	75.15	67.49	48.77	5.017	1522
45	late sowing date 1 2015	90	121	31	67	0.23	0.84	363.3	1784	19.66	69.06	74.95	67	49.1	5.4	1784
46	late sowing date 1 2015	91	121	30	93	0.28	0.88	312.5	1734	18.82	77.3	76.17	69.79	44.1	4.454	1734
47	late sowing date 1 2015	89	122.5	33.5	64	0.2	0.82	411.6	1584	19.06	67.81	73.17	67.41	46.57	5.584	1584
48	late sowing date 1 2015	91.5	121	29.5	60.5	0.21	0.82	406.9	1978	19.35	71.74	72.61	67.8	47.94	4.912	1978
49	late sowing date 1 2015	95.5	121	25.5	98	0.25	0.67	285.2	1537	17.59	73.66	72.74	64.13	44.06	5.141	1537

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
50	late sowing date 1 2015	89.5	121	31.5	80	0.25	0.82	328	1469	17.3	70.8	76.52	66.82	39.58	2.554	1469
51	late sowing date 1 2015	91	122.5	31.5	102	0.23	0.85	393.5	1450	17.38	83.08	75.8	68.05	41.43	3.25	1450
52	late sowing date 1 2015	91	129	38	95.5	0.3	0.8	270.6	1691	17.64	78.75	73.84	67.33	43.21	4.629	1691
53	late sowing date 1 2015	91	127.5	36.5	73.5	0.28	0.89	317.2	756	19.81	74.73	77.99	69.87	50.82	2.492	756
54	late sowing date 1 2015	91	129	38	93	0.24	0.79	332.9	631	19.56	74.95	73.62	66.4	46.57	4.608	631
55	late sowing date 1 2015	91	124	33	78.5	0.23	0.83	368.2	2125	19.86	87.39	77.75	66.04	45.94	4.186	2125
56	late sowing date 1 2015	90	129	39	101	0.27	0.81	305.6	919	16.56	84.87	73.32	63.84	39.35	4.701	919
57	late sowing date 1 2015	91	125.5	34.5	86	0.23	0.87	388.7	2081	18.74	71.21	76.42	69.88	43.48	6.502	2081
58	late sowing date 1 2015	90.5	121	30.5	67	0.22	0.82	379.8	1475	20.95	70.44	75.91	67.94	49.71	4.727	1475
59	late sowing date 1 2015	89.5	139	49.5	96	0.22	0.86	388.9	997	19.16	82.11	77.92	67.59	44.2	1.934	997
60	late sowing date 1 2015	90.5	129	38.5	67	0.24	0.67	281	1787	20.15	75.05	74.83	68.57	47.27	4.935	1787
61	late sowing date 1 2015	94.5	121	26.5	58.5	0.24	0.85	354.8	2506	18.4	73.9	72.76	68.58	40.18	6.013	2506
62	late sowing date 1 2015	88.5	125.5	37	69.5	0.22	0.84	388.3	1834	19.93	71.3	75.68	68.79	47.19	6.633	1834
63	late sowing date 1 2015	90.5	121	30.5	68.5	0.25	0.77	325.3	1912	20.27	69.93	76.75	68.52	48.67	5.616	1912
64	late sowing date 1 2015	90.5	125.5	35	72.5	0.25	0.47	188	1928	19.86	73.82	75.04	69.99	47.11	6.334	1928
65	late sowing date 1 2015	90	121	31	67	0.25	0.81	352	1875	20.26	74.48	74.04	69.86	46.26	5.853	1875
66	late sowing date 1 2015	90.5	125.5	35	91.5	0.24	0.81	337.5	2059	19.83	72.02	73.78	69.67	45.38	6.574	2059
67	late sowing date 1 2015	90.5	124	33.5	63.5	0.24	0.81	349.3	1884	19.61	73.39	76.15	68.75	46.58	5.573	1884
68	late sowing date 1 2015	89	121	32	80	0.28	0.78	277.6	1941	20.26	74.06	72.43	69.11	46.13	6.267	1941
69	late sowing date 1 2015	91	127	36	71.5	0.25	0.76	314	1503	20.43	71.7	75.24	69.1	47.56	5.21	1503
70	late sowing date 1 2015	94	122.5	28.5	86	0.21	0.8	417.4	1981	19.06	75.08	76.86	69.36	46.55	6.07	1981
71	late sowing date 1 2015	90.5	122.5	32	71	0.24	0.81	348.5	1987	19.62	75.56	76.24	69.46	45.86	4.98	1987
72	late sowing date 1 2015	91	105.5	14.5	56.5	0.24	0.85	352.1	1816	19.82	74.17	74.91	68.65	45.61	4.598	1816
73	late sowing date 1 2015	90	121	31	64.5	0.28	0.82	292.9	2228	20.2	77.29	73.84	68.42	45.19	4.589	2228
74	late sowing date 1 2015	93.5	121	27.5	93	0.24	0.87	377.4	2272	19.32	74.55	73.47	69.81	44.14	5.734	2272
75	late sowing date 1 2015	91.5	121	29.5	65	0.22	0.83	386.6	1762	19.92	75.44	74.45	69.21	47.83	5.304	1762

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
76	late sowing date 1 2015	90.5	124	33.5	77.5	0.24	0.79	336.3	2066	19.79	78.82	76.18	70.22	46.52	5.407	2066
77	late sowing date 1 2015	90.5	121	30.5	81	0.24	0.8	340.7	1712	20.32	77.95	74.42	69.16	47.08	4.482	1712
78	late sowing date 1 2015	91	121	30	77	0.27	0.81	303.9	1762	18.91	71.17	74.81	70.06	45.36	6.449	1762
79	late sowing date 1 2015	89	121	32	83	0.2	0.83	432.8	2153	19.27	77.3	73.95	67.97	43.19	4.699	2153
80	late sowing date 1 2015	94.5	125.5	31	71.5	0.24	0.77	325.9	2094	19.68	77.7	74.02	68.2	44.08	4.644	2094
81	late sowing date 1 2015	90	125.5	35.5	79	0.26	0.75	297	1750	20.11	73.1	75.12	70.34	45.93	5.129	1750
82	late sowing date 1 2015	91	121	30	89.5	0.22	0.84	395.5	2434	18.57	74.55	75.5	68.65	42.26	5.233	2434
83	late sowing date 1 2015	89.5	122.5	33	83	0.28	0.82	296.6	1909	20.17	69.5	74.51	68.16	46.72	5.714	1909
84	late sowing date 1 2015	94.5	121	26.5	60	0.24	0.85	354.2	1637	19.43	75.43	75.65	69.16	45.83	4.921	1637
85	late sowing date 1 2015	88.5	121	32.5	65	0.26	0.74	280.7	2072	19.83	71.73	75.27	68.54	47.51	5.717	2072
86	late sowing date 1 2015	92	125.5	33.5	72.5	0.22	0.8	377.2	2162	19.71	76.11	74.67	69.09	46.2	5.415	2162
87	late sowing date 1 2015	91	121	30	59.5	0.23	0.86	372.5	1728	19.28	74.56	74.32	68.82	45.49	5.7	1728
88	late sowing date 1 2015	91	122.5	31.5	88.5	0.29	0.84	290.8	1916	19.61	70.66	76.84	67.83	47.45	5.359	1916
89	late sowing date 1 2015	91.5	122.5	31	75.5	0.25	0.83	338.1	1947	19.18	69.82	76.28	68.83	45.47	5.649	1947
90	late sowing date 1 2015	94.5	122.5	28	76	0.23	0.77	333.9	1972	20.52	75.13	74.62	67.38	48.57	4.331	1972
91	late sowing date 1 2015	90	124	34	72.5	0.21	0.82	410.3	1800	20.59	74.91	74.87	68.04	48.92	4.933	1800
92	late sowing date 1 2015	91	121	30	57	0.23	0.86	372.3	2172	19.26	75.41	74.37	68.72	43.88	5.52	2172
93	late sowing date 1 2015	88.5	121	32.5	67	0.19	0.84	470.9	1866	19.39	74.56	75.8	70.01	45.24	6.114	1866
94	late sowing date 1 2015	90.5	121	30.5	73	0.27	0.84	322.6	1828	19.48	75.32	74.59	69.92	44.96	6.437	1828
95	late sowing date 1 2015	89.5	121	31.5	84.5	0.23	0.79	355.5	1544	19.79	71.59	76.39	69.22	47.38	5.894	1544
96	late sowing date 1 2015	90	122.5	32.5	77	0.24	0.82	347.3	1731	20.33	71.54	74.04	69.34	48.07	6.372	1731
97	late sowing date 1 2015	89.5	121	31.5	95.5	0.23	0.81	352.5	1456	19.67	75.77	76.71	70.2	47.4	5.306	1456
98	late sowing date 1 2015	88.5	122.5	34	85.5	0.25	0.81	325.3	1287	16.61	76.11	72.96	65.4	39.29	3.84	1287
99	late sowing date 1 2015	91	129	38	104.5	0.25	0.76	310.9	831	18.19	78.88	75.5	68.53	43.99	4.031	831
100	late sowing date 1 2015	92.5	129	36.5	67.5	0.23	0.89	397.9	2072	19.23	78.44	75.33	69.86	46.35	6.073	2072
101	late sowing date 1 2015	89.5	121	31.5	64.5	0.25	0.83	338.8	1975	19.93	75.16	72.46	69.96	44.83	6.655	1975

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
102	late sowing date 1 2015	90.5	121	30.5	73	0.27	0.86	327.8	1838	19.87	74.94	74.64	69.85	47.17	6.251	1838
103	late sowing date 1 2015	89.5	125.5	36	70	0.23	0.78	350	2359	18.82	74.03	76	69.82	44.28	6.989	2359
104	late sowing date 1 2015	95	125.5	30.5	85	0.23	0.84	387.3	2019	19.39	75.2	75.18	69.35	45.57	6.904	2019
105	late sowing date 1 2015	91	121	30	78.5	0.27	0.78	294.2	1659	20.61	72.18	75.79	68.88	48.44	5.355	1659
106	late sowing date 1 2015	94.5	122.5	28	74	0.2	0.87	432.5	2316	19.49	69.2	74.79	68.47	47.03	6.325	2316
107	late sowing date 1 2015	90.5	121	30.5	82.5	0.26	0.81	311.5	2081	20.42	71.83	75	69.1	47.54	7.149	2081
108	late sowing date 1 2015	91	121	30	97	0.22	0.87	406.6	1881	19.84	75.78	74.75	69.45	47.57	6.652	1881
109	late sowing date 1 2015	90	121	31	77	0.3	0.86	286.7	2178	20.26	73.4	74.97	69.62	47.23	6.762	2178
110	late sowing date 1 2015	91	121	30	65.5	0.21	0.79	394.5	1491	20.08	75.42	75.52	69.45	46.44	5.566	1491
111	late sowing date 1 2015	91	121	30	76	0.21	0.77	376.1	2269	19	75.18	75.64	70.21	45.14	6.533	2269
112	late sowing date 1 2015	90.5	125.5	35	60.5	0.3	0.78	263	2287	17.43	75.88	75.8	70.53	40.73	6.076	2287
113	late sowing date 1 2015	91	127.5	36.5	58.5	0.22	0.84	392.9	1775	18.28	80.29	75.32	70.7	41.58	6.216	1775
114	late sowing date 1 2015	95	121	26	83	0.27	0.87	327.6	1819	19.77	73.11	75.23	69.83	46.81	5.832	1819
115	late sowing date 1 2015	95.5	127	31.5	67.5	0.22	0.74	347.3	1925	19.47	76.23	75.76	69.56	44.95	5.703	1925
116	late sowing date 1 2015	91	124	33	77.5	0.23	0.85	369.7	2288	17.92	78.03	76.39	70.29	41.56	5.626	2288
117	late sowing date 1 2015	89.5	121	31.5	78.5	0.24	0.83	346.4	2038	18.72	77.11	76.38	69.02	44.49	5.522	2038
118	late sowing date 1 2015	94	121	27	75.5	0.23	0.79	341.4	2091	18.64	77.09	75.12	70.41	44	6.317	2091
119	late sowing date 1 2015	93.5	121	27.5	77	0.28	0.83	300.2	1350	21.36	73.96	74.22	69.01	48.98	4.655	1350
120	late sowing date 1 2015	91	125.5	34.5	59.5	0.21	0.86	408	1853	20.15	72.76	76.74	69.01	47.99	6.168	1853
1	late sowing date 2 2015	61	101	40	68	0.11	0.7	635	2028	15.66	79.66	83.25	71.81	38.79	3.356	2028
2	late sowing date 2 2015	63	93	30	72	0.13	0.72	559.5	1541	16.03	84.14	78.33	70.51	39.12	2.685	1541
3	late sowing date 2 2015	65	93	28	89.5	0.1	0.68	706.7	1241	18.18	84.44	75.12	69.35	39.75	4.315	1241
4	late sowing date 2 2015	73	93	20	98	0.11	0.73	713.9	344	19.01	86.12	75.35	68.16	41.86	4.182	344
5	late sowing date 2 2015	73	93	20	93.5	0.11	0.74	704.1	1831	16.86	88.59	77.49	69.21	38.73	3.563	1831
6	late sowing date 2 2015	58	93	35	45	0.11	0.73	711.1	2469	15.87	78.52	77.77	70.19	36.73	6.47	2469
7	late sowing date 2 2015	58	93	35	52.5	0.12	0.63	525	1597	17.08	78.86	79.33	70.31	41	2.431	1597

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
8	late sowing date 2 2015	62	93	31	60.5	0.1	0.65	650	1916	15.67	81.98	80.18	71.77	37.01	2.999	1916
9	late sowing date 2 2015	58	92	34	78	0.13	0.74	605	1831	15.74	74.01	76.83	68.4	37.55	4.982	1831
10	late sowing date 2 2015	60	101	41	48	0.12	0.78	645.8	2291	14.71	78.86	76.42	71.02	33.24	7.097	2291
11	late sowing date 2 2015	73	93	20	69	0.11	0.66	630.9	1534	14.08	88.76	71.89	65.35	32.26	5.009	1534
12	late sowing date 2 2015	62	93	31	75	0.1	0.73	770.6	1437	18.24	84.02	77.03	67.25	43.37	3.508	1437
13	late sowing date 2 2015	63	93	30	89	0.14	0.76	561.8	1184	17.12	83.28	77.68	70.07	39.21	3.96	1184
14	late sowing date 2 2015	73	93	20	112.5	0.11	0.7	653	822	19.09	85.64	76.69	68.91	42.88	2.451	822
15	late sowing date 2 2015	73	93	20	73	0.11	0.65	619.1	966	16.15	81.96	77.18	67.37	38.25	2.605	966
16	late sowing date 2 2015	71	93	22	82.5	0.09	0.66	733.3	2084	14.85	84.74	79.7	70.72	34.65	3.852	2084
17	late sowing date 2 2015	62	93	31	64.5	0.15	0.64	438.6	1600	16.8	89.42	78.79	70.94	38.97	3.249	1600
18	late sowing date 2 2015	67	101	34	54.5	0.12	0.69	615.9	1559	17.06	82.23	79.24	70.26	40.15	5.027	1559
19	late sowing date 2 2015	57	82	25	52	0.15	0.71	507.7	1903	16.01	75.01	77.8	71.07	38.46	5.171	1903
20	late sowing date 2 2015	60	101	41	69.5	0.11	0.69	665.3	2059	15.08	78.91	79.49	72.11	37.23	3.977	2059
21	late sowing date 2 2015	69	93	24	68	0.12	0.83	690	1769	16.21	86.87	73.87	66.34	40.7	3.686	1769
22	late sowing date 2 2015	61	92	31	67	0.11	0.72	686.4	2006	16.29	69.09	79.62	69.35	37.76	2.612	2006
23	late sowing date 2 2015	62	94	32	51	0.13	0.75	625	2097	16.47	79.76	77.44	68.36	35.38	3.107	2097
24	late sowing date 2 2015	67	93	26	85.5	0.11	0.66	642.3	1766	14.82	81.91	74.04	64.69	33.62	4.87	1766
25	late sowing date 2 2015	62	93	31	60	0.13	0.62	493.9	1475	17.75	82.24	75.97	70.08	40	4.057	1475
26	late sowing date 2 2015	61	94	33	55	0.09	0.61	685	2309	16.28	75.91	78.35	69.43	41.03	6.191	2309
27	late sowing date 2 2015	57	94	37	58.5	0.11	0.72	658.3	1478	17.37	71.68	78.03	69.53	43.05	6.101	1478
28	late sowing date 2 2015	61	94	33	78	0.1	0.75	784.4	1734	16.73	72.55	78.31	70.34	38.69	4.477	1734
29	late sowing date 2 2015	69	94	25	49.5	0.12	0.75	727.1	1603	16.93	75.76	75.58	68.04	39.96	4.83	1603
30	late sowing date 2 2015	57	93	36	65.5	0.12	0.72	627.3	1584	17.52	75.14	77.37	71.14	41.21	5.537	1584
31	late sowing date 2 2015	58	93	35	69.5	0.11	0.73	691.8	2391	16.69	75.64	77.42	70.03	39.07	5.489	2391
32	late sowing date 2 2015	62	85.5	23.5	50	0.11	0.68	655.6	2150	15.79	74.62	76.87	70.47	38.19	6.407	2150
33	late sowing date 2 2015	57	93	36	73	0.12	0.65	586.7	1950	16.88	79.54	76.28	71.52	40.2	5.966	1950

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
34	late sowing date 2 2015	62	93	31	56.5	0.11	0.67	604.5	1466	16.28	74.2	77.81	70.93	40.51	5.389	1466
35	late sowing date 2 2015	58	94	36	66	0.14	0.72	542.5	2191	15.77	76.19	75.2	68.52	33.62	5.528	2191
36	late sowing date 2 2015	58	97	39	53	0.1	0.69	720.8	1703	17	76.44	74.02	69.58	39.38	5.635	1703
37	late sowing date 2 2015	65	101	36	44.5	0.11	0.69	652.7	2244	16.3	73.77	77.11	69.59	39.76	5.697	2244
38	late sowing date 2 2015	60	97	37	68.5	0.12	0.66	575.8	1934	17.93	72.58	75.85	68.76	45.72	5.857	1934
39	late sowing date 2 2015	59	97	38	65.5	0.11	0.63	572.7	1784	18.01	76.53	74.51	68.35	42.7	6.475	1784
40	late sowing date 2 2015	62	101	39	52	0.14	0.7	534.1	2106	16.61	73.07	78.06	69.24	41.15	6.379	2106
41	late sowing date 2 2015	61	94	33	47	0.09	0.69	772.5	1881	16.21	74.75	78.31	71.4	39.61	6.647	1881
42	late sowing date 2 2015	60	101	41	59	0.12	0.78	679.9	1525	18.33	75.37	72.84	69.73	43.43	6.682	1525
43	late sowing date 2 2015	57	94	37	59.5	0.12	0.75	640	1912	16.48	70.25	79.78	69.86	43.19	6.186	1912
44	late sowing date 2 2015	57	94	37	69.5	0.1	0.65	687.5	1850	17.56	72.84	77.5	68.25	43.04	5.795	1850
45	late sowing date 2 2015	58	97	39	38	0.12	0.66	571.6	1003	19.32	69.64	73.59	67.24	47.29	5.214	1003
46	late sowing date 2 2015	61	93	32	30.5	0.09	0.73	805.6	1938	15.62	79.52	79.4	71.04	36.79	4.572	1938
47	late sowing date 2 2015	64	95	31	53	0.12	0.71	652	1556	15.31	71.97	78	69.84	38.32	6.655	1556
48	late sowing date 2 2015	57	101	44	56	0.1	0.64	688.1	1153	19.16	74.39	74.5	70.47	45.31	5.586	1153
49	late sowing date 2 2015	57	92	35	60	0.11	0.73	697.7	1384	16.46	74.78	76.48	65.01	41.62	4.347	1384
50	late sowing date 2 2015	59	101	42	68	0.11	0.67	659.7	544	18.19	77.57	78.77	69.05	43.62	2.32	544
51	late sowing date 2 2015	65	93	28	75.5	0.1	0.74	741.4	1856	14.89	85.05	77.64	70.14	33.26	4.234	1856
52	late sowing date 2 2015	66	93	27	55.5	0.14	0.69	550	1441	16.97	79.06	77.1	68.46	40.55	4.343	1441
53	late sowing date 2 2015	58	101	43	48.5	0.11	0.66	637.2	1444	17.06	75.72	81.35	70.9	42.61	1.833	1444
54	late sowing date 2 2015	61	93	32	74.5	0.12	0.67	582.6	1041	18.1	71.71	77.47	67.12	43.06	3.858	1041
55	late sowing date 2 2015	67	93	26	55	0.12	0.74	617.1	2362	14.79	82.22	80.17	69.96	34.62	3.039	2362
56	late sowing date 2 2015	65	93	28	64	0.13	0.67	511.5	1116	14.42	91.47	73.96	66.1	30.11	5.349	1116
57	late sowing date 2 2015	62	101	39	53.5	0.12	0.68	591.9	2428	14.31	73.23	76.6	70.24	31.8	6.45	2428
58	late sowing date 2 2015	61	94	33	55.5	0.12	0.69	586.4	1409	17.53	72.59	79.2	69.94	42.09	4.693	1409
59	late sowing date 2 2015	66	93	27	106	0.12	0.65	580.4	1603	17.83	80.78	76.81	69.04	40.62	4.211	1603

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
60	late sowing date 2 2015	62	93	31	49	0.12	0.67	561.9	1688	18.27	77.48	75.23	70.55	41.66	5.254	1688
61	late sowing date 2 2015	59	101	42	47	0.1	0.73	733.8	1778	16.09	76.2	75.04	70.71	35.05	5.819	1778
62	late sowing date 2 2015	59	93	34	44.5	0.11	0.61	570	1884	17.62	73.01	78.17	71.01	40.91	6.463	1884
63	late sowing date 2 2015	58	94	36	57.5	0.14	0.71	503.6	2047	17.57	73.54	77.51	70.19	41.72	6.448	2047
64	late sowing date 2 2015	65	93	28	50	0.12	0.68	603.3	2459	16.77	80.39	76.6	72.36	38.88	6.123	2459
65	late sowing date 2 2015	61	93	32	58.5	0.11	0.78	747.2	1987	16.78	80.8	76.69	72.07	37.46	6.029	1987
66	late sowing date 2 2015	64	93	29	60.5	0.1	0.57	587.5	2047	17.61	75.64	77.46	72.43	41.24	6.346	2047
67	late sowing date 2 2015	61	93	32	47	0.13	0.66	503.3	1619	16.6	75.92	78.37	70.86	37.66	6.263	1619
68	late sowing date 2 2015	59	97	38	51.5	0.11	0.64	646.2	2147	16.05	77.94	75.91	71.15	35.05	6.806	2147
69	late sowing date 2 2015	60	101	41	56.5	0.1	0.7	730.6	2347	16.39	74.85	76.93	71.98	37.51	6.729	2347
70	late sowing date 2 2015	60	93	33	45	0.13	0.61	488.5	1694	16.87	78.28	75.21	70.06	38.55	6.077	1694
71	late sowing date 2 2015	65	93	28	52	0.09	0.67	791	2419	17.03	80.34	75.3	71.39	37.98	5.813	2419
72	late sowing date 2 2015	66	93	27	48.5	0.1	0.69	718.8	1484	18.36	81.39	75.56	69.46	40.87	3.987	1484
73	late sowing date 2 2015	61	93	32	54.5	0.12	0.7	606.1	2053	17.21	78.95	76.79	69.96	37.81	5.297	2053
74	late sowing date 2 2015	62	93	31	52.5	0.12	0.71	597.9	1859	17.26	78.41	75.98	71.42	40.02	5.944	1859
75	late sowing date 2 2015	61	93	32	60	0.11	0.68	674.5	1709	18.28	77.94	75.63	70.13	43.77	5.177	1709
76	late sowing date 2 2015	63	93	30	47.5	0.11	0.71	676.8	1541	18.2	81.95	74.76	71.58	41.27	5.71	1541
77	late sowing date 2 2015	64	93	29	53.5	0.12	0.68	588.3	1259	18.1	81.21	76.23	70.49	40.59	5.081	1259
78	late sowing date 2 2015	61	85.5	24.5	50.5	0.1	0.69	697	1203	17.56	72.2	79.17	70.67	40.92	5.557	1203
79	late sowing date 2 2015	58	94	36	56.5	0.12	0.62	516.4	1581	16.71	77.13	74.88	69.23	36.32	5.167	1581
80	late sowing date 2 2015	58	93	35	51.5	0.11	0.7	631.8	1666	16.41	77.02	74.7	68.69	35.74	5.093	1666
81	late sowing date 2 2015	61	93	32	56.5	0.1	0.69	727.8	2372	16.54	76.69	77.94	71.64	37.97	6.074	2372
82	late sowing date 2 2015	61	93	32	52.5	0.13	0.7	588.3	2044	17.06	76.31	76.27	70.34	39.47	5.109	2044
83	late sowing date 2 2015	61	93	32	44	0.15	0.72	476.7	1859	17.71	74.4	76.53	69.34	40.61	5.982	1859
84	late sowing date 2 2015	64	93	29	55.5	0.12	0.62	536.4	2378	16.36	77.72	77.27	71.22	37.79	5.585	2378
85	late sowing date 2 2015	63	97	34	51.5	0.11	0.67	654.2	1897	16.91	74.14	77.04	70.79	39.77	6.351	1897

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
86	late sowing date 2 2015	67	93	26	52	0.15	0.72	493.1	1647	17.63	76.11	76.11	70.87	39.73	6.071	1647
87	late sowing date 2 2015	62	85.5	23.5	49.5	0.13	0.68	519.2	1747	17.02	76.65	77.47	71.08	39.81	5.39	1747
88	late sowing date 2 2015	61	93	32	48.5	0.09	0.72	800	2247	16.19	73.13	77.88	68.89	37.82	6.233	2247
89	late sowing date 2 2015	68	93	25	51.5	0.13	0.7	571.7	2384	15.41	78.56	75.85	71.41	35.58	6.777	2384
90	late sowing date 2 2015	58	93	35	56.5	0.12	0.74	639.8	2112	17.37	75.93	75.59	69.95	39.38	5.483	2112
91	late sowing date 2 2015	63	93	30	49.5	0.1	0.75	791.1	2534	16.07	80.26	76.81	71.68	36.35	6.356	2534
92	late sowing date 2 2015	59	101	42	43.5	0.12	0.63	520.8	1788	17.44	79.32	76.11	71.71	38.21	5.541	1788
93	late sowing date 2 2015	73	93	20	82	0.12	0.65	586.7	1966	16.22	82.36	76.73	70.87	36.12	5.789	1966
94	late sowing date 2 2015	57	94	37	46	0.1	0.66	711.4	2225	15.84	77.89	78.52	71.33	36.84	6.739	2225
95	late sowing date 2 2015	57	97	40	45	0.1	0.67	704.4	2259	15.1	74.71	76.82	71.95	34.44	7.585	2259
96	late sowing date 2 2015	62	93	31	55	0.15	0.61	418.3	1722	15.57	73.98	78.07	71.88	35.21	7.265	1722
97	late sowing date 2 2015	58	85.5	27.5	57.5	0.12	0.63	525	1903	16.07	76.49	76.71	71.92	38.25	7.151	1903
98	late sowing date 2 2015	69	93	24	53.5	0.11	0.71	650	1950	14.26	79.77	75.72	65.61	33.63	3.113	1950
99	late sowing date 2 2015	65	93	28	73	0.13	0.7	542.3	1147	16.72	82.31	77.32	69.82	38.85	5.097	1147
100	late sowing date 2 2015	60	93	33	54.5	0.12	0.68	580	1956	17.64	78.03	77.01	70.08	41.5	5.876	1956
101	late sowing date 2 2015	59	97	38	51	0.1	0.68	570	1419	18.16	72.98	76.85	69.83	42.25	5.895	1419
102	late sowing date 2 2015	59	85.5	26.5	44	0.12	0.68	568.2	2294	16.32	76.63	78.29	70.8	38.12	7	2294
103	late sowing date 2 2015	67	97	30	48	0.11	0.71	693.1	2238	16.37	76.61	79.37	71.08	38.55	6.686	2238
104	late sowing date 2 2015	69	85.5	16.5	48	0.11	0.61	615.3	2166	16.25	77.08	78.86	71.66	39.66	6.983	2166
105	late sowing date 2 2015	63	95	32	50	0.1	0.63	590	2450	15.24	78.85	78.44	71.57	35.64	5.585	2450
106	late sowing date 2 2015	58	97	39	55	0.14	0.77	580.4	2303	16.29	72.59	77.38	69.81	39.2	7.11	2303
107	late sowing date 2 2015	60	97	37	35.5	0.12	0.73	607	1950	17.13	78.28	76.77	71.65	39.43	6.858	1950
108	late sowing date 2 2015	58	94	36	41.5	0.1	0.73	801.7	1947	16.6	75.89	77.94	70.9	39.57	7.168	1947
109	late sowing date 2 2015	60	101	41	51	0.11	0.71	653.3	2488	16.64	75.18	78.93	71.45	38.93	7.478	2488
110	late sowing date 2 2015	62	94	32	61	0.12	0.62	510.5	2606	15.27	79.73	77.32	71.02	34.42	6.08	2606
111	late sowing date 2 2015	62	93	31	55	0.08	0.73	906.3	2544	14.31	80.22	75.53	71.32	30.61	7.276	2544

ENTRY	Environment	Days to heading	days to maturity	days to grain-fill	Height	GC% 1	GC% 2	GC rate	Yield	Protein	SKHI	HLW	SY	WG	Y-Pig	Yield Kg/ha
112	late sowing date 2 2015	63	93	30	50.5	0.11	0.64	608.2	2319	15.67	78.84	73.18	70.93	36.07	6.952	2319
113	late sowing date 2 2015	62	93	31	43.5	0.12	0.65	541.7	2525	15.37	80.05	78.29	71.26	35.07	6.437	2525
114	late sowing date 2 2015	62	93	31	56	0.11	0.7	663.6	2809	15.19	81.88	75.9	71.44	33.73	6.705	2809
115	late sowing date 2 2015	61	93	32	44.5	0.13	0.62	540.6	2462	15.58	80.13	76.01	70.82	35.95	6.724	2462
116	late sowing date 2 2015	60	94	34	51.5	0.09	0.66	809.3	2478	14.36	82.67	76.02	71.33	34.11	6.478	2478
117	late sowing date 2 2015	66	94	28	46	0.11	0.61	620.7	2369	14.96	81.43	75.17	71.45	35	6.491	2369
118	late sowing date 2 2015	63	93	30	52.5	0.11	0.62	591.4	2797	15.12	80.02	76.59	71.17	34.1	7.263	2797
119	late sowing date 2 2015	60	93	33	57	0.13	0.71	546.4	2350	15.53	79.69	74.19	70.73	33.96	6.238	2350
120	late sowing date 2 2015	68	93	25	43.5	0.1	0.69	690	3128	13.83	77.84	80.81	71.64	33.62	6.568	3128

Table 4: Durum wheat predicted means for MPH, MPT, RBD, WA8, WAP, flour yield for early sowing 2014, late sowing 2014, early sowing date 1 2015 and late sowing date 2 2015

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
1	early sowing 2014	66.92	2.91	86.97	2.573	19.9	63.63
2	early sowing 2014	70.47	2.365	70.07	7.065	23.38	57.24
6	early sowing 2014	55.8	3.125	50.19	12.185	24.6	62.06
7	early sowing 2014	55.75	3.345	47.96	8.45	16.11	60.15
8	early sowing 2014	50.92	2.305	84.71	2.781	18.18	61.76
9	early sowing 2014	51.8	2.275	95.09	0.586	11.94	59.97
10	early sowing 2014	52.66	3.215	65.32	9.82	32.26	57.21
13	early sowing 2014	58.64	2.335	95.53	0.55	12.62	54.53
14	early sowing 2014	64.54	2.335	87.55	1.775	14.22	59.58
15	early sowing 2014	51.83	2.255	93.6	0.751	11.86	58.68
16	early sowing 2014	60.67	2.765	81.21	2.59	13.74	58.99
17	early sowing 2014	59.19	2.65	75.83	3.36	13.97	56.23
18	early sowing 2014	63.1	2.515	81.88	2.921	15.8	56.54
21	early sowing 2014	58.8	1.86	95.94	0.551	13.58	38.27
22	early sowing 2014	48.49	3.88	61.8	2.559	9.51	54.34
25	early sowing 2014	62.87	2.06	82.23	3.247	18.43	60.92
26	early sowing 2014	59.92	2.515	74.85	6.893	28.19	65.14
28	early sowing 2014	62.34	2.41	67.48	7.898	27.04	59.16
31	early sowing 2014	58.22	2.5	67.63	5.892	18.41	64.77
34	early sowing 2014	63.99	2.655	85.53	2.829	20.78	57.33
38	early sowing 2014	60.27	2.275	90.4	1.648	15.87	57.86

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
39	early sowing 2014	54.35	2.455	71.83	4.293	14.79	56.43
45	early sowing 2014	67.77	2.335	80	3.961	21.17	59.6
48	early sowing 2014	47.74	3.2	75.06	3.371	11.76	61.18
49	early sowing 2014	57.92	2.445	91.78	1.082	13.72	59.66
51	early sowing 2014	50.06	3.16	88.84	2.145	19.8	48.3
52	early sowing 2014	30.31	2.415	88.32	1.14	10.53	52.2
53	early sowing 2014	54.26	2.225	94.74	0.565	10.84	58.27
55	early sowing 2014	49.39	2.365	79.52	5.55	30.45	55.79
57	early sowing 2014	61.56	3.1	51.88	11.06	23.03	64.07
61	early sowing 2014	59.69	4.39	41.16	10.633	18.13	55.61
91	early sowing 2014	55.66	3.265	40.98	14.408	29.08	60.11
98	early sowing 2014	36.06	2.415	88.99	1.605	14.56	58.17
99	early sowing 2014	50.23	2.38	95.11	0.524	10.62	59.93
100	early sowing 2014	70.62	2.685	64.43	9.86	28.7	60.01
101	early sowing 2014	70.87	3.55	38.61	14.92	24.38	59.41
106	early sowing 2014	55.72	2.75	54.3	11.026	26.54	60.46
114	early sowing 2014	58.03	3.65	34.67	11.621	18.34	57.17
1	late sowing 2014	71.61	3.675	80.1	2.641	17.72	53.19
2	late sowing 2014	67.57	2.465	71.43	4.427	18.77	56.02
6	late sowing 2014	73.55	3.025	62.36	10.218	27.72	60.09
7	late sowing 2014	63.57	3.14	56.01	10.899	24.89	53.65
8	late sowing 2014	63.03	1.91	89.5	1.69	16.09	60.71
9	late sowing 2014	59.53	2.415	86.59	2.144	15.91	61.15
10	late sowing 2014	60.13	3.24	49.23	11.303	22.29	63.4
13	late sowing 2014	54.49	2.355	88.33	1.554	13.81	46.86

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
14	late sowing 2014	57.4	2.19	88.9	1.53	13.2	54
15	late sowing 2014	52.29	2.2	87.2	1.391	11.26	59.42
16	late sowing 2014	62.56	2.32	81.81	2.386	13.12	61.06
17	late sowing 2014	62.19	2.04	90.59	1.277	14.03	55.93
18	late sowing 2014	56.95	2.2	88.11	1.572	12.71	54.88
21	late sowing 2014	63.06	2.19	80	5.137	25.35	54.68
22	late sowing 2014	61.35	2.19	96.7	0.814	22.46	35.22
25	late sowing 2014	53.92	2.67	78.11	2.913	10.91	54.28
26	late sowing 2014	69.12	2.645	71.89	7.206	25.33	59.12
28	late sowing 2014	64.86	2.575	70.57	6.007	20.15	57.94
31	late sowing 2014	57.27	2.97	69.76	6.379	20.84	66.05
34	late sowing 2014	59.13	2.085	87.47	4.382	34.56	58.5
38	late sowing 2014	63.76	2.64	78.83	4.758	23.13	59.12
39	late sowing 2014	60.16	2.13	73.67	6.668	25.85	58.31
45	late sowing 2014	54.89	2.44	68.43	8.531	27.47	59.19
48	late sowing 2014	61.89	2.605	81.16	3.341	17.99	55.92
49	late sowing 2014	74.09	2.355	89.01	1.984	18.33	56.77
51	late sowing 2014	66.44	3.15	84.41	2.392	15.77	53.51
52	late sowing 2014	54.35	2.12	87.38	1.355	10.87	59.6
53	late sowing 2014	70.17	2.405	81.16	2.45	13.23	66.13
55	late sowing 2014	65.76	2.73	70.25	6.734	25.79	54.89
57	late sowing 2014	66.83	3.26	53.51	13.167	28.52	59.79
61	late sowing 2014	68.75	4.295	44.5	15.137	27.53	59.68
91	late sowing 2014	58.39	4.765	43.14	10.46	21.48	62.37
98	late sowing 2014	68.37	2.505	68.77	5.922	17.2	60.48

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
99	late sowing 2014	48.91	2.385	96.15	0.58	14.94	61.95
100	late sowing 2014	62.53	2.865	66.92	6.855	21.12	53.9
101	late sowing 2014	47.35	4.47	37.31	15.205	24.29	58.33
106	late sowing 2014	63.28	3.125	58.55	11.177	27.44	59.45
114	late sowing 2014	53.81	5.21	42.08	8.022	13.95	61.61
1	early sowing date 1 2015	69.99	3.23	75.19	4.666	19.31	59.01
2	early sowing date 1 2015	76.05	3.09	50	9.185	18.85	57.54
6	early sowing date 1 2015	64.15	3.59	19.36	14.12	17.49	57.74
7	early sowing date 1 2015	52.58	2.89	67.53	9.085	28.37	59.29
8	early sowing date 1 2015	63.85	2.13	89.3	1.514	14.68	54.61
9	early sowing date 1 2015	59.56	2.525	93.83	0.719	12.67	60.04
10	early sowing date 1 2015	59.51	4.425	29.26	11.709	16.78	56.26
13	early sowing date 1 2015	61.04	2.75	78.61	4.259	17.26	54.12
14	early sowing date 1 2015	63.02	2.41	91.39	1.351	17.08	53.86
15	early sowing date 1 2015	53.27	2.095	96.81	0.427	13.35	53.5
16	early sowing date 1 2015	58.54	3.09	42.61	6.63	11.56	58.09
17	early sowing date 1 2015	60.02	1.925	96.12	0.725	18.47	57.73
18	early sowing date 1 2015	59.48	2.055	93.57	1.071	16.56	54.93
21	early sowing date 1 2015	63.86	2.495	60.53	9.701	25.24	56.44
22	early sowing date 1 2015	53.52	2.28	97.75	0.33	14.62	59.51
25	early sowing date 1 2015	70.49	1.925	81.93	3.767	18.82	59.32
26	early sowing date 1 2015	56.44	3.165	64.08	5.687	17	62.49
28	early sowing date 1 2015	65.08	2.475	57.94	10.025	23.49	59.45
31	early sowing date 1 2015	69.04	2.59	61	10.39	26.66	62.81
34	early sowing date 1 2015	63.19	2.445	70.33	7.055	23.85	57.29

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
38	early sowing date 1 2015	62.83	1.945	71.57	6.93	25.1	59.46
39	early sowing date 1 2015	71.54	2.275	55.56	10.83	24.54	58.99
45	early sowing date 1 2015	69.78	2.12	71.93	7.23	26.34	59.91
48	early sowing date 1 2015	65.44	2.055	81.69	4.495	23.42	60.42
49	early sowing date 1 2015	57.98	2.435	86.98	1.585	12.49	60.89
51	early sowing date 1 2015	60.93	3.79	61.47	8.443	21.91	55.74
52	early sowing date 1 2015	73.39	2.18	77.02	6.465	28.21	53.77
53	early sowing date 1 2015	41.62	2.125	71.24	5.871	21.26	59.14
55	early sowing date 1 2015	53.34	2.915	63.32	7.715	21.18	56.93
57	early sowing date 1 2015	64.47	3.71	39.42	15.355	25.22	60.3
61	early sowing date 1 2015	52.85	3.58	39.22	16.92	27.82	58.25
91	early sowing date 1 2015	60.82	4.535	36.22	13.803	24.27	63.13
98	early sowing date 1 2015	72.31	2.17	76.23	5.18	24.78	58.32
99	early sowing date 1 2015	64.31	2.59	82.5	2.165	12.52	56.27
100	early sowing date 1 2015	71.16	2.585	61.89	9.455	25.22	57.3
101	early sowing date 1 2015	51.23	4.055	43.03	14.825	26.35	56.87
106	early sowing date 1 2015	59.61	3.053	59.97	12.468	31.43	59.69
114	early sowing date 1 2015	54.57	3.92	33.55	11.71	17.81	60.79
1	late sowing date 2 2015	63.05	2.765	95.71	0.615	15.51	65.53
2	late sowing date 2 2015	64.36	2.915	77.89	3.28	14.8	65.73
6	late sowing date 2 2015	42.78	3.64	46.18	7.95	14.81	66.19
7	late sowing date 2 2015	49.52	2.705	59.16	9.95	24.6	65.12
8	late sowing date 2 2015	49.8	2.56	89.09	1.555	14.45	66.97
9	late sowing date 2 2015	51.64	2.865	92.72	1.075	14.89	66.19
10	late sowing date 2 2015	56.49	3.53	44.37	9.364	17.34	67.37

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
13	late sowing date 2 2015	56.48	2.425	91.39	0.824	9.57	63.81
14	late sowing date 2 2015	63.55	2.435	95.52	0.644	14.35	61.33
15	late sowing date 2 2015	56.02	2.33	90.72	0.758	9.18	62.3
16	late sowing date 2 2015	49.39	3.055	85.22	1.348	8.99	65.68
17	late sowing date 2 2015	52.96	2.57	96.06	0.476	10.49	58.73
18	late sowing date 2 2015	60.22	2.055	81.95	2.354	12.75	60.83
21	late sowing date 2 2015	59.36	2.185	91.86	1.476	17.04	56.99
22	late sowing date 2 2015	70.81	3.185	91.8	1.222	16.71	62.07
25	late sowing date 2 2015	60.67	2.107	84.39	2.262	14.37	63.92
26	late sowing date 2 2015	66.47	2.37	87.06	3.17	24.72	62.27
28	late sowing date 2 2015	61.3	2.665	93.34	0.898	13.45	64.32
31	late sowing date 2 2015	57.68	2.77	78.63	3.88	18.29	66.74
34	late sowing date 2 2015	56.51	2.93	92.54	1.488	17.33	62.5
38	late sowing date 2 2015	51.1	2.88	87.42	1.605	14.3	62.51
39	late sowing date 2 2015	60.87	1.93	88.07	2.326	20.13	60.87
45	late sowing date 2 2015	60.33	2.62	80.21	3.258	19.42	59.07
48	late sowing date 2 2015	70.51	2.61	90.29	1.893	18.89	56.69
49	late sowing date 2 2015	66.15	2.305	93.62	0.86	13.57	64.08
51	late sowing date 2 2015	56.33	3.31	93.6	0.872	13.12	56.44
52	late sowing date 2 2015	54.1	1.86	97.73	0.256	11.38	55.96
53	late sowing date 2 2015	57.69	2.15	94.39	0.603	11	62.65
55	late sowing date 2 2015	49.42	4.415	37.76	8.746	15.41	58.71
57	late sowing date 2 2015	49.8	3.165	67.04	8.392	25.76	66.27
61	late sowing date 2 2015	65.28	3.42	66.35	10.424	31.26	62.3
91	late sowing date 2 2015	56.24	3.28	60.87	7.608	19.69	65.68

Entry	Environment	MPH	MPT	RBD	WA8	WAP	Flour yield %
98	late sowing date 2 2015	54.38	2.19	94.38	0.695	13.34	62.6
99	late sowing date 2 2015	24.89	2.13	98.47	0.172	11.15	54.95
100	late sowing date 2 2015	71.37	2.415	61.19	7.48	19.21	52.37
101	late sowing date 2 2015	59.95	3.77	48.45	10.782	22.23	54.48
106	late sowing date 2 2015	61.04	2.915	71.8	5.111	16.16	63.34
114	late sowing date 2 2015	50.66	3.895	44.99	13.607	24.72	61.13

Table 5: Durum wheat predicted means for screenings% and TKW in 2014 and 2015 all times of sowing

ENTRY	Environment	Screenings%	TKW
1	early sowing 2014	6.76	30.25
2	early sowing 2014	2.27	41
3	early sowing 2014	14.35	26.5
4	early sowing 2014	3.84	32.25
5	early sowing 2014	17.02	26.25
6	early sowing 2014	5.07	31.25
7	early sowing 2014	4.74	35
8	early sowing 2014	4.51	31
9	early sowing 2014	2.59	35.25
10	early sowing 2014	8.78	31.25
11	early sowing 2014	13.49	23.25
12	early sowing 2014	8.68	25.5

ENTRY	Environment	Screenings%	TKW
13	early sowing 2014	1.82	36
14	early sowing 2014	6.57	30.25
15	early sowing 2014	2.67	38.25
16	early sowing 2014	6.05	31.5
17	early sowing 2014	6.13	29.25
18	early sowing 2014	3.39	34.75
19	early sowing 2014	6.99	31.25
20	early sowing 2014	3.72	34.25
21	early sowing 2014	4.31	33.25
22	early sowing 2014	1.85	34.25
24	early sowing 2014	6.91	27.5
25	early sowing 2014	1.65	37.5
26	early sowing 2014	1.97	39
27	early sowing 2014	1.87	37.75
28	early sowing 2014	2.09	37.25
29	early sowing 2014	3.49	32.25
30	early sowing 2014	7.54	25
31	early sowing 2014	1.6	36.75
32	early sowing 2014	5.39	29.25
33	early sowing 2014	2.2	35.75
34	early sowing 2014	6.8	26
35	early sowing 2014	3.5	31.5
37	early sowing 2014	2.39	34

ENTRY	Environment	Screenings%	TKW
38	early sowing 2014	2.45	34.5
39	early sowing 2014	1.72	34
40	early sowing 2014	2.15	39.5
42	early sowing 2014	4.32	33.25
43	early sowing 2014	1.2	44.5
44	early sowing 2014	1.92	41.25
45	early sowing 2014	2.9	31.5
46	early sowing 2014	4.84	32.25
47	early sowing 2014	4.82	32
48	early sowing 2014	4.31	31.75
50	early sowing 2014	3.79	29.5
51	early sowing 2014	5.52	29.75
52	early sowing 2014	5.99	28.75
53	early sowing 2014	2.15	37.5
54	early sowing 2014	7.44	26.75
55	early sowing 2014	1.42	38
56	early sowing 2014	8.22	22.5
57	early sowing 2014	6.35	30.5
58	early sowing 2014	1.75	40
59	early sowing 2014	10.31	30
60	early sowing 2014	2.15	36.75
61	early sowing 2014	3.92	32.75
62	early sowing 2014	1.77	36.25

ENTRY	Environment	Screenings%	TKW
63	early sowing 2014	1.42	40.25
64	early sowing 2014	2.4	38.25
65	early sowing 2014	3.57	35.75
66	early sowing 2014	1.8	37.5
67	early sowing 2014	1.6	33.75
68	early sowing 2014	4.3	34
69	early sowing 2014	3.25	35.75
70	early sowing 2014	1.22	43
71	early sowing 2014	2	37
72	early sowing 2014	2.37	33.25
73	early sowing 2014	2	33
74	early sowing 2014	1.25	40.75
75	early sowing 2014	3.25	34.25
76	early sowing 2014	2.57	35.25
77	early sowing 2014	1.9	37.75
78	early sowing 2014	3.05	31.75
80	early sowing 2014	3.32	32.5
81	early sowing 2014	5.04	28
82	early sowing 2014	4.19	33
83	early sowing 2014	1.77	34.5
85	early sowing 2014	2.27	36.75
86	early sowing 2014	2.38	38
87	early sowing 2014	4.27	31.5

ENTRY	Environment	Screenings%	TKW
88	early sowing 2014	1.92	38.25
89	early sowing 2014	3.89	32.75
90	early sowing 2014	3.12	35.5
91	early sowing 2014	4.62	31
92	early sowing 2014	2.32	37.5
93	early sowing 2014	4.5	32.5
94	early sowing 2014	2.57	36
95	early sowing 2014	3.24	37
96	early sowing 2014	4.89	31.75
97	early sowing 2014	1.4	41.75
98	early sowing 2014	6.87	33.25
99	early sowing 2014	3.27	31.25
100	early sowing 2014	7.1	29.75
101	early sowing 2014	2.67	32.75
102	early sowing 2014	5.13	32.25
103	early sowing 2014	4.34	31.75
104	early sowing 2014	6.21	31
105	early sowing 2014	11.37	29
106	early sowing 2014	2.47	36.75
107	early sowing 2014	4.82	31.25
108	early sowing 2014	7.61	31.5
109	early sowing 2014	5.94	29.75
110	early sowing 2014	4.4	37

ENTRY	Environment	Screenings%	TKW
111	early sowing 2014	9.32	29.5
112	early sowing 2014	11.14	27.75
113	early sowing 2014	4.89	32.75
114	early sowing 2014	6.33	28
115	early sowing 2014	5.7	33
116	early sowing 2014	5.85	31.25
117	early sowing 2014	5.47	34
118	early sowing 2014	5.55	32
119	early sowing 2014	8.01	29.75
120	early sowing 2014	9.27	29
1	late sowing 2014	50.78	21
2	late sowing 2014	5.55	29.5
3	late sowing 2014	33.99	24.25
4	late sowing 2014	9.76	26
5	late sowing 2014	39.81	21.5
6	late sowing 2014	14.2	23
7	late sowing 2014	16.03	22.25
8	late sowing 2014	25.84	26.25
9	late sowing 2014	20.8	21
10	late sowing 2014	20.89	23.5
11	late sowing 2014	14.66	23.75
12	late sowing 2014	39.56	16.5
13	late sowing 2014	9.88	27

ENTRY	Environment	Screenings%	TKW
14	late sowing 2014	9.13	28.5
15	late sowing 2014	5.84	27.25
16	late sowing 2014	10.79	24
17	late sowing 2014	16.28	22.75
18	late sowing 2014	4.1	29.5
19	late sowing 2014	38.83	19
20	late sowing 2014	13.05	20.5
21	late sowing 2014	23.23	24.25
22	late sowing 2014	45.38	20
24	late sowing 2014	15.8	23.25
25	late sowing 2014	3.7	31.5
26	late sowing 2014	21.5	21.5
27	late sowing 2014	18.84	24
28	late sowing 2014	9.86	28.5
29	late sowing 2014	19.83	21.5
30	late sowing 2014	22.75	22
31	late sowing 2014	12.5	23
32	late sowing 2014	31.5	17
33	late sowing 2014	8.8	25.5
34	late sowing 2014	13.83	22.5
35	late sowing 2014	13.12	23.25
37	late sowing 2014	10.94	21
38	late sowing 2014	7.09	27.5

ENTRY	Environment	Screenings%	TKW
39	late sowing 2014	3.95	31
40	late sowing 2014	10.11	25
42	late sowing 2014	15.24	20.5
43	late sowing 2014	6.32	27.25
44	late sowing 2014	5.53	29.25
45	late sowing 2014	8.36	25.25
46	late sowing 2014	15.9	21.5
47	late sowing 2014	30.19	20
48	late sowing 2014	13.36	22.5
50	late sowing 2014	12.21	26.25
51	late sowing 2014	25.01	23
52	late sowing 2014	12.44	24
53	late sowing 2014	18.84	23
54	late sowing 2014	18.5	22.5
55	late sowing 2014	6.96	28.75
56	late sowing 2014	7.95	22.5
57	late sowing 2014	27.78	18
58	late sowing 2014	9.77	21
59	late sowing 2014	10.27	27
60	late sowing 2014	7.45	21.5
61	late sowing 2014	10.95	23.25
62	late sowing 2014	8.62	23.75
63	late sowing 2014	12.25	26

ENTRY	Environment	Screenings%	TKW
64	late sowing 2014	12.05	30
65	late sowing 2014	11.61	24.5
66	late sowing 2014	15.65	21
67	late sowing 2014	14.24	25
68	late sowing 2014	16.14	22.5
69	late sowing 2014	19.28	24.5
70	late sowing 2014	9.75	17
71	late sowing 2014	10.25	25.5
72	late sowing 2014	12.24	24
73	late sowing 2014	9.69	25.5
74	late sowing 2014	6.5	28
75	late sowing 2014	10.23	25.5
76	late sowing 2014	11.3	24.25
77	late sowing 2014	11.5	25.5
78	late sowing 2014	9.85	25.75
80	late sowing 2014	9.96	27.5
81	late sowing 2014	15.94	22.75
82	late sowing 2014	15.5	23.5
83	late sowing 2014	18.06	22.25
85	late sowing 2014	11.37	24.5
86	late sowing 2014	10.57	26.5
87	late sowing 2014	16.38	23
88	late sowing 2014	8.19	22

ENTRY	Environment	Screenings%	TKW
89	late sowing 2014	9.4	26.5
90	late sowing 2014	9.69	25.75
91	late sowing 2014	17.71	25
92	late sowing 2014	12.18	26.25
93	late sowing 2014	10.84	23.5
94	late sowing 2014	5.63	27.25
95	late sowing 2014	14.2	23.5
96	late sowing 2014	19.94	22.25
97	late sowing 2014	8.2	26
98	late sowing 2014	11.74	25.75
99	late sowing 2014	10.9	22
100	late sowing 2014	19.25	24
101	late sowing 2014	14.39	24.5
102	late sowing 2014	18.89	23
103	late sowing 2014	12.42	24.75
104	late sowing 2014	20.42	24
105	late sowing 2014	18.95	22.5
106	late sowing 2014	9.72	25.75
107	late sowing 2014	19.83	21.5
108	late sowing 2014	20.48	23.25
109	late sowing 2014	19.27	20.5
110	late sowing 2014	17.24	21.5
111	late sowing 2014	26.01	21.5

ENTRY	Environment	Screenings%	TKW
112	late sowing 2014	22.41	20.5
113	late sowing 2014	14.29	23.25
114	late sowing 2014	25.8	21.75
115	late sowing 2014	13.42	25.75
116	late sowing 2014	17.11	23.5
117	late sowing 2014	24.28	25.25
118	late sowing 2014	13.78	23.25
119	late sowing 2014	32.87	17.5
120	late sowing 2014	29.92	21
1	early sowing date 1 2015	21.45	27.5
2	early sowing date 1 2015	9.5	21.75
3	early sowing date 1 2015	14.2	26.75
4	early sowing date 1 2015	10.47	29
5	early sowing date 1 2015	20.83	32.5
6	early sowing date 1 2015	10.02	26.25
7	early sowing date 1 2015	3.83	28.88
8	early sowing date 1 2015	11.77	27.5
9	early sowing date 1 2015	12.75	24
10	early sowing date 1 2015	6.35	31
11	early sowing date 1 2015	15.25	27.25
12	early sowing date 1 2015	8.55	32
13	early sowing date 1 2015	3.13	24.5
14	early sowing date 1 2015	16.88	33

ENTRY	Environment	Screenings%	TKW
15	early sowing date 1 2015	7.92	30
16	early sowing date 1 2015	13.97	32
17	early sowing date 1 2015	5.07	33.5
18	early sowing date 1 2015	11.53	35.5
19	early sowing date 1 2015	7.48	28.25
20	early sowing date 1 2015	20.1	29
21	early sowing date 1 2015	9.02	32.5
22	early sowing date 1 2015	4.5	28.5
24	early sowing date 1 2015	7.12	34.75
25	early sowing date 1 2015	6.2	32.25
26	early sowing date 1 2015	2.4	27.75
27	early sowing date 1 2015	5.97	36.25
28	early sowing date 1 2015	3.5	25.63
29	early sowing date 1 2015	5.38	28.75
30	early sowing date 1 2015	2.65	34.5
31	early sowing date 1 2015	4.82	33.75
32	early sowing date 1 2015	6.2	32.38
33	early sowing date 1 2015	3.6	32
34	early sowing date 1 2015	2.57	27.75
35	early sowing date 1 2015	6.55	29.5
37	early sowing date 1 2015	4.27	31
38	early sowing date 1 2015	2.2	37.25
39	early sowing date 1 2015	1.13	22

ENTRY	Environment	Screenings%	TKW
40	early sowing date 1 2015	9.92	28
42	early sowing date 1 2015	3.77	26.75
43	early sowing date 1 2015	7.15	22.88
44	early sowing date 1 2015	3.57	28.75
45	early sowing date 1 2015	5.17	28
46	early sowing date 1 2015	4.42	33.25
47	early sowing date 1 2015	2.75	34
48	early sowing date 1 2015	12.07	36
50	early sowing date 1 2015	11.55	29
51	early sowing date 1 2015	9.5	23
52	early sowing date 1 2015	9.12	28.75
53	early sowing date 1 2015	11.05	23.38
54	early sowing date 1 2015	19.5	32
55	early sowing date 1 2015	2.87	31
56	early sowing date 1 2015	5.87	25.25
57	early sowing date 1 2015	4.45	26.75
58	early sowing date 1 2015	23.62	24.5
59	early sowing date 1 2015	21.25	24
60	early sowing date 1 2015	3.25	37.75
61	early sowing date 1 2015	6.7	34.75
62	early sowing date 1 2015	4.7	36.25
63	early sowing date 1 2015	5.87	24.13
64	early sowing date 1 2015	4.12	32

ENTRY	Environment	Screenings%	TKW
65	early sowing date 1 2015	4	32.75
66	early sowing date 1 2015	3.4	28
67	early sowing date 1 2015	15.5	30.5
68	early sowing date 1 2015	7.8	27
69	early sowing date 1 2015	4.85	32
70	early sowing date 1 2015	3.35	29
71	early sowing date 1 2015	2.95	29.38
72	early sowing date 1 2015	2.45	36.75
73	early sowing date 1 2015	1.77	30.25
74	early sowing date 1 2015	2.95	26
75	early sowing date 1 2015	3.57	32
76	early sowing date 1 2015	2.85	37
77	early sowing date 1 2015	5.27	30.5
78	early sowing date 1 2015	6.07	33
80	early sowing date 1 2015	6.67	26.5
81	early sowing date 1 2015	6.1	35
82	early sowing date 1 2015	3.07	32.5
83	early sowing date 1 2015	4.95	29
85	early sowing date 1 2015	4.17	34
86	early sowing date 1 2015	6.05	33
87	early sowing date 1 2015	7.6	31.5
88	early sowing date 1 2015	3.1	36.5
89	early sowing date 1 2015	1.8	32.88

ENTRY	Environment	Screenings%	TKW
90	early sowing date 1 2015	12.35	29.25
91	early sowing date 1 2015	3.52	36.25
92	early sowing date 1 2015	5.65	31.5
93	early sowing date 1 2015	8.2	30.5
94	early sowing date 1 2015	2.8	34.5
95	early sowing date 1 2015	4.55	35
96	early sowing date 1 2015	3.47	29.63
97	early sowing date 1 2015	5.9	32
98	early sowing date 1 2015	5.6	28.25
99	early sowing date 1 2015	7.6	30.25
100	early sowing date 1 2015	7.9	25.5
101	early sowing date 1 2015	7.6	25.5
102	early sowing date 1 2015	6.3	34.25
103	early sowing date 1 2015	11.6	28.25
104	early sowing date 1 2015	18.05	22.25
105	early sowing date 1 2015	4.67	25.88
106	early sowing date 1 2015	2.37	25.88
107	early sowing date 1 2015	11.57	35
108	early sowing date 1 2015	6.75	29.13
109	early sowing date 1 2015	8.52	27.75
110	early sowing date 1 2015	9.92	31.5
111	early sowing date 1 2015	10.52	35
112	early sowing date 1 2015	12.72	26.5

ENTRY	Environment	Screenings%	TKW
113	early sowing date 1 2015	9.72	30
114	early sowing date 1 2015	11.07	29.5
115	early sowing date 1 2015	8.8	30.25
116	early sowing date 1 2015	5.87	32.5
117	early sowing date 1 2015	6.8	32.25
118	early sowing date 1 2015	9.5	29.5
119	early sowing date 1 2015	14.3	28.75
120	early sowing date 1 2015	14.15	27
1	early sowing date 2 2015	18.35	25
2	early sowing date 2 2015	5.62	33.5
3	early sowing date 2 2015	17.25	24
4	early sowing date 2 2015	6.2	34.5
5	early sowing date 2 2015	13.55	25.5
6	early sowing date 2 2015	10.85	33.5
7	early sowing date 2 2015	12.75	28.5
8	early sowing date 2 2015	18.67	23.5
9	early sowing date 2 2015	18.95	22.5
10	early sowing date 2 2015	18.25	22.5
11	early sowing date 2 2015	9.35	28
12	early sowing date 2 2015	7.22	29
13	early sowing date 2 2015	8.95	30
14	early sowing date 2 2015	7.45	32
15	early sowing date 2 2015	9.72	35

ENTRY	Environment	Screenings%	TKW
16	early sowing date 2 2015	4.27	26.5
17	early sowing date 2 2015	6.5	31.5
18	early sowing date 2 2015	6.07	33.5
19	early sowing date 2 2015	31.02	20
20	early sowing date 2 2015	11.4	29.5
21	early sowing date 2 2015	10.92	31
22	early sowing date 2 2015	7.42	29.5
24	early sowing date 2 2015	6.65	31
25	early sowing date 2 2015	2.3	34.5
26	early sowing date 2 2015	9.17	34
27	early sowing date 2 2015	3.72	32
28	early sowing date 2 2015	4.4	29
29	early sowing date 2 2015	10.55	27
30	early sowing date 2 2015	10.47	31
31	early sowing date 2 2015	6.02	28.5
32	early sowing date 2 2015	14.88	28.5
33	early sowing date 2 2015	11.77	30.5
34	early sowing date 2 2015	10.6	26.5
35	early sowing date 2 2015	7.15	27
37	early sowing date 2 2015	12.3	24.5
38	early sowing date 2 2015	7.75	31
39	early sowing date 2 2015	7.27	35.5
40	early sowing date 2 2015	5.12	35

ENTRY	Environment	Screenings%	TKW
42	early sowing date 2 2015	10.05	24
43	early sowing date 2 2015	9.27	36
44	early sowing date 2 2015	4.27	33
45	early sowing date 2 2015	5.4	29.5
46	early sowing date 2 2015	19.17	24
47	early sowing date 2 2015	17.92	26
48	early sowing date 2 2015	10.25	29.5
50	early sowing date 2 2015	15.47	26.5
51	early sowing date 2 2015	7.52	29.5
52	early sowing date 2 2015	7.05	21
53	early sowing date 2 2015	12.6	31
54	early sowing date 2 2015	11.77	29
55	early sowing date 2 2015	10.3	27
56	early sowing date 2 2015	3.4	26
57	early sowing date 2 2015	22.85	23.5
58	early sowing date 2 2015	6.15	27
59	early sowing date 2 2015	5.35	30
60	early sowing date 2 2015	5.97	34
61	early sowing date 2 2015	8.85	28
62	early sowing date 2 2015	4.8	33.5
63	early sowing date 2 2015	5.3	33
64	early sowing date 2 2015	11.57	30
65	early sowing date 2 2015	10.2	28.5

ENTRY	Environment	Screenings%	TKW
66	early sowing date 2 2015	10.7	31
67	early sowing date 2 2015	9.02	30
68	early sowing date 2 2015	10.15	25
69	early sowing date 2 2015	13.6	26
70	early sowing date 2 2015	7.67	31
71	early sowing date 2 2015	8.87	29.5
72	early sowing date 2 2015	8.95	26
73	early sowing date 2 2015	12.45	33
74	early sowing date 2 2015	14.65	30
75	early sowing date 2 2015	9.67	25.5
76	early sowing date 2 2015	6.75	28
77	early sowing date 2 2015	5.1	33
78	early sowing date 2 2015	16.35	24.5
80	early sowing date 2 2015	6.87	31
81	early sowing date 2 2015	10	29.5
82	early sowing date 2 2015	13.85	26
83	early sowing date 2 2015	9.52	28.5
85	early sowing date 2 2015	9.6	28.5
86	early sowing date 2 2015	8.47	30
87	early sowing date 2 2015	9.42	30
88	early sowing date 2 2015	9.3	33
89	early sowing date 2 2015	7.15	28.5
90	early sowing date 2 2015	14.5	31

ENTRY	Environment	Screenings%	TKW
91	early sowing date 2 2015	15.25	33
92	early sowing date 2 2015	4.85	32
93	early sowing date 2 2015	9.98	33.5
94	early sowing date 2 2015	6.3	26
95	early sowing date 2 2015	9.6	27.5
96	early sowing date 2 2015	14.02	23.5
97	early sowing date 2 2015	7.77	29
98	early sowing date 2 2015	23.7	19.5
99	early sowing date 2 2015	4.75	31.5
100	early sowing date 2 2015	16.73	26.5
101	early sowing date 2 2015	3.65	30
102	early sowing date 2 2015	10.98	27
103	early sowing date 2 2015	7.12	29
104	early sowing date 2 2015	16.37	24.5
105	early sowing date 2 2015	25.3	24
106	early sowing date 2 2015	4.5	30
107	early sowing date 2 2015	11.1	25
108	early sowing date 2 2015	20.35	23.5
109	early sowing date 2 2015	22.75	24.5
110	early sowing date 2 2015	19.02	26.5
111	early sowing date 2 2015	15.1	23.5
112	early sowing date 2 2015	14.27	24
113	early sowing date 2 2015	14.9	27.5

ENTRY	Environment	Screenings%	TKW
114	early sowing date 2 2015	15.32	24.5
115	early sowing date 2 2015	15.32	27
116	early sowing date 2 2015	10.9	27.5
117	early sowing date 2 2015	7.75	25.5
118	early sowing date 2 2015	11.45	26
119	early sowing date 2 2015	20.6	25
120	early sowing date 2 2015	20.22	27
1	late sowing date 1 2015	9.5	33
2	late sowing date 1 2015	11.52	27.5
3	late sowing date 1 2015	13.05	25
4	late sowing date 1 2015	19.4	28
5	late sowing date 1 2015	18.65	26.5
6	late sowing date 1 2015	11.45	29
7	late sowing date 1 2015	14.77	32.5
8	late sowing date 1 2015	18.63	26.5
9	late sowing date 1 2015	8.05	25
10	late sowing date 1 2015	23.15	23
11	late sowing date 1 2015	6.68	29
12	late sowing date 1 2015	9.75	26
13	late sowing date 1 2015	9.18	28
14	late sowing date 1 2015	11.75	31
15	late sowing date 1 2015	11.83	25
16	late sowing date 1 2015	5.78	26

ENTRY	Environment	Screenings%	TKW
17	late sowing date 1 2015	12.2	29.5
18	late sowing date 1 2015	14.5	34.5
19	late sowing date 1 2015	21.7	22.5
20	late sowing date 1 2015	11.15	25.5
21	late sowing date 1 2015	18.47	26.5
22	late sowing date 1 2015	16.68	29.5
24	late sowing date 1 2015	10.7	30.5
25	late sowing date 1 2015	7.73	34.5
26	late sowing date 1 2015	8.18	33.5
27	late sowing date 1 2015	6.03	29
28	late sowing date 1 2015	7.1	33.5
29	late sowing date 1 2015	6.45	27.5
30	late sowing date 1 2015	13.1	22.5
31	late sowing date 1 2015	10.7	29
32	late sowing date 1 2015	14.72	27
33	late sowing date 1 2015	13.92	30.5
34	late sowing date 1 2015	13.2	25.5
35	late sowing date 1 2015	13.67	26
37	late sowing date 1 2015	10	29.5
38	late sowing date 1 2015	10.05	35.5
39	late sowing date 1 2015	7.37	29
40	late sowing date 1 2015	10.15	33
42	late sowing date 1 2015	13.8	26

ENTRY	Environment	Screenings%	TKW
43	late sowing date 1 2015	8.47	33.5
44	late sowing date 1 2015	11.9	32
45	late sowing date 1 2015	16.5	26.5
46	late sowing date 1 2015	20.78	26.5
47	late sowing date 1 2015	15.57	30.5
48	late sowing date 1 2015	15.22	29.5
50	late sowing date 1 2015	14.8	24.5
51	late sowing date 1 2015	7.13	30
52	late sowing date 1 2015	7.73	26
53	late sowing date 1 2015	7.9	28
54	late sowing date 1 2015	9.53	26
55	late sowing date 1 2015	17.17	25
56	late sowing date 1 2015	11.4	26
57	late sowing date 1 2015	24.87	23.5
58	late sowing date 1 2015	11.32	32
59	late sowing date 1 2015	6.08	25.5
60	late sowing date 1 2015	9.62	28
61	late sowing date 1 2015	7.38	32.5
62	late sowing date 1 2015	7.28	31.5
63	late sowing date 1 2015	8.38	29
64	late sowing date 1 2015	13.65	27.5
65	late sowing date 1 2015	5.55	27.5
66	late sowing date 1 2015	12.47	28.5

ENTRY	Environment	Screenings%	TKW
67	late sowing date 1 2015	14.18	32
68	late sowing date 1 2015	17.07	31.5
69	late sowing date 1 2015	15.4	26.5
70	late sowing date 1 2015	5.5	32
71	late sowing date 1 2015	13.77	22
72	late sowing date 1 2015	16.8	29.5
73	late sowing date 1 2015	7.83	24.5
74	late sowing date 1 2015	14.8	31
75	late sowing date 1 2015	9.5	34
76	late sowing date 1 2015	5.62	28.5
77	late sowing date 1 2015	10.85	31.5
78	late sowing date 1 2015	11.28	34
80	late sowing date 1 2015	5.88	32.5
81	late sowing date 1 2015	10.72	24.5
82	late sowing date 1 2015	16.82	27
83	late sowing date 1 2015	10.98	27.5
85	late sowing date 1 2015	9.73	24
86	late sowing date 1 2015	11.17	27.5
87	late sowing date 1 2015	6.58	31
88	late sowing date 1 2015	14.5	27.5
89	late sowing date 1 2015	13.18	25.5
90	late sowing date 1 2015	8.45	31
91	late sowing date 1 2015	12.45	30

ENTRY	Environment	Screenings%	TKW
92	late sowing date 1 2015	9.22	32
93	late sowing date 1 2015	6.98	28.5
94	late sowing date 1 2015	9.45	27.5
95	late sowing date 1 2015	8.78	31
96	late sowing date 1 2015	18.4	25.5
97	late sowing date 1 2015	11.45	24
98	late sowing date 1 2015	13.65	28
99	late sowing date 1 2015	6.63	32
100	late sowing date 1 2015	16.58	26
101	late sowing date 1 2015	12	29.5
102	late sowing date 1 2015	11.78	32
103	late sowing date 1 2015	10.85	28
104	late sowing date 1 2015	15.52	23
105	late sowing date 1 2015	18.9	22.5
106	late sowing date 1 2015	10.27	28
107	late sowing date 1 2015	9.2	28
108	late sowing date 1 2015	21.65	26
109	late sowing date 1 2015	13.4	23
110	late sowing date 1 2015	20.68	29
111	late sowing date 1 2015	20.53	25
112	late sowing date 1 2015	21.62	29.5
113	late sowing date 1 2015	6.93	27.5
114	late sowing date 1 2015	23.6	25.5

ENTRY	Environment	Screenings%	TKW
115	late sowing date 1 2015	15.55	21
116	late sowing date 1 2015	15.4	31
117	late sowing date 1 2015	19.92	28
118	late sowing date 1 2015	16.92	29.5
119	late sowing date 1 2015	23.55	30
120	late sowing date 1 2015	29.5	22.5
1	late sowing date 2 2015	5.38	34
2	late sowing date 2 2015	12.23	31.5
3	late sowing date 2 2015	19.62	22
4	late sowing date 2 2015	15.68	27
5	late sowing date 2 2015	10.53	33
6	late sowing date 2 2015	12.17	27.5
7	late sowing date 2 2015	15.52	34.5
8	late sowing date 2 2015	10.4	25.5
9	late sowing date 2 2015	9.7	30.5
10	late sowing date 2 2015	12.75	33
11	late sowing date 2 2015	7.28	31
12	late sowing date 2 2015	7.15	31
13	late sowing date 2 2015	11.32	30
14	late sowing date 2 2015	29.08	24.5
15	late sowing date 2 2015	15.35	23.5
16	late sowing date 2 2015	5.78	32
17	late sowing date 2 2015	6.35	35

ENTRY	Environment	Screenings%	TKW
18	late sowing date 2 2015	12.88	24
19	late sowing date 2 2015	8.1	31
20	late sowing date 2 2015	10.5	31.5
21	late sowing date 2 2015	11.9	33.5
22	late sowing date 2 2015	8.6	32
24	late sowing date 2 2015	4.58	31.5
25	late sowing date 2 2015	14.08	20.5
26	late sowing date 2 2015	18.15	27
27	late sowing date 2 2015	8.7	32.5
28	late sowing date 2 2015	14.93	32
29	late sowing date 2 2015	8.68	24
30	late sowing date 2 2015	16.82	25.5
31	late sowing date 2 2015	9.25	35
32	late sowing date 2 2015	12.7	26.5
33	late sowing date 2 2015	15.85	23
34	late sowing date 2 2015	13	26
35	late sowing date 2 2015	8.53	32
37	late sowing date 2 2015	11.2	31.5
38	late sowing date 2 2015	6.58	28
39	late sowing date 2 2015	12.9	29.5
40	late sowing date 2 2015	12.5	31
42	late sowing date 2 2015	9.82	33.5
43	late sowing date 2 2015	10.7	34.5

ENTRY	Environment	Screenings%	TKW
44	late sowing date 2 2015	10.75	23.5
45	late sowing date 2 2015	10.4	27
46	late sowing date 2 2015	16.93	31
47	late sowing date 2 2015	12.98	27
48	late sowing date 2 2015	8.48	30
50	late sowing date 2 2015	10	27
51	late sowing date 2 2015	3.35	32.5
52	late sowing date 2 2015	12.75	23.5
53	late sowing date 2 2015	20.23	25.5
54	late sowing date 2 2015	8.55	31.5
55	late sowing date 2 2015	9.85	35.5
56	late sowing date 2 2015	12.62	24
57	late sowing date 2 2015	18.28	27
58	late sowing date 2 2015	16.32	34.5
59	late sowing date 2 2015	17.33	18
60	late sowing date 2 2015	10.38	34.5
61	late sowing date 2 2015	18.38	26
62	late sowing date 2 2015	16.4	30.5
63	late sowing date 2 2015	9.85	35
64	late sowing date 2 2015	9.62	26
65	late sowing date 2 2015	13.8	31.5
66	late sowing date 2 2015	14.95	29.5
67	late sowing date 2 2015	14.15	26.5

ENTRY	Environment	Screenings%	TKW
68	late sowing date 2 2015	17.9	31
69	late sowing date 2 2015	15.38	30
70	late sowing date 2 2015	19.08	30.5
71	late sowing date 2 2015	8.3	32
72	late sowing date 2 2015	15.23	32
73	late sowing date 2 2015	10.6	27.5
74	late sowing date 2 2015	11.43	32.5
75	late sowing date 2 2015	9.5	26
76	late sowing date 2 2015	9.55	33.5
77	late sowing date 2 2015	13.73	27.5
78	late sowing date 2 2015	20.43	34
80	late sowing date 2 2015	9.48	35.5
81	late sowing date 2 2015	10.93	28
82	late sowing date 2 2015	12.23	32
83	late sowing date 2 2015	10.05	34
85	late sowing date 2 2015	14.03	33
86	late sowing date 2 2015	9.73	28
87	late sowing date 2 2015	11.33	24
88	late sowing date 2 2015	10.23	28
89	late sowing date 2 2015	19.78	32.5
90	late sowing date 2 2015	9.23	34
91	late sowing date 2 2015	15.33	24
92	late sowing date 2 2015	6.78	32.5

ENTRY	Environment	Screenings%	TKW
93	late sowing date 2 2015	15.6	34
94	late sowing date 2 2015	9.23	28
95	late sowing date 2 2015	18.45	30
96	late sowing date 2 2015	19.2	21.5
97	late sowing date 2 2015	19	26
98	late sowing date 2 2015	12.85	29.5
99	late sowing date 2 2015	15.2	28
100	late sowing date 2 2015	8.08	30
101	late sowing date 2 2015	13.68	34
102	late sowing date 2 2015	15.3	33
103	late sowing date 2 2015	15.7	25.5
104	late sowing date 2 2015	8.2	28.5
105	late sowing date 2 2015	17.33	28
106	late sowing date 2 2015	21.55	25
107	late sowing date 2 2015	12.38	31.5
108	late sowing date 2 2015	18.23	34
109	late sowing date 2 2015	11.83	34.5
110	late sowing date 2 2015	15.43	35.5
111	late sowing date 2 2015	13.43	23
112	late sowing date 2 2015	15	27.5
113	late sowing date 2 2015	10.05	28
114	late sowing date 2 2015	11.58	27.5
115	late sowing date 2 2015	11.53	31.5

ENTRY	Environment	Screenings%	TKW
116	late sowing date 2 2015	19.72	23.5
117	late sowing date 2 2015	18.93	28
118	late sowing date 2 2015	17.45	23.5
119	late sowing date 2 2015	15.18	28
120	late sowing date 2 2015	14.95	23.5

Table 6: Durum predicted means for NDVI and CT at heading for early sowing 2014, late sowing 2014, early sowing date 1 2015, early sowing date 2 2015 and late sowing date 2 for NDVI

Entry	Environment	NDVI heading	Entry	Environment	CT heading
1	early sowing 2014	0.7309	1	early sowing 2014	19.35
2	early sowing 2014	0.7092	2	early sowing 2014	18.98
3	early sowing 2014	0.7452	3	early sowing 2014	18.43
4	early sowing 2014	0.7473	4	early sowing 2014	20.05
5	early sowing 2014	0.7187	5	early sowing 2014	19.63

Entry	Environment	NDVI heading	Entry	Environment	CT heading
6	early sowing 2014	0.758	6	early sowing 2014	20.38
7	early sowing 2014	0.7549	7	early sowing 2014	20.2
8	early sowing 2014	0.7255	8	early sowing 2014	18.75
9	early sowing 2014	0.722	9	early sowing 2014	21.13
10	early sowing 2014	0.7395	10	early sowing 2014	20.23
11	early sowing 2014	0.7297	11	early sowing 2014	20.27
12	early sowing 2014	0.7142	12	early sowing 2014	20.55
13	early sowing 2014	0.7153	13	early sowing 2014	19.38
14	early sowing 2014	0.7163	14	early sowing 2014	19.27
15	early sowing 2014	0.7092	15	early sowing 2014	20.02
16	early sowing 2014	0.7431	16	early sowing 2014	19.35
17	early sowing 2014	0.7294	17	early sowing 2014	19.22
18	early sowing 2014	0.7463	18	early sowing 2014	18.8
19	early sowing 2014	0.7633	19	early sowing 2014	20.1

Entry	Environment	NDVI heading	Entry	Environment	CT heading
20	early sowing 2014	0.7517	20	early sowing 2014	19.77
21	early sowing 2014	0.7276	21	early sowing 2014	19.78
22	early sowing 2014	0.6805	22	early sowing 2014	19.23
23	early sowing 2014	0.7508	23	early sowing 2014	20.23
24	early sowing 2014	0.7352	24	early sowing 2014	19.85
25	early sowing 2014	0.7183	25	early sowing 2014	19.38
26	early sowing 2014	0.7237	26	early sowing 2014	19.9
27	early sowing 2014	0.7212	27	early sowing 2014	18.82
28	early sowing 2014	0.7092	28	early sowing 2014	17.25
29	early sowing 2014	0.7549	29	early sowing 2014	21.9
30	early sowing 2014	0.7746	30	early sowing 2014	21.55
31	early sowing 2014	0.8001	31	early sowing 2014	20.85
32	early sowing 2014	0.7717	32	early sowing 2014	20.55
33	early sowing 2014	0.6994	33	early sowing 2014	19.2

Entry	Environment	NDVI heading	Entry	Environment	CT heading
34	early sowing 2014	0.7649	34	early sowing 2014	19.88
35	early sowing 2014	0.7591	35	early sowing 2014	19.48
36	early sowing 2014	0.7438	36	early sowing 2014	20.42
37	early sowing 2014	0.7646	37	early sowing 2014	19.48
38	early sowing 2014	0.7206	38	early sowing 2014	19.18
39	early sowing 2014	0.7152	39	early sowing 2014	19.35
40	early sowing 2014	0.7452	40	early sowing 2014	19.23
41	early sowing 2014	0.7362	41	early sowing 2014	18.67
42	early sowing 2014	0.7352	42	early sowing 2014	20.53
43	early sowing 2014	0.7571	43	early sowing 2014	19.45
44	early sowing 2014	0.7113	44	early sowing 2014	18.97
45	early sowing 2014	0.7339	45	early sowing 2014	19.43
46	early sowing 2014	0.7791	46	early sowing 2014	20.62
47	early sowing 2014	0.7402	47	early sowing 2014	19.35

Entry	Environment	NDVI heading	Entry	Environment	CT heading
48	early sowing 2014	0.8023	48	early sowing 2014	20.72
49	early sowing 2014	0.6904	49	early sowing 2014	18.95
50	early sowing 2014	0.6808	50	early sowing 2014	18.95
51	early sowing 2014	0.745	51	early sowing 2014	18.9
52	early sowing 2014	0.7199	52	early sowing 2014	20.37
53	early sowing 2014	0.6971	53	early sowing 2014	19.68
54	early sowing 2014	0.6849	54	early sowing 2014	21.35
55	early sowing 2014	0.7318	55	early sowing 2014	21.07
56	early sowing 2014	0.718	56	early sowing 2014	20.3
57	early sowing 2014	0.7719	57	early sowing 2014	21.32
58	early sowing 2014	0.7458	58	early sowing 2014	20.52
59	early sowing 2014	0.7205	59	early sowing 2014	18.8
60	early sowing 2014	0.7664	60	early sowing 2014	21.12
61	early sowing 2014	0.7692	61	early sowing 2014	19.8

Entry	Environment	NDVI heading	Entry	Environment	CT heading
62	early sowing 2014	0.7748	62	early sowing 2014	21.13
63	early sowing 2014	0.7326	63	early sowing 2014	20.02
64	early sowing 2014	0.773	64	early sowing 2014	20.45
65	early sowing 2014	0.7669	65	early sowing 2014	20.55
66	early sowing 2014	0.7464	66	early sowing 2014	20.9
67	early sowing 2014	0.7583	67	early sowing 2014	20.83
68	early sowing 2014	0.7374	68	early sowing 2014	20.88
69	early sowing 2014	0.7437	69	early sowing 2014	20.33
70	early sowing 2014	0.7403	70	early sowing 2014	19.57
71	early sowing 2014	0.7549	71	early sowing 2014	21.72
72	early sowing 2014	0.7502	72	early sowing 2014	20.67
73	early sowing 2014	0.7519	73	early sowing 2014	20.25
74	early sowing 2014	0.7178	74	early sowing 2014	20.63
75	early sowing 2014	0.7834	75	early sowing 2014	19.82

Entry	Environment	NDVI heading	Entry	Environment	CT heading
76	early sowing 2014	0.7649	76	early sowing 2014	21.57
77	early sowing 2014	0.7275	77	early sowing 2014	21.02
78	early sowing 2014	0.714	78	early sowing 2014	20.4
79	early sowing 2014	0.7289	79	early sowing 2014	20.27
80	early sowing 2014	0.7559	80	early sowing 2014	19.77
81	early sowing 2014	0.7436	81	early sowing 2014	20.78
82	early sowing 2014	0.7661	82	early sowing 2014	20.02
83	early sowing 2014	0.7673	83	early sowing 2014	19.83
84	early sowing 2014	0.7762	84	early sowing 2014	19.83
85	early sowing 2014	0.7643	85	early sowing 2014	19.33
86	early sowing 2014	0.763	86	early sowing 2014	19.87
87	early sowing 2014	0.764	87	early sowing 2014	20.32
88	early sowing 2014	0.7386	88	early sowing 2014	18.75
89	early sowing 2014	0.7896	89	early sowing 2014	19.83

Entry	Environment	NDVI heading	Entry	Environment	CT heading
90	early sowing 2014	0.7692	90	early sowing 2014	19.58
91	early sowing 2014	0.7565	91	early sowing 2014	20.83
92	early sowing 2014	0.7536	92	early sowing 2014	20.83
93	early sowing 2014	0.7104	93	early sowing 2014	21.3
94	early sowing 2014	0.7642	94	early sowing 2014	20.43
95	early sowing 2014	0.7613	95	early sowing 2014	21.18
96	early sowing 2014	0.7797	96	early sowing 2014	20.47
97	early sowing 2014	0.7479	97	early sowing 2014	19.37
98	early sowing 2014	0.7481	98	early sowing 2014	21.47
99	early sowing 2014	0.7698	99	early sowing 2014	18.85
100	early sowing 2014	0.7669	100	early sowing 2014	19.15
101	early sowing 2014	0.7704	101	early sowing 2014	20.12
102	early sowing 2014	0.7332	102	early sowing 2014	20.75
103	early sowing 2014	0.7422	103	early sowing 2014	21.15

Entry	Environment	NDVI heading	Entry	Environment	CT heading
104	early sowing 2014	0.7881	104	early sowing 2014	20.6
105	early sowing 2014	0.7423	105	early sowing 2014	20.52
106	early sowing 2014	0.7446	106	early sowing 2014	21.55
107	early sowing 2014	0.7614	107	early sowing 2014	20.22
108	early sowing 2014	0.7768	108	early sowing 2014	20.5
109	early sowing 2014	0.7753	109	early sowing 2014	21.3
110	early sowing 2014	0.7486	110	early sowing 2014	20.97
111	early sowing 2014	0.7425	111	early sowing 2014	21.02
112	early sowing 2014	0.7546	112	early sowing 2014	20.88
113	early sowing 2014	0.7624	113	early sowing 2014	20.47
114	early sowing 2014	0.7382	114	early sowing 2014	20.18
115	early sowing 2014	0.7784	115	early sowing 2014	21.93
116	early sowing 2014	0.7526	116	early sowing 2014	19.98
117	early sowing 2014	0.7211	117	early sowing 2014	20.3

Entry	Environment	NDVI heading	Entry	Environment	CT heading
118	early sowing 2014	0.7547	118	early sowing 2014	20.28
119	early sowing 2014	0.7819	119	early sowing 2014	21.75
120	early sowing 2014	0.7623	120	early sowing 2014	19.82
1	late sowing 2014	0.5664	1	late sowing 2014	24.43
2	late sowing 2014	0.5141	2	late sowing 2014	26.57
3	late sowing 2014	0.5731	3	late sowing 2014	25.93
4	late sowing 2014	0.6701	4	late sowing 2014	28.88
5	late sowing 2014	0.5946	5	late sowing 2014	26.82
6	late sowing 2014	0.6598	6	late sowing 2014	27.13
7	late sowing 2014	0.6115	7	late sowing 2014	26.55
8	late sowing 2014	0.5983	8	late sowing 2014	26.2
9	late sowing 2014	0.5803	9	late sowing 2014	25.75
10	late sowing 2014	0.6565	10	late sowing 2014	25.47
11	late sowing 2014	0.6186	11	late sowing 2014	26.68

Entry	Environment	NDVI heading	Entry	Environment	CT heading
12	late sowing 2014	0.5427	12	late sowing 2014	28.17
13	late sowing 2014	0.5677	13	late sowing 2014	25.47
14	late sowing 2014	0.6193	14	late sowing 2014	25.37
15	late sowing 2014	0.5772	15	late sowing 2014	25.18
16	late sowing 2014	0.6353	16	late sowing 2014	26.3
17	late sowing 2014	0.6114	17	late sowing 2014	25.67
18	late sowing 2014	0.6064	18	late sowing 2014	27.7
19	late sowing 2014	0.6229	19	late sowing 2014	28.43
20	late sowing 2014	0.6589	20	late sowing 2014	25.55
21	late sowing 2014	0.6133	21	late sowing 2014	24.88
22	late sowing 2014	0.5543	22	late sowing 2014	26.67
23	late sowing 2014	0.5831	23	late sowing 2014	24.37
24	late sowing 2014	0.6209	24	late sowing 2014	25.93
25	late sowing 2014	0.6112	25	late sowing 2014	26.83

Entry	Environment	NDVI heading	Entry	Environment	CT heading
26	late sowing 2014	0.5794	26	late sowing 2014	27.77
27	late sowing 2014	0.549	27	late sowing 2014	26.98
28	late sowing 2014	0.5209	28	late sowing 2014	25.82
29	late sowing 2014	0.6205	29	late sowing 2014	27.27
30	late sowing 2014	0.6325	30	late sowing 2014	27.47
31	late sowing 2014	0.5926	31	late sowing 2014	28.23
32	late sowing 2014	0.6086	32	late sowing 2014	27.17
33	late sowing 2014	0.5065	33	late sowing 2014	26.6
34	late sowing 2014	0.6729	34	late sowing 2014	27.37
35	late sowing 2014	0.5548	35	late sowing 2014	25.28
36	late sowing 2014	0.5595	36	late sowing 2014	25.83
37	late sowing 2014	0.5949	37	late sowing 2014	27.17
38	late sowing 2014	0.5975	38	late sowing 2014	27
39	late sowing 2014	0.5706	39	late sowing 2014	27.33

Entry	Environment	NDVI heading	Entry	Environment	CT heading
40	late sowing 2014	0.5608	40	late sowing 2014	26.45
41	late sowing 2014	0.5341	41	late sowing 2014	26.63
42	late sowing 2014	0.6435	42	late sowing 2014	27.67
43	late sowing 2014	0.5821	43	late sowing 2014	27.12
44	late sowing 2014	0.5484	44	late sowing 2014	24.35
45	late sowing 2014	0.6178	45	late sowing 2014	26.17
46	late sowing 2014	0.6723	46	late sowing 2014	26.45
47	late sowing 2014	0.5512	47	late sowing 2014	26.15
48	late sowing 2014	0.6535	48	late sowing 2014	26.03
49	late sowing 2014	0.4585	49	late sowing 2014	27.12
50	late sowing 2014	0.539	50	late sowing 2014	26.6
51	late sowing 2014	0.6096	51	late sowing 2014	25.75
52	late sowing 2014	0.6372	52	late sowing 2014	26.8
53	late sowing 2014	0.5484	53	late sowing 2014	27.55

Entry	Environment	NDVI heading	Entry	Environment	CT heading
54	late sowing 2014	0.5406	54	late sowing 2014	28.65
55	late sowing 2014	0.5645	55	late sowing 2014	25.37
56	late sowing 2014	0.6113	56	late sowing 2014	25.28
57	late sowing 2014	0.6451	57	late sowing 2014	26.67
58	late sowing 2014	0.6039	58	late sowing 2014	24.53
59	late sowing 2014	0.5899	59	late sowing 2014	25.97
60	late sowing 2014	0.623	60	late sowing 2014	25.45
61	late sowing 2014	0.5882	61	late sowing 2014	25.52
62	late sowing 2014	0.6307	62	late sowing 2014	26.5
63	late sowing 2014	0.6301	63	late sowing 2014	26.98
64	late sowing 2014	0.6164	64	late sowing 2014	25.98
65	late sowing 2014	0.6221	65	late sowing 2014	26.42
66	late sowing 2014	0.5797	66	late sowing 2014	28.52
67	late sowing 2014	0.6284	67	late sowing 2014	25.82

Entry	Environment	NDVI heading	Entry	Environment	CT heading
68	late sowing 2014	0.6412	68	late sowing 2014	27.27
69	late sowing 2014	0.6087	69	late sowing 2014	27.75
70	late sowing 2014	0.6246	70	late sowing 2014	27.2
71	late sowing 2014	0.6478	71	late sowing 2014	27.23
72	late sowing 2014	0.6236	72	late sowing 2014	26.35
73	late sowing 2014	0.6314	73	late sowing 2014	25.5
74	late sowing 2014	0.6433	74	late sowing 2014	26.52
75	late sowing 2014	0.6415	75	late sowing 2014	26.67
76	late sowing 2014	0.5924	76	late sowing 2014	26.03
77	late sowing 2014	0.5994	77	late sowing 2014	26.35
78	late sowing 2014	0.6116	78	late sowing 2014	26.35
79	late sowing 2014	0.5908	79	late sowing 2014	26.78
80	late sowing 2014	0.617	80	late sowing 2014	24.97
81	late sowing 2014	0.6063	81	late sowing 2014	27.3

Entry	Environment	NDVI heading	Entry	Environment	CT heading
82	late sowing 2014	0.6145	82	late sowing 2014	25.67
83	late sowing 2014	0.5938	83	late sowing 2014	27.07
84	late sowing 2014	0.598	84	late sowing 2014	27.2
85	late sowing 2014	0.6259	85	late sowing 2014	27
86	late sowing 2014	0.655	86	late sowing 2014	25.07
87	late sowing 2014	0.6097	87	late sowing 2014	26.6
88	late sowing 2014	0.6435	88	late sowing 2014	26.1
89	late sowing 2014	0.6209	89	late sowing 2014	27.92
90	late sowing 2014	0.6051	90	late sowing 2014	26.9
91	late sowing 2014	0.648	91	late sowing 2014	27.18
92	late sowing 2014	0.621	92	late sowing 2014	24.85
93	late sowing 2014	0.617	93	late sowing 2014	25.22
94	late sowing 2014	0.6179	94	late sowing 2014	26.27
95	late sowing 2014	0.6034	95	late sowing 2014	26.72

Entry	Environment	NDVI heading	Entry	Environment	CT heading
96	late sowing 2014	0.5876	96	late sowing 2014	25.9
97	late sowing 2014	0.5904	97	late sowing 2014	27.6
98	late sowing 2014	0.6554	98	late sowing 2014	25.55
99	late sowing 2014	0.5936	99	late sowing 2014	26.88
100	late sowing 2014	0.648	100	late sowing 2014	28.42
101	late sowing 2014	0.608	101	late sowing 2014	26.58
102	late sowing 2014	0.6543	102	late sowing 2014	26.98
103	late sowing 2014	0.6087	103	late sowing 2014	26.02
104	late sowing 2014	0.6492	104	late sowing 2014	26.68
105	late sowing 2014	0.6302	105	late sowing 2014	27.77
106	late sowing 2014	0.6391	106	late sowing 2014	26.78
107	late sowing 2014	0.6158	107	late sowing 2014	25.98
108	late sowing 2014	0.6508	108	late sowing 2014	28.05
109	late sowing 2014	0.6284	109	late sowing 2014	26.88

Entry	Environment	NDVI heading	Entry	Environment	CT heading
110	late sowing 2014	0.655	110	late sowing 2014	27.23
111	late sowing 2014	0.6585	111	late sowing 2014	27.07
112	late sowing 2014	0.6487	112	late sowing 2014	27.18
113	late sowing 2014	0.6341	113	late sowing 2014	26.83
114	late sowing 2014	0.6548	114	late sowing 2014	28.38
115	late sowing 2014	0.6314	115	late sowing 2014	26.77
116	late sowing 2014	0.6055	116	late sowing 2014	27.85
117	late sowing 2014	0.6179	117	late sowing 2014	28.35
118	late sowing 2014	0.6693	118	late sowing 2014	25.67
119	late sowing 2014	0.6402	119	late sowing 2014	27.38
120	late sowing 2014	0.6442	120	late sowing 2014	27.42
1	early sowing date 1 2015	0.81	1	early sowing date 1 2015	13.1
2	early sowing date 1 2015	0.795	2	early sowing date 1 2015	13.87
3	early sowing date 1 2015	0.785	3	early sowing date 1 2015	12.4

Entry	Environment	NDVI heading	Entry	Environment	CT heading
4	early sowing date 1 2015	0.775	4	early sowing date 1 2015	10.57
5	early sowing date 1 2015	0.755	5	early sowing date 1 2015	12.67
6	early sowing date 1 2015	0.755	6	early sowing date 1 2015	12.2
7	early sowing date 1 2015	0.795	7	early sowing date 1 2015	14.47
8	early sowing date 1 2015	0.785	8	early sowing date 1 2015	11.85
9	early sowing date 1 2015	0.755	9	early sowing date 1 2015	11.6
10	early sowing date 1 2015	0.74	10	early sowing date 1 2015	11.02
11	early sowing date 1 2015	0.8	11	early sowing date 1 2015	13.28
12	early sowing date 1 2015	0.805	12	early sowing date 1 2015	11.83
13	early sowing date 1 2015	0.77	13	early sowing date 1 2015	14.58
14	early sowing date 1 2015	0.78	14	early sowing date 1 2015	12.7
15	early sowing date 1 2015	0.815	15	early sowing date 1 2015	12.52
16	early sowing date 1 2015	0.775	16	early sowing date 1 2015	14.45
17	early sowing date 1 2015	0.775	17	early sowing date 1 2015	11.78

Entry	Environment	NDVI heading	Entry	Environment	CT heading
18	early sowing date 1 2015	0.765	18	early sowing date 1 2015	13.38
19	early sowing date 1 2015	0.82	19	early sowing date 1 2015	12.43
20	early sowing date 1 2015	0.795	20	early sowing date 1 2015	12.48
21	early sowing date 1 2015	0.81	21	early sowing date 1 2015	11.38
22	early sowing date 1 2015	0.775	22	early sowing date 1 2015	12.18
23	early sowing date 1 2015	0.795	23	early sowing date 1 2015	13.38
24	early sowing date 1 2015	0.805	24	early sowing date 1 2015	11.67
25	early sowing date 1 2015	0.81	25	early sowing date 1 2015	12.55
26	early sowing date 1 2015	0.805	26	early sowing date 1 2015	12.17
27	early sowing date 1 2015	0.79	27	early sowing date 1 2015	12.77
28	early sowing date 1 2015	0.785	28	early sowing date 1 2015	13.03
29	early sowing date 1 2015	0.785	29	early sowing date 1 2015	13.88
30	early sowing date 1 2015	0.815	30	early sowing date 1 2015	13.03
31	early sowing date 1 2015	0.79	31	early sowing date 1 2015	12.47

Entry	Environment	NDVI heading	Entry	Environment	CT heading
32	early sowing date 1 2015	0.815	32	early sowing date 1 2015	11.07
33	early sowing date 1 2015	0.74	33	early sowing date 1 2015	12.75
34	early sowing date 1 2015	0.765	34	early sowing date 1 2015	11.9
35	early sowing date 1 2015	0.785	35	early sowing date 1 2015	12.53
36	early sowing date 1 2015	0.805	36	early sowing date 1 2015	12.2
37	early sowing date 1 2015	0.765	37	early sowing date 1 2015	13.93
38	early sowing date 1 2015	0.76	38	early sowing date 1 2015	12.07
39	early sowing date 1 2015	0.8	39	early sowing date 1 2015	12.75
40	early sowing date 1 2015	0.76	40	early sowing date 1 2015	12.8
41	early sowing date 1 2015	0.79	41	early sowing date 1 2015	13.13
42	early sowing date 1 2015	0.775	42	early sowing date 1 2015	13.07
43	early sowing date 1 2015	0.78	43	early sowing date 1 2015	12.75
44	early sowing date 1 2015	0.795	44	early sowing date 1 2015	13.27
45	early sowing date 1 2015	0.8	45	early sowing date 1 2015	12.12

Entry	Environment	NDVI heading	Entry	Environment	CT heading
46	early sowing date 1 2015	0.77	46	early sowing date 1 2015	12.25
47	early sowing date 1 2015	0.765	47	early sowing date 1 2015	12.68
48	early sowing date 1 2015	0.78	48	early sowing date 1 2015	11.33
49	early sowing date 1 2015	0.765	49	early sowing date 1 2015	13.68
50	early sowing date 1 2015	0.8	50	early sowing date 1 2015	13.33
51	early sowing date 1 2015	0.81	51	early sowing date 1 2015	12.85
52	early sowing date 1 2015	0.79	52	early sowing date 1 2015	14.28
53	early sowing date 1 2015	0.8	53	early sowing date 1 2015	13.57
54	early sowing date 1 2015	0.745	54	early sowing date 1 2015	14.45
55	early sowing date 1 2015	0.77	55	early sowing date 1 2015	13.17
56	early sowing date 1 2015	0.84	56	early sowing date 1 2015	12.53
57	early sowing date 1 2015	0.805	57	early sowing date 1 2015	13.1
58	early sowing date 1 2015	0.785	58	early sowing date 1 2015	13.03
59	early sowing date 1 2015	0.78	59	early sowing date 1 2015	12.27

Entry	Environment	NDVI heading	Entry	Environment	CT heading
60	early sowing date 1 2015	0.78	60	early sowing date 1 2015	14.4
61	early sowing date 1 2015	0.755	61	early sowing date 1 2015	12.27
62	early sowing date 1 2015	0.785	62	early sowing date 1 2015	13.47
63	early sowing date 1 2015	0.81	63	early sowing date 1 2015	10.98
64	early sowing date 1 2015	0.785	64	early sowing date 1 2015	13.05
65	early sowing date 1 2015	0.79	65	early sowing date 1 2015	13.3
66	early sowing date 1 2015	0.79	66	early sowing date 1 2015	13.57
67	early sowing date 1 2015	0.78	67	early sowing date 1 2015	12.18
68	early sowing date 1 2015	0.79	68	early sowing date 1 2015	13.37
69	early sowing date 1 2015	0.8	69	early sowing date 1 2015	11.67
70	early sowing date 1 2015	0.805	70	early sowing date 1 2015	13.4
71	early sowing date 1 2015	0.785	71	early sowing date 1 2015	13.07
72	early sowing date 1 2015	0.78	72	early sowing date 1 2015	13.93
73	early sowing date 1 2015	0.785	73	early sowing date 1 2015	12.6

Entry	Environment	NDVI heading	Entry	Environment	CT heading
74	early sowing date 1 2015	0.765	74	early sowing date 1 2015	12.87
75	early sowing date 1 2015	0.805	75	early sowing date 1 2015	13.52
76	early sowing date 1 2015	0.77	76	early sowing date 1 2015	13.02
77	early sowing date 1 2015	0.775	77	early sowing date 1 2015	13.8
78	early sowing date 1 2015	0.805	78	early sowing date 1 2015	12.22
79	early sowing date 1 2015	0.8	79	early sowing date 1 2015	13.65
80	early sowing date 1 2015	0.81	80	early sowing date 1 2015	14
81	early sowing date 1 2015	0.77	81	early sowing date 1 2015	13.38
82	early sowing date 1 2015	0.795	82	early sowing date 1 2015	12.48
83	early sowing date 1 2015	0.805	83	early sowing date 1 2015	14.65
84	early sowing date 1 2015	0.79	84	early sowing date 1 2015	12.87
85	early sowing date 1 2015	0.78	85	early sowing date 1 2015	12.4
86	early sowing date 1 2015	0.795	86	early sowing date 1 2015	13.73
87	early sowing date 1 2015	0.785	87	early sowing date 1 2015	14.12

Entry	Environment	NDVI heading	Entry	Environment	CT heading
88	early sowing date 1 2015	0.785	88	early sowing date 1 2015	12.83
89	early sowing date 1 2015	0.755	89	early sowing date 1 2015	13.3
90	early sowing date 1 2015	0.76	90	early sowing date 1 2015	11.42
91	early sowing date 1 2015	0.78	91	early sowing date 1 2015	14.63
92	early sowing date 1 2015	0.775	92	early sowing date 1 2015	14.15
93	early sowing date 1 2015	0.81	93	early sowing date 1 2015	12.67
94	early sowing date 1 2015	0.765	94	early sowing date 1 2015	12.85
95	early sowing date 1 2015	0.725	95	early sowing date 1 2015	13.22
96	early sowing date 1 2015	0.76	96	early sowing date 1 2015	13.15
97	early sowing date 1 2015	0.79	97	early sowing date 1 2015	11.93
98	early sowing date 1 2015	0.805	98	early sowing date 1 2015	12.12
99	early sowing date 1 2015	0.79	99	early sowing date 1 2015	13.42
100	early sowing date 1 2015	0.8	100	early sowing date 1 2015	13.22
101	early sowing date 1 2015	0.8	101	early sowing date 1 2015	11.32

Entry	Environment	NDVI heading	Entry	Environment	CT heading
102	early sowing date 1 2015	0.78	102	early sowing date 1 2015	10.77
103	early sowing date 1 2015	0.75	103	early sowing date 1 2015	12.08
104	early sowing date 1 2015	0.76	104	early sowing date 1 2015	12.85
105	early sowing date 1 2015	0.795	105	early sowing date 1 2015	12.98
106	early sowing date 1 2015	0.78	106	early sowing date 1 2015	11.82
107	early sowing date 1 2015	0.79	107	early sowing date 1 2015	11.93
108	early sowing date 1 2015	0.795	108	early sowing date 1 2015	12.93
109	early sowing date 1 2015	0.795	109	early sowing date 1 2015	11.1
110	early sowing date 1 2015	0.785	110	early sowing date 1 2015	14.3
111	early sowing date 1 2015	0.805	111	early sowing date 1 2015	12.93
112	early sowing date 1 2015	0.8	112	early sowing date 1 2015	12.47
113	early sowing date 1 2015	0.79	113	early sowing date 1 2015	12.57
114	early sowing date 1 2015	0.785	114	early sowing date 1 2015	12.02
115	early sowing date 1 2015	0.795	115	early sowing date 1 2015	13.02

Entry	Environment	NDVI heading	Entry	Environment	CT heading
116	early sowing date 1 2015	0.75	116	early sowing date 1 2015	11.63
117	early sowing date 1 2015	0.775	117	early sowing date 1 2015	12.67
118	early sowing date 1 2015	0.795	118	early sowing date 1 2015	12.08
119	early sowing date 1 2015	0.725	119	early sowing date 1 2015	11.57
120	early sowing date 1 2015	0.795	120	early sowing date 1 2015	13.1
1	early sowing date 2 2015	0.825	1	early sowing date 2 2015	13.5
2	early sowing date 2 2015	0.81	2	early sowing date 2 2015	14.4
3	early sowing date 2 2015	0.805	3	early sowing date 2 2015	14.77
4	early sowing date 2 2015	0.82	4	early sowing date 2 2015	16.5
5	early sowing date 2 2015	0.81	5	early sowing date 2 2015	14.33
6	early sowing date 2 2015	0.825	6	early sowing date 2 2015	14.98
7	early sowing date 2 2015	0.805	7	early sowing date 2 2015	15.28
8	early sowing date 2 2015	0.77	8	early sowing date 2 2015	14.65
9	early sowing date 2 2015	0.815	9	early sowing date 2 2015	14.13

Entry	Environment	NDVI heading	Entry	Environment	CT heading
10	early sowing date 2 2015	0.805	10	early sowing date 2 2015	15.65
11	early sowing date 2 2015	0.815	11	early sowing date 2 2015	14.62
12	early sowing date 2 2015	0.82	12	early sowing date 2 2015	14.33
13	early sowing date 2 2015	0.79	13	early sowing date 2 2015	16.07
14	early sowing date 2 2015	0.815	14	early sowing date 2 2015	14.27
15	early sowing date 2 2015	0.815	15	early sowing date 2 2015	14.5
16	early sowing date 2 2015	0.805	16	early sowing date 2 2015	14.88
17	early sowing date 2 2015	0.81	17	early sowing date 2 2015	15.55
18	early sowing date 2 2015	0.8	18	early sowing date 2 2015	14.9
19	early sowing date 2 2015	0.82	19	early sowing date 2 2015	14.7
20	early sowing date 2 2015	0.815	20	early sowing date 2 2015	15.68
21	early sowing date 2 2015	0.805	21	early sowing date 2 2015	14.65
22	early sowing date 2 2015	0.81	22	early sowing date 2 2015	14.53
23	early sowing date 2 2015	0.77	23	early sowing date 2 2015	14.77

Entry	Environment	NDVI heading	Entry	Environment	CT heading
24	early sowing date 2 2015	0.79	24	early sowing date 2 2015	15.58
25	early sowing date 2 2015	0.83	25	early sowing date 2 2015	15.1
26	early sowing date 2 2015	0.795	26	early sowing date 2 2015	15.38
27	early sowing date 2 2015	0.815	27	early sowing date 2 2015	15.18
28	early sowing date 2 2015	0.77	28	early sowing date 2 2015	14.17
29	early sowing date 2 2015	0.825	29	early sowing date 2 2015	15.37
30	early sowing date 2 2015	0.79	30	early sowing date 2 2015	15.42
31	early sowing date 2 2015	0.815	31	early sowing date 2 2015	14.82
32	early sowing date 2 2015	0.8	32	early sowing date 2 2015	14.27
33	early sowing date 2 2015	0.815	33	early sowing date 2 2015	13.73
34	early sowing date 2 2015	0.795	34	early sowing date 2 2015	14.68
35	early sowing date 2 2015	0.795	35	early sowing date 2 2015	15.57
36	early sowing date 2 2015	0.805	36	early sowing date 2 2015	15.02
37	early sowing date 2 2015	0.835	37	early sowing date 2 2015	15.73

Entry	Environment	NDVI heading	Entry	Environment	CT heading
38	early sowing date 2 2015	0.82	38	early sowing date 2 2015	14.57
39	early sowing date 2 2015	0.765	39	early sowing date 2 2015	15.88
40	early sowing date 2 2015	0.81	40	early sowing date 2 2015	15
41	early sowing date 2 2015	0.8	41	early sowing date 2 2015	14.88
42	early sowing date 2 2015	0.805	42	early sowing date 2 2015	15.88
43	early sowing date 2 2015	0.82	43	early sowing date 2 2015	14.63
44	early sowing date 2 2015	0.82	44	early sowing date 2 2015	14.13
45	early sowing date 2 2015	0.82	45	early sowing date 2 2015	16.12
46	early sowing date 2 2015	0.825	46	early sowing date 2 2015	14.32
47	early sowing date 2 2015	0.8	47	early sowing date 2 2015	15.17
48	early sowing date 2 2015	0.815	48	early sowing date 2 2015	16.73
49	early sowing date 2 2015	0.82	49	early sowing date 2 2015	15.5
50	early sowing date 2 2015	0.805	50	early sowing date 2 2015	15.75
51	early sowing date 2 2015	0.79	51	early sowing date 2 2015	15.27

Entry	Environment	NDVI heading	Entry	Environment	CT heading
52	early sowing date 2 2015	0.8	52	early sowing date 2 2015	14.05
53	early sowing date 2 2015	0.79	53	early sowing date 2 2015	14.83
54	early sowing date 2 2015	0.8	54	early sowing date 2 2015	13.78
55	early sowing date 2 2015	0.77	55	early sowing date 2 2015	13.52
56	early sowing date 2 2015	0.815	56	early sowing date 2 2015	16.15
57	early sowing date 2 2015	0.79	57	early sowing date 2 2015	14.42
58	early sowing date 2 2015	0.83	58	early sowing date 2 2015	13.77
59	early sowing date 2 2015	0.76	59	early sowing date 2 2015	14.92
60	early sowing date 2 2015	0.805	60	early sowing date 2 2015	13.88
61	early sowing date 2 2015	0.815	61	early sowing date 2 2015	14.67
62	early sowing date 2 2015	0.79	62	early sowing date 2 2015	15.33
63	early sowing date 2 2015	0.825	63	early sowing date 2 2015	14.68
64	early sowing date 2 2015	0.78	64	early sowing date 2 2015	15.1
65	early sowing date 2 2015	0.825	65	early sowing date 2 2015	14.83

Entry	Environment	NDVI heading	Entry	Environment	CT heading
66	early sowing date 2 2015	0.825	66	early sowing date 2 2015	16.22
67	early sowing date 2 2015	0.805	67	early sowing date 2 2015	16
68	early sowing date 2 2015	0.805	68	early sowing date 2 2015	14.28
69	early sowing date 2 2015	0.82	69	early sowing date 2 2015	14.08
70	early sowing date 2 2015	0.79	70	early sowing date 2 2015	14.15
71	early sowing date 2 2015	0.8	71	early sowing date 2 2015	15.45
72	early sowing date 2 2015	0.795	72	early sowing date 2 2015	15.43
73	early sowing date 2 2015	0.79	73	early sowing date 2 2015	14.22
74	early sowing date 2 2015	0.825	74	early sowing date 2 2015	13.85
75	early sowing date 2 2015	0.81	75	early sowing date 2 2015	14.73
76	early sowing date 2 2015	0.815	76	early sowing date 2 2015	16.25
77	early sowing date 2 2015	0.82	77	early sowing date 2 2015	14.87
78	early sowing date 2 2015	0.825	78	early sowing date 2 2015	15.03
79	early sowing date 2 2015	0.785	79	early sowing date 2 2015	14.48

Entry	Environment	NDVI heading	Entry	Environment	CT heading
80	early sowing date 2 2015	0.805	80	early sowing date 2 2015	15.72
81	early sowing date 2 2015	0.82	81	early sowing date 2 2015	14.08
82	early sowing date 2 2015	0.8	82	early sowing date 2 2015	15.5
83	early sowing date 2 2015	0.82	83	early sowing date 2 2015	13.98
84	early sowing date 2 2015	0.82	84	early sowing date 2 2015	15.57
85	early sowing date 2 2015	0.81	85	early sowing date 2 2015	14.98
86	early sowing date 2 2015	0.795	86	early sowing date 2 2015	15.68
87	early sowing date 2 2015	0.82	87	early sowing date 2 2015	14.58
88	early sowing date 2 2015	0.82	88	early sowing date 2 2015	15.97
89	early sowing date 2 2015	0.81	89	early sowing date 2 2015	14.28
90	early sowing date 2 2015	0.82	90	early sowing date 2 2015	14.62
91	early sowing date 2 2015	0.81	91	early sowing date 2 2015	15.23
92	early sowing date 2 2015	0.825	92	early sowing date 2 2015	15.1
93	early sowing date 2 2015	0.81	93	early sowing date 2 2015	14.72

Entry	Environment	NDVI heading	Entry	Environment	CT heading
94	early sowing date 2 2015	0.835	94	early sowing date 2 2015	13.93
95	early sowing date 2 2015	0.825	95	early sowing date 2 2015	15.85
96	early sowing date 2 2015	0.815	96	early sowing date 2 2015	15.67
97	early sowing date 2 2015	0.82	97	early sowing date 2 2015	15.35
98	early sowing date 2 2015	0.815	98	early sowing date 2 2015	14.65
99	early sowing date 2 2015	0.81	99	early sowing date 2 2015	16.32
100	early sowing date 2 2015	0.83	100	early sowing date 2 2015	14.03
101	early sowing date 2 2015	0.815	101	early sowing date 2 2015	14.85
102	early sowing date 2 2015	0.795	102	early sowing date 2 2015	15.28
103	early sowing date 2 2015	0.82	103	early sowing date 2 2015	14.65
104	early sowing date 2 2015	0.785	104	early sowing date 2 2015	17.32
105	early sowing date 2 2015	0.795	105	early sowing date 2 2015	14.22
106	early sowing date 2 2015	0.81	106	early sowing date 2 2015	16.37
107	early sowing date 2 2015	0.795	107	early sowing date 2 2015	17.08

Entry	Environment	NDVI heading	Entry	Environment	CT heading
108	early sowing date 2 2015	0.815	108	early sowing date 2 2015	14.8
109	early sowing date 2 2015	0.815	109	early sowing date 2 2015	17.97
110	early sowing date 2 2015	0.83	110	early sowing date 2 2015	15.72
111	early sowing date 2 2015	0.8	111	early sowing date 2 2015	15.58
112	early sowing date 2 2015	0.805	112	early sowing date 2 2015	15.93
113	early sowing date 2 2015	0.815	113	early sowing date 2 2015	16.27
114	early sowing date 2 2015	0.825	114	early sowing date 2 2015	15.72
115	early sowing date 2 2015	0.81	115	early sowing date 2 2015	15.15
116	early sowing date 2 2015	0.815	116	early sowing date 2 2015	16.87
117	early sowing date 2 2015	0.78	117	early sowing date 2 2015	14.38
118	early sowing date 2 2015	0.825	118	early sowing date 2 2015	15.83
119	early sowing date 2 2015	0.805	119	early sowing date 2 2015	14.45
120	early sowing date 2 2015	0.835	120	early sowing date 2 2015	16.47
1	late sowing date 2 2015	0.69			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
2	late sowing date 2 2015	0.76			
3	late sowing date 2 2015	0.655			
4	late sowing date 2 2015	0.665			
5	late sowing date 2 2015	0.685			
6	late sowing date 2 2015	0.7			
7	late sowing date 2 2015	0.63			
8	late sowing date 2 2015	0.64			
9	late sowing date 2 2015	0.64			
10	late sowing date 2 2015	0.63			
11	late sowing date 2 2015	0.65			
12	late sowing date 2 2015	0.655			
13	late sowing date 2 2015	0.72			
14	late sowing date 2 2015	0.715			
15	late sowing date 2 2015	0.65			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
16	late sowing date 2 2015	0.68			
17	late sowing date 2 2015	0.67			
18	late sowing date 2 2015	0.68			
19	late sowing date 2 2015	0.7			
20	late sowing date 2 2015	0.66			
21	late sowing date 2 2015	0.695			
22	late sowing date 2 2015	0.675			
23	late sowing date 2 2015	0.67			
24	late sowing date 2 2015	0.695			
25	late sowing date 2 2015	0.52			
26	late sowing date 2 2015	0.68			
27	late sowing date 2 2015	0.685			
28	late sowing date 2 2015	0.67			
29	late sowing date 2 2015	0.68			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
30	late sowing date 2 2015	0.68			
31	late sowing date 2 2015	0.67			
32	late sowing date 2 2015	0.62			
33	late sowing date 2 2015	0.645			
34	late sowing date 2 2015	0.645			
35	late sowing date 2 2015	0.655			
36	late sowing date 2 2015	0.69			
37	late sowing date 2 2015	0.705			
38	late sowing date 2 2015	0.62			
39	late sowing date 2 2015	0.64			
40	late sowing date 2 2015	0.735			
41	late sowing date 2 2015	0.66			
42	late sowing date 2 2015	0.635			
43	late sowing date 2 2015	0.69			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
44	late sowing date 2 2015	0.715			
45	late sowing date 2 2015	0.605			
46	late sowing date 2 2015	0.655			
47	late sowing date 2 2015	0.685			
48	late sowing date 2 2015	0.735			
49	late sowing date 2 2015	0.605			
50	late sowing date 2 2015	0.675			
51	late sowing date 2 2015	0.735			
52	late sowing date 2 2015	0.63			
53	late sowing date 2 2015	0.585			
54	late sowing date 2 2015	0.715			
55	late sowing date 2 2015	0.68			
56	late sowing date 2 2015	0.645			
57	late sowing date 2 2015	0.67			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
58	late sowing date 2 2015	0.605			
59	late sowing date 2 2015	0.66			
60	late sowing date 2 2015	0.645			
61	late sowing date 2 2015	0.69			
62	late sowing date 2 2015	0.525			
63	late sowing date 2 2015	0.69			
64	late sowing date 2 2015	0.625			
65	late sowing date 2 2015	0.64			
66	late sowing date 2 2015	0.71			
67	late sowing date 2 2015	0.72			
68	late sowing date 2 2015	0.715			
69	late sowing date 2 2015	0.65			
70	late sowing date 2 2015	0.625			
71	late sowing date 2 2015	0.67			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
72	late sowing date 2 2015	0.64			
73	late sowing date 2 2015	0.715			
74	late sowing date 2 2015	0.67			
75	late sowing date 2 2015	0.675			
76	late sowing date 2 2015	0.69			
77	late sowing date 2 2015	0.695			
78	late sowing date 2 2015	0.615			
79	late sowing date 2 2015	0.695			
80	late sowing date 2 2015	0.7			
81	late sowing date 2 2015	0.565			
82	late sowing date 2 2015	0.72			
83	late sowing date 2 2015	0.64			
84	late sowing date 2 2015	0.665			
85	late sowing date 2 2015	0.715			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
86	late sowing date 2 2015	0.705			
87	late sowing date 2 2015	0.67			
88	late sowing date 2 2015	0.695			
89	late sowing date 2 2015	0.675			
90	late sowing date 2 2015	0.61			
91	late sowing date 2 2015	0.695			
92	late sowing date 2 2015	0.65			
93	late sowing date 2 2015	0.6			
94	late sowing date 2 2015	0.685			
95	late sowing date 2 2015	0.69			
96	late sowing date 2 2015	0.735			
97	late sowing date 2 2015	0.7			
98	late sowing date 2 2015	0.65			
99	late sowing date 2 2015	0.655			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
100	late sowing date 2 2015	0.725			
101	late sowing date 2 2015	0.705			
102	late sowing date 2 2015	0.715			
103	late sowing date 2 2015	0.595			
104	late sowing date 2 2015	0.59			
105	late sowing date 2 2015	0.715			
106	late sowing date 2 2015	0.68			
107	late sowing date 2 2015	0.665			
108	late sowing date 2 2015	0.65			
109	late sowing date 2 2015	0.655			
110	late sowing date 2 2015	0.635			
111	late sowing date 2 2015	0.67			
112	late sowing date 2 2015	0.72			
113	late sowing date 2 2015	0.685			

Entry	Environment	NDVI heading	Entry	Environment	CT heading
114	late sowing date 2 2015	0.645			
115	late sowing date 2 2015	0.69			
116	late sowing date 2 2015	0.675			
117	late sowing date 2 2015	0.735			
118	late sowing date 2 2015	0.66			
119	late sowing date 2 2015	0.645			
120	late sowing date 2 2015	0.64			

Table 7: Durum wheat predicted means for NDVI at early sowing 2014 and early sowing date 2 2014, CT at early sowing date 1 2015 and early sowing date 2 2015

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
1	early sowing 2014	0.6878	1	early sowing date 1 2015	18.4
2	early sowing 2014	0.6886	2	early sowing date 1 2015	19.17
3	early sowing 2014	0.6491	3	early sowing date 1 2015	18.47
4	early sowing 2014	0.7144	4	early sowing date 1 2015	19.12
5	early sowing 2014	0.693	5	early sowing date 1 2015	18.88
6	early sowing 2014	0.7367	6	early sowing date 1 2015	21.88
7	early sowing 2014	0.6348	7	early sowing date 1 2015	19.38
8	early sowing 2014	0.6784	8	early sowing date 1 2015	22.22
9	early sowing 2014	0.6286	9	early sowing date 1 2015	21.67
10	early sowing 2014	0.7095	10	early sowing date 1 2015	20.87
11	early sowing 2014	0.3999	11	early sowing date 1 2015	20.73
12	early sowing 2014	0.667	12	early sowing date 1 2015	18.88
13	early sowing 2014	0.6583	13	early sowing date 1 2015	18.43
14	early sowing 2014	0.6824	14	early sowing date 1 2015	18.28
15	early sowing 2014	0.689	15	early sowing date 1 2015	19.02
16	early sowing 2014	0.7076	16	early sowing date 1 2015	19.32
17	early sowing 2014	0.6874	17	early sowing date 1 2015	18.15

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
18	early sowing 2014	0.707	18	early sowing date 1 2015	17.78
19	early sowing 2014	0.7129	19	early sowing date 1 2015	18.95
20	early sowing 2014	0.4085	20	early sowing date 1 2015	20.8
21	early sowing 2014	0.6928	21	early sowing date 1 2015	21.17
22	early sowing 2014	0.6162	22	early sowing date 1 2015	20.62
23	early sowing 2014	0.7174	23	early sowing date 1 2015	19.7
24	early sowing 2014	0.7382	24	early sowing date 1 2015	19.17
25	early sowing 2014	0.6722	25	early sowing date 1 2015	18.53
26	early sowing 2014	0.6816	26	early sowing date 1 2015	20.88
27	early sowing 2014	0.3803	27	early sowing date 1 2015	19.38
28	early sowing 2014	0.6143	28	early sowing date 1 2015	21.93
29	early sowing 2014	0.7103	29	early sowing date 1 2015	21.63
30	early sowing 2014	0.6995	30	early sowing date 1 2015	19.67
31	early sowing 2014	0.4163	31	early sowing date 1 2015	22.27
32	early sowing 2014	0.7244	32	early sowing date 1 2015	18.8
33	early sowing 2014	0.6315	33	early sowing date 1 2015	20.58
34	early sowing 2014	0.7276	34	early sowing date 1 2015	20.87

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
35	early sowing 2014	0.6875	35	early sowing date 1 2015	20.45
36	early sowing 2014	0.6373	36	early sowing date 1 2015	21.75
37	early sowing 2014	0.7055	37	early sowing date 1 2015	19.82
38	early sowing 2014	0.3854	38	early sowing date 1 2015	17.48
39	early sowing 2014	0.6451	39	early sowing date 1 2015	18.78
40	early sowing 2014	0.0897	40	early sowing date 1 2015	18.47
41	early sowing 2014	0.6667	41	early sowing date 1 2015	21.17
42	early sowing 2014	0.3923	42	early sowing date 1 2015	19.15
43	early sowing 2014	0.6685	43	early sowing date 1 2015	20.1
44	early sowing 2014	0.6167	44	early sowing date 1 2015	18.78
45	early sowing 2014	0.6712	45	early sowing date 1 2015	22.05
46	early sowing 2014	0.3735	46	early sowing date 1 2015	18.48
47	early sowing 2014	0.6658	47	early sowing date 1 2015	18
48	early sowing 2014	0.7465	48	early sowing date 1 2015	18.5
49	early sowing 2014	0.6528	49	early sowing date 1 2015	17.82
50	early sowing 2014	0.6526	50	early sowing date 1 2015	18.32
51	early sowing 2014	0.3882	51	early sowing date 1 2015	17.77

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
52	early sowing 2014	0.7003	52	early sowing date 1 2015	18.38
53	early sowing 2014	0.6394	53	early sowing date 1 2015	18.37
54	early sowing 2014	0.6786	54	early sowing date 1 2015	19.77
55	early sowing 2014	0.39	55	early sowing date 1 2015	18.75
56	early sowing 2014	0.3944	56	early sowing date 1 2015	22.2
57	early sowing 2014	0.728	57	early sowing date 1 2015	19.32
58	early sowing 2014	0.7016	58	early sowing date 1 2015	20.77
59	early sowing 2014	0.6644	59	early sowing date 1 2015	18.95
60	early sowing 2014	0.4079	60	early sowing date 1 2015	17.7
61	early sowing 2014	0.4067	61	early sowing date 1 2015	20.85
62	early sowing 2014	0.7102	62	early sowing date 1 2015	18.85
63	early sowing 2014	0.7156	63	early sowing date 1 2015	21.15
64	early sowing 2014	0.7203	64	early sowing date 1 2015	20.3
65	early sowing 2014	0.7195	65	early sowing date 1 2015	18.28
66	early sowing 2014	0.3896	66	early sowing date 1 2015	17.78
67	early sowing 2014	0.6918	67	early sowing date 1 2015	19.73
68	early sowing 2014	0.7199	68	early sowing date 1 2015	20.97

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
69	early sowing 2014	0.718	69	early sowing date 1 2015	19.33
70	early sowing 2014	0.6929	70	early sowing date 1 2015	21.05
71	early sowing 2014	0.7149	71	early sowing date 1 2015	18
72	early sowing 2014	0.7143	72	early sowing date 1 2015	18.8
73	early sowing 2014	0.7069	73	early sowing date 1 2015	18.6
74	early sowing 2014	0.7156	74	early sowing date 1 2015	21
75	early sowing 2014	0.7263	75	early sowing date 1 2015	17.12
76	early sowing 2014	0.7304	76	early sowing date 1 2015	17.93
77	early sowing 2014	0.4014	77	early sowing date 1 2015	19.02
78	early sowing 2014	0.705	78	early sowing date 1 2015	18.5
79	early sowing 2014	0.7076	79	early sowing date 1 2015	17.8
80	early sowing 2014	0.6903	80	early sowing date 1 2015	22.72
81	early sowing 2014	0.4134	81	early sowing date 1 2015	19.17
82	early sowing 2014	0.7269	82	early sowing date 1 2015	18.45
83	early sowing 2014	0.7019	83	early sowing date 1 2015	22.03
84	early sowing 2014	0.7139	84	early sowing date 1 2015	21.63
85	early sowing 2014	0.4142	85	early sowing date 1 2015	18.9

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
86	early sowing 2014	0.7101	86	early sowing date 1 2015	20.72
87	early sowing 2014	0.7042	87	early sowing date 1 2015	18.6
88	early sowing 2014	0.721	88	early sowing date 1 2015	21.35
89	early sowing 2014	0.7311	89	early sowing date 1 2015	20.23
90	early sowing 2014	0.419	90	early sowing date 1 2015	18.13
91	early sowing 2014	0.7272	91	early sowing date 1 2015	22.25
92	early sowing 2014	0.7211	92	early sowing date 1 2015	20.32
93	early sowing 2014	0.4145	93	early sowing date 1 2015	19.97
94	early sowing 2014	0.4155	94	early sowing date 1 2015	18.25
95	early sowing 2014	0.699	95	early sowing date 1 2015	18.63
96	early sowing 2014	0.7337	96	early sowing date 1 2015	20.32
97	early sowing 2014	0.7106	97	early sowing date 1 2015	22.48
98	early sowing 2014	0.4067	98	early sowing date 1 2015	18.97
99	early sowing 2014	0.6716	99	early sowing date 1 2015	21.38
100	early sowing 2014	0.7308	100	early sowing date 1 2015	21.45
101	early sowing 2014	0.4094	101	early sowing date 1 2015	17.62
102	early sowing 2014	0.7226	102	early sowing date 1 2015	21.7

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
103	early sowing 2014	0.4145	103	early sowing date 1 2015	19.52
104	early sowing 2014	0.7604	104	early sowing date 1 2015	18.38
105	early sowing 2014	0.7074	105	early sowing date 1 2015	18.75
106	early sowing 2014	0.7126	106	early sowing date 1 2015	20.08
107	early sowing 2014	0.4202	107	early sowing date 1 2015	22.02
108	early sowing 2014	0.7345	108	early sowing date 1 2015	18.83
109	early sowing 2014	0.4158	109	early sowing date 1 2015	21.67
110	early sowing 2014	0.7156	110	early sowing date 1 2015	21.8
111	early sowing 2014	0.7068	111	early sowing date 1 2015	18.63
112	early sowing 2014	0.4074	112	early sowing date 1 2015	17.57
113	early sowing 2014	0.4127	113	early sowing date 1 2015	18.77
114	early sowing 2014	0.6933	114	early sowing date 1 2015	21.43
115	early sowing 2014	0.7372	115	early sowing date 1 2015	22.43
116	early sowing 2014	0.7081	116	early sowing date 1 2015	18.08
117	early sowing 2014	0.7117	117	early sowing date 1 2015	17.95
118	early sowing 2014	0.717	118	early sowing date 1 2015	21.33
119	early sowing 2014	0.7191	119	early sowing date 1 2015	21.37

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
120	early sowing 2014	0.4132	120	early sowing date 1 2015	19.33
1	early sowing date 2 2015	0.77	1	early sowing date 2 2015	17.57
2	early sowing date 2 2015	0.805	2	early sowing date 2 2015	18.27
3	early sowing date 2 2015	0.8	3	early sowing date 2 2015	16.6
4	early sowing date 2 2015	0.735	4	early sowing date 2 2015	17.35
5	early sowing date 2 2015	0.78	5	early sowing date 2 2015	18.1
6	early sowing date 2 2015	0.815	6	early sowing date 2 2015	16.13
7	early sowing date 2 2015	0.74	7	early sowing date 2 2015	17.55
8	early sowing date 2 2015	0.72	8	early sowing date 2 2015	18.52
9	early sowing date 2 2015	0.69	9	early sowing date 2 2015	18.25
10	early sowing date 2 2015	0.795	10	early sowing date 2 2015	18.37
11	early sowing date 2 2015	0.725	11	early sowing date 2 2015	18.78
12	early sowing date 2 2015	0.755	12	early sowing date 2 2015	17.35
13	early sowing date 2 2015	0.73	13	early sowing date 2 2015	18.13
14	early sowing date 2 2015	0.765	14	early sowing date 2 2015	17.78
15	early sowing date 2 2015	0.77	15	early sowing date 2 2015	17.83
16	early sowing date 2 2015	0.755	16	early sowing date 2 2015	17.35

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
17	early sowing date 2 2015	0.785	17	early sowing date 2 2015	17.15
18	early sowing date 2 2015	0.76	18	early sowing date 2 2015	17.17
19	early sowing date 2 2015	0.785	19	early sowing date 2 2015	17.15
20	early sowing date 2 2015	0.79	20	early sowing date 2 2015	18.93
21	early sowing date 2 2015	0.78	21	early sowing date 2 2015	18.2
22	early sowing date 2 2015	0.62	22	early sowing date 2 2015	18.05
23	early sowing date 2 2015	0.735	23	early sowing date 2 2015	17.07
24	early sowing date 2 2015	0.765	24	early sowing date 2 2015	19.12
25	early sowing date 2 2015	0.8	25	early sowing date 2 2015	18.37
26	early sowing date 2 2015	0.665	26	early sowing date 2 2015	16.68
27	early sowing date 2 2015	0.74	27	early sowing date 2 2015	17.9
28	early sowing date 2 2015	34.835	28	early sowing date 2 2015	18.3
29	early sowing date 2 2015	0.725	29	early sowing date 2 2015	17.48
30	early sowing date 2 2015	0.785	30	early sowing date 2 2015	17.9
31	early sowing date 2 2015	0.775	31	early sowing date 2 2015	19.08
32	early sowing date 2 2015	0.73	32	early sowing date 2 2015	17.67
33	early sowing date 2 2015	0.77	33	early sowing date 2 2015	17.95

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
34	early sowing date 2 2015	0.745	34	early sowing date 2 2015	18.87
35	early sowing date 2 2015	0.75	35	early sowing date 2 2015	18.03
36	early sowing date 2 2015	0.72	36	early sowing date 2 2015	17.42
37	early sowing date 2 2015	0.77	37	early sowing date 2 2015	17.1
38	early sowing date 2 2015	0.755	38	early sowing date 2 2015	18.33
39	early sowing date 2 2015	0.725	39	early sowing date 2 2015	18.7
40	early sowing date 2 2015	0.75	40	early sowing date 2 2015	18.43
41	early sowing date 2 2015	0.76	41	early sowing date 2 2015	18.22
42	early sowing date 2 2015	0.725	42	early sowing date 2 2015	20.02
43	early sowing date 2 2015	0.78	43	early sowing date 2 2015	17.43
44	early sowing date 2 2015	0.685	44	early sowing date 2 2015	18.42
45	early sowing date 2 2015	0.755	45	early sowing date 2 2015	17.32
46	early sowing date 2 2015	0.79	46	early sowing date 2 2015	17.57
47	early sowing date 2 2015	0.69	47	early sowing date 2 2015	18.2
48	early sowing date 2 2015	0.735	48	early sowing date 2 2015	17.87
49	early sowing date 2 2015	0.67	49	early sowing date 2 2015	17.02
50	early sowing date 2 2015	0.73	50	early sowing date 2 2015	17.67

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
51	early sowing date 2 2015	0.72	51	early sowing date 2 2015	19
52	early sowing date 2 2015	0.74	52	early sowing date 2 2015	17.93
53	early sowing date 2 2015	0.74	53	early sowing date 2 2015	17.2
54	early sowing date 2 2015	0.785	54	early sowing date 2 2015	17.17
55	early sowing date 2 2015	0.765	55	early sowing date 2 2015	16.83
56	early sowing date 2 2015	0.78	56	early sowing date 2 2015	16.57
57	early sowing date 2 2015	0.81	57	early sowing date 2 2015	17.87
58	early sowing date 2 2015	0.77	58	early sowing date 2 2015	17.03
59	early sowing date 2 2015	0.765	59	early sowing date 2 2015	17.97
60	early sowing date 2 2015	0.81	60	early sowing date 2 2015	17.7
61	early sowing date 2 2015	0.755	61	early sowing date 2 2015	18.82
62	early sowing date 2 2015	0.78	62	early sowing date 2 2015	16.78
63	early sowing date 2 2015	0.775	63	early sowing date 2 2015	17.73
64	early sowing date 2 2015	0.79	64	early sowing date 2 2015	17.3
65	early sowing date 2 2015	0.78	65	early sowing date 2 2015	18.02
66	early sowing date 2 2015	0.78	66	early sowing date 2 2015	18.32
67	early sowing date 2 2015	0.735	67	early sowing date 2 2015	17.37

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
68	early sowing date 2 2015	0.79	68	early sowing date 2 2015	16.9
69	early sowing date 2 2015	0.79	69	early sowing date 2 2015	18.22
70	early sowing date 2 2015	0.77	70	early sowing date 2 2015	17.42
71	early sowing date 2 2015	0.79	71	early sowing date 2 2015	19.25
72	early sowing date 2 2015	0.71	72	early sowing date 2 2015	17.67
73	early sowing date 2 2015	0.79	73	early sowing date 2 2015	17.07
74	early sowing date 2 2015	0.765	74	early sowing date 2 2015	18.22
75	early sowing date 2 2015	0.75	75	early sowing date 2 2015	17.9
76	early sowing date 2 2015	0.74	76	early sowing date 2 2015	17.9
77	early sowing date 2 2015	0.765	77	early sowing date 2 2015	17.6
78	early sowing date 2 2015	0.72	78	early sowing date 2 2015	18.97
79	early sowing date 2 2015	0.775	79	early sowing date 2 2015	17.18
80	early sowing date 2 2015	0.76	80	early sowing date 2 2015	18.17
81	early sowing date 2 2015	0.77	81	early sowing date 2 2015	17
82	early sowing date 2 2015	0.765	82	early sowing date 2 2015	17.35
83	early sowing date 2 2015	0.755	83	early sowing date 2 2015	17.9
84	early sowing date 2 2015	0.74	84	early sowing date 2 2015	18.2

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
85	early sowing date 2 2015	0.795	85	early sowing date 2 2015	16.92
86	early sowing date 2 2015	0.78	86	early sowing date 2 2015	18.27
87	early sowing date 2 2015	0.79	87	early sowing date 2 2015	17.58
88	early sowing date 2 2015	0.765	88	early sowing date 2 2015	17.13
89	early sowing date 2 2015	0.785	89	early sowing date 2 2015	17.85
90	early sowing date 2 2015	0.78	90	early sowing date 2 2015	18.22
91	early sowing date 2 2015	0.77	91	early sowing date 2 2015	18.4
92	early sowing date 2 2015	0.755	92	early sowing date 2 2015	19.23
93	early sowing date 2 2015	0.76	93	early sowing date 2 2015	17.52
94	early sowing date 2 2015	0.74	94	early sowing date 2 2015	16.42
95	early sowing date 2 2015	0.75	95	early sowing date 2 2015	17.87
96	early sowing date 2 2015	0.775	96	early sowing date 2 2015	17.63
97	early sowing date 2 2015	0.765	97	early sowing date 2 2015	16.75
98	early sowing date 2 2015	0.72	98	early sowing date 2 2015	17.95
99	early sowing date 2 2015	0.745	99	early sowing date 2 2015	17.83
100	early sowing date 2 2015	0.81	100	early sowing date 2 2015	18.12
101	early sowing date 2 2015	0.75	101	early sowing date 2 2015	18.3

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
102	early sowing date 2 2015	0.755	102	early sowing date 2 2015	19.7
103	early sowing date 2 2015	0.795	103	early sowing date 2 2015	17.48
104	early sowing date 2 2015	0.67	104	early sowing date 2 2015	18.92
105	early sowing date 2 2015	0.805	105	early sowing date 2 2015	17.08
106	early sowing date 2 2015	0.81	106	early sowing date 2 2015	15.65
107	early sowing date 2 2015	0.77	107	early sowing date 2 2015	17.38
108	early sowing date 2 2015	0.815	108	early sowing date 2 2015	17.67
109	early sowing date 2 2015	0.79	109	early sowing date 2 2015	19.33
110	early sowing date 2 2015	0.815	110	early sowing date 2 2015	18.55
111	early sowing date 2 2015	0.795	111	early sowing date 2 2015	17.7
112	early sowing date 2 2015	0.785	112	early sowing date 2 2015	20.33
113	early sowing date 2 2015	0.775	113	early sowing date 2 2015	17.18
114	early sowing date 2 2015	0.795	114	early sowing date 2 2015	17.93
115	early sowing date 2 2015	0.78	115	early sowing date 2 2015	18.17
116	early sowing date 2 2015	0.74	116	early sowing date 2 2015	17.68
117	early sowing date 2 2015	0.715	117	early sowing date 2 2015	18.05
118	early sowing date 2 2015	0.81	118	early sowing date 2 2015	16.78

Entry	Environment	NDVI early grain-fill	ENTRY	Environment	CT early grain-fill
119	early sowing date 2 2015	0.8	119	early sowing date 2 2015	17.18
120	early sowing date 2 2015	0.795	120	early sowing date 2 2015	18.88

Table 8: durum predicted means for NDVI jointing taken on early sowing date 1 2015, early sowing date 2 2015 and CT jointing taken on early sowing date 1 2015

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
1	early sowing date 1 2015	0.7755	1	early sowing date 1 2015	11
2	early sowing date 1 2015	0.7759	2	early sowing date 1 2015	11.85
3	early sowing date 1 2015	0.7802	3	early sowing date 1 2015	11.93
4	early sowing date 1 2015	0.8105	4	early sowing date 1 2015	11.02
5	early sowing date 1 2015	0.8312	5	early sowing date 1 2015	11.22
6	early sowing date 1 2015	0.7896	6	early sowing date 1 2015	12.75
7	early sowing date 1 2015	0.7995	7	early sowing date 1 2015	11.77
8	early sowing date 1 2015	0.795	8	early sowing date 1 2015	11.93

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
9	early sowing date 1 2015	0.7954	9	early sowing date 1 2015	11.3
10	early sowing date 1 2015	0.8196	10	early sowing date 1 2015	11.75
11	early sowing date 1 2015	0.782	11	early sowing date 1 2015	11.32
12	early sowing date 1 2015	0.8245	12	early sowing date 1 2015	11.33
13	early sowing date 1 2015	0.778	13	early sowing date 1 2015	11.18
14	early sowing date 1 2015	0.7753	14	early sowing date 1 2015	12.38
15	early sowing date 1 2015	0.813	15	early sowing date 1 2015	11.35
16	early sowing date 1 2015	0.8247	16	early sowing date 1 2015	12.9
17	early sowing date 1 2015	0.8254	17	early sowing date 1 2015	11.7
18	early sowing date 1 2015	0.8049	18	early sowing date 1 2015	9.65
19	early sowing date 1 2015	0.7919	19	early sowing date 1 2015	12.35
20	early sowing date 1 2015	0.7695	20	early sowing date 1 2015	10.75
21	early sowing date 1 2015	0.7634	21	early sowing date 1 2015	12.1
22	early sowing date 1 2015	0.7806	22	early sowing date 1 2015	11.52
23	early sowing date 1 2015	0.8112	23	early sowing date 1 2015	11.5
24	early sowing date 1 2015	0.8047	24	early sowing date 1 2015	11.32
25	early sowing date 1 2015	0.8146	25	early sowing date 1 2015	12.53

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
26	early sowing date 1 2015	0.846	26	early sowing date 1 2015	11.33
27	early sowing date 1 2015	0.763	27	early sowing date 1 2015	11.42
28	early sowing date 1 2015	0.7689	28	early sowing date 1 2015	10.8
29	early sowing date 1 2015	0.8336	29	early sowing date 1 2015	10.82
30	early sowing date 1 2015	0.8354	30	early sowing date 1 2015	11.42
31	early sowing date 1 2015	0.8273	31	early sowing date 1 2015	10.45
32	early sowing date 1 2015	0.8109	32	early sowing date 1 2015	10.85
33	early sowing date 1 2015	0.7994	33	early sowing date 1 2015	11.8
34	early sowing date 1 2015	0.8111	34	early sowing date 1 2015	11.58
35	early sowing date 1 2015	0.7738	35	early sowing date 1 2015	11.33
36	early sowing date 1 2015	0.7815	36	early sowing date 1 2015	11.9
37	early sowing date 1 2015	0.8271	37	early sowing date 1 2015	11.82
38	early sowing date 1 2015	0.8086	38	early sowing date 1 2015	11.75
39	early sowing date 1 2015	0.7352	39	early sowing date 1 2015	11.7
40	early sowing date 1 2015	0.8162	40	early sowing date 1 2015	12.55
41	early sowing date 1 2015	0.8109	41	early sowing date 1 2015	10.88
42	early sowing date 1 2015	0.7913	42	early sowing date 1 2015	11.52

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
43	early sowing date 1 2015	0.7997	43	early sowing date 1 2015	11.47
44	early sowing date 1 2015	0.7415	44	early sowing date 1 2015	11.35
45	early sowing date 1 2015	0.7929	45	early sowing date 1 2015	10.9
46	early sowing date 1 2015	0.8108	46	early sowing date 1 2015	11.88
47	early sowing date 1 2015	0.7956	47	early sowing date 1 2015	11.55
48	early sowing date 1 2015	0.7693	48	early sowing date 1 2015	11.95
49	early sowing date 1 2015	0.7863	49	early sowing date 1 2015	11.37
50	early sowing date 1 2015	0.7901	50	early sowing date 1 2015	11.92
51	early sowing date 1 2015	0.8096	51	early sowing date 1 2015	11.32
52	early sowing date 1 2015	0.7899	52	early sowing date 1 2015	11.87
53	early sowing date 1 2015	0.7867	53	early sowing date 1 2015	11.1
54	early sowing date 1 2015	0.7832	54	early sowing date 1 2015	12.45
55	early sowing date 1 2015	0.8095	55	early sowing date 1 2015	12.23
56	early sowing date 1 2015	0.7606	56	early sowing date 1 2015	12.08
57	early sowing date 1 2015	0.8296	57	early sowing date 1 2015	12.23
58	early sowing date 1 2015	0.8123	58	early sowing date 1 2015	12.78
59	early sowing date 1 2015	0.8239	59	early sowing date 1 2015	11.23

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
60	early sowing date 1 2015	0.7781	60	early sowing date 1 2015	11.53
61	early sowing date 1 2015	0.7824	61	early sowing date 1 2015	11.6
62	early sowing date 1 2015	0.745	62	early sowing date 1 2015	12.8
63	early sowing date 1 2015	0.8113	63	early sowing date 1 2015	11.38
64	early sowing date 1 2015	0.7409	64	early sowing date 1 2015	12.65
65	early sowing date 1 2015	0.7848	65	early sowing date 1 2015	11.73
66	early sowing date 1 2015	0.7714	66	early sowing date 1 2015	10.37
67	early sowing date 1 2015	0.8236	67	early sowing date 1 2015	12.03
68	early sowing date 1 2015	0.7626	68	early sowing date 1 2015	11.17
69	early sowing date 1 2015	0.755	69	early sowing date 1 2015	11.4
70	early sowing date 1 2015	0.7691	70	early sowing date 1 2015	10.9
71	early sowing date 1 2015	0.7859	71	early sowing date 1 2015	11.9
72	early sowing date 1 2015	0.8251	72	early sowing date 1 2015	11.97
73	early sowing date 1 2015	0.789	73	early sowing date 1 2015	11.78
74	early sowing date 1 2015	0.8186	74	early sowing date 1 2015	12.17
75	early sowing date 1 2015	0.831	75	early sowing date 1 2015	12.08
76	early sowing date 1 2015	0.7798	76	early sowing date 1 2015	11.68

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
77	early sowing date 1 2015	0.8143	77	early sowing date 1 2015	12.35
78	early sowing date 1 2015	0.8031	78	early sowing date 1 2015	11.02
79	early sowing date 1 2015	0.8014	79	early sowing date 1 2015	10.58
80	early sowing date 1 2015	0.8099	80	early sowing date 1 2015	12.05
81	early sowing date 1 2015	0.8218	81	early sowing date 1 2015	11.38
82	early sowing date 1 2015	0.7785	82	early sowing date 1 2015	13.4
83	early sowing date 1 2015	0.7988	83	early sowing date 1 2015	11.63
84	early sowing date 1 2015	0.8129	84	early sowing date 1 2015	10.72
85	early sowing date 1 2015	0.7674	85	early sowing date 1 2015	11.58
86	early sowing date 1 2015	0.8255	86	early sowing date 1 2015	11.45
87	early sowing date 1 2015	0.7629	87	early sowing date 1 2015	11.55
88	early sowing date 1 2015	0.7535	88	early sowing date 1 2015	11.7
89	early sowing date 1 2015	0.7825	89	early sowing date 1 2015	10.75
90	early sowing date 1 2015	0.809	90	early sowing date 1 2015	11.85
91	early sowing date 1 2015	0.7781	91	early sowing date 1 2015	11.38
92	early sowing date 1 2015	0.8171	92	early sowing date 1 2015	10.82
93	early sowing date 1 2015	0.7958	93	early sowing date 1 2015	11.78

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
94	early sowing date 1 2015	0.7927	94	early sowing date 1 2015	11.5
95	early sowing date 1 2015	0.8108	95	early sowing date 1 2015	11.8
96	early sowing date 1 2015	0.8092	96	early sowing date 1 2015	12.05
97	early sowing date 1 2015	0.7537	97	early sowing date 1 2015	11.27
98	early sowing date 1 2015	0.7996	98	early sowing date 1 2015	10.62
99	early sowing date 1 2015	0.8104	99	early sowing date 1 2015	11.12
100	early sowing date 1 2015	0.7429	100	early sowing date 1 2015	11
101	early sowing date 1 2015	0.8217	101	early sowing date 1 2015	11.27
102	early sowing date 1 2015	0.8307	102	early sowing date 1 2015	10.6
103	early sowing date 1 2015	0.8041	103	early sowing date 1 2015	11.47
104	early sowing date 1 2015	0.7983	104	early sowing date 1 2015	11.13
105	early sowing date 1 2015	0.7679	105	early sowing date 1 2015	11.35
106	early sowing date 1 2015	0.7758	106	early sowing date 1 2015	12.28
107	early sowing date 1 2015	0.8048	107	early sowing date 1 2015	10.2
108	early sowing date 1 2015	0.8108	108	early sowing date 1 2015	12.15
109	early sowing date 1 2015	0.8161	109	early sowing date 1 2015	11.5
110	early sowing date 1 2015	0.7553	110	early sowing date 1 2015	11.2

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
111	early sowing date 1 2015	0.7895	111	early sowing date 1 2015	11.4
112	early sowing date 1 2015	0.7898	112	early sowing date 1 2015	10.47
113	early sowing date 1 2015	0.7867	113	early sowing date 1 2015	12.1
114	early sowing date 1 2015	0.7969	114	early sowing date 1 2015	11.12
115	early sowing date 1 2015	0.8527	115	early sowing date 1 2015	10.78
116	early sowing date 1 2015	0.7886	116	early sowing date 1 2015	11.9
117	early sowing date 1 2015	0.7986	117	early sowing date 1 2015	11.95
118	early sowing date 1 2015	0.7921	118	early sowing date 1 2015	12.65
119	early sowing date 1 2015	0.7961	119	early sowing date 1 2015	11.35
120	early sowing date 1 2015	0.7403	120	early sowing date 1 2015	10.92
1	early sowing date 2 2015	0.7619			
2	early sowing date 2 2015	0.4148			
3	early sowing date 2 2015	0.7329			
4	early sowing date 2 2015	0.6985			
5	early sowing date 2 2015	0.6187			
6	early sowing date 2 2015	0.5293			
7	early sowing date 2 2015	0.683			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
8	early sowing date 2 2015	0.5475			
9	early sowing date 2 2015	0.7266			
10	early sowing date 2 2015	0.6498			
11	early sowing date 2 2015	0.6774			
12	early sowing date 2 2015	0.679			
13	early sowing date 2 2015	0.5227			
14	early sowing date 2 2015	0.5023			
15	early sowing date 2 2015	0.4642			
16	early sowing date 2 2015	0.714			
17	early sowing date 2 2015	0.4659			
18	early sowing date 2 2015	0.6724			
19	early sowing date 2 2015	0.6028			
20	early sowing date 2 2015	0.7648			
21	early sowing date 2 2015	0.6763			
22	early sowing date 2 2015	0.795			
23	early sowing date 2 2015	0.6714			
24	early sowing date 2 2015	0.7381			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
25	early sowing date 2 2015	0.6664			
26	early sowing date 2 2015	0.514			
27	early sowing date 2 2015	0.6829			
28	early sowing date 2 2015	0.6136			
29	early sowing date 2 2015	0.728			
30	early sowing date 2 2015	0.702			
31	early sowing date 2 2015	0.7047			
32	early sowing date 2 2015	0.739			
33	early sowing date 2 2015	0.6005			
34	early sowing date 2 2015	0.4866			
35	early sowing date 2 2015	0.6199			
36	early sowing date 2 2015	0.7335			
37	early sowing date 2 2015	0.6251			
38	early sowing date 2 2015	0.6627			
39	early sowing date 2 2015	0.6904			
40	early sowing date 2 2015	0.7022			
41	early sowing date 2 2015	0.7274			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
42	early sowing date 2 2015	0.7612			
43	early sowing date 2 2015	0.7423			
44	early sowing date 2 2015	0.6559			
45	early sowing date 2 2015	0.513			
46	early sowing date 2 2015	0.7418			
47	early sowing date 2 2015	0.6535			
48	early sowing date 2 2015	0.7206			
49	early sowing date 2 2015	0.4657			
50	early sowing date 2 2015	0.5347			
51	early sowing date 2 2015	0.7397			
52	early sowing date 2 2015	0.4713			
53	early sowing date 2 2015	0.7657			
54	early sowing date 2 2015	0.7036			
55	early sowing date 2 2015	0.2467			
56	early sowing date 2 2015	0.7221			
57	early sowing date 2 2015	0.6829			
58	early sowing date 2 2015	0.7518			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
59	early sowing date 2 2015	0.6672			
60	early sowing date 2 2015	0.6517			
61	early sowing date 2 2015	0.6787			
62	early sowing date 2 2015	0.4563			
63	early sowing date 2 2015	0.4166			
64	early sowing date 2 2015	0.5424			
65	early sowing date 2 2015	0.7266			
66	early sowing date 2 2015	0.7227			
67	early sowing date 2 2015	0.7351			
68	early sowing date 2 2015	0.4496			
69	early sowing date 2 2015	0.681			
70	early sowing date 2 2015	0.6239			
71	early sowing date 2 2015	0.7535			
72	early sowing date 2 2015	0.7085			
73	early sowing date 2 2015	0.6788			
74	early sowing date 2 2015	0.7454			
75	early sowing date 2 2015	0.6809			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
76	early sowing date 2 2015	0.6101			
77	early sowing date 2 2015	0.7574			
78	early sowing date 2 2015	0.7432			
79	early sowing date 2 2015	0.7331			
80	early sowing date 2 2015	0.7073			
81	early sowing date 2 2015	0.7616			
82	early sowing date 2 2015	0.5459			
83	early sowing date 2 2015	0.6945			
84	early sowing date 2 2015	0.6832			
85	early sowing date 2 2015	0.5393			
86	early sowing date 2 2015	0.4954			
87	early sowing date 2 2015	0.435			
88	early sowing date 2 2015	0.4787			
89	early sowing date 2 2015	0.7672			
90	early sowing date 2 2015	0.7241			
91	early sowing date 2 2015	0.6546			
92	early sowing date 2 2015	0.7537			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
93	early sowing date 2 2015	0.6953			
94	early sowing date 2 2015	0.4955			
95	early sowing date 2 2015	0.7292			
96	early sowing date 2 2015	0.7053			
97	early sowing date 2 2015	0.6688			
98	early sowing date 2 2015	0.7409			
99	early sowing date 2 2015	0.7691			
100	early sowing date 2 2015	0.6858			
101	early sowing date 2 2015	0.7176			
102	early sowing date 2 2015	0.4742			
103	early sowing date 2 2015	0.6264			
104	early sowing date 2 2015	0.5654			
105	early sowing date 2 2015	0.4555			
106	early sowing date 2 2015	0.4328			
107	early sowing date 2 2015	0.538			
108	early sowing date 2 2015	0.699			
109	early sowing date 2 2015	0.7728			

Entry	Environment	2015 NDVI jointing	ENTRY	early sowing date 1 2015	2015 CT jointing
110	early sowing date 2 2015	0.6749			
111	early sowing date 2 2015	0.7548			
112	early sowing date 2 2015	0.7804			
113	early sowing date 2 2015	0.4468			
114	early sowing date 2 2015	0.7487			
115	early sowing date 2 2015	0.7629			
116	early sowing date 2 2015	0.4114			
117	early sowing date 2 2015	0.7133			
118	early sowing date 2 2015	0.7482			
119	early sowing date 2 2015	0.6107			
120	early sowing date 2 2015	0.7674			

Table 9: Durum predicted means for NDVI at mid boot stage taken at late sowing date 1 2015 and CT at mid boot stage taken at early sowing date 2 2015, late sowing date 1 2015 and late sowing date 2 2015

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
1	early sowing date 2 2015	11.7	late sowing date 1 2015	1	0.805
2	early sowing date 2 2015	12.02	late sowing date 1 2015	2	0.815
3	early sowing date 2 2015	13.73	late sowing date 1 2015	3	0.795
4	early sowing date 2 2015	14	late sowing date 1 2015	4	0.815
5	early sowing date 2 2015	13.13	late sowing date 1 2015	5	0.81
6	early sowing date 2 2015	12.1	late sowing date 1 2015	6	0.82
7	early sowing date 2 2015	12.25	late sowing date 1 2015	7	0.83
8	early sowing date 2 2015	11.85	late sowing date 1 2015	8	0.8
9	early sowing date 2 2015	13.53	late sowing date 1 2015	9	0.795
10	early sowing date 2 2015	12.25	late sowing date 1 2015	10	0.785
11	early sowing date 2 2015	13.1	late sowing date 1 2015	11	0.8
12	early sowing date 2 2015	13.02	late sowing date 1 2015	12	0.82
13	early sowing date 2 2015	12.12	late sowing date 1 2015	13	0.785
14	early sowing date 2 2015	13.13	late sowing date 1 2015	14	0.82
15	early sowing date 2 2015	12.92	late sowing date 1 2015	15	0.79
16	early sowing date 2 2015	12.05	late sowing date 1 2015	16	0.76
17	early sowing date 2 2015	13.02	late sowing date 1 2015	17	0.815
18	early sowing date 2 2015	14.07	late sowing date 1 2015	18	0.8
19	early sowing date 2 2015	12.33	late sowing date 1 2015	19	0.77
20	early sowing date 2 2015	13.37	late sowing date 1 2015	20	0.805

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
21	early sowing date 2 2015	12.15	late sowing date 1 2015	21	0.81
22	early sowing date 2 2015	12.95	late sowing date 1 2015	22	0.825
23	early sowing date 2 2015	13.28	late sowing date 1 2015	23	0.775
24	early sowing date 2 2015	11.5	late sowing date 1 2015	24	0.795
25	early sowing date 2 2015	14	late sowing date 1 2015	25	0.82
26	early sowing date 2 2015	12.72	late sowing date 1 2015	26	0.8
27	early sowing date 2 2015	13.23	late sowing date 1 2015	27	0.785
28	early sowing date 2 2015	11.78	late sowing date 1 2015	28	0.77
29	early sowing date 2 2015	15.92	late sowing date 1 2015	29	0.81
30	early sowing date 2 2015	13.87	late sowing date 1 2015	30	0.77
31	early sowing date 2 2015	12.62	late sowing date 1 2015	31	0.815
32	early sowing date 2 2015	13.48	late sowing date 1 2015	32	0.8
33	early sowing date 2 2015	11.77	late sowing date 1 2015	33	0.79
34	early sowing date 2 2015	12.68	late sowing date 1 2015	34	0.8
35	early sowing date 2 2015	12.7	late sowing date 1 2015	35	0.795
36	early sowing date 2 2015	12.58	late sowing date 1 2015	36	0.805
37	early sowing date 2 2015	13.13	late sowing date 1 2015	37	0.83
38	early sowing date 2 2015	11.5	late sowing date 1 2015	38	0.805
39	early sowing date 2 2015	13.27	late sowing date 1 2015	39	0.78
40	early sowing date 2 2015	11.87	late sowing date 1 2015	40	0.805
41	early sowing date 2 2015	11.98	late sowing date 1 2015	41	0.8
42	early sowing date 2 2015	13.53	late sowing date 1 2015	42	0.805
43	early sowing date 2 2015	13.62	late sowing date 1 2015	43	0.805
44	early sowing date 2 2015	12.8	late sowing date 1 2015	44	0.815
45	early sowing date 2 2015	12.42	late sowing date 1 2015	45	0.8

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
46	early sowing date 2 2015	12.7	late sowing date 1 2015	46	0.81
47	early sowing date 2 2015	14.2	late sowing date 1 2015	47	0.785
48	early sowing date 2 2015	13.52	late sowing date 1 2015	48	0.795
49	early sowing date 2 2015	13.18	late sowing date 1 2015	49	0.78
50	early sowing date 2 2015	12.03	late sowing date 1 2015	50	0.78
51	early sowing date 2 2015	13.58	late sowing date 1 2015	51	0.78
52	early sowing date 2 2015	12.9	late sowing date 1 2015	52	0.81
53	early sowing date 2 2015	11.97	late sowing date 1 2015	53	0.79
54	early sowing date 2 2015	11.92	late sowing date 1 2015	54	0.805
55	early sowing date 2 2015	11.5	late sowing date 1 2015	55	0.79
56	early sowing date 2 2015	13.32	late sowing date 1 2015	56	0.82
57	early sowing date 2 2015	14.05	late sowing date 1 2015	57	0.775
58	early sowing date 2 2015	12.47	late sowing date 1 2015	58	0.805
59	early sowing date 2 2015	12.27	late sowing date 1 2015	59	0.8
60	early sowing date 2 2015	12.48	late sowing date 1 2015	60	0.825
61	early sowing date 2 2015	12.82	late sowing date 1 2015	61	0.805
62	early sowing date 2 2015	12.45	late sowing date 1 2015	62	0.8
63	early sowing date 2 2015	13.27	late sowing date 1 2015	63	0.8
64	early sowing date 2 2015	12.68	late sowing date 1 2015	64	0.82
65	early sowing date 2 2015	13.3	late sowing date 1 2015	65	0.815
66	early sowing date 2 2015	13.47	late sowing date 1 2015	66	0.81
67	early sowing date 2 2015	13	late sowing date 1 2015	67	0.795
68	early sowing date 2 2015	12.73	late sowing date 1 2015	68	0.815
69	early sowing date 2 2015	12.43	late sowing date 1 2015	69	0.795
70	early sowing date 2 2015	12.98	late sowing date 1 2015	70	0.805

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
71	early sowing date 2 2015	12.98	late sowing date 1 2015	71	0.815
72	early sowing date 2 2015	14.73	late sowing date 1 2015	72	0.795
73	early sowing date 2 2015	13.22	late sowing date 1 2015	73	0.8
74	early sowing date 2 2015	12.55	late sowing date 1 2015	74	0.805
75	early sowing date 2 2015	12.77	late sowing date 1 2015	75	0.775
76	early sowing date 2 2015	12.83	late sowing date 1 2015	76	0.79
77	early sowing date 2 2015	12.45	late sowing date 1 2015	77	0.785
78	early sowing date 2 2015	13.38	late sowing date 1 2015	78	0.81
79	early sowing date 2 2015	12.88	late sowing date 1 2015	79	0.78
80	early sowing date 2 2015	13.48	late sowing date 1 2015	80	0.81
81	early sowing date 2 2015	12.6	late sowing date 1 2015	81	0.775
82	early sowing date 2 2015	14.1	late sowing date 1 2015	82	0.775
83	early sowing date 2 2015	12.23	late sowing date 1 2015	83	0.805
84	early sowing date 2 2015	12.27	late sowing date 1 2015	84	0.81
85	early sowing date 2 2015	12.63	late sowing date 1 2015	85	0.75
86	early sowing date 2 2015	13.17	late sowing date 1 2015	86	0.825
87	early sowing date 2 2015	11.98	late sowing date 1 2015	87	0.81
88	early sowing date 2 2015	13.02	late sowing date 1 2015	88	0.81
89	early sowing date 2 2015	14.22	late sowing date 1 2015	89	0.81
90	early sowing date 2 2015	13.3	late sowing date 1 2015	90	0.8
91	early sowing date 2 2015	13.33	late sowing date 1 2015	91	0.82
92	early sowing date 2 2015	12.83	late sowing date 1 2015	92	0.81
93	early sowing date 2 2015	14.93	late sowing date 1 2015	93	0.81
94	early sowing date 2 2015	13.12	late sowing date 1 2015	94	0.815
95	early sowing date 2 2015	13.68	late sowing date 1 2015	95	0.815

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
96	early sowing date 2 2015	12.85	late sowing date 1 2015	96	0.81
97	early sowing date 2 2015	12.37	late sowing date 1 2015	97	0.735
98	early sowing date 2 2015	12.25	late sowing date 1 2015	98	0.765
99	early sowing date 2 2015	12.58	late sowing date 1 2015	99	0.79
100	early sowing date 2 2015	12.07	late sowing date 1 2015	100	0.8
101	early sowing date 2 2015	12.9	late sowing date 1 2015	101	0.815
102	early sowing date 2 2015	13.25	late sowing date 1 2015	102	0.825
103	early sowing date 2 2015	12.07	late sowing date 1 2015	103	0.805
104	early sowing date 2 2015	12.53	late sowing date 1 2015	104	0.81
105	early sowing date 2 2015	13.63	late sowing date 1 2015	105	0.805
106	early sowing date 2 2015	11.73	late sowing date 1 2015	106	0.815
107	early sowing date 2 2015	12.32	late sowing date 1 2015	107	0.81
108	early sowing date 2 2015	13.82	late sowing date 1 2015	108	0.81
109	early sowing date 2 2015	13.15	late sowing date 1 2015	109	0.81
110	early sowing date 2 2015	14.78	late sowing date 1 2015	110	0.78
111	early sowing date 2 2015	14.07	late sowing date 1 2015	111	0.805
112	early sowing date 2 2015	13.38	late sowing date 1 2015	112	0.815
113	early sowing date 2 2015	13.02	late sowing date 1 2015	113	0.82
114	early sowing date 2 2015	13.95	late sowing date 1 2015	114	0.815
115	early sowing date 2 2015	13.53	late sowing date 1 2015	115	0.79
116	early sowing date 2 2015	15.35	late sowing date 1 2015	116	0.78
117	early sowing date 2 2015	13.22	late sowing date 1 2015	117	0.815
118	early sowing date 2 2015	14.15	late sowing date 1 2015	118	0.815
119	early sowing date 2 2015	13.47	late sowing date 1 2015	119	0.77
120	early sowing date 2 2015	13.18	late sowing date 1 2015	120	0.82

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
1	late sowing date 1 2015	17.9			
2	late sowing date 1 2015	17.28			
3	late sowing date 1 2015	19.43			
4	late sowing date 1 2015	18.32			
5	late sowing date 1 2015	20.65			
6	late sowing date 1 2015	20.78			
7	late sowing date 1 2015	18.2			
8	late sowing date 1 2015	16.9			
9	late sowing date 1 2015	21.4			
10	late sowing date 1 2015	20.98			
11	late sowing date 1 2015	23.98			
12	late sowing date 1 2015	21.48			
13	late sowing date 1 2015	23.05			
14	late sowing date 1 2015	21.17			
15	late sowing date 1 2015	17.95			
16	late sowing date 1 2015	19.95			
17	late sowing date 1 2015	23.4			
18	late sowing date 1 2015	21.88			
19	late sowing date 1 2015	16.98			
20	late sowing date 1 2015	20.02			
21	late sowing date 1 2015	22.82			
22	late sowing date 1 2015	21.03			
23	late sowing date 1 2015	22.32			
24	late sowing date 1 2015	20.57			
25	late sowing date 1 2015	18.73			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
26	late sowing date 1 2015	18.78			
27	late sowing date 1 2015	20.48			
28	late sowing date 1 2015	16.87			
29	late sowing date 1 2015	23.83			
30	late sowing date 1 2015	16.63			
31	late sowing date 1 2015	22.12			
32	late sowing date 1 2015	22.07			
33	late sowing date 1 2015	22.1			
34	late sowing date 1 2015	22.7			
35	late sowing date 1 2015	16.58			
36	late sowing date 1 2015	17.47			
37	late sowing date 1 2015	19.77			
38	late sowing date 1 2015	19.75			
39	late sowing date 1 2015	19.52			
40	late sowing date 1 2015	17.33			
41	late sowing date 1 2015	24.7			
42	late sowing date 1 2015	19.77			
43	late sowing date 1 2015	17.4			
44	late sowing date 1 2015	18.63			
45	late sowing date 1 2015	19.87			
46	late sowing date 1 2015	17.5			
47	late sowing date 1 2015	21.42			
48	late sowing date 1 2015	21.27			
49	late sowing date 1 2015	19.18			
50	late sowing date 1 2015	20.9			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
51	late sowing date 1 2015	19.6			
52	late sowing date 1 2015	17.98			
53	late sowing date 1 2015	16.9			
54	late sowing date 1 2015	21.53			
55	late sowing date 1 2015	21.73			
56	late sowing date 1 2015	19.32			
57	late sowing date 1 2015	18.73			
58	late sowing date 1 2015	23			
59	late sowing date 1 2015	22.05			
60	late sowing date 1 2015	18.32			
61	late sowing date 1 2015	23.35			
62	late sowing date 1 2015	16.75			
63	late sowing date 1 2015	20.52			
64	late sowing date 1 2015	20.22			
65	late sowing date 1 2015	21.43			
66	late sowing date 1 2015	23.83			
67	late sowing date 1 2015	22.17			
68	late sowing date 1 2015	19.77			
69	late sowing date 1 2015	23.47			
70	late sowing date 1 2015	18.68			
71	late sowing date 1 2015	16.95			
72	late sowing date 1 2015	23.85			
73	late sowing date 1 2015	22.18			
74	late sowing date 1 2015	19.25			
75	late sowing date 1 2015	18.33			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
76	late sowing date 1 2015	20.17			
77	late sowing date 1 2015	24.03			
78	late sowing date 1 2015	21.77			
79	late sowing date 1 2015	17.3			
80	late sowing date 1 2015	21.88			
81	late sowing date 1 2015	19.88			
82	late sowing date 1 2015	17.57			
83	late sowing date 1 2015	17.45			
84	late sowing date 1 2015	22.83			
85	late sowing date 1 2015	18.62			
86	late sowing date 1 2015	24.08			
87	late sowing date 1 2015	21.1			
88	late sowing date 1 2015	23.5			
89	late sowing date 1 2015	22.65			
90	late sowing date 1 2015	16.82			
91	late sowing date 1 2015	20.37			
92	late sowing date 1 2015	21.53			
93	late sowing date 1 2015	17.32			
94	late sowing date 1 2015	23.07			
95	late sowing date 1 2015	21.47			
96	late sowing date 1 2015	20.82			
97	late sowing date 1 2015	22.12			
98	late sowing date 1 2015	20.7			
99	late sowing date 1 2015	18.47			
100	late sowing date 1 2015	20.08			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
101	late sowing date 1 2015	18.42			
102	late sowing date 1 2015	17.67			
103	late sowing date 1 2015	16.38			
104	late sowing date 1 2015	17.52			
105	late sowing date 1 2015	23.67			
106	late sowing date 1 2015	21.28			
107	late sowing date 1 2015	18.48			
108	late sowing date 1 2015	21.22			
109	late sowing date 1 2015	19.67			
110	late sowing date 1 2015	18.55			
111	late sowing date 1 2015	19.77			
112	late sowing date 1 2015	22			
113	late sowing date 1 2015	20.83			
114	late sowing date 1 2015	19.25			
115	late sowing date 1 2015	19.55			
116	late sowing date 1 2015	18.03			
117	late sowing date 1 2015	22.77			
118	late sowing date 1 2015	18.98			
119	late sowing date 1 2015	19.35			
120	late sowing date 1 2015	18.28			
1	late sowing date 2 2015	22.02			
2	late sowing date 2 2015	25.5			
3	late sowing date 2 2015	23.58			
4	late sowing date 2 2015	24.2			
5	late sowing date 2 2015	25.42			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
6	late sowing date 2 2015	21.48			
7	late sowing date 2 2015	24.97			
8	late sowing date 2 2015	22.98			
9	late sowing date 2 2015	24.55			
10	late sowing date 2 2015	24.5			
11	late sowing date 2 2015	24.42			
12	late sowing date 2 2015	26.78			
13	late sowing date 2 2015	21.82			
14	late sowing date 2 2015	23.83			
15	late sowing date 2 2015	23.03			
16	late sowing date 2 2015	26.45			
17	late sowing date 2 2015	23.95			
18	late sowing date 2 2015	24.95			
19	late sowing date 2 2015	24.5			
20	late sowing date 2 2015	24.5			
21	late sowing date 2 2015	21.42			
22	late sowing date 2 2015	20.62			
23	late sowing date 2 2015	24.77			
24	late sowing date 2 2015	25.38			
25	late sowing date 2 2015	22.35			
26	late sowing date 2 2015	22.98			
27	late sowing date 2 2015	26.77			
28	late sowing date 2 2015	23.3			
29	late sowing date 2 2015	28.65			
30	late sowing date 2 2015	25.68			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
31	late sowing date 2 2015	22.47			
32	late sowing date 2 2015	24.25			
33	late sowing date 2 2015	24.28			
34	late sowing date 2 2015	24.1			
35	late sowing date 2 2015	22.78			
36	late sowing date 2 2015	23.53			
37	late sowing date 2 2015	24.75			
38	late sowing date 2 2015	24.73			
39	late sowing date 2 2015	23.17			
40	late sowing date 2 2015	24.12			
41	late sowing date 2 2015	20.5			
42	late sowing date 2 2015	25.85			
43	late sowing date 2 2015	22.73			
44	late sowing date 2 2015	22.18			
45	late sowing date 2 2015	24.58			
46	late sowing date 2 2015	26			
47	late sowing date 2 2015	24.77			
48	late sowing date 2 2015	22.05			
49	late sowing date 2 2015	21.33			
50	late sowing date 2 2015	24.45			
51	late sowing date 2 2015	24.77			
52	late sowing date 2 2015	23.83			
53	late sowing date 2 2015	23.6			
54	late sowing date 2 2015	22.28			
55	late sowing date 2 2015	23.17			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
56	late sowing date 2 2015	25.7			
57	late sowing date 2 2015	23.98			
58	late sowing date 2 2015	25.43			
59	late sowing date 2 2015	22.3			
60	late sowing date 2 2015	20.97			
61	late sowing date 2 2015	24.82			
62	late sowing date 2 2015	24.62			
63	late sowing date 2 2015	23.93			
64	late sowing date 2 2015	24.82			
65	late sowing date 2 2015	22.57			
66	late sowing date 2 2015	24.17			
67	late sowing date 2 2015	23.6			
68	late sowing date 2 2015	24.42			
69	late sowing date 2 2015	23.08			
70	late sowing date 2 2015	22.58			
71	late sowing date 2 2015	24.97			
72	late sowing date 2 2015	22.7			
73	late sowing date 2 2015	24.55			
74	late sowing date 2 2015	23.17			
75	late sowing date 2 2015	26.13			
76	late sowing date 2 2015	24.98			
77	late sowing date 2 2015	22.58			
78	late sowing date 2 2015	23.6			
79	late sowing date 2 2015	21.8			
80	late sowing date 2 2015	25			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
81	late sowing date 2 2015	21.78			
82	late sowing date 2 2015	23.6			
83	late sowing date 2 2015	26			
84	late sowing date 2 2015	24.37			
85	late sowing date 2 2015	27.37			
86	late sowing date 2 2015	21.4			
87	late sowing date 2 2015	24.77			
88	late sowing date 2 2015	22.15			
89	late sowing date 2 2015	24.8			
90	late sowing date 2 2015	21.52			
91	late sowing date 2 2015	23.92			
92	late sowing date 2 2015	23.92			
93	late sowing date 2 2015	23.05			
94	late sowing date 2 2015	25.83			
95	late sowing date 2 2015	24.47			
96	late sowing date 2 2015	23.77			
97	late sowing date 2 2015	23.95			
98	late sowing date 2 2015	23.2			
99	late sowing date 2 2015	23.53			
100	late sowing date 2 2015	24.15			
101	late sowing date 2 2015	23.3			
102	late sowing date 2 2015	24.25			
103	late sowing date 2 2015	24.72			
104	late sowing date 2 2015	29.08			
105	late sowing date 2 2015	25.03			

ENTRY	Environment	2015 CT mid boot stage	Environment	ENTRY	2015 NDVI mid boot stage
106	late sowing date 2 2015	23.6			
107	late sowing date 2 2015	24.23			
108	late sowing date 2 2015	26.07			
109	late sowing date 2 2015	25.93			
110	late sowing date 2 2015	21.25			
111	late sowing date 2 2015	23.02			
112	late sowing date 2 2015	25.08			
113	late sowing date 2 2015	22.97			
114	late sowing date 2 2015	22.5			
115	late sowing date 2 2015	24.28			
116	late sowing date 2 2015	22.87			
117	late sowing date 2 2015	22.02			
118	late sowing date 2 2015	25.68			
119	late sowing date 2 2015	21.37			
120	late sowing date 2 2015	24.72			

Table 10: Durum predicted means for NDVI at mid grain-fill taken at early sowing date 1 2015 and early sowing date 2 2015 and CT at mid grain-fill taken at early sowing date 1 2015

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
1	early sowing date 1 2015	0.765	1	early sowing date 1 2015	23.13
2	early sowing date 1 2015	0.76	2	early sowing date 1 2015	22.87
3	early sowing date 1 2015	0.72	3	early sowing date 1 2015	21.65
4	early sowing date 1 2015	0.74	4	early sowing date 1 2015	22.05
5	early sowing date 1 2015	0.705	5	early sowing date 1 2015	22.22
6	early sowing date 1 2015	0.64	6	early sowing date 1 2015	25.9
7	early sowing date 1 2015	0.715	7	early sowing date 1 2015	21.72
8	early sowing date 1 2015	0.73	8	early sowing date 1 2015	18.6
9	early sowing date 1 2015	0.635	9	early sowing date 1 2015	23.17
10	early sowing date 1 2015	0.68	10	early sowing date 1 2015	25.38
11	early sowing date 1 2015	0.695	11	early sowing date 1 2015	23
12	early sowing date 1 2015	0.705	12	early sowing date 1 2015	24.3
13	early sowing date 1 2015	0.68	13	early sowing date 1 2015	25.62
14	early sowing date 1 2015	0.66	14	early sowing date 1 2015	23.3
15	early sowing date 1 2015	0.635	15	early sowing date 1 2015	26.33
16	early sowing date 1 2015	0.7	16	early sowing date 1 2015	23.6
17	early sowing date 1 2015	0.64	17	early sowing date 1 2015	27.87
18	early sowing date 1 2015	0.71	18	early sowing date 1 2015	21.48
19	early sowing date 1 2015	0.695	19	early sowing date 1 2015	25.18
20	early sowing date 1 2015	0.725	20	early sowing date 1 2015	21.55
21	early sowing date 1 2015	0.61	21	early sowing date 1 2015	25.08
22	early sowing date 1 2015	0.705	22	early sowing date 1 2015	19.92
23	early sowing date 1 2015	0.72	23	early sowing date 1 2015	24.63
24	early sowing date 1 2015	0.76	24	early sowing date 1 2015	24.47
25	early sowing date 1 2015	0.615	25	early sowing date 1 2015	21.37

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
26	early sowing date 1 2015	0.71	26	early sowing date 1 2015	22.5
27	early sowing date 1 2015	0.68	27	early sowing date 1 2015	24
28	early sowing date 1 2015	0.665	28	early sowing date 1 2015	21.93
29	early sowing date 1 2015	0.685	29	early sowing date 1 2015	23.52
30	early sowing date 1 2015	0.65	30	early sowing date 1 2015	23.15
31	early sowing date 1 2015	0.72	31	early sowing date 1 2015	21.15
32	early sowing date 1 2015	0.705	32	early sowing date 1 2015	21.52
33	early sowing date 1 2015	0.735	33	early sowing date 1 2015	20.78
34	early sowing date 1 2015	0.655	34	early sowing date 1 2015	20.33
35	early sowing date 1 2015	0.73	35	early sowing date 1 2015	21.48
36	early sowing date 1 2015	0.68	36	early sowing date 1 2015	23.87
37	early sowing date 1 2015	0.68	37	early sowing date 1 2015	23.1
38	early sowing date 1 2015	0.735	38	early sowing date 1 2015	26.43
39	early sowing date 1 2015	0.715	39	early sowing date 1 2015	25.07
40	early sowing date 1 2015	0.685	40	early sowing date 1 2015	25.52
41	early sowing date 1 2015	0.675	41	early sowing date 1 2015	24.3
42	early sowing date 1 2015	0.67	42	early sowing date 1 2015	24.98
43	early sowing date 1 2015	0.71	43	early sowing date 1 2015	23.22
44	early sowing date 1 2015	0.715	44	early sowing date 1 2015	26.52
45	early sowing date 1 2015	0.705	45	early sowing date 1 2015	26.2
46	early sowing date 1 2015	0.695	46	early sowing date 1 2015	19.55
47	early sowing date 1 2015	0.735	47	early sowing date 1 2015	27.13
48	early sowing date 1 2015	0.7	48	early sowing date 1 2015	24.72
49	early sowing date 1 2015	0.72	49	early sowing date 1 2015	20.28
50	early sowing date 1 2015	0.71	50	early sowing date 1 2015	24.27

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
51	early sowing date 1 2015	0.765	51	early sowing date 1 2015	20.45
52	early sowing date 1 2015	0.74	52	early sowing date 1 2015	22.78
53	early sowing date 1 2015	0.765	53	early sowing date 1 2015	26.05
54	early sowing date 1 2015	0.66	54	early sowing date 1 2015	25.4
55	early sowing date 1 2015	0.685	55	early sowing date 1 2015	26.92
56	early sowing date 1 2015	0.715	56	early sowing date 1 2015	24.4
57	early sowing date 1 2015	0.72	57	early sowing date 1 2015	20.9
58	early sowing date 1 2015	0.72	58	early sowing date 1 2015	22.62
59	early sowing date 1 2015	0.69	59	early sowing date 1 2015	20.4
60	early sowing date 1 2015	0.695	60	early sowing date 1 2015	23.65
61	early sowing date 1 2015	0.69	61	early sowing date 1 2015	22.1
62	early sowing date 1 2015	0.77	62	early sowing date 1 2015	22.68
63	early sowing date 1 2015	0.77	63	early sowing date 1 2015	21.88
64	early sowing date 1 2015	0.72	64	early sowing date 1 2015	20.6
65	early sowing date 1 2015	0.645	65	early sowing date 1 2015	23.23
66	early sowing date 1 2015	0.71	66	early sowing date 1 2015	24.43
67	early sowing date 1 2015	0.68	67	early sowing date 1 2015	25.73
68	early sowing date 1 2015	0.72	68	early sowing date 1 2015	22.93
69	early sowing date 1 2015	0.71	69	early sowing date 1 2015	22.82
70	early sowing date 1 2015	0.72	70	early sowing date 1 2015	21.47
71	early sowing date 1 2015	37.87	71	early sowing date 1 2015	21.82
72	early sowing date 1 2015	0.69	72	early sowing date 1 2015	24.55
73	early sowing date 1 2015	0.67	73	early sowing date 1 2015	24.85
74	early sowing date 1 2015	0.69	74	early sowing date 1 2015	23.83
75	early sowing date 1 2015	0.73	75	early sowing date 1 2015	22.65

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
76	early sowing date 1 2015	0.49	76	early sowing date 1 2015	19.68
77	early sowing date 1 2015	0.725	77	early sowing date 1 2015	26.28
78	early sowing date 1 2015	0.74	78	early sowing date 1 2015	24.73
79	early sowing date 1 2015	0.69	79	early sowing date 1 2015	26
80	early sowing date 1 2015	0.72	80	early sowing date 1 2015	22.67
81	early sowing date 1 2015	0.73	81	early sowing date 1 2015	24.13
82	early sowing date 1 2015	0.67	82	early sowing date 1 2015	22.2
83	early sowing date 1 2015	0.745	83	early sowing date 1 2015	20.97
84	early sowing date 1 2015	0.73	84	early sowing date 1 2015	22.85
85	early sowing date 1 2015	0.675	85	early sowing date 1 2015	23.53
86	early sowing date 1 2015	0.705	86	early sowing date 1 2015	23.22
87	early sowing date 1 2015	0.705	87	early sowing date 1 2015	22.4
88	early sowing date 1 2015	0.7	88	early sowing date 1 2015	22.57
89	early sowing date 1 2015	0.57	89	early sowing date 1 2015	20.57
90	early sowing date 1 2015	0.665	90	early sowing date 1 2015	21.88
91	early sowing date 1 2015	0.695	91	early sowing date 1 2015	21.52
92	early sowing date 1 2015	0.665	92	early sowing date 1 2015	20.73
93	early sowing date 1 2015	0.73	93	early sowing date 1 2015	21.85
94	early sowing date 1 2015	0.625	94	early sowing date 1 2015	22.53
95	early sowing date 1 2015	0.61	95	early sowing date 1 2015	23.95
96	early sowing date 1 2015	0.695	96	early sowing date 1 2015	25.63
97	early sowing date 1 2015	0.75	97	early sowing date 1 2015	20.05
98	early sowing date 1 2015	0.75	98	early sowing date 1 2015	22.27
99	early sowing date 1 2015	0.695	99	early sowing date 1 2015	26.85
100	early sowing date 1 2015	0.68	100	early sowing date 1 2015	20.08

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
101	early sowing date 1 2015	0.745	101	early sowing date 1 2015	22.95
102	early sowing date 1 2015	0.68	102	early sowing date 1 2015	22.18
103	early sowing date 1 2015	0.705	103	early sowing date 1 2015	23.22
104	early sowing date 1 2015	0.73	104	early sowing date 1 2015	25.33
105	early sowing date 1 2015	0.715	105	early sowing date 1 2015	21.78
106	early sowing date 1 2015	0.7	106	early sowing date 1 2015	24.33
107	early sowing date 1 2015	0.705	107	early sowing date 1 2015	22.68
108	early sowing date 1 2015	0.665	108	early sowing date 1 2015	25.72
109	early sowing date 1 2015	0.74	109	early sowing date 1 2015	23.3
110	early sowing date 1 2015	0.71	110	early sowing date 1 2015	19.77
111	early sowing date 1 2015	0.715	111	early sowing date 1 2015	20.93
112	early sowing date 1 2015	0.75	112	early sowing date 1 2015	25.7
113	early sowing date 1 2015	0.67	113	early sowing date 1 2015	23.23
114	early sowing date 1 2015	0.745	114	early sowing date 1 2015	21.18
115	early sowing date 1 2015	0.73	115	early sowing date 1 2015	22.57
116	early sowing date 1 2015	0.63	116	early sowing date 1 2015	25.08
117	early sowing date 1 2015	0.68	117	early sowing date 1 2015	23.97
118	early sowing date 1 2015	0.71	118	early sowing date 1 2015	22.3
119	early sowing date 1 2015	0.675	119	early sowing date 1 2015	20.43
120	early sowing date 1 2015	0.665	120	early sowing date 1 2015	24.13
1	early sowing date 2 2015	0.62			
2	early sowing date 2 2015	0.66			
3	early sowing date 2 2015	0.645			
4	early sowing date 2 2015	0.68			
5	early sowing date 2 2015	0.64			

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
6	early sowing date 2 2015	0.69			
7	early sowing date 2 2015	0.355			
8	early sowing date 2 2015	0.5			
9	early sowing date 2 2015	0.25			
10	early sowing date 2 2015	0.625			
11	early sowing date 2 2015	0.455			
12	early sowing date 2 2015	0.56			
13	early sowing date 2 2015	0.5			
14	early sowing date 2 2015	0.69			
15	early sowing date 2 2015	0.43			
16	early sowing date 2 2015	0.62			
17	early sowing date 2 2015	0.685			
18	early sowing date 2 2015	0.61			
19	early sowing date 2 2015	0.505			
20	early sowing date 2 2015	0.455			
21	early sowing date 2 2015	0.68			
22	early sowing date 2 2015	0.67			
23	early sowing date 2 2015	0.475			
24	early sowing date 2 2015	0.64			
25	early sowing date 2 2015	0.615			
26	early sowing date 2 2015	0.65			
27	early sowing date 2 2015	0.5			
28	early sowing date 2 2015	0.48			
29	early sowing date 2 2015	0.495			
30	early sowing date 2 2015	0.41			

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
31	early sowing date 2 2015	0.545			
32	early sowing date 2 2015	0.445			
33	early sowing date 2 2015	0.41			
34	early sowing date 2 2015	0.555			
35	early sowing date 2 2015	0.505			
36	early sowing date 2 2015	0.55			
37	early sowing date 2 2015	0.565			
38	early sowing date 2 2015	0.49			
39	early sowing date 2 2015	0.555			
40	early sowing date 2 2015	0.57			
41	early sowing date 2 2015	0.64			
42	early sowing date 2 2015	0.35			
43	early sowing date 2 2015	0.46			
44	early sowing date 2 2015	0.605			
45	early sowing date 2 2015	0.595			
46	early sowing date 2 2015	0.45			
47	early sowing date 2 2015	0.445			
48	early sowing date 2 2015	0.52			
49	early sowing date 2 2015	0.395			
50	early sowing date 2 2015	0.52			
51	early sowing date 2 2015	0.605			
52	early sowing date 2 2015	0.645			
53	early sowing date 2 2015	0.505			
54	early sowing date 2 2015	0.505			
55	early sowing date 2 2015	0.59			

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
56	early sowing date 2 2015	0.74			
57	early sowing date 2 2015	0.48			
58	early sowing date 2 2015	0.47			
59	early sowing date 2 2015	0.545			
60	early sowing date 2 2015	0.58			
61	early sowing date 2 2015	0.595			
62	early sowing date 2 2015	0.57			
63	early sowing date 2 2015	0.59			
64	early sowing date 2 2015	0.62			
65	early sowing date 2 2015	0.505			
66	early sowing date 2 2015	0.545			
67	early sowing date 2 2015	0.39			
68	early sowing date 2 2015	0.63			
69	early sowing date 2 2015	0.48			
70	early sowing date 2 2015	0.625			
71	early sowing date 2 2015	0.55			
72	early sowing date 2 2015	0.415			
73	early sowing date 2 2015	0.455			
74	early sowing date 2 2015	0.455			
75	early sowing date 2 2015	0.57			
76	early sowing date 2 2015	0.495			
77	early sowing date 2 2015	0.515			
78	early sowing date 2 2015	0.425			
79	early sowing date 2 2015	0.52			
80	early sowing date 2 2015	0.56			

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
81	early sowing date 2 2015	0.61			
82	early sowing date 2 2015	0.59			
83	early sowing date 2 2015	0.465			
84	early sowing date 2 2015	0.58			
85	early sowing date 2 2015	0.65			
86	early sowing date 2 2015	0.605			
87	early sowing date 2 2015	0.605			
88	early sowing date 2 2015	0.67			
89	early sowing date 2 2015	0.555			
90	early sowing date 2 2015	0.525			
91	early sowing date 2 2015	0.495			
92	early sowing date 2 2015	0.52			
93	early sowing date 2 2015	0.465			
94	early sowing date 2 2015	0.515			
95	early sowing date 2 2015	0.515			
96	early sowing date 2 2015	0.54			
97	early sowing date 2 2015	0.535			
98	early sowing date 2 2015	0.495			
99	early sowing date 2 2015	0.575			
100	early sowing date 2 2015	0.635			
101	early sowing date 2 2015	0.52			
102	early sowing date 2 2015	0.515			
103	early sowing date 2 2015	0.585			
104	early sowing date 2 2015	0.515			
105	early sowing date 2 2015	0.65			

Entry	Environment	2015 NDVI mid grain-fill	ENTRY	Environment	2015 CT mid grain-fill
106	early sowing date 2 2015	0.635			
107	early sowing date 2 2015	0.525			
108	early sowing date 2 2015	0.57			
109	early sowing date 2 2015	0.63			
110	early sowing date 2 2015	0.56			
111	early sowing date 2 2015	0.615			
112	early sowing date 2 2015	0.545			
113	early sowing date 2 2015	0.725			
114	early sowing date 2 2015	0.595			
115	early sowing date 2 2015	0.54			
116	early sowing date 2 2015	0.62			
117	early sowing date 2 2015	0.44			
118	early sowing date 2 2015	0.585			
119	early sowing date 2 2015	0.68			
120	early sowing date 2 2015	0.555			

Table 11: Durum predicted means for CT late boot stage taken on early sowing date 2 2015 and NDVI late boot stage taken on late sowing date 1 2015

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
1	early sowing date 2 2015	11.7	1	late sowing date 1 2015	0.685
2	early sowing date 2 2015	12.02	2	late sowing date 1 2015	0.725
3	early sowing date 2 2015	13.73	3	late sowing date 1 2015	0.705
4	early sowing date 2 2015	14	4	late sowing date 1 2015	0.71
5	early sowing date 2 2015	13.13	5	late sowing date 1 2015	0.75
6	early sowing date 2 2015	12.1	6	late sowing date 1 2015	0.74
7	early sowing date 2 2015	12.25	7	late sowing date 1 2015	0.72
8	early sowing date 2 2015	11.85	8	late sowing date 1 2015	0.76
9	early sowing date 2 2015	13.53	9	late sowing date 1 2015	0.665
10	early sowing date 2 2015	12.25	10	late sowing date 1 2015	0.725
11	early sowing date 2 2015	13.1	11	late sowing date 1 2015	0.745
12	early sowing date 2 2015	13.02	12	late sowing date 1 2015	0.755
13	early sowing date 2 2015	12.12	13	late sowing date 1 2015	0.62
14	early sowing date 2 2015	13.13	14	late sowing date 1 2015	0.735
15	early sowing date 2 2015	12.92	15	late sowing date 1 2015	0.645
16	early sowing date 2 2015	12.05	16	late sowing date 1 2015	0.69

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
17	early sowing date 2 2015	13.02	17	late sowing date 1 2015	0.74
18	early sowing date 2 2015	14.07	18	late sowing date 1 2015	0.755
19	early sowing date 2 2015	12.33	19	late sowing date 1 2015	0.57
20	early sowing date 2 2015	13.37	20	late sowing date 1 2015	0.685
21	early sowing date 2 2015	12.15	21	late sowing date 1 2015	0.725
22	early sowing date 2 2015	12.95	22	late sowing date 1 2015	0.675
23	early sowing date 2 2015	13.28	23	late sowing date 1 2015	0.78
24	early sowing date 2 2015	11.5	24	late sowing date 1 2015	0.69
25	early sowing date 2 2015	14	25	late sowing date 1 2015	0.75
26	early sowing date 2 2015	12.72	26	late sowing date 1 2015	0.64
27	early sowing date 2 2015	13.23	27	late sowing date 1 2015	0.665
28	early sowing date 2 2015	11.78	28	late sowing date 1 2015	0.64
29	early sowing date 2 2015	15.92	29	late sowing date 1 2015	0.74
30	early sowing date 2 2015	13.87	30	late sowing date 1 2015	0.77
31	early sowing date 2 2015	12.62	31	late sowing date 1 2015	0.725
32	early sowing date 2 2015	13.48	32	late sowing date 1 2015	0.65
33	early sowing date 2 2015	11.77	33	late sowing date 1 2015	0.61
34	early sowing date 2 2015	12.68	34	late sowing date 1 2015	0.705

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
35	early sowing date 2 2015	12.7	35	late sowing date 1 2015	0.7
36	early sowing date 2 2015	12.58	36	late sowing date 1 2015	0.68
37	early sowing date 2 2015	13.13	37	late sowing date 1 2015	0.73
38	early sowing date 2 2015	11.5	38	late sowing date 1 2015	0.71
39	early sowing date 2 2015	13.27	39	late sowing date 1 2015	0.685
40	early sowing date 2 2015	11.87	40	late sowing date 1 2015	0.695
41	early sowing date 2 2015	11.98	41	late sowing date 1 2015	0.725
42	early sowing date 2 2015	13.53	42	late sowing date 1 2015	0.635
43	early sowing date 2 2015	13.62	43	late sowing date 1 2015	0.72
44	early sowing date 2 2015	12.8	44	late sowing date 1 2015	0.68
45	early sowing date 2 2015	12.42	45	late sowing date 1 2015	0.72
46	early sowing date 2 2015	12.7	46	late sowing date 1 2015	0.72
47	early sowing date 2 2015	14.2	47	late sowing date 1 2015	0.675
48	early sowing date 2 2015	13.52	48	late sowing date 1 2015	0.66
49	early sowing date 2 2015	13.18	49	late sowing date 1 2015	0.59
50	early sowing date 2 2015	12.03	50	late sowing date 1 2015	0.725
51	early sowing date 2 2015	13.58	51	late sowing date 1 2015	0.765
52	early sowing date 2 2015	12.9	52	late sowing date 1 2015	0.735
53	early sowing date 2 2015	11.97	53	late sowing date 1 2015	0.705
54	early sowing date 2 2015	11.92	54	late sowing date 1 2015	0.715

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
55	early sowing date 2 2015	11.5	55	late sowing date 1 2015	0.64
56	early sowing date 2 2015	13.32	56	late sowing date 1 2015	0.77
57	early sowing date 2 2015	14.05	57	late sowing date 1 2015	0.775
58	early sowing date 2 2015	12.47	58	late sowing date 1 2015	0.695
59	early sowing date 2 2015	12.27	59	late sowing date 1 2015	0.715
60	early sowing date 2 2015	12.48	60	late sowing date 1 2015	0.715
61	early sowing date 2 2015	12.82	61	late sowing date 1 2015	0.715
62	early sowing date 2 2015	12.45	62	late sowing date 1 2015	0.67
63	early sowing date 2 2015	13.27	63	late sowing date 1 2015	0.735
64	early sowing date 2 2015	12.68	64	late sowing date 1 2015	0.74
65	early sowing date 2 2015	13.3	65	late sowing date 1 2015	0.68
66	early sowing date 2 2015	13.47	66	late sowing date 1 2015	0.695
67	early sowing date 2 2015	13	67	late sowing date 1 2015	0.69
68	early sowing date 2 2015	12.73	68	late sowing date 1 2015	0.715
69	early sowing date 2 2015	12.43	69	late sowing date 1 2015	0.695
70	early sowing date 2 2015	12.98	70	late sowing date 1 2015	0.7
71	early sowing date 2 2015	12.98	71	late sowing date 1 2015	0.74
72	early sowing date 2 2015	14.73	72	late sowing date 1 2015	0.64

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
73	early sowing date 2 2015	13.22	73	late sowing date 1 2015	0.72
74	early sowing date 2 2015	12.55	74	late sowing date 1 2015	0.7
75	early sowing date 2 2015	12.77	75	late sowing date 1 2015	0.69
76	early sowing date 2 2015	12.83	76	late sowing date 1 2015	0.705
77	early sowing date 2 2015	12.45	77	late sowing date 1 2015	0.715
78	early sowing date 2 2015	13.38	78	late sowing date 1 2015	0.71
79	early sowing date 2 2015	12.88	79	late sowing date 1 2015	0.66
80	early sowing date 2 2015	13.48	80	late sowing date 1 2015	0.665
81	early sowing date 2 2015	12.6	81	late sowing date 1 2015	0.705
82	early sowing date 2 2015	14.1	82	late sowing date 1 2015	0.745
83	early sowing date 2 2015	12.23	83	late sowing date 1 2015	0.715
84	early sowing date 2 2015	12.27	84	late sowing date 1 2015	0.74
85	early sowing date 2 2015	12.63	85	late sowing date 1 2015	0.775
86	early sowing date 2 2015	13.17	86	late sowing date 1 2015	0.76
87	early sowing date 2 2015	11.98	87	late sowing date 1 2015	0.65
88	early sowing date 2 2015	13.02	88	late sowing date 1 2015	0.73
89	early sowing date 2 2015	14.22	89	late sowing date 1 2015	0.73
90	early sowing date 2 2015	13.3	90	late sowing date 1 2015	0.74
91	early sowing date 2 2015	13.33	91	late sowing date 1 2015	0.75
92	early sowing date 2 2015	12.83	92	late sowing date 1 2015	0.755

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
93	early sowing date 2 2015	14.93	93	late sowing date 1 2015	0.715
94	early sowing date 2 2015	13.12	94	late sowing date 1 2015	0.7
95	early sowing date 2 2015	13.68	95	late sowing date 1 2015	0.65
96	early sowing date 2 2015	12.85	96	late sowing date 1 2015	0.68
97	early sowing date 2 2015	12.37	97	late sowing date 1 2015	0.615
98	early sowing date 2 2015	12.25	98	late sowing date 1 2015	0.765
99	early sowing date 2 2015	12.58	99	late sowing date 1 2015	0.735
100	early sowing date 2 2015	12.07	100	late sowing date 1 2015	0.76
101	early sowing date 2 2015	12.9	101	late sowing date 1 2015	0.675
102	early sowing date 2 2015	13.25	102	late sowing date 1 2015	0.68
103	early sowing date 2 2015	12.07	103	late sowing date 1 2015	0.725
104	early sowing date 2 2015	12.53	104	late sowing date 1 2015	0.77
105	early sowing date 2 2015	13.63	105	late sowing date 1 2015	0.655
106	early sowing date 2 2015	11.73	106	late sowing date 1 2015	0.725
107	early sowing date 2 2015	12.32	107	late sowing date 1 2015	0.74
108	early sowing date 2 2015	13.82	108	late sowing date 1 2015	0.695
109	early sowing date 2 2015	13.15	109	late sowing date 1 2015	0.745
110	early sowing date 2 2015	14.78	110	late sowing date 1 2015	0.705

ENTRY	Environment	CT late boot stage	ENTRY	Environment	NDVI late boot stage
111	early sowing date 2 2015	14.07	111	late sowing date 1 2015	0.725
112	early sowing date 2 2015	13.38	112	late sowing date 1 2015	0.71
113	early sowing date 2 2015	13.02	113	late sowing date 1 2015	0.745
114	early sowing date 2 2015	13.95	114	late sowing date 1 2015	0.775
115	early sowing date 2 2015	13.53	115	late sowing date 1 2015	0.765
116	early sowing date 2 2015	15.35	116	late sowing date 1 2015	0.705
117	early sowing date 2 2015	13.22	117	late sowing date 1 2015	0.66
118	early sowing date 2 2015	14.15	118	late sowing date 1 2015	0.695
119	early sowing date 2 2015	13.47	119	late sowing date 1 2015	0.74
120	early sowing date 2 2015	13.18	120	late sowing date 1 2015	0.73

Table 12: Durum wheat predicted means for NDVI late grain-fill taken on late sowing date 2 2015 and NDVI early boot stage taken on early sowing date 1 2015

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
1	late sowing date 2 2015	0.42	1	early sowing date 1 2015	0.7629
2	late sowing date 2 2015	0.415	2	early sowing date 1 2015	0.4078
3	late sowing date 2 2015	0.485	3	early sowing date 1 2015	0.4031
4	late sowing date 2 2015	0.5	4	early sowing date 1 2015	0.0882

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
5	late sowing date 2 2015	0.26	5	early sowing date 1 2015	0.426
6	late sowing date 2 2015	0.53	6	early sowing date 1 2015	0.0895
7	late sowing date 2 2015	0.53	7	early sowing date 1 2015	0.0891
8	late sowing date 2 2015	0.495	8	early sowing date 1 2015	0.0889
9	late sowing date 2 2015	0.365	9	early sowing date 1 2015	0.0881
10	late sowing date 2 2015	0.33	10	early sowing date 1 2015	0.4314
11	late sowing date 2 2015	0.355	11	early sowing date 1 2015	0.0846
12	late sowing date 2 2015	0.34	12	early sowing date 1 2015	0.426
13	late sowing date 2 2015	0.365	13	early sowing date 1 2015	0.0824
14	late sowing date 2 2015	0.26	14	early sowing date 1 2015	0.4017
15	late sowing date 2 2015	0.32	15	early sowing date 1 2015	0.0882
16	late sowing date 2 2015	0.39	16	early sowing date 1 2015	0.0894
17	late sowing date 2 2015	0.25	17	early sowing date 1 2015	0.0887
18	late sowing date 2 2015	0.52	18	early sowing date 1 2015	0.0883
19	late sowing date 2 2015	0.32	19	early sowing date 1 2015	0.409

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
20	late sowing date 2 2015	0.355	20	early sowing date 1 2015	0.0854
21	late sowing date 2 2015	0.275	21	early sowing date 1 2015	0.4069
22	late sowing date 2 2015	0.335	22	early sowing date 1 2015	0.3929
23	late sowing date 2 2015	0.46	23	early sowing date 1 2015	0.0879
24	late sowing date 2 2015	0.395	24	early sowing date 1 2015	0.4277
25	late sowing date 2 2015	0.67	25	early sowing date 1 2015	0.4207
26	late sowing date 2 2015	0.425	26	early sowing date 1 2015	0.4161
27	late sowing date 2 2015	0.245	27	early sowing date 1 2015	0.711
28	late sowing date 2 2015	0.34	28	early sowing date 1 2015	0.6954
29	late sowing date 2 2015	0.4	29	early sowing date 1 2015	0.0864
30	late sowing date 2 2015	0.335	30	early sowing date 1 2015	0.0861
31	late sowing date 2 2015	0.35	31	early sowing date 1 2015	0.0843
32	late sowing date 2 2015	0.52	32	early sowing date 1 2015	0.4041
33	late sowing date 2 2015	0.36	33	early sowing date 1 2015	0.4038
34	late sowing date 2 2015	0.365	34	early sowing date 1 2015	0.0883
35	late sowing date 2 2015	0.41	35	early sowing date 1 2015	0.3825
36	late sowing date 2 2015	0.365	36	early sowing date 1 2015	0.3872

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
37	late sowing date 2 2015	0.275	37	early sowing date 1 2015	0.0815
38	late sowing date 2 2015	0.285	38	early sowing date 1 2015	0.0892
39	late sowing date 2 2015	0.49	39	early sowing date 1 2015	0.4079
40	late sowing date 2 2015	0.44	40	early sowing date 1 2015	0.0874
41	late sowing date 2 2015	0.285	41	early sowing date 1 2015	0.0839
42	late sowing date 2 2015	0.36	42	early sowing date 1 2015	0.0878
43	late sowing date 2 2015	0.365	43	early sowing date 1 2015	0.0878
44	late sowing date 2 2015	0.3	44	early sowing date 1 2015	0.3877
45	late sowing date 2 2015	0.285	45	early sowing date 1 2015	0.3059
46	late sowing date 2 2015	0.205	46	early sowing date 1 2015	0.4044
47	late sowing date 2 2015	0.465	47	early sowing date 1 2015	0.7207
48	late sowing date 2 2015	0.3	48	early sowing date 1 2015	0.0846
49	late sowing date 2 2015	0.28	49	early sowing date 1 2015	0.0853
50	late sowing date 2 2015	0.38	50	early sowing date 1 2015	0.4317
51	late sowing date 2 2015	0.52	51	early sowing date 1 2015	0.0889

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
52	late sowing date 2 2015	0.425	52	early sowing date 1 2015	0.0895
53	late sowing date 2 2015	0.515	53	early sowing date 1 2015	0.0886
54	late sowing date 2 2015	0.425	54	early sowing date 1 2015	0.4083
55	late sowing date 2 2015	0.24	55	early sowing date 1 2015	0.0838
56	late sowing date 2 2015	0.52	56	early sowing date 1 2015	0.0879
57	late sowing date 2 2015	0.35	57	early sowing date 1 2015	0.7488
58	late sowing date 2 2015	0.34	58	early sowing date 1 2015	0.0895
59	late sowing date 2 2015	0.39	59	early sowing date 1 2015	0.0877
60	late sowing date 2 2015	0.475	60	early sowing date 1 2015	0.0875
61	late sowing date 2 2015	0.365	61	early sowing date 1 2015	0.4232
62	late sowing date 2 2015	0.25	62	early sowing date 1 2015	0.7216
63	late sowing date 2 2015	0.33	63	early sowing date 1 2015	0.431
64	late sowing date 2 2015	0.29	64	early sowing date 1 2015	0.4204
65	late sowing date 2 2015	0.375	65	early sowing date 1 2015	0.0892
66	late sowing date 2 2015	0.415	66	early sowing date 1 2015	0.0882
67	late sowing date 2 2015	0.485	67	early sowing date 1 2015	0.0887
68	late sowing date 2 2015	0.28	68	early sowing date 1 2015	0.7159

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
69	late sowing date 2 2015	0.405	69	early sowing date 1 2015	0.087
70	late sowing date 2 2015	0.29	70	early sowing date 1 2015	0.0839
71	late sowing date 2 2015	0.29	71	early sowing date 1 2015	0.087
72	late sowing date 2 2015	0.395	72	early sowing date 1 2015	0.4234
73	late sowing date 2 2015	0.425	73	early sowing date 1 2015	0.7581
74	late sowing date 2 2015	0.48	74	early sowing date 1 2015	0.09
75	late sowing date 2 2015	0.355	75	early sowing date 1 2015	0.086
76	late sowing date 2 2015	0.325	76	early sowing date 1 2015	0.0886
77	late sowing date 2 2015	0.385	77	early sowing date 1 2015	0.4345
78	late sowing date 2 2015	0.245	78	early sowing date 1 2015	0.0842
79	late sowing date 2 2015	0.37	79	early sowing date 1 2015	0.0882
80	late sowing date 2 2015	0.44	80	early sowing date 1 2015	0.085
81	late sowing date 2 2015	0.375	81	early sowing date 1 2015	0.0868
82	late sowing date 2 2015	0.32	82	early sowing date 1 2015	0.0897
83	late sowing date 2 2015	0.335	83	early sowing date 1 2015	0.0846

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
84	late sowing date 2 2015	0.315	84	early sowing date 1 2015	0.0892
85	late sowing date 2 2015	0.245	85	early sowing date 1 2015	0.3944
86	late sowing date 2 2015	0.355	86	early sowing date 1 2015	0.084
87	late sowing date 2 2015	0.335	87	early sowing date 1 2015	0.0843
88	late sowing date 2 2015	0.395	88	early sowing date 1 2015	0.3836
89	late sowing date 2 2015	0.365	89	early sowing date 1 2015	0.4129
90	late sowing date 2 2015	0.305	90	early sowing date 1 2015	0.7391
91	late sowing date 2 2015	0.455	91	early sowing date 1 2015	0.0897
92	late sowing date 2 2015	0.38	92	early sowing date 1 2015	0.43
93	late sowing date 2 2015	0.325	93	early sowing date 1 2015	0.4086
94	late sowing date 2 2015	0.365	94	early sowing date 1 2015	0.4044
95	late sowing date 2 2015	0.375	95	early sowing date 1 2015	0.0877
96	late sowing date 2 2015	0.42	96	early sowing date 1 2015	0.4049
97	late sowing date 2 2015	0.545	97	early sowing date 1 2015	0.371
98	late sowing date 2 2015	0.465	98	early sowing date 1 2015	0.0888
99	late sowing date 2 2015	0.33	99	early sowing date 1 2015	0.4236
100	late sowing date 2 2015	0.56	100	early sowing date 1 2015	0.0832

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
101	late sowing date 2 2015	0.28	101	early sowing date 1 2015	0.0873
102	late sowing date 2 2015	0.4	102	early sowing date 1 2015	0.0897
103	late sowing date 2 2015	0.31	103	early sowing date 1 2015	0.7738
104	late sowing date 2 2015	0.47	104	early sowing date 1 2015	0.0866
105	late sowing date 2 2015	0.255	105	early sowing date 1 2015	0.3931
106	late sowing date 2 2015	0.335	106	early sowing date 1 2015	0.4218
107	late sowing date 2 2015	0.285	107	early sowing date 1 2015	0.4213
108	late sowing date 2 2015	0.29	108	early sowing date 1 2015	0.0876
109	late sowing date 2 2015	0.475	109	early sowing date 1 2015	0.0885
110	late sowing date 2 2015	0.5	110	early sowing date 1 2015	0.7401
111	late sowing date 2 2015	0.485	111	early sowing date 1 2015	0.7531
112	late sowing date 2 2015	0.405	112	early sowing date 1 2015	0.0849
113	late sowing date 2 2015	0.315	113	early sowing date 1 2015	0.7444
114	late sowing date 2 2015	0.495	114	early sowing date 1 2015	0.088
115	late sowing date 2 2015	0.35	115	early sowing date 1 2015	0.7882

ENTRY	Environment	NDVI late grain-fill	Entry	Environment	NDVI early boot stage
116	late sowing date 2 2015	0.34	116	early sowing date 1 2015	0.0867
117	late sowing date 2 2015	0.285	117	early sowing date 1 2015	0.3999
118	late sowing date 2 2015	0.425	118	early sowing date 1 2015	0.0891
119	late sowing date 2 2015	0.29	119	early sowing date 1 2015	0.4139
120	late sowing date 2 2015	0.365	120	early sowing date 1 2015	0.0889

Table 13: Chemical spray application in 2014

Date	Chemical group	Commercial name	Usage	Chemical active ingredient
17/10/2014	C	Rebuke 430	145 mL/ha	Tebuconazole
26/6/2014	I	Tordon 242	1 L/ha	Picloram
26/6/2014	B	Metfuron	5 g/ha	Metsulfuron methyl
26/6/2014	3	Folicur 430SC	145 mL/ha	Tebuconazole
26/6/2014	Wetter	BS1000	100 mL/ha	Alcohol alkoxylate

Table 14: Chemical spray applications in 2015

Date	Chemical group	Commercial name	Usage	Chemical active ingredient
21/09/2015	3	Folicur	145 mL/ha	Tebuconazole
21/09/2015	B	Ally	7 g/ha	Metsulfuron methyl
1/09/2015	I	LVE MCPA	500 mL/ha	2-Ethyl Hexyl Ester
1/09/2015	B	Ally	5 g/ha	Metsulfuron methyl
1/09/2015	3	Folicur	145 mL/ha	Tebuconazole
1/09/2015	Wetter	BS1000	100 mL/ha	Alcohol alkoxylate

Table 15: yield, TKW and Screenings means from the phenotypic analysis used for GWAS

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
GOUBARA-1/2*SOKOLL	CMSA04M01020T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-12ZTM-02Y-0B	1	1	1	4236.8	36.5	5.5
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-1WGY-0B	2	1	1	4352.5	40.4	5.0
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-23AP-0AP-0AP-8AP-0AP	3	1	1	4111.1	39.5	5.4
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-35ZTM-02Y-0B	4	1	1	4300.8	38.7	5.7
INQALAB 91*2/TUKURU//WHEAR	CGSS05Y00463S-0B-099Y-099M-099NJ-099NJ-3WGY-0B	5	1	1	4330.2	39.2	5.6
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B	6	1	1	4365.9	36.4	5.7
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-6B	7	1	1	4482.1	39.8	5.3
PBW343	CM85836-4Y-0M-0Y-8M-0Y-0IND	8	1	1	4360.7	37.7	5.8
JANZ	JANZ	9	1	1	4259.1	35.6	5.2
N-ABYAD-13	N-ABYAD-13	10	1	1	4336.4	37.5	5.7
WH 542	WH 542	11	1	1	4341.8	37.1	5.5
CRUSADER	CRUSADER	12	1	1	4474.1	39.3	5.5
SOKOLL	CMSS97M00316S-0P5M-0P5Y-42M-0Y	13	1	1	4362.8	38.4	5.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ZAKIA-10	ICW98.0030-1AP-0APS-030AP-8AP-1AP-0AP	14	1	1	4264.8	40.1	5.3
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-2ZTM-03Y-0B	15	1	1	4304.5	38.9	5.5
BERKUT	CMSS96M05638T-040Y-5M-010SY-010M-010SY-1M-0Y	16	1	1	4377.5	37.0	5.0
LIVINGSTON	LIVINGSTON	17	1	1	4477.1	38.0	6.2
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-11M-0Y	18	1	1	4403.2	38.4	5.9
EGA GREGORY	EGA GREGORY	19	1	1	4320.4	38.1	5.8
ATTILA*2/PBW65	CGSS96B00123F-099M-037Y-099M-26Y-0B-0SY	20	1	1	4156.5	36.6	5.5
SPITFIRE	SPITFIRE	21	1	1	4394.5	38.7	6.0
WAXWING*2/TUKURU	CGSS01B00058T-099Y-099M-099M-099Y-099M-49Y-0B	157	1	1	4285.7	39.4	5.6
QG 4.37A/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92	CMSA05M00708T-050Y-040ZTM-040ZTY-4ZTM-04Y-0B	223	1	1	4343.4	39.1	5.6
NSM*4/14-2//FRTL/2*PIFED/3/VORB	CMSA05M00650T-050Y-040ZTM-040ZTY-21ZTM-02Y-0B	224	1	1	4428.6	39.0	5.6
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-8ZTM-03Y-0B	225	1	1	4366.6	39.0	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B	226	1	1	4404.3	40.0	5.6
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-32ZTM-02Y-0B	227	1	1	4416.1	39.7	5.6
SOKOLL//PBW343*2/KUKUNA/3/ATTILA/PASTOR	CMSA05Y01188T-040M-040ZTP0Y-040ZTM-040SY-2ZTM-01Y-0B	228	1	1	4410.4	39.4	5.6
SOKOLL*2//TACUPETO F2001*2/KUKUNA	CMSA05Y01226T-040M-040ZTP0Y-040ZTM-040SY-22ZTM-04Y-0B	229	1	1	4394.2	39.7	5.6
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV 92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-9ZTM-04Y-0B	230	1	1	4389.6	39.7	5.6
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV 92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-15ZTM-01Y-0B	231	1	1	4343.6	39.9	5.6
SW89-5124*2/FASAN/3/ALTAR 84/AE.SQ//2*OPATA	CMSA04M00335S-040ZTP0Y-040ZTM-040SY-16ZTM-04Y-0B	232	1	1	4410.1	39.3	5.6
SOKOLL//TACUPETO F2001*2/KUKUNA	CMSA04M00346S-040ZTP0Y-040ZTM-040SY-28ZTM-01Y-0B	233	1	1	4432.7	39.7	5.6
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-19ZTM-03Y-0B	234	1	1	4362.3	39.0	5.6
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-4ZTM-04Y-0B	235	1	1	4340.7	39.7	5.6
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON	CMSA05Y00178S-040ZTY-040ZTM-040Y-6ZTM-02Y-0B	236	1	1	4381.6	39.3	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PI94625/AE.SQUARROSA (372)//3*PASTOR							
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	237	1	1	4381.6	39.5	5.6
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-24ZTM-04Y-0B	238	1	1	4349.2	39.5	5.6
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-5ZTM-03Y-0B	239	1	1	4362.7	39.7	5.6
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	240	1	1	4369.2	39.4	5.6
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-2ZTM-01Y-0B	241	1	1	4304.1	39.5	5.6
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-01Y-0B	242	1	1	4339.3	39.6	5.6
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-03Y-0B	243	1	1	4321.8	39.5	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-3B	244	1	1	4428.6	39.5	5.6
ATTILA*2//CHIL/BUC*2/3/KUKUNA	CMSS05Y00671T-099TOPM-099Y-099M-099Y-099ZTM-2WGY-0B	245	1	1	4398.1	39.1	5.6
CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/PASTOR/7/KAUZ/PASTOR//PBW343	CMSS05B00592S-099Y-099M-099Y-099ZTM-17WGY-0B	246	1	1	4361.5	39.7	5.6
ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARROSA (224)//2*OPATA	CMSS05B00663S-099Y-099M-099Y-099ZTM-13WGY-0B	247	1	1	4377.2	39.4	5.6
WBLL1*2/KUKUNA*2//WHEAR	CGSS05B00174T-099TOPY-099M-099NJ-099NJ-5WGY-0B	248	1	1	4418.1	39.6	5.6
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099Y-099ZTM-10WGY-0B	249	1	1	4354.2	39.6	5.6
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-3WGY-0B	250	1	1	4346.3	39.3	5.6
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-5WGY-0B	251	1	1	4299.7	39.3	5.6
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099Y-099ZTM-12WGY-0B	252	1	1	4391.0	40.0	5.6
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-2WGY-0B	253	1	1	4302.9	39.8	5.6
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-6WGY-0B	254	1	1	4394.2	39.6	5.6
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-8WGY-0B	255	1	1	4330.3	39.6	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW343*2/KHVAKI//PARUS/3/PBW343/PASTOR	CGSS05B00271T-099TOPY-099M-099NJ-099NJ-17WGY-0B	256	1	1	4385.2	39.8	5.6
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-17WGY-0B	257	1	1	4377.2	39.4	5.6
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-20WGY-0B	258	1	1	4377.2	39.4	5.6
ATTILA*2/PBW65//KIRITATI/3/WAXWING/KIRITATI	CGSS05B00299T-099TOPY-099M-099Y-099ZTM-19WGY-0B	259	1	1	4334.3	39.6	5.6
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-3AP-0AP	260	1	1	4261.1	39.8	5.6
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-5AP-0AP	261	1	1	4309.8	39.7	5.6
ALTAR 84/AE.SQUARROSA (191)//OPATA/3/SKAUZ	CMSS98Y05580S-040Y-0B-0MXI-0AP-0AP-15AP-0AP	262	1	1	4398.0	38.9	5.6
VANS/3/CNDRS/ANA//CNDRS/MUSS/4/CHAM-6	ICW99-0336-12AP-0AP-0AP-7AP-0AP	263	1	1	4340.6	39.5	5.6
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-13AP-0AP-0AP-5AP-0AP	264	1	1	4358.1	39.0	5.6
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-2AP-0AP	265	1	1	4329.9	39.0	5.6
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-5AP-0AP	266	1	1	4437.4	39.6	5.6
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-8AP-0AP	267	1	1	4358.6	39.5	5.6
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-12AP-0AP-0AP-45AP-0AP	268	1	1	4377.2	39.4	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-4AP-0AP-0AP-29AP-0AP	269	1	1	4377.2	39.4	5.6
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-4AP-0AP	270	1	1	4464.2	38.8	5.6
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-9AP-0AP	271	1	1	4377.0	39.5	5.6
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-25AP-0AP-0AP-4AP-0AP	272	1	1	4482.6	39.3	5.6
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-7M-0Y-01B-0Y	273	1	1	4355.1	39.0	5.6
SUNCO	SUNCO	274	1	1	4355.2	38.7	5.6
SHIHAB-3	CMSS97M00652S-0B-0AP-1AP-0APS-0AP-11AP-3AP-0AP	275	1	1	4427.2	38.7	5.6
LEITH-3	ICW97.0717-0APS-1AP-0APS-050AP-0APS-16AP-0AP	276	1	1	4390.3	39.4	5.6
PBW343*2/KUKUNA//PBW343*2/KUKUNA	CGSS04Y00099S-099Y-099M-099Y-099M-8WGY-0B	277	1	1	4421.8	39.6	5.6
PRL/2*PASTOR//PBW343*2/KUKUNA	CMSS04Y00086S-0Y-099ZTM-099Y-099M-4WGY-0B	278	1	1	4436.1	39.6	5.6
CROC_1/AE.SQUARROSA (213)//PGO/3/CMH81.38/2*KAUZ/4/BERKUT	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-7ZTY-03M-0Y	279	1	1	4351.2	39.3	5.6
ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE #10/8/OPATA/10/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/2*WEAVER/11/PRL/2*PASTOR	CMSA02Y00426T-040M-040P0Y-040ZTM-040SY-040M-5ZTY-01M-0Y	280	1	1	4377.2	39.4	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-7ZTM-03Y-0B	281	1	1	4369.6	39.0	5.6
BERKUT/HTG	CMSA04Y00607S-130ZTP0Y-010M-010SY-2M-04Y-0B	282	1	1	4426.3	39.1	5.6
SOKOLL//PRL/2*PASTOR	CMSA04Y00608S-150ZTP0Y-010M-010SY-3M-02Y-0B	283	1	1	4410.4	39.6	5.6
SW89-5124*2/FASAN/6/CHIBIA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER	CMSA02Y00249S-040ZTM-040HTY-040M-040SY-10M-0Y	284	1	1	4399.8	40.2	5.6
SOKOLL/WBLL1	PTSS02Y00021S-0Y-030ZTM-040SY-040M-14Y-0M-0SY	285	1	1	4434.7	39.1	5.6
CROC_1/AE.SQUARROSA (224)//OPATA/3/SOKOLL	PTSS02B00065S-0Y-0B-0Y-0B-32Y-0M-0SY	286	1	1	4394.7	39.5	5.6
MEX94.2.19/PUB94.15.1.12	PTSS02B00074S-0Y-0B-0Y-0B-32Y-0M-0SY	287	1	1	4322.0	39.0	5.6
SOKOLL//W15.92/WBLL1	PTSS02B00088T-0TOPY-0B-0Y-0B-5Y-0M-0SY	288	1	1	4340.4	39.2	5.6
OAX93.24.35//SOKOLL/WBLL1	PTSS02B00099T-0TOPY-0B-0Y-0B-35Y-0M-0SY	289	1	1	4401.2	39.6	5.6
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	PTSS02B00102T-0TOPY-0B-0Y-0B-11Y-0M-0SY	290	1	1	4423.3	39.0	5.6
WBLL4//OAX93.24.35/WBLL1	PTSS02B00110T-0TOPY-0B-0Y-0B-21Y-0M-0SY	291	1	1	4355.6	39.4	5.6
SUNTOP	SUNTOP	22	4	1	4455.7	38.0	7.3
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAU	CMSS06B00734T-099TOPY-099ZTM-099Y-099M-25WGY-0B	23	4	1	4205.9	41.1	5.3

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
Z/4/HUITES/6/KAUZ//							
ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES BECARD/5/PGO//CROC_1/AE.SQUARROSA (224)/3/2*BORL95/4/CIRCUS	CMSS06B00411S-0Y-099ZTM-099Y-099M-12WGY-0B	24	4	1	4485.8	39.7	6.0
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/VORB	CMSA06M00431S-040ZTM-040ZTY-31ZTM-04Y-0B	25	4	1	4441.7	40.6	5.6
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-67ZTM-0Y-0B	26	4	1	4467.9	40.4	5.6
PBW343*2/KUKUNA/3/PGO/SERI//BAV92	CMSS06B00495S-0Y-099ZTM-099NJ-099NJ-12WGY-0B	101	4	1	4344.1	40.9	6.4
FRTL/2*PIFED/4/CROC_1/AE.SQUARROSA (205)//KAUZ/3/PIFED		103	4	1	4304.8	38.5	5.7
T.DICOCCON PI225332/AE.SQUARROSA (895)//WBLL1/3/2*WBLL1/4/SOKOLL	CMSA06M00709S-040ZTM-040ZTY-21ZTM-0Y-0B	104	4	1	4359.8	40.1	5.3
Wyalkatchem	MACHETE/84W129-504	156	4	1	4368.8	39.1	5.6
QAFZAH-31	CMSS93Y00621S-4AP-3AP-4AP-0APS-0AP	158	4	1	4350.8	39.7	5.6
ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/URES/JUN//KAUZ/4/WBLL1/5/MILAN/S87230//BAV92	CMSS06B00201S-0Y-099ZTM-099Y-099M-14WGY-0B	159	4	1	4395.5	39.0	5.6
QUAIU #3//MILAN/AMSEL	CMSS06B00640S-0Y-099ZTM-099Y-099M-7WGY-0B	160	4	1	4377.2	39.4	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B	161	4	1	4324.0	39.7	5.6
WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN	CMSS06B00787T-099TOPY-099ZTM-099Y-099M-6WGY-0B	162	4	1	4386.0	39.5	5.6
WBLL1*2/KURUKU/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/7/WBLL1*2/KURUKU	CMSS06B00802T-099TOPY-099ZTM-099Y-099M-12WGY-0B	163	4	1	4349.2	39.2	5.6
WAXWING*2/HEILO	CMSS06B00915T-099TOPY-099ZTM-099Y-099M-8WGY-0B	164	4	1	4375.9	39.0	5.6
BAV92//IRENA/KAUZ/3/HUITES/4/GONDO/TNMU/5/BAV92//IRENA/KAUZ/3/HUITES	CMSS06B00918T-099TOPY-099ZTM-099Y-0FUS-6WGY-0B	165	4	1	4363.3	39.5	5.6
ATTILA*2/PBW65*2/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B	166	4	1	4355.3	39.4	5.6
ROLF07*2/3/PRINIA/PASTOR//HUITES	CMSS06Y00609T-099TOPM-099Y-099ZTM-099Y-099M-19WGY-0B	167	4	1	4359.9	39.3	5.6
MUNAL #1/FRANCOLIN #1	CMSS06B00001S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	168	4	1	4377.2	39.4	5.6
TRCH/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00314S-0Y-099ZTM-099NJ-099NJ-21WGY-0B	169	4	1	4377.6	39.1	5.6
PFAU/SERI.1B//AMAD/3/WAXWING/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00318S-0Y-099ZTM-099NJ-099NJ-25WGY-0B	170	4	1	4393.4	39.3	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KBIRD//INQALAB 91*2/TUKURU	CMSS06B00485S-0Y-099ZTM-099Y-099M-7WGY-0B	171	4	1	4348.4	39.7	5.6
FRNCLN/ROLF07	CMSS06B00013S-0Y-099ZTM-099Y-099M-9WGY-0B	172	4	1	4400.8	39.1	5.6
PVN/5/2*REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00975T-099TOPY-099ZTM-099Y-099M-9WGY-0B	173	4	1	4428.5	39.1	5.6
WBLL1*2/BRAMBLING/5/WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ		174	4	1	4377.2	39.4	5.6
WBLL1*2/TUKURU//FN/2*PASTOR/3/FRET2/KIRITATI	CMSS06B00926T-099TOPY-099ZTM-099Y-0FUS-18WGY-0B	175	4	1	4205.4	39.7	5.6
FRAME*2/3/URES/JUN//KAUZ/4/BAU//PRL/VEE#6/3/FRAME/5/SLVS/ATTILA//WBLL1	CMSA06M00058T-034(PINBD1BHET)Y-040ZTM-021(PINBD1BPOS)ZTY-12ZTM-04Y-0B	176	4	1	4377.2	39.4	5.6
ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC		177	4	1	4353.6	39.2	5.6
PFAU/SERI.1B//AMAD/3/WAXWING/4/BABAX/LR42//BABAX*2/3/KURUKU	CMSS06B00033S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	178	4	1	4340.5	39.2	5.6
QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CMSS06B00109S-0Y-099ZTM-099NJ-099NJ-13WGY-0B	179	4	1	4377.2	39.4	5.6
PAURAQ/4/PFAU/SERI.1B//AMAD/3/WAXWING	CMSS06B00015S-0Y-099ZTM-099NJ-099NJ-1WGY-0B	180	4	1	4349.2	38.7	5.6
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-5WGY-0B	181	4	1	4430.9	39.0	5.6
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-	182	4	1	4386.3	39.2	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
	099ZTM-099NJ-099NJ-22WGY-0B						
WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX	CMSS06Y00885T-099TOPM-099Y-099ZTM-099NJ-099NJ-26WGY-0B	183	4	1	4419.6	39.3	5.6
DUCULA/GONDO//SOKOLL	CMSA06M00645S-040ZTM-040ZTY-19ZTM-03Y-0B	184	4	1	4383.4	39.6	5.6
EGA BONNIE ROCK/4/MILAN/KAUZ//PRINIA/3/BAV92	CMSA06Y00125S-040ZTP0Y-040ZTM-040SY-2ZTM-02Y-0B	185	4	1	4398.2	39.8	5.6
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-20ZTM-0Y-0B	186	4	1	4413.6	38.8	5.6
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-28ZTM-01Y-0B	187	4	1	4383.2	39.0	5.6
MILAN/KAUZ//PRINIA/3/BAV92/4/2*SOKOLL	CMSA06M00017T-030(CSLV34HET)Y-040ZTM-049(CSLV34POS)ZTY-68ZTM-0Y-0B	188	4	1	4295.6	40.1	5.6
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-11ZTM-0Y-0B	189	4	1	4339.0	39.9	5.6
ANNUELLO*2/4/92.001E7.32.5/3/PRL/SARA//TSI/VEE#5	CMSA06Y00718T-085(CRE1M19)M-040ZTP0Y-040ZTM-040SY-6ZTM-0Y-0B	190	4	1	4377.2	39.4	5.6
HUANIL/5/2*CNO79//PF70354/MUS/3/PASTOR/4/BAV92	CMSA05M00750T-050Y-041ZTM-040ZTY-040ZTM-040SY-10ZTM-0Y-0B	191	4	1	4337.5	38.7	5.6
EGA BONNIE ROCK/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.	CMSA05M00023S-0130ZTM-039(LR34HOM+HET)Z	192	4	1	4347.8	39.3	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SQUARROSA (208)/5/2*WESTONIA	TY-040ZTM-040SY-6ZTM-0Y-0B						
PBW343*2/KUKUNA//WBLL1*2/KUKUNA	CMSA05M00118S-0100ZTM-029(LR34 HOM+HET)ZTY-040ZTM-040SY-45ZTM-0Y-0B	193	4	1	4377.4	39.7	5.6
SLVS/ATTILA//WBLL1/4/FRAME*2/3/URES/JUN//KAUZ	CMSA05M00140S-021(CRE1M19-GWM577BO1)M-028(BO1 POS& CRE1 POS)ZTY-040ZTM-040SY-11ZTM-0Y-0B	194	4	1	4405.1	39.3	5.6
VORB/4/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/5/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM	CMSA06Y00835T-040ZTM-040ZTP0Y-040ZTM-040P0Y-3ZTM-02Y-0B	195	4	1	4365.6	39.1	5.6
VORB/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA/7/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	CMSA06Y00836T-040ZTM-040ZTP0Y-040ZTM-040P0Y-26ZTM-01Y-0B	196	4	1	4381.1	39.0	5.6
CHIH95.7.4//INQALAB91*2/KUKUNA	PTSS06GHB00007S-0Y-040ZTM-040ZTY-11ZTM-0Y-0B	197	4	1	4275.7	38.7	5.6
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/SKAUZ/BAV92	CMSA06M00430S-040ZTM-0NJ-0NJ-18Y-3B-0Y	198	4	1	4341.6	39.3	5.6
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-4Y-1B-0Y	199	4	1	4353.8	39.1	5.6
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-9Y-1B-0Y	200	4	1	4349.5	39.5	5.6
MACE	WYALKATCHEM/STYLET//WYALKATCHEM	201	4	1	4354.5	38.5	5.6

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SCOUT	SCOUT	202	4	1	4398.3	38.9	5.6
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	SHAMIEKH-3	203	4	1	4420.3	39.5	5.6
BABAX/LR39//BABAX/3/VORB/4/SUNCO/2*PASTOR	CMSA06Y00792T-040ZTM-040ZTP0Y-040ZTM-040SY-28ZTM-02Y-0B	204	4	1	4378.5	39.8	5.6
HEILO//SUNCO/2*PASTOR	CMSA06Y00492S-040ZTY-040ZTM-040SY-6ZTM-0Y-0B	205	4	1	4440.5	39.2	5.6
CHAM-4/SHUHAS/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB	REYNA-24	206	4	1	4375.9	39.3	5.6
SOKOLL//INQALAB 91*2/KUKUNA	PTSS06GHB00021S-0Y-040ZTM-040ZTY-5ZTM-0Y-0B	207	4	1	4356.0	39.2	5.6
ZAIN-4	ZAIN-4	208	4	1	4371.8	39.4	5.6
HAALA-49	HAALA-49	209	4	1	4364.3	39.5	5.6
ZAKIA-15	ZAKIA-15	210	4	1	4402.6	38.7	5.6
ALATHEER-5	ALATHEER-5	211	4	1	4437.1	38.8	5.6
ZAHABYA-2	ZAHABYA-2	212	4	1	4378.9	39.0	5.6
AL-ANWAR-1	AL-ANWAR-1	213	4	1	4331.4	39.4	5.6
HAALA-26	HAALA-26	214	4	1	4430.7	38.7	5.6
KAUZS//TSI/SNBS	ALMAZ-19 = SIDS-13	215	4	1	4423.7	38.6	5.6
SHAFAQ-1	SHAFAQ-1	216	4	1	4350.1	40.0	5.6
ALATHEER-4	ALATHEER-4	217	4	1	4459.7	39.0	5.6
QAFZAH-11/BASHIQ-1	QAFZAH-11/BASHIQ-1	218	4	1	4355.5	39.2	5.6
BT1735/ACHTAR//HUBARA-8	MORSUD-16	219	4	1	4341.8	39.0	5.6
FIDIYA-9	FIDIYA-9	220	4	1	4436.8	39.1	5.6
DIYAR-7	DIYAR-7	221	4	1	4287.0	39.5	5.6
AAFAQ-2	AAFAQ-2	222	4	1	4413.8	39.0	5.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
TACUPETO F2001*2/KIRITATI//VILLA JUAREZ F2009	CMSS07B00094S-099M-099NJ-099NJ-16WGY-0B	27	8	1	4488.3	40.7	6.2
WBLL1*2/BRAMBLING//QUAIU	CMSS07B00224S-099M-099Y-099M-18WGY-0B	28	8	1	4493.4	40.8	5.6
KAUZ/PASTOR//PBW343/3/KIRITATI/4/FRNCLN	CMSS07B00585T-099TOPY-099M-099Y-099M-11WGY-0B	29	8	1	4490.4	39.7	5.9
PFAU/SERI.1B//AMAD/3/WAXWING*2/4/TECUE #1	CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-0B	30	8	1	4377.2	39.4	5.6
PFAU/SERI.1B//AMAD/3/WAXWING/4/WBLL1*2/BRAMBLING	CMSS07Y00196S-0B-099Y-099M-099NJ-099NJ-6WGY-0B	31	8	1	4443.8	40.8	5.7
BANA-1///NS732/HER//SHUHA-15	ICW01.00053-0AP-8AP-0AP-0AP-7AP-0AP	32	8	1	4368.1	38.3	6.3
PRL/2*PASTOR	CGSS97Y00034M-099TOPB-027Y-099M-099Y-099M-27Y-0B	33	8	1	4386.7	39.1	5.4
PFAU/SERI.1B//AMAD/3/WAXWING	CGSS02Y00153S-099M-099Y-099M-46Y-0B	34	8	1	4504.2	39.6	6.0
TEVEE-3/SHUHA-20//SERI 82/SHUHAS	ICW02.00130-9APTS-0AP-0AP-1AP-0AP-0DZAP-0DZKULSINAP-0NJAP	35	8	1	4428.1	39.4	5.0
FERROUG-2/POTAM*2KS811261-8//ZEMAMRA-8	ICW01.21116-5AP-11AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP	36	8	1	4255.3	38.3	6.2
WORRAKATTA/2*PASTOR//DANPHE #1	CMSA07M00403S-040ZTM-040ZTY-15ZTM-010Y-01B-0Y	37	8	1	4377.2	39.4	5.6
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-9AP-0AP	38	8	1	4549.5	38.1	6.4
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-5AP-0AP-0DZAP-0DZKULSINAP-0NJAP	39	8	1	4285.4	40.0	5.8

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-1N-99N	40	8	1	4406.3	40.3	5.1
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-19N-99N	41	8	1	4361.2	40.2	5.5
QAFZAH-11/ICW93.0045-1AP-0L-1AP-0L-2AP-0AP	ICW01.00220-0AP-5AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	105	8	1	4407.4	39.3	5.7
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-3AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	106	8	1	4408.1	39.8	5.8
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-16AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	107	8	1	4334.0	38.6	5.3
KA/NAC//TRCH/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA07M00444S-040M-0NJ-0NJ-6Y-0B	108	8	1	4360.6	40.7	6.9
INQALAB 91/CMSW94WM00188S-0300M-0100Y-0100M-13Y-4M-0Y-0AP	ICW02.00354-9APTS-0AP-0AP-3AP-030KUL-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	109	8	1	4399.8	39.8	5.7
CMT/ALD//ZARZOUR/5/AU//KAL/BB/3/BON/4/HPO	ICW99.0181-2AP-0AP-0AP-22AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	110	8	1	4430.2	39.5	5.5
PAVON 76/HAMAM-4/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ	ICW02.20146-7APTS-0AP-0AP-17AP-0AP	111	8	1	4429.9	40.0	6.1
KACHU/BECARD//WBLL1*2/BRAMBLING	CMSS07B00580T-099TOPY-099M-099Y-099M-10WGY-0B	112	8	1	4430.9	40.7	5.9
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-1AP-1AP-0AP-0AP-15AP-0AP	113	8	1	4393.3	38.9	5.7
SERI 82/SHUHAS//CM84655	ICW02.00470-16APTS-0AP-0AP-4AP-0AP	114	8	1	4438.7	39.7	5.7

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
-02AP-300AP-300L-3AP-300L-3AP-0L-0AP							
ATTILA*2/PBW65*2//KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-13WGY-0B	115	8	1	4494.8	38.8	5.6
ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2	CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B	116	8	1	4346.4	40.5	5.8
KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU	CMSS06Y00946T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	117	8	1	4377.2	39.4	5.6
SAUAL/3/ACHTAR*3//KANZ/KS85-8-4/4/SAUAL	CMSS06Y01171T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	118	8	1	4471.1	40.1	5.7
MUNAL #1	CGSS01B00054T-099Y-099M-099M-099Y-099M-13Y-0B	119	8	1	4377.2	39.4	5.6
BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	CMSS07Y00288S-0B-099Y-099M-099Y-17M-0WGY	120	8	1	4377.2	39.4	5.6
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-6AP-9AP-0AP-0AP-7AP-0AP	121	8	1	4420.1	40.0	6.0
WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING	CMSS07Y00348S-0B-099Y-099M-099Y-19M-0WGY	122	8	1	4322.5	40.2	6.0
DORADE/KAPSW	ICW98.0120-3AP-0APS-030AP-10AP-5AP-0AP	123	8	1	4412.2	39.4	5.5
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-4AP-0AP	124	8	1	4435.8	39.0	5.8
QAFZAH-33/ICW84.0074-09AP-300L-1AP-300L-8AP-0L-0AP	ICW02.00423-3APTS-0AP-0AP-7AP-0AP	125	8	1	4409.3	40.3	6.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-18AP-0AP	126	8	1	4446.4	40.5	5.7
ICW91.0145-4AP-0TS-2AP-0L-0AP/4/NAI60/HN7//SX/3/JUNS	ICW02.00493-7APTS-0AP-0AP-17AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	127	8	1	4466.0	38.5	6.7
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-9AP-0AP	128	8	1	4392.4	40.5	5.8
KIRITATI/WBLL1//MESIA/3/KIRITATI/WBLL1	CMSS07Y00847T-099TOPM-099Y-099M-099Y-53M-0WGY	129	8	1	4423.2	40.4	6.2
NS732/HER//SAADA///SAADA	ICW00.0885-8AP-0AP-0AP-6APMOR-0APMOR-0AP	130	8	1	4421.8	38.2	5.5
FRNCLN*2/TECUE #1	CMSS07Y00941T-099TOPM-099Y-099M-099Y-11M-0WGY	131	8	1	4377.2	39.4	5.6
ACHTAR/IG 132176	MOROCCO F2-17 00/01-27AP-0AP-0AP-11APMOR-0APMOR-0AP	132	8	1	4455.7	39.3	5.8
ACHTAR/IG 132176	MOROCCO F2-17 00/01-47AP-0AP-0AP-9APMOR-0APMOR-0AP	133	8	1	4195.7	40.8	5.0
BT1735/ACHTAR//ASFOOR-1	ICW01.00164-0AP-2AP-0AP-0AP-8APMOR-0APMOR-0AP	134	8	1	4352.9	39.2	6.0
ESWYT99#18/ARRIHANE	MOROCCO F2-23 00/01-17AP-0AP-0AP-17APMOR-0APMOR-0AP	135	8	1	4377.2	39.4	5.6
KACHU//WBLL1*2/BRAMBLING	CMSS07Y00124S-0B-099Y-099M-099NJ-099NJ-9WGY-0B	136	8	1	4464.7	40.2	6.2
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/	ICW00.0634-6AP-0AP-0AP-13AP-0AP-0DZAP-	137	8	1	4351.1	38.6	5.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KVZ/HYS//YMH/TOB/ 4/BOW	0DZKULSINAP- 0NJAP-0ALKAP						
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-2N-99N	138	8	1	4456.4	40.7	5.7
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-8N-99N	139	8	1	4405.1	39.9	5.9
PBW550//PBW550/1834 3 KC75	PBI09C036-BC-0C-4N-99N	140	8	1	4258.4	41.1	5.4
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-8N-99N	141	8	1	4382.0	40.8	5.5
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-14N-99N	142	8	1	4371.4	39.9	5.4
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-26N-99N	143	8	1	4380.2	40.0	5.4
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-19N-99N	144	8	1	4392.5	39.2	5.3
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-17N-99N	145	8	1	4339.6	38.7	5.1
PBW550//PBW550/1834 3 KC75	PBI09C036-BC-0C-8N-99N	146	8	1	4301.3	40.3	5.6
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-3N-99N	147	8	1	4366.0	40.5	5.4
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-7N-99N	148	8	1	4372.2	39.0	5.4
WAXWING*2/KIRITAT I ///WAXWING*2/KIRIT ATI // 35891 M500281	PBI09C027-BC-0C-12N-99N	149	8	1	4397.9	39.8	5.4
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-13N-99N	150	8	1	4404.5	39.3	5.1
DBW16//DBW16 / 18293 KC75	PBI09C042-BC-0C-10N-99N	151	8	1	4325.2	40.0	5.4
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-27N-99N	152	8	1	4330.7	38.9	5.3
PBW550//PBW550/1834 3 KC75	PBI09C036-BC-0C-2N-99N	153	8	1	4305.2	41.1	5.4
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-18N-99N	154	8	1	4331.9	40.7	5.5
KAUZ/PASTOR/3/ALT AR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-16AP-0AP	42	12	1	4366.8	39.2	5.7

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KAUZ/PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-1AP-0AP	43	12	1	4368.3	39.4	5.5
KARAWAN-1/TALLO 3//JADIDA-2	ICW04.0146-1AP-0AP-0AP-9AP-0AP	44	12	1	4370.3	39.4	5.5
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-4AP-0AP-0AP-16AP-0AP	45	12	1	4363.6	39.1	5.1
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-9AP-0AP-0AP-4AP-0AP	46	12	1	4432.6	38.6	5.4
HUBARA-3*2/SHUHA-4	ICW04.20024-17AP-0AP-0AP-6AP-0AP	47	12	1	4357.7	38.7	5.7
HUBARA-3*2/SHUHA-4	ICW04.20024-26AP-0AP-0AP-1AP-0AP	48	12	1	4335.7	39.0	5.2
HUBARA-3*2/SHUHA-4	ICW04.20024-47AP-0AP-0AP-5AP-0AP	49	12	1	4441.1	39.3	5.2
ATTILA-7/KATILA-12	ICW04.0054-1AP-0AP-0AP-3AP-0AP	50	12	1	4372.2	38.9	5.8
FLORKWA-2/6/SAKERS/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOWS/7/DAJAJ-6	ICW04.0169-4AP-0AP-0AP-7AP-0AP	51	12	1	4357.4	39.7	5.5
HUBARA-3*2/SHUHA-4	ICW04.20024-10AP-0AP-0AP-3AP-0AP	52	12	1	4300.5	39.6	5.3
HUBARA-3*2/SHUHA-4	ICW04.20024-9AP-0AP-0AP-9AP-0AP	53	12	1	4405.7	39.4	5.6
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-1AP-0AP-0AP-6AP-0AP	54	12	1	4340.9	38.9	6.0
PASTOR-2*2//ACSAD 685/ACSAD 639	ICW04.20124-5AP-0AP-0AP-1AP-0AP	55	12	1	4414.4	39.0	5.3
PASTOR-2/HUBARA-5	ICW04.0037-6AP-0AP-0AP-7AP-0AP	56	12	1	4421.4	39.3	5.3
HUBARA-15/CATBIRD//PASTOR-2	ICW04.20029-40AP-0AP-0AP-8AP-0AP	57	12	1	4368.0	39.6	5.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-14AP-0AP-0AP-0AP-2AP-0AP	58	12	1	4330.6	38.9	6.3
HUBARA-3/SHUHA-4//PASTOR-2	ICW04.20025-43AP-0AP-0AP-0AP-2AP-0AP	59	12	1	4396.7	39.2	5.5
KACHU//KIRITATI/2*TRCH	CMSS08Y00152S-099Y-099M-099NJ-099NJ-41WGY-0B	60	12	1	4239.4	39.5	5.4
PFAU/SERI.1B//AMAD/3/WAXWING/4/QUAIU #2	CMSS08Y00269S-099Y-099M-099NJ-9WGY-0B	61	12	1	4377.2	39.4	5.6
PFAU/SERI.1B//AMAD/3/WAXWING/4/ND643/2*WBLL1	CMSS08Y00274S-099Y-099M-099NJ-099NJ-12WGY-0B	62	12	1	4362.3	39.3	5.8
SAAR//INQALAB 91*2/KUKUNA/3/KIRITATI/2*TRCH	CMSS08Y00299S-099Y-099M-099NJ-099NJ-19WGY-0B	63	12	1	4391.3	40.5	5.4
VILLA JUAREZ F2009/DANPHE #1	CMSS08Y00415S-099Y-099M-099NJ-31WGY-0B	64	12	1	4377.2	39.4	5.6
WBLL1/KUKUNA//TACUPETO F2001/3/FRANCOLIN #1	CMSS08Y00447S-099Y-099M-099NJ-29WGY-0B	65	12	1	4377.2	39.4	5.6
WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08Y00477S-099Y-099M-099NJ-7WGY-0B	66	12	1	4459.5	38.8	5.8
QUAIU//2*BRBT1*2/KIRITATI	CMSS08Y00623T-099TOPM-099Y-099M-099NJ-099NJ-7WGY-0B	67	12	1	4440.3	39.6	5.6
MUU/FRNCLN//FRANCOLIN #1	CMSS08Y00728T-099TOPM-099Y-099M-099Y-20M-0WGY	68	12	1	4377.2	39.4	5.6
PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI*2/5/CHONTE	CMSS08Y00731T-099TOPM-099Y-099M-099Y-8M-0WGY	69	12	1	4356.7	39.3	5.8

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
TOBA97/PASTOR*2//KBIRD	CMSS08Y00760T-099TOPM-099Y-099M-099Y-11M-0WGY	70	12	1	4328.1	39.2	5.5
VILLA JUAREZ F2009//KIRITATI/2*TRCH/3/WBLL1*2/BRAMBLING	CMSS08Y00784T-099TOPM-099Y-099M-099NJ-099NJ-9WGY-0B	71	12	1	4453.2	39.7	5.6
FRNCLN/3/ND643//2*PRL/2*PASTOR/4/FRANCOLIN #1	CMSS08Y00896T-099TOPM-099Y-099M-099NJ-24WGY-0B	72	12	1	4377.2	39.4	5.6
FRNCLN/3/KIRITATI//HUW234+LR34/PRINIA/4/FRANCOLIN #1	CMSS08Y00900T-099TOPM-099Y-099M-099NJ-6WGY-0B	73	12	1	4377.2	39.4	5.6
PFAU/MILAN/4/VEE/TRAP#1//ANGRA/3/PASTOR/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08B00137S-099M-099NJ-099NJ-50WGY-0B	74	12	1	4377.2	39.4	5.6
MP4010/MUNAL #1	CMSS08B00576S-099M-099Y-14M-0WGY	75	12	1	4377.2	39.4	5.6
TRCH*2//ND643/2*WBLL1	CMSS08B00602T-099TOPY-099M-099NJ-099NJ-4WGY-0B	76	12	1	4370.9	38.6	6.2
QUAIU #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/6/BECARD	CMSS08B00645T-099TOPY-099M-099NJ-099NJ-6WGY-0B	77	12	1	4377.2	39.4	5.6
QUAIU/BECARD//BECARD	CMSS08B00648T-099TOPY-099M-099NJ-2WGY-0B	78	12	1	4497.3	39.4	5.6
FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KIRITATI/2*TRCH/6/BAJ #1	CMSS08B00678T-099TOPY-099M-099NJ-099NJ-4WGY-0B	79	12	1	4377.2	39.4	5.6
KACHU*2/CHONTE	CMSS08B00714T-099TOPY-099M-099Y-22M-0WGY	80	12	1	4439.2	39.0	5.8
MILAN/S87230//BAV92/3/KIRITATI/2*TRCH/4/WHEAR/KRONSTAD F2004	CMSS08B00764T-099TOPY-099M-099NJ-26WGY-0B	81	12	1	4422.4	39.1	5.9

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ND643/2*WBLL1//KIRITATI/2*TRCH/3/ND643/2*WBLL1	CMSS08B00772T-099TOPY-099M-099Y-21M-0WGY	82	12	1	4350.5	38.6	5.5
BECARD//KIRITATI/2*TRCH/3/BECARD	CMSS08B00888T-099TOPY-099M-099NJ-20WGY-0B	83	12	1	4378.1	40.7	5.5
FALCIN/AE.SQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/MUU/6/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA08Y00099T-099B-050Y-040M-0NJ-0NJ-4Y-0B	84	12	1	4432.8	39.9	5.3
PASTOR/3/VEE#5//DOVE/BUC/4/DANPHE #1	CMSA08Y00613S-050Y-050ZTM-050Y-59BMX-010Y-0B	85	12	1	4377.2	39.4	5.6
GLADIUS/3/2*KA/NAC//TRCH	CMSA08M00007T-030(AWW5L7BO1HET)Y-040M-0NJ-4Y-0B	86	12	1	4457.3	39.8	5.5
RAC 1192/4/2*ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00008T-040Y-050ZTM-050Y-13ZTM-010Y-0B	87	12	1	4395.3	40.2	5.4
TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1/4/ATTILA/PASTOR	CMSA08M00289S-040ZTM-050Y-40ZTM-010Y-0B	88	12	1	4424.2	39.6	5.6
VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/11/CROC_1/AE.SQUARROSA (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	CMSA08M00364S-040ZTM-050Y-1ZTM-010Y-0B	89	12	1	4377.2	39.4	5.6
SOKOLL/WBLL1/4/ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00393S-040ZTM-050Y-41ZTM-010Y-0B	90	12	1	4377.7	38.8	5.6
SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR	PTSA08M00046S-050ZTM-050Y-85ZTM-010Y-0B	91	12	1	4371.7	40.0	5.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH10	92	12	1	4371.6	39.3	5.5
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH63	93	12	1	4369.7	39.4	5.2
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH81	94	12	1	4330.4	39.1	5.4
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH17	95	12	1	4398.1	39.3	5.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH22	96	12	1	4352.7	39.4	5.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH21	97	12	1	4358.9	39.2	5.2
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH1	98	12	1	4382.1	39.3	5.3
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH56	99	12	1	4369.5	40.1	5.6
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH16	100	12	1	4391.3	39.6	5.5
GOUBARA-1/2*SOKOLL	CMSA04M01020T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-12ZTM-02Y-0B	1	2	2	2973.1	31.4	8.6
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-1WGY-0B	2	2	2	3017.5	31.4	10.0
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-23AP-0AP-0AP-8AP-0AP	3	2	2	2978.7	31.4	8.6
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-35ZTM-02Y-0B	4	2	2	2980.8	31.4	9.4
INQALAB 91*2/TUKURU//WHEAR	CGSS05Y00463S-0B-099Y-099M-099NJ-099NJ-3WGY-0B	5	2	2	2988.5	31.4	9.1
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B	6	2	2	2973.1	31.4	8.8

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-6B	7	2	2	2997.0	31.4	8.8
PBW343	CM85836-4Y-0M-0Y-8M-0Y-0IND	8	2	2	2982.7	31.4	9.0
JANZ	JANZ	9	2	2	2967.4	31.4	9.2
N-ABYAD-13	N-ABYAD-13	10	2	2	2989.8	31.4	10.2
WH 542	WH 542	11	2	2	2974.0	31.4	8.9
CRUSADER	CRUSADER	12	2	2	2990.6	31.4	8.9
SOKOLL	CMSS97M00316S-0P5M-0P5Y-42M-0Y	13	2	2	2991.2	31.4	8.6
ZAKIA-10	ICW98.0030-1AP-0APS-030AP-8AP-1AP-0AP	14	2	2	2991.7	31.4	8.6
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-2ZTM-03Y-0B	15	2	2	2997.8	31.4	8.7
BERKUT	CMSS96M05638T-040Y-5M-010SY-010M-010SY-1M-0Y	16	2	2	2971.9	31.4	8.5
LIVINGSTON	LIVINGSTON	17	2	2	2981.0	31.4	9.6
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-11M-0Y	18	2	2	2989.4	31.4	9.8
EGA GREGORY	EGA GREGORY	19	2	2	2973.1	31.4	9.4
ATTILA*2/PBW65	CGSS96B00123F-099M-037Y-099M-26Y-0B-0SY	20	2	2	2957.6	31.4	9.0
SPITFIRE	SPITFIRE	21	2	2	2971.7	31.4	10.0
WAXWING*2/TUKURU	CGSS01B00058T-099Y-099M-099M-099Y-099M-49Y-0B	157	2	2	2981.6	31.4	9.1
QG 4.37A/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MI	CMSA05M00708T-050Y-040ZTM-040ZTY-4ZTM-04Y-0B	223	2	2	2990.3	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
LAN/KAUZ//PRINIA/3/BAV92							
NSM*4/14-2//FRTL/2*PIFED/3/VORB	CMSA05M00650T-050Y-040ZTM-040ZTY-21ZTM-02Y-0B	224	2	2	2994.4	31.4	9.1
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-8ZTM-03Y-0B	225	2	2	2989.6	31.4	9.1
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B	226	2	2	2991.5	31.4	9.1
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-32ZTM-02Y-0B	227	2	2	2990.5	31.4	9.1
SOKOLL//PBW343*2/KUKUNA/3/ATTILA/PASTOR	CMSA05Y01188T-040M-040ZTP0Y-040ZTM-040SY-2ZTM-01Y-0B	228	2	2	2991.4	31.4	9.1
SOKOLL*2//TACUPETO F2001*2/KUKUNA	CMSA05Y01226T-040M-040ZTP0Y-040ZTM-040SY-22ZTM-04Y-0B	229	2	2	2987.6	31.4	9.1
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-9ZTM-04Y-0B	230	2	2	2991.6	31.4	9.1
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-15ZTM-01Y-0B	231	2	2	2986.2	31.4	9.1
SW89-5124*2/FASAN/3/ALTAR 84/AE.SQ//2*OPATA	CMSA04M00335S-040ZTP0Y-040ZTM-040SY-16ZTM-04Y-0B	232	2	2	2991.8	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SOKOLL//TACUPETO F2001*2/KUKUNA	CMSA04M00346S-040ZTP0Y-040ZTM-040SY-28ZTM-01Y-0B	233	2	2	2990.3	31.4	9.1
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-19ZTM-03Y-0B	234	2	2	2993.3	31.4	9.1
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-4ZTM-04Y-0B	235	2	2	2987.9	31.4	9.1
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-6ZTM-02Y-0B	236	2	2	2989.2	31.4	9.1
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	237	2	2	2991.3	31.4	9.1
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-24ZTM-04Y-0B	238	2	2	2994.9	31.4	9.1
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-5ZTM-03Y-0B	239	2	2	2992.7	31.4	9.1
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	240	2	2	2987.9	31.4	9.1
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-2ZTM-01Y-0B	241	2	2	2991.5	31.4	9.1
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/	CMSA04M01201T-050Y-040ZTP0M-	242	2	2	2992.2	31.4	9.1

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	040ZTY-040ZTM-040SY-6ZTM-01Y-0B						
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-03Y-0B	243	2	2	2993.6	31.4	9.1
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-3B	244	2	2	2989.1	31.4	9.1
ATTILA*2//CHIL/BUC*2/3/KUKUNA	CMSS05Y00671T-099TOPM-099Y-099M-099Y-099ZTM-2WGY-0B	245	2	2	2986.6	31.4	9.1
CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/PASTOR/7/KAUZ/PASTOR//PBW343	CMSS05B00592S-099Y-099M-099Y-099ZTM-17WGY-0B	246	2	2	2993.0	31.4	9.1
ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARROSA (224)//2*OPATA	CMSS05B00663S-099Y-099M-099Y-099ZTM-13WGY-0B	247	2	2	2990.0	31.4	9.1
WBLL1*2/KUKUNA*2//WHEAR	CGSS05B00174T-099TOPY-099M-099NJ-099NJ-5WGY-0B	248	2	2	2990.2	31.4	9.1
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099Y-099ZTM-10WGY-0B	249	2	2	2988.2	31.4	9.1
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-3WGY-0B	250	2	2	2995.2	31.4	9.1
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-5WGY-0B	251	2	2	2993.1	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099Y-099ZTM-12WGY-0B	252	2	2	2992.9	31.4	9.1
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-2WGY-0B	253	2	2	2994.3	31.4	9.1
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-6WGY-0B	254	2	2	2999.4	31.4	9.1
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-8WGY-0B	255	2	2	2990.1	31.4	9.1
PBW343*2/KHVAKI//PARUS/3/PBW343/PASTOR	CGSS05B00271T-099TOPY-099M-099NJ-099NJ-17WGY-0B	256	2	2	2993.8	31.4	9.1
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-17WGY-0B	257	2	2	2990.0	31.4	9.1
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-20WGY-0B	258	2	2	2990.0	31.4	9.1
ATTILA*2/PBW65//KIRITATI/3/WAXWING/KIRITATI	CGSS05B00299T-099TOPY-099M-099Y-099ZTM-19WGY-0B	259	2	2	2990.3	31.4	9.1
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-3AP-0AP	260	2	2	2977.7	31.4	9.1
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-5AP-0AP	261	2	2	2987.0	31.4	9.1
ALTAR 84/AE.SQUARROSA (191)//OPATA/3/SKAUZ	CMSS98Y05580S-040Y-0B-0MXI-0AP-0AP-15AP-0AP	262	2	2	2988.3	31.4	9.1
VANS/3/CNDRS/ANA//CNDRS/MUSS/4/CHAM-6	ICW99-0336-12AP-0AP-0AP-7AP-0AP	263	2	2	2988.4	31.4	9.1

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-13AP-0AP-0AP-5AP-0AP	264	2	2	2987.3	31.4	9.1
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-2AP-0AP	265	2	2	2985.4	31.4	9.1
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-5AP-0AP	266	2	2	2981.5	31.4	9.1
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-8AP-0AP	267	2	2	2984.4	31.4	9.1
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-12AP-0AP-0AP-45AP-0AP	268	2	2	2990.0	31.4	9.1
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-4AP-0AP-0AP-29AP-0AP	269	2	2	2990.0	31.4	9.1
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-4AP-0AP	270	2	2	2988.3	31.4	9.1
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-9AP-0AP	271	2	2	2986.2	31.4	9.1
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-25AP-0AP-0AP-4AP-0AP	272	2	2	2991.1	31.4	9.1
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-7M-0Y-01B-0Y	273	2	2	2996.7	31.4	9.1
SUNCO	SUNCO	274	2	2	2979.9	31.4	9.1
SHIHAB-3	CMSS97M00652S-0B-0AP-1AP-0APS-0AP-11AP-3AP-0AP	275	2	2	2986.1	31.4	9.1
LEITH-3	ICW97.0717-0APS-1AP-0APS-050AP-0APS-16AP-0AP	276	2	2	2984.1	31.4	9.1
PBW343*2/KUKUNA//PBW343*2/KUKUNA	CGSS04Y00099S-099Y-099M-099Y-099M-8WGY-0B	277	2	2	2989.9	31.4	9.1
PRL/2*PASTOR//PBW343*2/KUKUNA	CMSS04Y00086S-0Y-099ZTM-099Y-099M-4WGY-0B	278	2	2	2992.7	31.4	9.1
CROC_1/AE.SQUARROSA	CMSA02Y00059S-040P0Y-040ZTM-	279	2	2	2990.5	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
(213)//PGO/3/CMH81.38/2*KAUZ/4/BERKUT	040SY-040M-7ZTY-03M-0Y						
ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA/10/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/2*WEAVER/11/PRL/2*PASTOR	CMSA02Y00426T-040M-040P0Y-040ZTM-040SY-040M-5ZTY-01M-0Y	280	2	2	2990.0	31.4	9.1
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-7ZTM-03Y-0B	281	2	2	2989.4	31.4	9.1
BERKUT/HTG	CMSA04Y00607S-130ZTP0Y-010M-010SY-2M-04Y-0B	282	2	2	2993.0	31.4	9.1
SOKOLL//PRL/2*PASTOR	CMSA04Y00608S-150ZTP0Y-010M-010SY-3M-02Y-0B	283	2	2	2987.7	31.4	9.1
SW89-5124*2/FASAN/6/CHIBIA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER	CMSA02Y00249S-040ZTM-040HTY-040M-040SY-10M-0Y	284	2	2	2992.2	31.4	9.1
SOKOLL/WBLL1	PTSS02Y00021S-0Y-030ZTM-040SY-040M-14Y-0M-0SY	285	2	2	2985.4	31.4	9.1
CROC_1/AE.SQUARROSA (224)//OPATA/3/SOKOLL	PTSS02B00065S-0Y-0B-0Y-0B-32Y-0M-0SY	286	2	2	2988.1	31.4	9.1
MEX94.2.19/PUB94.15.1.12	PTSS02B00074S-0Y-0B-0Y-0B-32Y-0M-0SY	287	2	2	2985.9	31.4	9.1
SOKOLL//W15.92/WBLL1	PTSS02B00088T-0TOPY-0B-0Y-0B-5Y-0M-0SY	288	2	2	2990.8	31.4	9.1
OAX93.24.35//SOKOLL/WBLL1	PTSS02B00099T-0TOPY-0B-0Y-0B-35Y-0M-0SY	289	2	2	2993.7	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	PTSS02B00102T-0TOPY-0B-0Y-0B-11Y-0M-0SY	290	2	2	2989.5	31.4	9.1
WBLL4//OAX93.24.35/WBLL1	PTSS02B00110T-0TOPY-0B-0Y-0B-21Y-0M-0SY	291	2	2	2991.8	31.4	9.1
SUNTOP	SUNTOP	22	5	2	2989.1	31.4	9.5
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06B00734T-099TOPY-099ZTM-099Y-099M-25WGY-0B	23	5	2	3012.3	31.4	8.6
BECARD/5/PGO//CROC_1/AE.SQUARROSA (224)/3/2*BORL95/4/CIRCUS	CMSS06B00411S-0Y-099ZTM-099Y-099M-12WGY-0B	24	5	2	2999.5	31.4	9.2
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/VORB	CMSA06M00431S-040ZTM-040ZTY-31ZTM-04Y-0B	25	5	2	2990.6	31.4	8.8
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-67ZTM-0Y-0B	26	5	2	2987.6	31.4	8.9
PBW343*2/KUKUNA/3/PGO/SERI//BAV92	CMSS06B00495S-0Y-099ZTM-099NJ-099NJ-12WGY-0B	101	5	2	2998.7	31.4	9.8
FRTL/2*PIFED/4/CROC_1/AE.SQUARROSA (205)//KAUZ/3/PIFED		103	5	2	2986.6	31.4	9.1
T.DICOCCON PI225332/AE.SQUARROSA (895)//WBLL1/3/2*WBLL1/4/SOKOLL	CMSA06M00709S-040ZTM-040ZTY-21ZTM-0Y-0B	104	5	2	2989.1	31.4	9.0
Wyalkatchem	MACHETE/84W129-504	156	5	2	2990.2	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
QAFZAH-31	CMSS93Y00621S-4AP-3AP-4AP-0APS-0AP	158	5	2	2988.3	31.4	9.1
ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/URES/JUN//KAUZ/4/WBLL1/5/MILAN/S87230//BAV92	CMSS06B00201S-0Y-099ZTM-099Y-099M-14WGY-0B	159	5	2	2987.6	31.4	9.1
QUAIU #3//MILAN/AMSEL	CMSS06B00640S-0Y-099ZTM-099Y-099M-7WGY-0B	160	5	2	2990.0	31.4	9.1
ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B	161	5	2	2988.8	31.4	9.1
WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN	CMSS06B00787T-099TOPY-099ZTM-099Y-099M-6WGY-0B	162	5	2	2990.1	31.4	9.1
WBLL1*2/KURUKU/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/7/WBLL1*2/KURUKU	CMSS06B00802T-099TOPY-099ZTM-099Y-099M-12WGY-0B	163	5	2	2989.5	31.4	9.1
WAXWING*2/HEILO	CMSS06B00915T-099TOPY-099ZTM-099Y-099M-8WGY-0B	164	5	2	2989.9	31.4	9.1
BAV92//IRENA/KAUZ/3/HUITES/4/GONDO/TNMU/5/BAV92//IRENA/KAUZ/3/HUITES	CMSS06B00918T-099TOPY-099ZTM-099Y-0FUS-6WGY-0B	165	5	2	2989.2	31.4	9.1
ATTILA*2/PBW65*2/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B	166	5	2	2990.8	31.4	9.1
ROLF07*2/3/PRINIA/PASTOR//HUITES	CMSS06Y00609T-099TOPM-099Y-099ZTM-099Y-099M-19WGY-0B	167	5	2	2990.5	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MUNAL #1/FRANCOLIN #1	CMSS06B00001S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	168	5	2	2990.0	31.4	9.1
TRCH/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00314S-0Y-099ZTM-099NJ-099NJ-21WGY-0B	169	5	2	2989.6	31.4	9.1
PFAU/SERI.1B//AMAD/3/WAXWING/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00318S-0Y-099ZTM-099NJ-099NJ-25WGY-0B	170	5	2	2991.1	31.4	9.1
KBIRD//INQALAB 91*2/TUKURU	CMSS06B00485S-0Y-099ZTM-099Y-099M-7WGY-0B	171	5	2	2990.8	31.4	9.1
FRNCLN/ROLF07	CMSS06B00013S-0Y-099ZTM-099Y-099M-9WGY-0B	172	5	2	2990.0	31.4	9.1
PVN/5/2*REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00975T-099TOPY-099ZTM-099Y-099M-9WGY-0B	173	5	2	2990.0	31.4	9.1
WBLL1*2/BRAMBLING/5/WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ		174	5	2	2990.0	31.4	9.1
WBLL1*2/TUKURU//FN/2*PASTOR/3/FRET2/KIRITATI	CMSS06B00926T-099TOPY-099ZTM-099Y-0FUS-18WGY-0B	175	5	2	2989.8	31.4	9.1
FRAME*2/3/URES/JUN//KAUZ/4/BAU//PRL/VEE#6/3/FRAME/5/SLVS/ATTILA//WBLL1	CMSA06M00058T-034(PINBD1BHET)Y-040ZTM-021(PINBD1BPOS)ZTY-12ZTM-04Y-0B	176	5	2	2990.0	31.4	9.1
ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC		177	5	2	2990.5	31.4	9.1
PFAU/SERI.1B//AMAD/3/WAXWING/4/BABAX/LR42//BABAX*2/3/KURUKU	CMSS06B00033S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	178	5	2	2991.0	31.4	9.1
QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CMSS06B00109S-0Y-099ZTM-099NJ-099NJ-13WGY-0B	179	5	2	2990.0	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PAURAQ/4/PFAU/SERI.1B//AMAD/3/WAXWING	CMSS06B00015S-0Y-099ZTM-099NJ-099NJ-1WGY-0B	180	5	2	2990.0	31.4	9.1
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-5WGY-0B	181	5	2	2990.8	31.4	9.1
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-22WGY-0B	182	5	2	2990.5	31.4	9.1
WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX	CMSS06Y00885T-099TOPM-099Y-099ZTM-099NJ-099NJ-26WGY-0B	183	5	2	2990.2	31.4	9.1
DUCULA/GONDO//SOKOLL	CMSA06M00645S-040ZTM-040ZTY-19ZTM-03Y-0B	184	5	2	2990.6	31.4	9.1
EGA BONNIE ROCK/4/MILAN/KAUZ//PRINIA/3/BAV92	CMSA06Y00125S-040ZTP0Y-040ZTM-040SY-2ZTM-02Y-0B	185	5	2	2990.2	31.4	9.1
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-20ZTM-0Y-0B	186	5	2	2990.6	31.4	9.1
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-28ZTM-01Y-0B	187	5	2	2989.9	31.4	9.1
MILAN/KAUZ//PRINIA/3/BAV92/4/2*SOKOLL	CMSA06M00017T-030(CSLV34HET)Y-040ZTM-049(CSLV34POS)ZTY-68ZTM-0Y-0B	188	5	2	2990.1	31.4	9.1
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-11ZTM-0Y-0B	189	5	2	2988.2	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ANNUELLO*2/4/92.001E7.32.5/3/PRL/SARA//TSI/VEE#5	CMSA06Y00718T-085(CRE1M19)M-040ZTP0Y-040ZTM-040SY-6ZTM-0Y-0B	190	5	2	2990.0	31.4	9.1
HUANIL/5/2*CNO79//PF70354/MUS/3/PASTOR/4/BAV92	CMSA05M00750T-050Y-041ZTM-040ZTY-040ZTM-040SY-10ZTM-0Y-0B	191	5	2	2987.9	31.4	9.1
EGA BONNIE ROCK/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	CMSA05M00023S-0130ZTM-039(LR34HOM+HET)ZTY-040ZTM-040SY-6ZTM-0Y-0B	192	5	2	2988.4	31.4	9.1
PBW343*2/KUKUNA//WBLL1*2/KUKUNA	CMSA05M00118S-0100ZTM-029(LR34HOM+HET)ZTY-040ZTM-040SY-45ZTM-0Y-0B	193	5	2	2987.9	31.4	9.1
SLVS/ATTILA//WBLL1/4/FRAME*2/3/URES/JUN//KAUZ	CMSA05M00140S-021(CRE1M19-GWM577BO1)M-028(BO1 POS& CRE1 POS)ZTY-040ZTM-040SY-11ZTM-0Y-0B	194	5	2	2989.8	31.4	9.1
VORB/4/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/5/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM	CMSA06Y00835T-040ZTM-040ZTP0Y-040ZTM-040P0Y-3ZTM-02Y-0B	195	5	2	2991.0	31.4	9.1
VORB/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA/7/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	CMSA06Y00836T-040ZTM-040ZTP0Y-040ZTM-040P0Y-26ZTM-01Y-0B	196	5	2	2990.6	31.4	9.1
CHIH95.7.4//INQALAB91*2/KUKUNA	PTSS06GHB00007S-0Y-040ZTM-040ZTY-11ZTM-0Y-0B	197	5	2	2988.8	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/SKAUZ/BAV92	CMSA06M00430S-040ZTM-0NJ-0NJ-18Y-3B-0Y	198	5	2	2989.7	31.4	9.1
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-4Y-1B-0Y	199	5	2	2990.9	31.4	9.1
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-9Y-1B-0Y	200	5	2	2989.7	31.4	9.1
MACE	WYALKATCHEM/STYLET//WYALKATCHEM	201	5	2	2989.3	31.4	9.1
SCOUT	SCOUT	202	5	2	2987.8	31.4	9.1
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	SHAMIEKH-3	203	5	2	2987.5	31.4	9.1
BABAX/LR39//BABAX/3/VORB/4/SUNCO/2*PASTOR	CMSA06Y00792T-040ZTM-040ZTP0Y-040ZTM-040SY-28ZTM-02Y-0B	204	5	2	2987.8	31.4	9.1
HEILO//SUNCO/2*PASTOR	CMSA06Y00492S-040ZTY-040ZTM-040SY-6ZTM-0Y-0B	205	5	2	2989.9	31.4	9.1
CHAM-4/SHUHAS/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB	REYNA-24	206	5	2	2988.3	31.4	9.1
SOKOLL//INQALAB 91*2/KUKUNA	PTSS06GHB00021S-0Y-040ZTM-040ZTY-5ZTM-0Y-0B	207	5	2	2991.0	31.4	9.1
ZAIN-4	ZAIN-4	208	5	2	2988.4	31.4	9.1
HAALA-49	HAALA-49	209	5	2	2991.5	31.4	9.1
ZAKIA-15	ZAKIA-15	210	5	2	2988.7	31.4	9.1
ALATHEER-5	ALATHEER-5	211	5	2	2989.6	31.4	9.1
ZAHABYA-2	ZAHABYA-2	212	5	2	2991.2	31.4	9.1
AL-ANWAR-1	AL-ANWAR-1	213	5	2	2989.0	31.4	9.1
HAALA-26	HAALA-26	214	5	2	2989.3	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KAUZS//TSI/SNBS	ALMAZ-19 = SIDS-13	215	5	2	2991.0	31.4	9.1
SHAFAQ-1	SHAFAQ-1	216	5	2	2988.4	31.4	9.1
ALATHEER-4	ALATHEER-4	217	5	2	2989.2	31.4	9.1
QAFZAH-11/BASHIQ-1	QAFZAH-11/BASHIQ-1	218	5	2	2990.2	31.4	9.1
BT1735/ACHTAR//HUBARA-8	MORSUD-16	219	5	2	2990.3	31.4	9.1
FIDIYA-9	FIDIYA-9	220	5	2	2990.6	31.4	9.1
DIYAR-7	DIYAR-7	221	5	2	2989.4	31.4	9.1
AAFAQ-2	AAFAQ-2	222	5	2	2988.8	31.4	9.1
TACUPETO F2001*2/KIRITATI//VILLA JUAREZ F2009	CMSS07B00094S-099M-099NJ-099NJ-16WGY-0B	27	9	2	3002.9	31.4	9.0
WBLL1*2/BRAMBLING//QUAIU	CMSS07B00224S-099M-099Y-099M-18WGY-0B	28	9	2	3003.7	31.4	8.7
KAUZ/PASTOR//PBW343/3/KIRITATI/4/FRNCLN	CMSS07B00585T-099TOPY-099M-099Y-099M-11WGY-0B	29	9	2	3002.4	31.4	9.0
PFAU/SERI.1B//AMAD/3/WAXWING*2/4/TECUE #1	CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-0B	30	9	2	2990.0	31.4	9.1
PFAU/SERI.1B//AMAD/3/WAXWING/4/WBLL1*2/BRAMBLING	CMSS07Y00196S-0B-099Y-099M-099NJ-099NJ-6WGY-0B	31	9	2	3006.2	31.4	9.1
BANA-1///NS732/HER//SHUHA-15	ICW01.00053-0AP-8AP-0AP-0AP-7AP-0AP	32	9	2	2989.9	31.4	9.9
PRL/2*PASTOR	CGSS97Y00034M-099TOPB-027Y-099M-099Y-099M-27Y-0B	33	9	2	2986.3	31.4	8.8
PFAU/SERI.1B//AMAD/3/WAXWING	CGSS02Y00153S-099M-099Y-099M-46Y-0B	34	9	2	3000.3	31.4	9.0
TEVEE-3/SHUHA-20//SERI 82/SHUHAS	ICW02.00130-9APTS-0AP-0AP-1AP-0AP-0DZAP-0DZKULSINAP-0NJAP	35	9	2	3000.4	31.4	9.0

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
FERROUG-2/POTAM*2KS811261-8//ZEMAMRA-8	ICW01.21116-5AP-11AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP	36	9	2	2990.1	31.4	9.4
WORRAKATTA/2*PASTOR//DANPHE #1	CMSA07M00403S-040ZTM-040ZTY-15ZTM-010Y-01B-0Y	37	9	2	2990.0	31.4	9.1
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-9AP-0AP	38	9	2	2998.2	31.4	9.4
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-5AP-0AP-0DZAP-0DZKULSINAP-0NJAP	39	9	2	2999.8	31.4	9.1
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-1N-99N	40	9	2	2994.5	31.4	8.7
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-19N-99N	41	9	2	2990.7	31.4	8.9
QAFZAH-11/ICW93.0045-1AP-0L-1AP-0L-2AP-0AP	ICW01.00220-0AP-5AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	105	9	2	2985.9	31.4	9.3
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-3AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	106	9	2	2987.2	31.4	9.0
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-16AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	107	9	2	2983.5	31.4	9.1
KA/NAC//TRCH/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA07M00444S-040M-0NJ-0NJ-6Y-0B	108	9	2	3001.7	31.4	9.7
INQALAB 91/CMSW94WM00188S-0300M-0100Y-0100M-13Y-4M-0Y-0AP	ICW02.00354-9APTS-0AP-0AP-3AP-030KUL-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	109	9	2	2981.7	31.4	9.0

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
CMT/ALD//ZARZOUR/5/AU//KAL/BB/3/BON/4/HPO	ICW99.0181-2AP-0AP-0AP-22AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	110	9	2	2994.0	31.4	9.1
PAVON 76/HAMAM-4/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ	ICW02.20146-7APTS-0AP-0AP-17AP-0AP	111	9	2	2992.5	31.4	9.1
KACHU/BECARD//WBLL1*2/BRAMBLING	CMSS07B00580T-099TOPY-099M-099Y-099M-10WGY-0B	112	9	2	3009.3	31.4	9.0
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-1AP-1AP-0AP-0AP-15AP-0AP	113	9	2	2983.9	31.4	9.2
SERI 82/SHUHAS//CM84655-02AP-300AP-300L-3AP-300L-3AP-0L-0AP	ICW02.00470-16APTS-0AP-0AP-4AP-0AP	114	9	2	2991.1	31.4	9.0
ATTILA*2/PBW65*2//KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-13WGY-0B	115	9	2	2990.0	31.4	9.1
ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2	CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B	116	9	2	3000.5	31.4	9.1
KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU	CMSS06Y00946T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	117	9	2	2990.0	31.4	9.1
SAUAL/3/ACHTAR*3//KANZ/KS85-8-4/4/SAUAL	CMSS06Y01171T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	118	9	2	2998.6	31.4	9.0
MUNAL #1	CGSS01B00054T-099Y-099M-099M-099Y-099M-13Y-0B	119	9	2	2990.0	31.4	9.1
BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	CMSS07Y00288S-0B-099Y-099M-099Y-17M-0WGY	120	9	2	2990.0	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MONS/ALDS//ALDAN S/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-6AP-9AP-0AP-0AP-7AP-0AP	121	9	2	2993.0	31.4	9.1
WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING	CMSS07Y00348S-0B-099Y-099M-099Y-19M-0WGY	122	9	2	2999.3	31.4	9.0
DORADE/KAPSW	ICW98.0120-3AP-0APS-030AP-10AP-5AP-0AP	123	9	2	2990.6	31.4	9.1
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-4AP-0AP	124	9	2	2995.0	31.4	9.2
QAFZAH-33/ICW84.0074-09AP-300L-1AP-300L-8AP-0L-0AP	ICW02.00423-3APTS-0AP-0AP-7AP-0AP	125	9	2	2989.5	31.4	9.2
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-18AP-0AP	126	9	2	2993.6	31.4	9.1
ICW91.0145-4AP-0TS-2AP-0L-0AP/4/NAI60/HN7//SX/3/JUNS	ICW02.00493-7APTS-0AP-0AP-17AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	127	9	2	2987.9	31.4	9.3
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-9AP-0AP	128	9	2	2989.9	31.4	9.1
KIRITATI/WBLL1//MESIA/3/KIRITATI/WBLL1	CMSS07Y00847T-099TOPM-099Y-099M-099Y-53M-0WGY	129	9	2	2992.3	31.4	9.1
NS732/HER//SAADA///SAADA	ICW00.0885-8AP-0AP-0AP-6APMOR-0APMOR-0AP	130	9	2	2985.5	31.4	9.1
FRNCLN*2/TECUE #1	CMSS07Y00941T-099TOPM-099Y-099M-099Y-11M-0WGY	131	9	2	2990.0	31.4	9.1
ACHTAR/IG 132176	MOROCCO F2-17 00/01-27AP-0AP-0AP-11APMOR-0APMOR-0AP	132	9	2	2990.3	31.4	9.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ACHTAR/IG 132176	MOROCCO F2-17 00/01-47AP-0AP-0AP-9APMOR-0APMOR-0AP	133	9	2	2990.3	31.4	8.9
BT1735/ACHTAR//ASFOOR-1	ICW01.00164-0AP-2AP-0AP-0AP-8APMOR-0APMOR-0AP	134	9	2	2989.1	31.4	9.0
ESWYT99#18/ARRIHANE	MOROCCO F2-23 00/01-17AP-0AP-0AP-17APMOR-0APMOR-0AP	135	9	2	2990.0	31.4	9.1
KACHU//WBLL1*2/BRAMBLING	CMSS07Y00124S-0B-099Y-099M-099NJ-099NJ-9WGY-0B	136	9	2	2976.6	31.4	9.0
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-13AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	137	9	2	2985.0	31.4	9.0
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-2N-99N	138	9	2	2997.6	31.4	9.0
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-8N-99N	139	9	2	2995.8	31.4	9.0
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-4N-99N	140	9	2	2994.2	31.4	9.0
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-8N-99N	141	9	2	2995.8	31.4	9.0
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-14N-99N	142	9	2	2993.9	31.4	9.0
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-26N-99N	143	9	2	2988.5	31.4	9.1
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-19N-99N	144	9	2	2987.8	31.4	9.1
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-17N-99N	145	9	2	2990.8	31.4	9.1
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-8N-99N	146	9	2	2991.9	31.4	9.0
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-3N-99N	147	9	2	2995.0	31.4	9.0
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-7N-99N	148	9	2	2985.7	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
WAXWING*2/KIRITATI ///WAXWING*2/KIRITATI // 35891 M500281	PBI09C027-BC-0C-12N-99N	149	9	2	2990.2	31.4	9.1
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-13N-99N	150	9	2	2989.4	31.4	9.1
DBW16//DBW16 / 18293 KC75	PBI09C042-BC-0C-10N-99N	151	9	2	2984.8	31.4	9.1
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-27N-99N	152	9	2	2988.2	31.4	9.2
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-2N-99N	153	9	2	2991.1	31.4	9.0
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-18N-99N	154	9	2	2990.6	31.4	9.0
KAUZ/PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-16AP-0AP	42	13	2	2986.3	31.4	9.2
KAUZ/PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-1AP-0AP	43	13	2	2984.4	31.4	9.4
KARAWAN-1/TALLO3//JADIDA-2	ICW04.0146-1AP-0AP-0AP-9AP-0AP	44	13	2	2989.5	31.4	8.8
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-4AP-0AP-0AP-16AP-0AP	45	13	2	2988.5	31.4	8.8
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-9AP-0AP-0AP-4AP-0AP	46	13	2	2988.2	31.4	9.3
HUBARA-3*2/SHUHA-4	ICW04.20024-17AP-0AP-0AP-0AP-6AP-0AP	47	13	2	2992.7	31.4	9.2
HUBARA-3*2/SHUHA-4	ICW04.20024-26AP-0AP-0AP-0AP-1AP-0AP	48	13	2	2988.1	31.4	8.7
HUBARA-3*2/SHUHA-4	ICW04.20024-47AP-0AP-0AP-0AP-5AP-0AP	49	13	2	2991.2	31.4	8.7
ATTILA-7/KATILA-12	ICW04.0054-1AP-0AP-0AP-3AP-0AP	50	13	2	2986.7	31.4	9.0
FLORKWA-2/6/SAKERS/5/RBS/ANZA/3/KVZ/HYS//YMH/	ICW04.0169-4AP-0AP-0AP-7AP-0AP	51	13	2	2984.6	31.4	9.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
TOB/4/BOWS/7/DAJAJ -6							
HUBARA-3*2/SHUHA-4	ICW04.20024-10AP-0AP-0AP-0AP-3AP-0AP	52	13	2	2990.2	31.4	8.9
HUBARA-3*2/SHUHA-4	ICW04.20024-9AP-0AP-0AP-0AP-9AP-0AP	53	13	2	2996.5	31.4	8.9
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-1AP-0AP-0AP-0AP-6AP-0AP	54	13	2	2990.4	31.4	9.5
PASTOR-2*2//ACSAD 685/ACSAD 639	ICW04.20124-5AP-0AP-0AP-0AP-1AP-0AP	55	13	2	2990.2	31.4	9.1
PASTOR-2/HUBARA-5	ICW04.0037-6AP-0AP-0AP-7AP-0AP	56	13	2	2991.0	31.4	8.8
HUBARA-15/CATBIRD//PASTOR-2	ICW04.20029-40AP-0AP-0AP-0AP-8AP-0AP	57	13	2	2992.8	31.4	8.6
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-14AP-0AP-0AP-0AP-2AP-0AP	58	13	2	2991.8	31.4	9.1
HUBARA-3/SHUHA-4//PASTOR-2	ICW04.20025-43AP-0AP-0AP-0AP-2AP-0AP	59	13	2	2985.2	31.4	9.4
KACHU//KIRITATI/2*TRCH	CMSS08Y00152S-099Y-099M-099NJ-099NJ-41WGY-0B	60	13	2	2987.4	31.4	8.9
PFAU/SERI.1B//AMAD/3/WAXWING/4/QUAIU #2	CMSS08Y00269S-099Y-099M-099NJ-9WGY-0B	61	13	2	2990.0	31.4	9.1
PFAU/SERI.1B//AMAD/3/WAXWING/4/ND643/2*WBLL1	CMSS08Y00274S-099Y-099M-099NJ-099NJ-12WGY-0B	62	13	2	2986.0	31.4	9.4
SAAR//INQALAB 91*2/KUKUNA/3/KIRITATI/2*TRCH	CMSS08Y00299S-099Y-099M-099NJ-099NJ-19WGY-0B	63	13	2	2994.2	31.4	8.9
VILLA JUAREZ F2009/DANPHE #1	CMSS08Y00415S-099Y-099M-099NJ-31WGY-0B	64	13	2	2990.0	31.4	9.1
WBLL1/KUKUNA//TACUPETO	CMSS08Y00447S-099Y-099M-099NJ-29WGY-0B	65	13	2	2990.0	31.4	9.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
F2001/3/FRANCOLIN #1							
WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08Y00477S-099Y-099M-099NJ-7WGY-0B	66	13	2	2993.1	31.4	9.1
QUAIU//2*BRBT1*2/KIRITATI	CMSS08Y00623T-099TOPM-099Y-099M-099NJ-099NJ-7WGY-0B	67	13	2	2994.6	31.4	8.9
MUU/FRNCLN//FRANCOLIN #1	CMSS08Y00728T-099TOPM-099Y-099M-099Y-20M-0WGY	68	13	2	2990.0	31.4	9.1
PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI*2/5/CHONTE	CMSS08Y00731T-099TOPM-099Y-099M-099Y-8M-0WGY	69	13	2	2989.6	31.4	9.0
TOBA97/PASTOR*2//KBIRD	CMSS08Y00760T-099TOPM-099Y-099M-099Y-11M-0WGY	70	13	2	2992.5	31.4	8.9
VILLA JUAREZ F2009//KIRITATI/2*TRCH/3/WBLL1*2/BRAMBLING	CMSS08Y00784T-099TOPM-099Y-099M-099NJ-099NJ-9WGY-0B	71	13	2	2992.2	31.4	8.9
FRNCLN/3/ND643//2*PRL/2*PASTOR/4/FRANCOLIN #1	CMSS08Y00896T-099TOPM-099Y-099M-099NJ-24WGY-0B	72	13	2	2990.0	31.4	9.1
FRNCLN/3/KIRITATI//HUW234+LR34/PRINIA/4/FRANCOLIN #1	CMSS08Y00900T-099TOPM-099Y-099M-099NJ-6WGY-0B	73	13	2	2990.0	31.4	9.1
PFAU/MILAN/4/VEE/TRAP#1//ANGRA/3/PASTOR/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08B00137S-099M-099NJ-099NJ-50WGY-0B	74	13	2	2990.0	31.4	9.1
MP4010/MUNAL #1	CMSS08B00576S-099M-099Y-14M-0WGY	75	13	2	2990.0	31.4	9.1
TRCH*2//ND643/2*WBLL1	CMSS08B00602T-099TOPY-099M-099NJ-099NJ-4WGY-0B	76	13	2	2986.9	31.4	9.6

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
QUAIU #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/6/BECARD	CMSS08B00645T-099TOPY-099M-099NJ-099NJ-6WGY-0B	77	13	2	2990.0	31.4	9.1
QUAIU/BECARD//BECARD	CMSS08B00648T-099TOPY-099M-099NJ-2WGY-0B	78	13	2	2992.5	31.4	9.0
FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KIRITATI/2*TRCH/6/BAJ #1	CMSS08B00678T-099TOPY-099M-099NJ-099NJ-4WGY-0B	79	13	2	2990.0	31.4	9.1
KACHU*2/CHONTE	CMSS08B00714T-099TOPY-099M-099Y-22M-0WGY	80	13	2	2994.4	31.4	9.0
MILAN/S87230//BAV92/3/KIRITATI/2*TRCH/4/WHEAR/KRONSTAD F2004	CMSS08B00764T-099TOPY-099M-099NJ-26WGY-0B	81	13	2	2993.9	31.4	8.9
ND643/2*WBLL1//KIRITATI/2*TRCH/3/ND643/2*WBLL1	CMSS08B00772T-099TOPY-099M-099Y-21M-0WGY	82	13	2	2987.0	31.4	8.9
BECARD//KIRITATI/2*TRCH/3/BECARD	CMSS08B00888T-099TOPY-099M-099NJ-20WGY-0B	83	13	2	2991.7	31.4	8.7
FALCIN/AE.SQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/MUU/6/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA08Y00099T-099B-050Y-040M-0NJ-0NJ-4Y-0B	84	13	2	2990.8	31.4	9.3
PASTOR/3/VEE#5//DOVE/BUC/4/DANPHE #1	CMSA08Y00613S-050Y-050ZTM-050Y-59BMX-010Y-0B	85	13	2	2990.0	31.4	9.1
GLADIUS/3/2*KA/NAC//TRCH	CMSA08M00007T-030(AWW5L7BO1HET)Y-040M-0NJ-4Y-0B	86	13	2	2991.4	31.4	8.9
RAC 1192/4/2*ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00008T-040Y-050ZTM-050Y-13ZTM-010Y-0B	87	13	2	2991.4	31.4	8.9

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1/4/ATTILA/PASTOR	CMSA08M00289S-040ZTM-050Y-40ZTM-010Y-0B	88	13	2	2990.1	31.4	9.3
VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/11/CROC_1/AE.SQUARROSA (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	CMSA08M00364S-040ZTM-050Y-1ZTM-010Y-0B	89	13	2	2990.0	31.4	9.1
SOKOLL/WBLL1/4/ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00393S-040ZTM-050Y-41ZTM-010Y-0B	90	13	2	2991.5	31.4	8.9
SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR	PTSA08M00046S-050ZTM-050Y-85ZTM-010Y-0B	91	13	2	2987.8	31.4	8.9
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH10	92	13	2	2989.3	31.4	9.0
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH63	93	13	2	2987.9	31.4	8.9
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH81	94	13	2	2990.1	31.4	8.9
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH17	95	13	2	2988.4	31.4	9.0
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH22	96	13	2	2990.9	31.4	8.7
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH21	97	13	2	2991.5	31.4	8.8
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH1	98	13	2	2988.7	31.4	8.9
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH56	99	13	2	2987.7	31.4	8.7
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH16	100	13	2	2987.6	31.4	8.8
GOUBARA-1/2*SOKOLL	CMSA04M01020T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-12ZTM-02Y-0B	1	6	3	2551.2	29.1	17.9

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-1WGY-0B	2	6	3	2563.9	31.6	17.9
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-23AP-0AP-0AP-8AP-0AP	3	6	3	2521.9	31.8	17.7
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-35ZTM-02Y-0B	4	6	3	2527.4	29.9	19.1
INQALAB 91*2/TUKURU//WHEAR	CGSS05Y00463S-0B-099Y-099M-099NJ-099NJ-3WGY-0B	5	6	3	2583.5	31.6	18.1
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B	6	6	3	2575.9	29.6	17.8
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-6B	7	6	3	2565.2	31.4	17.8
PBW343	CM85836-4Y-0M-0Y-8M-0Y-0IND	8	6	3	2526.7	29.3	17.6
JANZ	JANZ	9	6	3	2542.8	28.6	18.3
N-ABYAD-13	N-ABYAD-13	10	6	3	2566.2	29.4	19.5
WH 542	WH 542	11	6	3	2549.2	29.3	17.8
CRUSADER	CRUSADER	12	6	3	2630.7	30.7	18.0
SOKOLL	CMSS97M00316S-0P5M-0P5Y-42M-0Y	13	6	3	2548.1	30.4	17.9
ZAKIA-10	ICW98.0030-1AP-0APS-030AP-8AP-1AP-0AP	14	6	3	2576.4	31.7	17.8
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-2ZTM-03Y-0B	15	6	3	2579.2	31.0	17.9
BERKUT	CMSS96M05638T-040Y-5M-010SY-010M-010SY-1M-0Y	16	6	3	2600.2	29.7	17.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
LIVINGSTON	LIVINGSTON	17	6	3	2593.3	30.1	18.7
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-11M-0Y	18	6	3	2589.0	29.8	19.1
EGA GREGORY	EGA GREGORY	19	6	3	2565.9	30.1	18.0
ATTILA*2/PBW65	CGSS96B00123F-099M-037Y-099M-26Y-0B-0SY	20	6	3	2496.8	29.2	17.7
SPITFIRE	SPITFIRE	21	6	3	2574.7	30.4	18.8
SUNTOP	SUNTOP	22	6	3	2570.7	30.8	18.7
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06B00734T-099TOPY-099ZTM-099Y-099M-25WGY-0B	23	6	3	2639.0	32.3	17.7
BECARD/5/PGO//CROC_1/AE.SQUARROSA (224)/3/2*BORL95/4/CIRCUS	CMSS06B00411S-0Y-099ZTM-099Y-099M-12WGY-0B	24	6	3	2583.5	31.4	18.4
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/VORB	CMSA06M00431S-040ZTM-040ZTY-31ZTM-04Y-0B	25	6	3	2645.8	32.5	17.6
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-67ZTM-0Y-0B	26	6	3	2609.3	31.2	18.1
PBW343*2/KUKUNA/3/PGO/SERI//BAV92	CMSS06B00495S-0Y-099ZTM-099NJ-099NJ-12WGY-0B	101	6	3	2596.9	32.2	18.1
FRTL/2*PIFED/4/CROC_1/AE.SQUARROSA (205)//KAUZ/3/PIFED		103	6	3	2577.1	31.0	18.3

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
T.DICOCCON PI225332/AE.SQUARROSA (895)//WBLL1/3/2*WBLL1/4/SOKOLL	CMSA06M00709S-040ZTM-040ZTY-21ZTM-0Y-0B	104	6	3	2572.3	31.8	18.0
Wyalkatchem	MACHETE/84W129-504	156	6	3	2532.7	29.7	18.3
WAXWING*2/TUKURU	CGSS01B00058T-099Y-099M-099M-099Y-099M-49Y-0B	157	6	3	2569.5	30.6	18.1
QAFZAH-31	CMSS93Y00621S-4AP-3AP-4AP-0APS-0AP	158	6	3	2566.9	31.0	18.2
ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/URES/JUN//KAUZ/4/WBLL1/5/MILAN/S87230//BAV92	CMSS06B00201S-0Y-099ZTM-099Y-099M-14WGY-0B	159	6	3	2585.7	30.7	18.1
QUAIU #3//MILAN/AMSEL	CMSS06B00640S-0Y-099ZTM-099Y-099M-7WGY-0B	160	6	3	2584.6	31.0	18.2
ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B	161	6	3	2580.9	31.5	18.1
WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN	CMSS06B00787T-099TOPY-099ZTM-099Y-099M-6WGY-0B	162	6	3	2590.5	30.9	18.3
WBLL1*2/KURUKU/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/7/WBLL1*2/KURUKU	CMSS06B00802T-099TOPY-099ZTM-099Y-099M-12WGY-0B	163	6	3	2579.1	31.3	18.4
WAXWING*2/HEILO	CMSS06B00915T-099TOPY-099ZTM-099Y-099M-8WGY-0B	164	6	3	2598.0	30.6	18.2
BAV92//IRENA/KAUZ/3/HUITES/4/GONDO/T	CMSS06B00918T-099TOPY-099ZTM-099Y-0FUS-6WGY-0B	165	6	3	2570.9	31.1	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
NMU/5/BAV92//IRENA/KAUZ/3/HUITES ATTILA*2/PBW65*2/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B	166	6	3	2617.3	31.0	18.1
ROLF07*2/3/PRINIA/PASTOR//HUITES	CMSS06Y00609T-099TOPM-099Y-099ZTM-099Y-099M-19WGY-0B	167	6	3	2606.3	30.9	18.2
MUNAL #1/FRANCOLIN #1	CMSS06B00001S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	168	6	3	2584.6	31.0	18.2
TRCH/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00314S-0Y-099ZTM-099NJ-099NJ-21WGY-0B	169	6	3	2599.2	30.8	18.3
PFAU/SERI.1B//AMAD/3/WAXWING/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00318S-0Y-099ZTM-099NJ-099NJ-25WGY-0B	170	6	3	2563.9	31.1	18.4
KBIRD//INQALAB 91*2/TUKURU	CMSS06B00485S-0Y-099ZTM-099Y-099M-7WGY-0B	171	6	3	2597.4	31.0	18.2
FRNCLN/ROLF07	CMSS06B00013S-0Y-099ZTM-099Y-099M-9WGY-0B	172	6	3	2580.8	31.0	18.3
PVN/5/2*REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00975T-099TOPY-099ZTM-099Y-099M-9WGY-0B	173	6	3	2587.7	31.1	18.1
WBLL1*2/BRAMBLING/5/WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ		174	6	3	2584.6	31.0	18.2
WBLL1*2/TUKURU//FN/2*PASTOR/3/FRET2/KIRITATI	CMSS06B00926T-099TOPY-099ZTM-099Y-0FUS-18WGY-0B	175	6	3	2581.3	31.7	18.2
FRAME*2/3/URES/JUN//KAUZ/4/BAU//PRL/VEE#6/3/FRAME/5/SLVS/ATTILA//WBLL1	CMSA06M00058T-034(PINBD1BHET)Y-040ZTM-021(PINBD1BPOS)ZTY-12ZTM-04Y-0B	176	6	3	2584.6	31.0	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC		177	6	3	2608.1	31.2	18.1
PFAU/SERI.1B//AMAD/3/WAXWING/4/BABAX/LR42//BABAX*2/3/KURUKU	CMSS06B00033S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	178	6	3	2617.2	31.7	18.2
QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CMSS06B00109S-0Y-099ZTM-099NJ-099NJ-13WGY-0B	179	6	3	2584.6	31.0	18.2
PAURAQ/4/PFAU/SERI.1B//AMAD/3/WAXWING	CMSS06B00015S-0Y-099ZTM-099NJ-099NJ-1WGY-0B	180	6	3	2556.7	29.8	18.2
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-5WGY-0B	181	6	3	2589.6	30.5	18.2
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-22WGY-0B	182	6	3	2587.4	30.8	18.1
WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX	CMSS06Y00885T-099TOPM-099Y-099ZTM-099NJ-099NJ-26WGY-0B	183	6	3	2600.4	31.3	18.2
DUCULA/GONDO//SOKOLL	CMSA06M00645S-040ZTM-040ZTY-19ZTM-03Y-0B	184	6	3	2609.8	31.3	18.1
EGA BONNIE ROCK/4/MILAN/KAUZ//PRINIA/3/BAV92	CMSA06Y00125S-040ZTP0Y-040ZTM-040SY-2ZTM-02Y-0B	185	6	3	2593.2	31.6	18.1
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-20ZTM-0Y-0B	186	6	3	2602.4	30.9	18.3
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-28ZTM-01Y-0B	187	6	3	2604.2	30.9	18.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MILAN/KAUZ//PRINIA/3/BAV92/4/2*SOKOLL	CMSA06M00017T-030(CSLV34HET)Y-040ZTM-049(CSLV34POS)ZTY-68ZTM-0Y-0B	188	6	3	2589.6	32.0	18.7
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-11ZTM-0Y-0B	189	6	3	2615.3	31.5	18.2
ANNUELLO*2/4/92.001E7.32.5/3/PRL/SARA//TSI/VEE#5	CMSA06Y00718T-085(CRE1M19)M-040ZTP0Y-040ZTM-040SY-6ZTM-0Y-0B	190	6	3	2584.6	31.0	18.2
HUANIL/5/2*CNO79//PF70354/MUS/3/PASTOR/4/BAV92	CMSA05M00750T-050Y-041ZTM-040ZTY-040ZTM-040SY-10ZTM-0Y-0B	191	6	3	2552.4	30.5	18.1
EGA BONNIE ROCK/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	CMSA05M00023S-0130ZTM-039(LR34HOM+HET)ZTY-040ZTM-040SY-6ZTM-0Y-0B	192	6	3	2564.6	30.9	18.1
PBW343*2/KUKUNA//WBLL1*2/KUKUNA	CMSA05M00118S-0100ZTM-029(LR34HOM+HET)ZTY-040ZTM-040SY-45ZTM-0Y-0B	193	6	3	2594.9	30.9	18.1
SLVS/ATTILA//WBLL1/4/FRAME*2/3/URES/JUN//KAUZ	CMSA05M00140S-021(CRE1M19-GWM577BO1)M-028(BO1 POS& CRE1 POS)ZTY-040ZTM-040SY-11ZTM-0Y-0B	194	6	3	2602.8	30.9	18.1
VORB/4/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/5/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM	CMSA06Y00835T-040ZTM-040ZTP0Y-040ZTM-040P0Y-3ZTM-02Y-0B	195	6	3	2533.1	30.6	18.2
VORB/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.	CMSA06Y00836T-040ZTM-040ZTP0Y-	196	6	3	2575.5	31.0	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SQUARROSA (208)/5/2*WESTONIA/7/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	040ZTM-040P0Y-26ZTM-01Y-0B						
CHIH95.7.4//INQALAB 91*2/KUKUNA	PTSS06GHB00007S-0Y-040ZTM-040ZTY-11ZTM-0Y-0B	197	6	3	2536.9	30.1	18.3
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/SKAUZ/BAV92	CMSA06M00430S-040ZTM-0NJ-0NJ-18Y-3B-0Y	198	6	3	2585.1	31.0	18.2
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-4Y-1B-0Y	199	6	3	2592.2	31.2	18.5
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-9Y-1B-0Y	200	6	3	2568.5	30.5	18.3
MACE	WYALKATCHEM/STYLET//WYALKATCHEM	201	6	3	2589.2	30.3	18.5
SCOUT	SCOUT	202	6	3	2595.7	30.5	18.2
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	SHAMIEKH-3	203	6	3	2634.7	31.0	18.1
BABAX/LR39//BABAX/3/VORB/4/SUNCO/2*PASTOR	CMSA06Y00792T-040ZTM-040ZTP0Y-040ZTM-040SY-28ZTM-02Y-0B	204	6	3	2602.9	30.8	18.3
HEILO//SUNCO/2*PASTOR	CMSA06Y00492S-040ZTY-040ZTM-040SY-6ZTM-0Y-0B	205	6	3	2580.3	30.8	18.1
CHAM-4/SHUHAS/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB	REYNA-24	206	6	3	2572.9	30.9	18.1
SOKOLL//INQALAB 91*2/KUKUNA	PTSS06GHB00021S-0Y-040ZTM-040ZTY-5ZTM-0Y-0B	207	6	3	2583.3	31.3	18.1
ZAIN-4	ZAIN-4	208	6	3	2606.8	30.9	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
HAALA-49	HAALA-49	209	6	3	2596.3	31.2	18.1
ZAKIA-15	ZAKIA-15	210	6	3	2604.2	30.0	18.2
ALATHEER-5	ALATHEER-5	211	6	3	2581.2	30.5	18.2
ZAHABYA-2	ZAHABYA-2	212	6	3	2617.0	30.9	18.2
AL-ANWAR-1	AL-ANWAR-1	213	6	3	2575.1	31.3	18.2
HAALA-26	HAALA-26	214	6	3	2579.8	30.2	18.3
KAUZS//TSI/SNBS	ALMAZ-19 = SIDS-13	215	6	3	2588.8	30.5	18.2
SHAFAQ-1	SHAFAQ-1	216	6	3	2567.8	31.6	18.2
ALATHEER-4	ALATHEER-4	217	6	3	2575.4	30.3	18.3
QAFZAH-11/BASHIQ-1	QAFZAH-11/BASHIQ-1	218	6	3	2582.6	30.5	18.3
BT1735/ACHTAR//HUBARA-8	MORSUD-16	219	6	3	2566.3	30.5	18.1
FIDIYA-9	FIDIYA-9	220	6	3	2595.2	31.0	18.2
DIYAR-7	DIYAR-7	221	6	3	2609.6	31.1	18.3
AAFAQ-2	AAFAQ-2	222	6	3	2586.3	30.8	18.2
TACUPETO F2001*2/KIRITATI//VILLA JUAREZ F2009	CMSS07B00094S-099M-099NJ-099NJ-16WGY-0B	27	10	3	2635.7	32.0	18.9
WBLL1*2/BRAMBLING//QUAIU	CMSS07B00224S-099M-099Y-099M-18WGY-0B	28	10	3	2615.7	32.3	17.7
KAUZ/PASTOR//PBW343/3/KIRITATI/4/FRNCLN	CMSS07B00585T-099TOPY-099M-099Y-099M-11WGY-0B	29	10	3	2637.4	31.4	17.9
PFAU/SERI.1B//AMAD/3/WAXWING*2/4/TECUE #1	CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-0B	30	10	3	2584.6	31.0	18.2
PFAU/SERI.1B//AMAD/3/WAXWING/4/WBLL1*2/BRAMBLING	CMSS07Y00196S-0B-099Y-099M-099NJ-099NJ-6WGY-0B	31	10	3	2640.0	31.8	18.1
BANA-1///NS732/HER//SHUHA-15	ICW01.00053-0AP-8AP-0AP-0AP-7AP-0AP	32	10	3	2587.8	30.2	19.1

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PRL/2*PASTOR	CGSS97Y00034M-099TOPB-027Y-099M-099Y-099M-27Y-0B	33	10	3	2649.3	30.9	18.1
PFAU/SERI.1B//AMAD/3/WAXWING	CGSS02Y00153S-099M-099Y-099M-46Y-0B	34	10	3	2598.3	30.4	18.3
TEVEE-3/SHUHA-20//SERI 82/SHUHAS	ICW02.00130-9APTS-0AP-0AP-1AP-0AP-0DZAP-0DZKULSINAP-0NJAP	35	10	3	2596.1	30.9	18.3
FERROUG-2/POTAM*2KS811261-8//ZEMAMRA-8	ICW01.21116-5AP-11AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP	36	10	3	2574.9	30.2	19.4
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-9AP-0AP	38	10	3	2573.4	30.1	19.1
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-5AP-0AP-0DZAP-0DZKULSINAP-0NJAP	39	10	3	2575.2	31.6	18.0
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-1N-99N	40	10	3	2584.9	31.9	17.6
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-19N-99N	41	10	3	2597.0	31.8	18.1
QAFZAH-11/ICW93.0045-1AP-0L-1AP-0L-2AP-0AP	ICW01.00220-0AP-5AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	105	10	3	2579.1	30.8	18.3
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-3AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	106	10	3	2582.4	31.9	18.1
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-16AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	107	10	3	2557.0	30.3	18.1
KA/NAC//TRCH/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA07M00444S-040M-0NJ-0NJ-6Y-0B	108	10	3	2581.8	31.4	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
INQALAB 91/CMSW94WM00188S-0300M-0100Y-0100M-13Y-4M-0Y-0AP	ICW02.00354-9APTS-0AP-0AP-3AP-030KUL-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	109	10	3	2566.0	31.3	18.1
CMT/ALD//ZARZOUR/5/AU//KAL/BB/3/BON/4/HPO	ICW99.0181-2AP-0AP-0AP-22AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	110	10	3	2577.5	30.5	18.3
PAVON 76/HAMAM-4/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ	ICW02.20146-7APTS-0AP-0AP-17AP-0AP	111	10	3	2574.3	31.4	18.1
KACHU/BECARD//WBLL1*2/BRAMBLING	CMSS07B00580T-099TOPY-099M-099Y-099M-10WGY-0B	112	10	3	2600.9	32.3	18.1
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-1AP-1AP-0AP-0AP-15AP-0AP	113	10	3	2569.2	31.0	18.2
SERI 82/SHUHAS//CM84655-02AP-300AP-300L-3AP-300L-3AP-0L-0AP	ICW02.00470-16APTS-0AP-0AP-4AP-0AP	114	10	3	2594.4	31.6	18.2
ATTILA*2/PBW65*2//KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-13WGY-0B	115	10	3	2581.9	30.4	18.3
ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2	CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B	116	10	3	2592.5	31.7	18.1
KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU	CMSS06Y00946T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	117	10	3	2584.6	31.0	18.2
SAUAL/3/ACHTAR*3//KANZ/KS85-8-4/4/SAUAL	CMSS06Y01171T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	118	10	3	2606.0	31.3	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MUNAL #1	CGSS01B00054T-099Y-099M-099Y-099M-13Y-0B	119	10	3	2584.6	31.0	18.2
BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	CMSS07Y00288S-0B-099Y-099M-099Y-17M-0WGY	120	10	3	2584.6	31.0	18.2
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-6AP-9AP-0AP-0AP-7AP-0AP	121	10	3	2597.8	31.3	18.4
WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING	CMSS07Y00348S-0B-099Y-099M-099Y-19M-0WGY	122	10	3	2613.7	32.2	18.1
DORADE/KAPSW	ICW98.0120-3AP-0APS-030AP-10AP-5AP-0AP	123	10	3	2574.9	31.5	18.2
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-4AP-0AP	124	10	3	2574.5	30.2	18.3
QAFZAH-33/ICW84.0074-09AP-300L-1AP-300L-8AP-0L-0AP	ICW02.00423-3APTS-0AP-0AP-7AP-0AP	125	10	3	2603.2	31.9	18.2
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-18AP-0AP	126	10	3	2560.2	31.4	18.1
ICW91.0145-4AP-0TS-2AP-0L-0AP/4/NAI60/HN7//SX/3/JUNS	ICW02.00493-7APTS-0AP-0AP-17AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	127	10	3	2616.6	30.3	18.3
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-9AP-0AP	128	10	3	2603.8	31.6	18.3
KIRITATI/WBLL1//MESIA/3/KIRITATI/WBLL1	CMSS07Y00847T-099TOPM-099Y-099M-099Y-53M-0WGY	129	10	3	2626.9	31.9	18.1
NS732/HER//SAADA///SAADA	ICW00.0885-8AP-0AP-0AP-6APMOR-0APMOR-0AP	130	10	3	2589.6	31.1	18.4
FRNCLN*2/TECUE #1	CMSS07Y00941T-099TOPM-099Y-099M-099Y-11M-0WGY	131	10	3	2584.6	31.0	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ACHTAR/IG 132176	MOROCCO F2-17 00/01-27AP-0AP-0AP-11APMOR-0APMOR-0AP	132	10	3	2559.2	30.8	18.2
ACHTAR/IG 132176	MOROCCO F2-17 00/01-47AP-0AP-0AP-9APMOR-0APMOR-0AP	133	10	3	2550.2	32.2	18.0
BT1735/ACHTAR//ASFOOR-1	ICW01.00164-0AP-2AP-0AP-0AP-8APMOR-0APMOR-0AP	134	10	3	2583.2	30.0	18.1
ESWYT99#18/ARRIHANE	MOROCCO F2-23 00/01-17AP-0AP-0AP-17APMOR-0APMOR-0AP	135	10	3	2584.6	31.0	18.2
KACHU//WBLL1*2/BRAMBLING	CMSS07Y00124S-0B-099Y-099M-099NJ-099NJ-9WGY-0B	136	10	3	2612.7	31.9	18.3
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-13AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	137	10	3	2550.8	30.4	18.1
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-2N-99N	138	10	3	2565.2	31.6	18.2
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-8N-99N	139	10	3	2557.7	31.1	18.2
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-4N-99N	140	10	3	2563.4	31.6	18.1
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-8N-99N	141	10	3	2587.0	31.8	18.7
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-14N-99N	142	10	3	2579.3	31.5	18.1
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-26N-99N	143	10	3	2563.5	31.1	18.2
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-19N-99N	144	10	3	2571.0	31.2	18.2
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-17N-99N	145	10	3	2563.8	31.0	18.2
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-8N-99N	146	10	3	2590.1	31.9	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-3N-99N	147	10	3	2572.1	31.3	18.1
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-7N-99N	148	10	3	2568.3	31.2	18.2
WAXWING*2/KIRITAT I ///WAXWING*2/KIRIT ATI // 35891 M500281	PBI09C027-BC-0C-12N-99N	149	10	3	2562.9	31.1	18.2
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-13N-99N	150	10	3	2571.8	31.2	18.2
DBW16//DBW16 / 18293 KC75	PBI09C042-BC-0C-10N-99N	151	10	3	2572.5	31.0	18.2
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-27N-99N	152	10	3	2580.5	30.9	18.2
PBW550//PBW550/1834 3 KC75	PBI09C036-BC-0C-2N-99N	153	10	3	2580.5	31.8	18.1
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-18N-99N	154	10	3	2577.0	31.4	18.2
WORRAKATTA/2*PAS TOR//DANPHE #1	CMSA07M00403S-040ZTM-040ZTY-15ZTM-010Y-01B-0Y	37	14	3	2584.6	31.0	18.2
KAUZ/PASTOR/3/ALT AR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-16AP-0AP	42	14	3	2573.9	31.0	18.3
KAUZ/PASTOR/3/ALT AR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-1AP-0AP	43	14	3	2594.4	31.0	18.1
KARAWAN-1/TALLO 3//JADIDA-2	ICW04.0146-1AP-0AP-0AP-9AP-0AP	44	14	3	2582.3	30.7	18.1
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-4AP-0AP-0AP-16AP-0AP	45	14	3	2564.8	30.6	18.4
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-9AP-0AP-0AP-4AP-0AP	46	14	3	2586.4	30.3	18.9
HUBARA-3*2/SHUHA-4	ICW04.20024-17AP-0AP-0AP-0AP-6AP-0AP	47	14	3	2597.4	30.4	18.4
HUBARA-3*2/SHUHA-4	ICW04.20024-26AP-0AP-0AP-0AP-1AP-0AP	48	14	3	2566.8	30.5	17.9

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
HUBARA-3*2/SHUHA-4	ICW04.20024-47AP-0AP-0AP-0AP-5AP-0AP	49	14	3	2588.9	31.0	17.9
ATTILA-7/KATILA-12	ICW04.0054-1AP-0AP-0AP-3AP-0AP	50	14	3	2612.3	30.5	18.3
FLORKWA-2/6/SAKERS/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOWS/7/DAJAJ-6	ICW04.0169-4AP-0AP-0AP-7AP-0AP	51	14	3	2546.5	30.7	18.7
HUBARA-3*2/SHUHA-4	ICW04.20024-10AP-0AP-0AP-0AP-3AP-0AP	52	14	3	2567.0	30.9	17.9
HUBARA-3*2/SHUHA-4	ICW04.20024-9AP-0AP-0AP-0AP-9AP-0AP	53	14	3	2578.9	30.5	18.7
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-1AP-0AP-0AP-0AP-6AP-0AP	54	14	3	2611.9	30.5	17.8
PASTOR-2*2//ACSAD 685/ACSAD 639	ICW04.20124-5AP-0AP-0AP-0AP-1AP-0AP	55	14	3	2579.1	30.4	18.1
PASTOR-2/HUBARA-5	ICW04.0037-6AP-0AP-0AP-7AP-0AP	56	14	3	2546.9	30.8	17.9
HUBARA-15/CATBIRD//PASTOR-2	ICW04.20029-40AP-0AP-0AP-0AP-8AP-0AP	57	14	3	2566.4	31.1	17.7
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-14AP-0AP-0AP-0AP-2AP-0AP	58	14	3	2597.9	30.9	18.0
HUBARA-3/SHUHA-4//PASTOR-2	ICW04.20025-43AP-0AP-0AP-0AP-2AP-0AP	59	14	3	2575.8	30.7	18.2
KACHU//KIRITATI/2*TRCH	CMSS08Y00152S-099Y-099M-099NJ-099NJ-41WGY-0B	60	14	3	2588.7	31.2	17.8
PFAU/SERI.1B//AMAD/3/WAXWING/4/QUAIU #2	CMSS08Y00269S-099Y-099M-099NJ-9WGY-0B	61	14	3	2584.6	31.0	18.2
PFAU/SERI.1B//AMAD/3/WAXWING/4/ND643/2*WBLL1	CMSS08Y00274S-099Y-099M-099NJ-099NJ-12WGY-0B	62	14	3	2596.2	30.3	18.7

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SAAR//INQALAB 91*2/KUKUNA/3/KIRITATI/2*TRCH	CMSS08Y00299S-099Y-099M-099NJ-099NJ-19WGY-0B	63	14	3	2628.0	31.6	17.9
VILLA JUAREZ F2009/DANPHE #1	CMSS08Y00415S-099Y-099M-099NJ-31WGY-0B	64	14	3	2584.6	31.0	18.2
WBLL1/KUKUNA//TACUPETO F2001/3/FRANCOLIN #1	CMSS08Y00447S-099Y-099M-099NJ-29WGY-0B	65	14	3	2584.6	31.0	18.2
WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08Y00477S-099Y-099M-099NJ-7WGY-0B	66	14	3	2581.7	30.8	18.3
QUAIU//2*BRBT1*2/KIRITATI	CMSS08Y00623T-099TOPM-099Y-099M-099NJ-099NJ-7WGY-0B	67	14	3	2566.1	31.5	17.9
MUU/FRNCLN//FRANCOLIN #1	CMSS08Y00728T-099TOPM-099Y-099M-099Y-20M-0WGY	68	14	3	2584.6	31.0	18.2
PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI*2/5/CHONTE	CMSS08Y00731T-099TOPM-099Y-099M-099Y-8M-0WGY	69	14	3	2596.3	30.7	18.2
TOBA97/PASTOR*2//KBIRD	CMSS08Y00760T-099TOPM-099Y-099M-099Y-11M-0WGY	70	14	3	2602.9	30.9	18.2
VILLA JUAREZ F2009//KIRITATI/2*TRCH/3/WBLL1*2/BRAMBLING	CMSS08Y00784T-099TOPM-099Y-099M-099NJ-099NJ-9WGY-0B	71	14	3	2609.0	31.4	18.3
FRNCLN/3/ND643//2*PRL/2*PASTOR/4/FRANCOLIN #1	CMSS08Y00896T-099TOPM-099Y-099M-099NJ-24WGY-0B	72	14	3	2584.6	31.0	18.2
FRNCLN/3/KIRITATI//HUW234+LR34/PRINIA/4/FRANCOLIN #1	CMSS08Y00900T-099TOPM-099Y-099M-099NJ-6WGY-0B	73	14	3	2584.6	31.0	18.2
PFAU/MILAN/4/VEE/TRAP#1//ANGRA/3/PASTOR/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08B00137S-099M-099NJ-099NJ-50WGY-0B	74	14	3	2584.6	31.0	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MP4010/MUNAL #1	CMSS08B00576S-099M-099Y-14M-0WGY	75	14	3	2584.6	31.0	18.2
TRCH*2//ND643/2*WBLL1	CMSS08B00602T-099TOPY-099M-099NJ-099NJ-4WGY-0B	76	14	3	2593.7	30.7	18.4
QUAIU #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/6/BECARD	CMSS08B00645T-099TOPY-099M-099NJ-099NJ-6WGY-0B	77	14	3	2584.6	31.0	18.2
QUAIU/BECARD//BECARD	CMSS08B00648T-099TOPY-099M-099NJ-2WGY-0B	78	14	3	2607.0	31.6	17.9
FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KIRITATI/2*TRCH/6/BAJ #1	CMSS08B00678T-099TOPY-099M-099NJ-099NJ-4WGY-0B	79	14	3	2584.6	31.0	18.2
KACHU*2/CHONTE	CMSS08B00714T-099TOPY-099M-099Y-22M-0WGY	80	14	3	2609.7	30.8	18.0
MILAN/S87230//BAV92/3/KIRITATI/2*TRCH/4/WHEAR/KRONSTAD F2004	CMSS08B00764T-099TOPY-099M-099NJ-26WGY-0B	81	14	3	2592.8	31.3	18.0
ND643/2*WBLL1//KIRITATI/2*TRCH/3/ND643/2*WBLL1	CMSS08B00772T-099TOPY-099M-099Y-21M-0WGY	82	14	3	2565.3	30.6	18.3
BECARD//KIRITATI/2*TRCH/3/BECARD	CMSS08B00888T-099TOPY-099M-099NJ-20WGY-0B	83	14	3	2599.5	31.8	17.8
FALCIN/AE.SQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/MUU/6/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA08Y00099T-099B-050Y-040M-0NJ-0NJ-4Y-0B	84	14	3	2618.2	31.0	18.3
PASTOR/3/VEE#5//DOVE/BUC/4/DANPHE #1	CMSA08Y00613S-050Y-050ZTM-050Y-59BMX-010Y-0B	85	14	3	2584.6	31.0	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
GLADIUS/3/2*KA/NAC//TRCH	CMSA08M00007T-030(AWW5L7BO1HET)Y-040M-0NJ-4Y-0B	86	14	3	2559.7	31.0	18.4
RAC 1192/4/2*ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00008T-040Y-050ZTM-050Y-13ZTM-010Y-0B	87	14	3	2575.3	30.9	18.1
TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1/4/ATTILA/PASTOR	CMSA08M00289S-040ZTM-050Y-40ZTM-010Y-0B	88	14	3	2607.3	31.1	18.1
VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/11/CROC_1/AE.SQUARROSA (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA	CMSA08M00364S-040ZTM-050Y-1ZTM-010Y-0B	89	14	3	2584.6	31.0	18.2
SOKOLL/WBLL1/4/ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00393S-040ZTM-050Y-41ZTM-010Y-0B	90	14	3	2598.5	30.7	18.3
SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR	PTSA08M00046S-050ZTM-050Y-85ZTM-010Y-0B	91	14	3	2615.7	31.9	17.4
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH10	92	14	3	2570.1	31.2	18.3
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH63	93	14	3	2588.3	31.2	18.0
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH81	94	14	3	2573.4	31.0	17.9
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH17	95	14	3	2598.5	31.2	18.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH22	96	14	3	2571.3	31.1	18.0
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH21	97	14	3	2577.9	31.3	17.7
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH1	98	14	3	2566.6	31.2	18.3
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH56	99	14	3	2592.3	31.8	17.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH16	100	14	3	2568.1	31.3	20.9
QG 4.37A/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92	CMSA05M00708T-050Y-040ZTM-040ZTY-4ZTM-04Y-0B	223	17	3	2573.2	31.1	18.1
NSM*4/14-2//FRTL/2*PIFED/3/VORB	CMSA05M00650T-050Y-040ZTM-040ZTY-21ZTM-02Y-0B	224	17	3	2601.3	30.4	18.2
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-8ZTM-03Y-0B	225	17	3	2547.1	30.5	18.2
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B	226	17	3	2614.7	31.9	18.1
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-32ZTM-02Y-0B	227	17	3	2547.2	31.3	18.4
SOKOLL//PBW343*2/KUKUNA/3/ATTILA/PASTOR	CMSA05Y01188T-040M-040ZTP0Y-040ZTM-040SY-2ZTM-01Y-0B	228	17	3	2595.8	31.5	18.1
SOKOLL*2//TACUPETO F2001*2/KUKUNA	CMSA05Y01226T-040M-040ZTP0Y-040ZTM-040SY-22ZTM-04Y-0B	229	17	3	2572.7	31.3	18.2
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-9ZTM-04Y-0B	230	17	3	2578.7	31.5	18.1
GK ARON/AG SECO 7846//2180/4/2*MILAN/	CMSA05Y00954T-040M-040ZTP0Y-	231	17	3	2581.9	31.2	18.3

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KAUZ//PRINIA/3/BAV 92	040ZTM-040SY-15ZTM-01Y-0B						
SW89-5124*2/FASAN/3/ALTAR 84/AE.SQ//2*OPATA	CMSA04M00335S-040ZTP0Y-040ZTM-040SY-16ZTM-04Y-0B	232	17	3	2599.6	31.1	18.1
SOKOLL//TACUPETO F2001*2/KUKUNA	CMSA04M00346S-040ZTP0Y-040ZTM-040SY-28ZTM-01Y-0B	233	17	3	2589.6	31.4	18.1
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-19ZTM-03Y-0B	234	17	3	2613.3	31.3	18.1
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-4ZTM-04Y-0B	235	17	3	2584.0	31.1	18.1
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-6ZTM-02Y-0B	236	17	3	2574.0	31.3	18.4
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	237	17	3	2596.0	31.3	18.2
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-24ZTM-04Y-0B	238	17	3	2580.5	31.2	18.1
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-5ZTM-03Y-0B	239	17	3	2581.5	31.2	18.1
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	240	17	3	2576.0	31.3	18.2
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTO	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-2ZTM-01Y-0B	241	17	3	2594.7	31.2	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
R//MILAN/KAUZ/3/BAV92							
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-01Y-0B	242	17	3	2582.9	31.2	18.1
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-03Y-0B	243	17	3	2580.2	31.0	18.1
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-3B	244	17	3	2614.2	31.2	18.3
ATTILA*2//CHIL/BUC*2/3/KUKUNA	CMSS05Y00671T-099TOPM-099Y-099M-099Y-099ZTM-2WGY-0B	245	17	3	2569.7	30.5	18.3
CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/PASTOR/7/KAUZ/PASTOR//PBW343	CMSS05B00592S-099Y-099M-099Y-099ZTM-17WGY-0B	246	17	3	2604.7	31.4	18.2
ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARROSA (224)//2*OPATA	CMSS05B00663S-099Y-099M-099Y-099ZTM-13WGY-0B	247	17	3	2584.6	31.0	18.2
WBLL1*2/KUKUNA*2//WHEAR	CGSS05B00174T-099TOPY-099M-099NJ-099NJ-5WGY-0B	248	17	3	2618.6	31.3	18.1
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099Y-099ZTM-10WGY-0B	249	17	3	2570.4	31.3	18.1

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-3WGY-0B	250	17	3	2608.4	30.9	18.2
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-5WGY-0B	251	17	3	2584.9	31.1	18.2
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099Y-099ZTM-12WGY-0B	252	17	3	2592.9	31.7	18.1
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-2WGY-0B	253	17	3	2589.4	31.1	18.1
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-6WGY-0B	254	17	3	2623.0	31.5	18.3
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-8WGY-0B	255	17	3	2578.1	31.0	18.4
PBW343*2/KHVAKI//PARUS/3/PBW343/PASTOR	CGSS05B00271T-099TOPY-099M-099NJ-099NJ-17WGY-0B	256	17	3	2595.3	31.5	18.1
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-17WGY-0B	257	17	3	2584.6	31.0	18.2
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-20WGY-0B	258	17	3	2584.6	31.0	18.2
ATTILA*2/PBW65//KIRITATI/3/WAXWING/KIRITATI	CGSS05B00299T-099TOPY-099M-099Y-099ZTM-19WGY-0B	259	17	3	2558.7	30.8	18.2
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-3AP-0AP	260	17	3	2550.6	31.9	18.0
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-5AP-0AP	261	17	3	2570.2	30.6	18.3

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
ALTAR 84/AE.SQUARROSA (191)//OPATA/3/SKAUZ	CMSS98Y05580S-040Y-0B-0MXI-0AP-0AP-15AP-0AP	262	17	3	2570.5	30.5	18.3
VANS/3/CNDRS/ANA//CNDRS/MUSS/4/CHAM-6	ICW99-0336-12AP-0AP-0AP-7AP-0AP	263	17	3	2584.6	31.0	18.2
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-13AP-0AP-0AP-5AP-0AP	264	17	3	2619.5	30.2	18.3
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-2AP-0AP	265	17	3	2575.7	30.3	18.3
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-5AP-0AP	266	17	3	2569.3	31.5	18.2
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-8AP-0AP	267	17	3	2585.0	31.0	18.2
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-12AP-0AP-0AP-45AP-0AP	268	17	3	2584.6	31.0	18.2
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-4AP-0AP-0AP-29AP-0AP	269	17	3	2584.6	31.0	18.2
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-4AP-0AP	270	17	3	2618.0	30.3	18.2
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-9AP-0AP	271	17	3	2590.1	30.7	18.1
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-25AP-0AP-0AP-4AP-0AP	272	17	3	2577.2	30.5	18.2
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-7M-0Y-01B-0Y	273	17	3	2629.6	30.9	18.2
SUNCO	SUNCO	274	17	3	2573.8	29.9	18.8
SHIHAB-3	CMSS97M00652S-0B-0AP-1AP-0APS-0AP-11AP-3AP-0AP	275	17	3	2563.3	30.0	18.5
LEITH-3	ICW97.0717-0APS-1AP-0APS-050AP-0APS-16AP-0AP	276	17	3	2592.1	30.8	18.4
PBW343*2/KUKUNA//PBW343*2/KUKUNA	CGSS04Y00099S-099Y-099M-099Y-099M-8WGY-0B	277	17	3	2578.2	30.9	18.2

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PRL/2*PASTOR//PBW343*2/KUKUNA	CMSS04Y00086S-0Y-099ZTM-099Y-099M-4WGY-0B	278	17	3	2606.8	31.0	18.2
CROC_1/AE.SQUARROSA (213)//PGO/3/CMH81.38/2*KAUZ/4/BERKUT	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-7ZTY-03M-0Y	279	17	3	2542.2	30.7	18.1
ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE#10/8/OPATA/10/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/2*WEAVER/11/PRL/2*PASTOR	CMSA02Y00426T-040M-040P0Y-040ZTM-040SY-040M-5ZTY-01M-0Y	280	17	3	2584.6	31.0	18.2
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-7ZTM-03Y-0B	281	17	3	2553.2	30.6	18.3
BERKUT/HTG	CMSA04Y00607S-130ZTP0Y-010M-010SY-2M-04Y-0B	282	17	3	2586.0	30.9	18.2
SOKOLL//PRL/2*PASTOR	CMSA04Y00608S-150ZTP0Y-010M-010SY-3M-02Y-0B	283	17	3	2607.2	31.2	18.1
SW89-5124*2/FASAN/6/CHIBIA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER	CMSA02Y00249S-040ZTM-040HTY-040M-040SY-10M-0Y	284	17	3	2585.4	31.4	18.2
SOKOLL/WBLL1	PTSS02Y00021S-0Y-030ZTM-040SY-040M-14Y-0M-0SY	285	17	3	2581.1	30.5	18.3
CROC_1/AE.SQUARROSA (224)//OPATA/3/SOKOLL	PTSS02B00065S-0Y-0B-0Y-0B-32Y-0M-0SY	286	17	3	2593.9	31.6	18.1
MEX94.2.19/PUB94.15.1.12	PTSS02B00074S-0Y-0B-0Y-0B-32Y-0M-0SY	287	17	3	2572.1	30.7	18.6

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SOKOLL//W15.92/WBLL1	PTSS02B00088T-0TOPY-0B-0Y-0B-5Y-0M-0SY	288	17	3	2590.1	31.1	18.1
OAX93.24.35//SOKOLL/WBLL1	PTSS02B00099T-0TOPY-0B-0Y-0B-35Y-0M-0SY	289	17	3	2575.5	31.2	18.2
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	PTSS02B00102T-0TOPY-0B-0Y-0B-11Y-0M-0SY	290	17	3	2608.2	31.0	18.2
WBLL4//OAX93.24.35/WBLL1	PTSS02B00110T-0TOPY-0B-0Y-0B-21Y-0M-0SY	291	17	3	2563.5	31.0	18.2
GOUBARA-1/2*SOKOLL	CMSA04M01020T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-12ZTM-02Y-0B	1	3	4	1596.1	28.2	21.4
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-1WGY-0B	2	3	4	1601.8	28.9	21.3
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-23AP-0AP-0AP-8AP-0AP	3	3	4	1536.8	28.9	21.3
BABAX/LR42//BABAX/3/BABAX/LR42//BABAX/4/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR/5/T.DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-35ZTM-02Y-0B	4	3	4	1569.5	28.6	21.6
INQALAB 91*2/TUKURU//WHEAR	CGSS05Y00463S-0B-099Y-099M-099NJ-099NJ-3WGY-0B	5	3	4	1615.5	28.7	21.4
GK ARON/AG SECO 7846//2180/4/2*MILAN/KAUZ//PRINIA/3/BAV92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-01Y-0B	6	3	4	1621.9	28.3	21.4
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-6B	7	3	4	1636.9	28.8	21.4
PBW343	CM85836-4Y-0M-0Y-8M-0Y-0IND	8	3	4	1470.4	28.2	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
JANZ	JANZ	9	3	4	1536.7	28.2	21.3
N-ABYAD-13	N-ABYAD-13	10	3	4	1530.2	28.5	21.5
WH 542	WH 542	11	3	4	1471.4	28.2	21.3
CRUSADER	CRUSADER	12	3	4	1526.7	28.8	21.3
SOKOLL	CMSS97M00316S-0P5M-0P5Y-42M-0Y	13	3	4	1640.0	28.7	21.3
ZAKIA-10	ICW98.0030-1AP-0APS-030AP-8AP-1AP-0AP	14	3	4	1554.2	28.7	21.4
SOKOLL//FRTL/2*PIFED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-2ZTM-03Y-0B	15	3	4	1589.2	28.6	21.3
BERKUT	CMSS96M05638T-040Y-5M-010SY-010M-010SY-1M-0Y	16	3	4	1588.1	28.3	21.3
LIVINGSTON	LIVINGSTON	17	3	4	1610.5	28.7	21.4
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-11M-0Y	18	3	4	1520.0	28.5	21.5
EGA GREGORY	EGA GREGORY	19	3	4	1629.0	28.6	21.3
ATTILA*2/PBW65	CGSS96B00123F-099M-037Y-099M-26Y-0B-0SY	20	3	4	1394.0	28.3	21.3
SPITFIRE	SPITFIRE	21	3	4	1589.8	28.6	21.4
WAXWING*2/TUKURU	CGSS01B00058T-099Y-099M-099M-099Y-099M-49Y-0B	157	3	4	1580.3	28.7	21.4
QG 4.37A/4/MILAN/KAUZ//PRINIA/3/BAV92/5/MILAN/KAUZ//PRINIA/3/BAV92	CMSA05M00708T-050Y-040ZTM-040ZTY-4ZTM-04Y-0B	223	3	4	1602.9	28.7	21.4
NSM*4/14-2//FRTL/2*PIFED/3/VORB	CMSA05M00650T-050Y-040ZTM-040ZTY-21ZTM-02Y-0B	224	3	4	1588.0	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
BABAX/LR42//BABAX /3/BABAX/LR42//BAB AX/4/T.DICOCCON PI94625/AE.SQUARRO SA (372)//3*PASTOR/5/T.D ICOCCON PI94625/AE.SQUARRO SA (372)//3*PASTOR	CMSA05M00772T-050Y-040ZTM-040ZTY-8ZTM-03Y-0B	225	3	4	1542.5	28.7	21.4
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-12ZTM-03Y-0B	226	3	4	1606.8	28.7	21.4
SOKOLL*2/TROST	CMSA05Y01186T-040M-040ZTP0Y-040ZTM-040SY-32ZTM-02Y-0B	227	3	4	1607.0	28.7	21.4
SOKOLL//PBW343*2/K UKUNA/3/ATTILA/PAS TOR	CMSA05Y01188T-040M-040ZTP0Y-040ZTM-040SY-2ZTM-01Y-0B	228	3	4	1566.9	28.7	21.4
SOKOLL*2//TACUPET O F2001*2/KUKUNA	CMSA05Y01226T-040M-040ZTP0Y-040ZTM-040SY-22ZTM-04Y-0B	229	3	4	1594.6	28.7	21.4
GK ARON/AG SECO 7846//2180/4/2*MILAN/ KAUZ//PRINIA/3/BAV 92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-9ZTM-04Y-0B	230	3	4	1614.7	28.7	21.4
GK ARON/AG SECO 7846//2180/4/2*MILAN/ KAUZ//PRINIA/3/BAV 92	CMSA05Y00954T-040M-040ZTP0Y-040ZTM-040SY-15ZTM-01Y-0B	231	3	4	1623.8	28.7	21.4
SW89-5124*2/FASAN/3/ALTA R 84/AE.SQ//2*OPATA	CMSA04M00335S-040ZTP0Y-040ZTM-040SY-16ZTM-04Y-0B	232	3	4	1563.8	28.7	21.4
SOKOLL//TACUPETO F2001*2/KUKUNA	CMSA04M00346S-040ZTP0Y-040ZTM-040SY-28ZTM-01Y-0B	233	3	4	1618.0	28.7	21.4
SOKOLL//FRTL/2*PIF ED	CMSA04M00552S-040ZTP0Y-040ZTM-040SY-19ZTM-03Y-0B	234	3	4	1594.2	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-4ZTM-04Y-0B	235	3	4	1547.4	28.7	21.4
TACUPETO F2001*2/KUKUNA/3/T. DICOCCON PI94625/AE.SQUARROSA (372)//3*PASTOR	CMSA05Y00178S-040ZTY-040ZTM-040Y-6ZTM-02Y-0B	236	3	4	1540.9	28.7	21.4
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	237	3	4	1624.2	28.7	21.4
SOKOLL*2/3/PASTOR//MUNIA/ALTAR 84	CMSA04M01131T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-24ZTM-04Y-0B	238	3	4	1578.1	28.7	21.4
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-5ZTM-03Y-0B	239	3	4	1586.5	28.7	21.4
SOKOLL*2/4/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/STAR	CMSA04M01132T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-16ZTM-02Y-0B	240	3	4	1573.9	28.7	21.4
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-2ZTM-01Y-0B	241	3	4	1598.7	28.7	21.4
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-01Y-0B	242	3	4	1596.4	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
BOW/VEE/5/ND/VG9144//KAL/BB/3/YACO/4/CHIL/6/CASKOR/3/CROC_1/AE.SQUARROSA (224)//OPATA/7/PASTOR//MILAN/KAUZ/3/BAV92	CMSA04M01201T-050Y-040ZTP0M-040ZTY-040ZTM-040SY-6ZTM-03Y-0B	243	3	4	1584.5	28.7	21.4
WHEAR//2*PRL/2*PASTOR	CGSS03B00090T-099Y-099M-099Y-099M-6WGY-0B-3B	244	3	4	1620.8	28.7	21.4
ATTILA*2//CHIL/BUC*2/3/KUKUNA	CMSS05Y00671T-099TOPM-099Y-099M-099Y-099ZTM-2WGY-0B	245	3	4	1612.2	28.7	21.4
CAL/NH//H567.71/3/SERI/4/CAL/NH//H567.71/5/2*KAUZ/6/PASTOR/7/KAUZ/PASTOR//PBW343	CMSS05B00592S-099Y-099M-099Y-099ZTM-17WGY-0B	246	3	4	1585.1	28.7	21.4
ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC_1/AE.SQUARROSA (224)//2*OPATA	CMSS05B00663S-099Y-099M-099Y-099ZTM-13WGY-0B	247	3	4	1584.8	28.7	21.4
WBLL1*2/KUKUNA*2//WHEAR	CGSS05B00174T-099TOPY-099M-099NJ-099NJ-5WGY-0B	248	3	4	1613.5	28.7	21.4
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099Y-099ZTM-10WGY-0B	249	3	4	1559.8	28.7	21.4
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-3WGY-0B	250	3	4	1542.3	28.7	21.4
PBW343*2/KUKUNA//PARUS/3/PBW343*2/KUKUNA	CGSS05B00256T-099TOPY-099M-099NJ-099NJ-5WGY-0B	251	3	4	1562.9	28.7	21.4
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099Y-099ZTM-12WGY-0B	252	3	4	1549.3	28.7	21.4

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW343*2/KUKUNA*2//YANAC	CGSS05B00258T-099TOPY-099M-099NJ-2WGY-0B	253	3	4	1580.5	28.7	21.4
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-6WGY-0B	254	3	4	1580.6	28.7	21.4
PBW343*2/KUKUNA//SRTU/3/PBW343*2/KHVAKI	CGSS05B00261T-099TOPY-099M-099NJ-099NJ-8WGY-0B	255	3	4	1596.5	28.7	21.4
PBW343*2/KHVAKI//PARUS/3/PBW343/PASTOR	CGSS05B00271T-099TOPY-099M-099NJ-099NJ-17WGY-0B	256	3	4	1584.2	28.7	21.4
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-17WGY-0B	257	3	4	1584.8	28.7	21.4
ATTILA*2/PBW65/6/PVN//CAR422/ANA/5/BOW/CROW//BUC/PVN/3/YR/4/TRAP#1/7/ATTILA/2*PASTOR	CGSS05B00290T-099TOPY-099M-099Y-099ZTM-20WGY-0B	258	3	4	1584.8	28.7	21.4
ATTILA*2/PBW65//KIRITATI/3/WAXWING/KIRITATI	CGSS05B00299T-099TOPY-099M-099Y-099ZTM-19WGY-0B	259	3	4	1577.0	28.7	21.4
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-3AP-0AP	260	3	4	1548.6	28.7	21.4
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	CMSS97M00517S-0B-0AP-4AP-0APS-0AP-12AP-5AP-0AP	261	3	4	1538.3	28.7	21.4
ALTAR 84/AE.SQUARROSA (191)//OPATA/3/SKAUZ	CMSS98Y05580S-040Y-0B-0MXI-0AP-0AP-15AP-0AP	262	3	4	1579.1	28.7	21.4
VANS/3/CNDRS/ANA//CNDRS/MUSS/4/CHAM-6	ICW99-0336-12AP-0AP-0AP-7AP-0AP	263	3	4	1586.0	28.7	21.4
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-13AP-0AP-0AP-5AP-0AP	264	3	4	1576.8	28.7	21.4
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-2AP-0AP	265	3	4	1510.0	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-5AP-0AP	266	3	4	1597.7	28.7	21.4
CHEN/AE.SQ//2*OPATA/3/BABAX	CMSS98Y00585S-040Y-0B-0MXI-0AP-0AP-8AP-0AP	267	3	4	1582.1	28.7	21.4
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-12AP-0AP-0AP-45AP-0AP	268	3	4	1584.8	28.7	21.4
MILAN/SHA7/3/NS732/HER//SUDAN #11	ICW99-0278-4AP-0AP-0AP-29AP-0AP	269	3	4	1584.8	28.7	21.4
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-4AP-0AP	270	3	4	1562.6	28.7	21.4
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-24AP-0AP-0AP-9AP-0AP	271	3	4	1611.8	28.7	21.4
CBRD-3/STORK X DICOCCOIDES	ICW99-0474-25AP-0AP-0AP-4AP-0AP	272	3	4	1572.5	28.7	21.4
FILIN/IRENA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/6/BERKUT	CMSA01M00072S-040P0M-040ZTM-040HTY-040M-040SY-7M-0Y-01B-0Y	273	3	4	1591.8	28.7	21.4
SUNCO	SUNCO	274	3	4	1567.3	28.7	21.4
SHIHAB-3	CMSS97M00652S-0B-0AP-1AP-0APS-0AP-11AP-3AP-0AP	275	3	4	1605.6	28.7	21.4
LEITH-3	ICW97.0717-0APS-1AP-0APS-050AP-0APS-16AP-0AP	276	3	4	1599.3	28.7	21.4
PBW343*2/KUKUNA//PBW343*2/KUKUNA	CGSS04Y00099S-099Y-099M-099Y-099M-8WGY-0B	277	3	4	1571.5	28.7	21.4
PRL/2*PASTOR//PBW343*2/KUKUNA	CMSS04Y00086S-0Y-099ZTM-099Y-099M-4WGY-0B	278	3	4	1575.0	28.7	21.4
CROC_1/AE.SQUARROSA (213)//PGO/3/CMH81.38/2*KAUZ/4/BERKUT	CMSA02Y00059S-040P0Y-040ZTM-040SY-040M-7ZTY-03M-0Y	279	3	4	1567.3	28.7	21.4
ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN/6/SERI/7/VEE	CMSA02Y00426T-040M-040P0Y-040ZTM-	280	3	4	1584.8	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
#10/8/OPATA/10/CHEN/AEGILOPS SQUARROSA (TAUS)//FCT/3/2*WEAVER/11/PRL/2*PASTOR	040SY-040M-5ZTY-01M-0Y						
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	CMSA02M00279S-040ZTM-040ZTY-040ZTM-040SY-7ZTM-03Y-0B	281	3	4	1591.1	28.7	21.4
BERKUT/HTG	CMSA04Y00607S-130ZTP0Y-010M-010SY-2M-04Y-0B	282	3	4	1593.4	28.7	21.4
SOKOLL//PRL/2*PASTOR	CMSA04Y00608S-150ZTP0Y-010M-010SY-3M-02Y-0B	283	3	4	1618.2	28.7	21.4
SW89-5124*2/FASAN/6/CHIBIA/5/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER	CMSA02Y00249S-040ZTM-040HTY-040M-040SY-10M-0Y	284	3	4	1613.9	28.7	21.4
SOKOLL/WBLL1	PTSS02Y00021S-0Y-030ZTM-040SY-040M-14Y-0M-0SY	285	3	4	1544.2	28.7	21.4
CROC_1/AE.SQUARROSA (224)//OPATA/3/SOKOLL	PTSS02B00065S-0Y-0B-0Y-0B-32Y-0M-0SY	286	3	4	1596.5	28.7	21.4
MEX94.2.19/PUB94.15.1.12	PTSS02B00074S-0Y-0B-0Y-0B-32Y-0M-0SY	287	3	4	1605.8	28.7	21.4
SOKOLL//W15.92/WBLL1	PTSS02B00088T-0TOPY-0B-0Y-0B-5Y-0M-0SY	288	3	4	1560.1	28.7	21.4
OAX93.24.35//SOKOLL/WBLL1	PTSS02B00099T-0TOPY-0B-0Y-0B-35Y-0M-0SY	289	3	4	1582.1	28.7	21.4
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	PTSS02B00102T-0TOPY-0B-0Y-0B-11Y-0M-0SY	290	3	4	1599.3	28.7	21.4
WBLL4//OAX93.24.35/WBLL1	PTSS02B00110T-0TOPY-0B-0Y-0B-21Y-0M-0SY	291	3	4	1600.0	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
SUNTOP	SUNTOP	22	7	4	1569.3	28.7	21.4
NAC/TH.AC//3*PVN/3/MIRLO/BUC/4/2*PASTOR/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES/6/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06B00734T-099TOPY-099ZTM-099Y-099M-25WGY-0B	23	7	4	1652.6	28.9	21.4
BECARD/5/PGO//CROC_1/AE.SQUARROSA (224)/3/2*BORL95/4/CIRCUS	CMSS06B00411S-0Y-099ZTM-099Y-099M-12WGY-0B	24	7	4	1633.8	28.8	21.5
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/VORB	CMSA06M00431S-040ZTM-040ZTY-31ZTM-04Y-0B	25	7	4	1641.5	28.9	21.3
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-67ZTM-0Y-0B	26	7	4	1664.2	28.7	21.4
PBW343*2/KUKUNA/3/PGO/SERI//BAV92	CMSS06B00495S-0Y-099ZTM-099NJ-099NJ-12WGY-0B	101	7	4	1607.7	28.8	21.4
FRTL/2*PIFED/4/CROC_1/AE.SQUARROSA (205)//KAUZ/3/PIFED		103	7	4	1600.4	28.6	21.5
T.DICOCCON PI225332/AE.SQUARROSA (895)//WBLL1/3/2*WBLL1/4/SOKOLL	CMSA06M00709S-040ZTM-040ZTY-21ZTM-0Y-0B	104	7	4	1624.5	28.7	21.2
Wyalkatchem	MACHETE/84W129-504	156	7	4	1562.5	28.7	21.4
QAFZAH-31	CMSS93Y00621S-4AP-3AP-4AP-0APS-0AP	158	7	4	1556.7	28.8	21.4
ALTAR 84/AE.SQUARROSA (221)//3*BORL95/3/URES/JUN//KAUZ/4/WBL	CMSS06B00201S-0Y-099ZTM-099Y-099M-14WGY-0B	159	7	4	1589.7	28.6	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
L1/5/MILAN/S87230//BAV92							
QUAIU #3//MILAN/AMSEL	CMSS06B00640S-0Y-099ZTM-099Y-099M-7WGY-0B	160	7	4	1584.8	28.7	21.4
ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00704T-099TOPY-099ZTM-099Y-099M-23WGY-0B	161	7	4	1594.9	28.7	21.4
WAXWING/4/BL 1496/MILAN/3/CROC_1/AE.SQUARROSA (205)//KAUZ/5/FRNCLN	CMSS06B00787T-099TOPY-099ZTM-099Y-099M-6WGY-0B	162	7	4	1588.1	28.7	21.4
WBLL1*2/KURUKU/6/CNDO/R143//ENTE/MEXI_2/3/AEGILOPS SQUARROSA (TAUS)/4/WEAVER/5/2*JANZ/7/WBLL1*2/KURUKU	CMSS06B00802T-099TOPY-099ZTM-099Y-099M-12WGY-0B	163	7	4	1586.6	28.7	21.4
WAXWING*2/HEILO	CMSS06B00915T-099TOPY-099ZTM-099Y-099M-8WGY-0B	164	7	4	1581.3	28.7	21.4
BAV92//IRENA/KAUZ/3/HUITES/4/GONDO/TNMU/5/BAV92//IRENA/KAUZ/3/HUITES	CMSS06B00918T-099TOPY-099ZTM-099Y-0FUS-6WGY-0B	165	7	4	1567.5	28.7	21.4
ATTILA*2/PBW65*2/5/KAUZ//ALTAR 84/AOS/3/MILAN/KAUZ/4/HUITES	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-10WGY-0B	166	7	4	1578.3	28.7	21.4
ROLF07*2/3/PRINIA/PASTOR//HUITES	CMSS06Y00609T-099TOPM-099Y-099ZTM-099Y-099M-19WGY-0B	167	7	4	1586.7	28.7	21.4
MUNAL #1/FRANCOLIN #1	CMSS06B00001S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	168	7	4	1584.8	28.7	21.4
TRCH/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00314S-0Y-099ZTM-099NJ-099NJ-21WGY-0B	169	7	4	1574.6	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PFAU/SERI.1B//AMAD/3/WAXWING/6/HPO/TAN//VEE/3/2*PGO/4/MILAN/5/SSERI1	CMSS06B00318S-0Y-099ZTM-099NJ-099NJ-25WGY-0B	170	7	4	1592.4	28.7	21.4
KBIRD//INQALAB 91*2/TUKURU	CMSS06B00485S-0Y-099ZTM-099Y-099M-7WGY-0B	171	7	4	1594.4	28.7	21.4
FRNCLN/ROLF07	CMSS06B00013S-0Y-099ZTM-099Y-099M-9WGY-0B	172	7	4	1584.3	28.7	21.4
PVN/5/2*REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES	CMSS06B00975T-099TOPY-099ZTM-099Y-099M-9WGY-0B	173	7	4	1562.7	28.7	21.4
WBLL1*2/BRAMBLING/5/WBLL1*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ		174	7	4	1584.8	28.7	21.4
WBLL1*2/TUKURU//FN/2*PASTOR/3/FRET2/KIRITATI	CMSS06B00926T-099TOPY-099ZTM-099Y-0FUS-18WGY-0B	175	7	4	1575.9	28.7	21.4
FRAME*2/3/URES/JUN//KAUZ/4/BAU//PRL/VEE#6/3/FRAME/5/SLVS/ATTILA//WBLL1	CMSA06M00058T-034(PINBD1BHET)Y-040ZTM-021(PINBD1BPOS)ZTY-12ZTM-04Y-0B	176	7	4	1584.8	28.7	21.4
ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC		177	7	4	1574.9	28.7	21.4
PFAU/SERI.1B//AMAD/3/WAXWING/4/BABAX/LR42//BABAX*2/3/KURUKU	CMSS06B00033S-0Y-099ZTM-099NJ-099NJ-4WGY-0B	178	7	4	1586.6	28.7	21.4
QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ	CMSS06B00109S-0Y-099ZTM-099NJ-099NJ-13WGY-0B	179	7	4	1584.8	28.7	21.4
PAURAQ/4/PFAU/SERI.1B//AMAD/3/WAXWING	CMSS06B00015S-0Y-099ZTM-099NJ-099NJ-1WGY-0B	180	7	4	1520.2	28.8	21.4
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-	181	7	4	1582.8	28.6	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
	099ZTM-099NJ-099NJ-5WGY-0B						
PBW343*2/KUKUNA*2//FRTL/PIFED	CMSS06Y00831T-099TOPM-099Y-099ZTM-099NJ-099NJ-22WGY-0B	182	7	4	1574.4	28.7	21.4
WBLL1*2/4/BABAX/LR42//BABAX/3/BABAX/LR42//BABAX	CMSS06Y00885T-099TOPM-099Y-099ZTM-099NJ-099NJ-26WGY-0B	183	7	4	1574.4	28.7	21.4
DUCULA/GONDO//SOKOLL	CMSA06M00645S-040ZTM-040ZTY-19ZTM-03Y-0B	184	7	4	1590.1	28.8	21.4
EGA BONNIE ROCK/4/MILAN/KAUZ//PRINIA/3/BAV92	CMSA06Y00125S-040ZTP0Y-040ZTM-040SY-2ZTM-02Y-0B	185	7	4	1570.7	28.7	21.4
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-20ZTM-0Y-0B	186	7	4	1608.9	28.7	21.4
BABAX/KS93U76//BABAX/3/2*SOKOLL	CMSA06M00008T-024(PINBD1BHET)Y-040ZTM-026(PINBD1BPOS)ZTY-28ZTM-01Y-0B	187	7	4	1586.4	28.7	21.4
MILAN/KAUZ//PRINIA/3/BAV92/4/2*SOKOLL	CMSA06M00017T-030(CSLV34HET)Y-040ZTM-049(CSLV34POS)ZTY-68ZTM-0Y-0B	188	7	4	1563.8	28.8	21.4
SLVS/ATTILA//WBLL1*2/3/GONDO/CBRD	CMSA06M00128T-029(PINBD1BHET)Y-040ZTM-029(PINBD1BPOS)ZTY-11ZTM-0Y-0B	189	7	4	1602.6	28.7	21.4
ANNUELLO*2/4/92.001E7.32.5/3/PRL/SARA//TSI/VEE#5	CMSA06Y00718T-085(CRE1M19)M-040ZTP0Y-040ZTM-040SY-6ZTM-0Y-0B	190	7	4	1584.8	28.7	21.4
HUANIL/5/2*CNO79//PF70354/MUS/3/PASTOR/4/BAV92	CMSA05M00750T-050Y-041ZTM-040ZTY-	191	7	4	1573.1	28.6	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
	040ZTM-040SY-10ZTM-0Y-0B						
EGA BONNIE ROCK/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE. SQUARROSA (208)/5/2*WESTONIA	CMSA05M00023S-0130ZTM-039(LR34HOM+HET)ZTY-040ZTM-040SY-6ZTM-0Y-0B	192	7	4	1606.3	28.7	21.4
PBW343*2/KUKUNA//WBLL1*2/KUKUNA	CMSA05M00118S-0100ZTM-029(LR34HOM+HET)ZTY-040ZTM-040SY-45ZTM-0Y-0B	193	7	4	1569.0	28.7	21.4
SLVS/ATTILA//WBLL1/4/FRAME*2/3/URES/JUN//KAUZ	CMSA05M00140S-021(CRE1M19-GWM577BO1)M-028(BO1 POS& CRE1 POS)ZTY-040ZTM-040SY-11ZTM-0Y-0B	194	7	4	1590.6	28.7	21.4
VORB/4/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/5/D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM	CMSA06Y00835T-040ZTM-040ZTP0Y-040ZTM-040P0Y-3ZTM-02Y-0B	195	7	4	1593.8	28.7	21.4
VORB/6/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE. SQUARROSA (208)/5/2*WESTONIA/7/CPI8/GEDIZ/3/GOO//ALB/CRA/4/AE.SQUARROSA (208)/5/2*WESTONIA	CMSA06Y00836T-040ZTM-040ZTP0Y-040ZTM-040P0Y-26ZTM-01Y-0B	196	7	4	1565.2	28.7	21.4
CHIH95.7.4//INQALAB91*2/KUKUNA	PTSS06GHB00007S-0Y-040ZTM-040ZTY-11ZTM-0Y-0B	197	7	4	1564.2	28.7	21.4
D67.2/P66.270//AE.SQUARROSA (320)/3/CUNNINGHAM/4/SKAUZ/BAV92	CMSA06M00430S-040ZTM-0NJ-0NJ-18Y-3B-0Y	198	7	4	1581.9	28.7	21.4
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-4Y-1B-0Y	199	7	4	1587.0	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KRICHAUFF/2*PASTOR//2*SOKOLL	CMSA06M00010T-040Y-040ZTM-0NJ-0NJ-9Y-1B-0Y	200	7	4	1585.2	28.7	21.4
MACE	WYALKATCHEM/STYLET//WYALKATCHEM	201	7	4	1611.3	28.7	21.4
SCOUT	SCOUT	202	7	4	1601.2	28.7	21.4
DUCULA//HUI/TUB/3/CAZO/4/CROC-1/AE.SQUARROSA (224)//OPATA	SHAMIEKH-3	203	7	4	1583.2	28.7	21.4
BABAX/LR39//BABAX/3/VORB/4/SUNCO/2*PASTOR	CMSA06Y00792T-040ZTM-040ZTP0Y-040ZTM-040SY-28ZTM-02Y-0B	204	7	4	1609.4	28.7	21.4
HEILO//SUNCO/2*PASTOR	CMSA06Y00492S-040ZTY-040ZTM-040SY-6ZTM-0Y-0B	205	7	4	1592.5	28.7	21.4
CHAM-4/SHUHAS/6/2*SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB	REYNA-24	206	7	4	1566.7	28.7	21.4
SOKOLL//INQALAB 91*2/KUKUNA	PTSS06GHB00021S-0Y-040ZTM-040ZTY-5ZTM-0Y-0B	207	7	4	1578.1	28.7	21.4
ZAIN-4	ZAIN-4	208	7	4	1545.0	28.7	21.4
HAALA-49	HAALA-49	209	7	4	1578.7	28.7	21.4
ZAKIA-15	ZAKIA-15	210	7	4	1601.2	28.7	21.4
ALATHEER-5	ALATHEER-5	211	7	4	1571.2	28.7	21.4
ZAHABYA-2	ZAHABYA-2	212	7	4	1601.7	28.7	21.4
AL-ANWAR-1	AL-ANWAR-1	213	7	4	1579.4	28.7	21.4
HAALA-26	HAALA-26	214	7	4	1587.2	28.7	21.4
KAUZS//TSI/SNBS	ALMAZ-19 = SIDS-13	215	7	4	1602.1	28.7	21.4
SHAFAQ-1	SHAFAQ-1	216	7	4	1581.0	28.7	21.4
ALATHEER-4	ALATHEER-4	217	7	4	1584.9	28.7	21.4
QAFZAH-11/BASHIQ-1	QAFZAH-11/BASHIQ-1	218	7	4	1598.8	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
BT1735/ACHTAR//HUBARA-8	MORSUD-16	219	7	4	1580.2	28.7	21.4
FIDIYA-9	FIDIYA-9	220	7	4	1595.2	28.7	21.4
DIYAR-7	DIYAR-7	221	7	4	1558.9	28.7	21.4
AAFAQ-2	AAFAQ-2	222	7	4	1585.3	28.7	21.4
TACUPETO F2001*2/KIRITATI//VILLA JUAREZ F2009	CMSS07B00094S-099M-099NJ-099NJ-16WGY-0B	27	11	4	1606.7	29.1	21.4
WBLL1*2/BRAMBLING//QUAIU	CMSS07B00224S-099M-099Y-099M-18WGY-0B	28	11	4	1613.8	28.9	21.4
KAUZ/PASTOR//PBW343/3/KIRITATI/4/FRNCLN	CMSS07B00585T-099TOPY-099M-099Y-099M-11WGY-0B	29	11	4	1629.4	28.7	21.4
PFAU/SERI.1B//AMAD/3/WAXWING*2/4/TECUE #1	CMSS07B00614T-099TOPY-099M-099Y-099M-49WGY-0B	30	11	4	1584.8	28.7	21.4
PFAU/SERI.1B//AMAD/3/WAXWING/4/WBLL1*2/BRAMBLING	CMSS07Y00196S-0B-099Y-099M-099NJ-099NJ-6WGY-0B	31	11	4	1576.9	28.8	21.4
BANA-1///NS732/HER//SHUHA-15	ICW01.00053-0AP-8AP-0AP-0AP-7AP-0AP	32	11	4	1619.0	28.6	21.4
PRL/2*PASTOR	CGSS97Y00034M-099TOPB-027Y-099M-099Y-099M-27Y-0B	33	11	4	1632.7	28.7	21.3
PFAU/SERI.1B//AMAD/3/WAXWING	CGSS02Y00153S-099M-099Y-099M-46Y-0B	34	11	4	1588.8	28.7	21.4
TEVEE-3/SHUHA-20//SERI 82/SHUHAS	ICW02.00130-9APTS-0AP-0AP-1AP-0AP-0DZAP-0DZKULSINAP-0NJAP	35	11	4	1636.9	28.8	21.4
FERROUG-2/POTAM*2KS811261-8//ZEMAMRA-8	ICW01.21116-5AP-11AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP	36	11	4	1627.0	28.7	21.4
WORRAKATTA/2*PASTOR//DANPHE #1	CMSA07M00403S-040ZTM-040ZTY-15ZTM-010Y-01B-0Y	37	11	4	1584.8	28.7	21.4

| NAME_IDENTIFIER | Pedigree | AllYearsEntry | Experiment | SowingTime | Yield | TKW | Screenings |

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-9AP-0AP	38	11	4	1583.4	28.6	21.4
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-5AP-0AP-0DZAP-0DZKULSINAP-0NJAP	39	11	4	1604.6	28.8	21.4
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-1N-99N	40	11	4	1643.6	28.8	21.3
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-19N-99N	41	11	4	1626.0	28.7	21.4
QAFZAH-11/ICW93.0045-1AP-0L-1AP-0L-2AP-0AP	ICW01.00220-0AP-5AP-0AP-0AP-8AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	105	11	4	1586.7	28.7	21.5
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-3AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	106	11	4	1577.1	28.8	21.3
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-16AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	107	11	4	1554.1	28.7	21.3
KA/NAC//TRCH/4/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA07M00444S-040M-0NJ-0NJ-6Y-0B	108	11	4	1588.1	28.7	21.5
INQALAB 91/CMSW94WM00188S-0300M-0100Y-0100M-13Y-4M-0Y-0AP	ICW02.00354-9APTS-0AP-0AP-3AP-030KUL-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	109	11	4	1559.3	28.7	21.3
CMT/ALD//ZARZOUR/5/AU//KAL/BB/3/BON/4/HPO	ICW99.0181-2AP-0AP-0AP-22AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	110	11	4	1589.8	28.7	21.3
PAVON 76/HAMAM-4/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ	ICW02.20146-7APTS-0AP-0AP-17AP-0AP	111	11	4	1561.9	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KACHU/BECARD//WBLL1*2/BRAMBLING	CMSS07B00580T-099TOPY-099M-099Y-099M-10WGY-0B	112	11	4	1586.1	28.8	21.4
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-1AP-1AP-0AP-0AP-15AP-0AP	113	11	4	1536.0	28.8	21.3
SERI 82/SHUHAS//CM84655-02AP-300AP-300L-3AP-300L-3AP-0L-0AP	ICW02.00470-16APTS-0AP-0AP-4AP-0AP	114	11	4	1588.5	28.7	21.4
ATTILA*2/PBW65*2//KACHU	CMSS06Y00582T-099TOPM-099Y-099ZTM-099Y-099M-13WGY-0B	115	11	4	1560.0	28.7	21.4
ROLF07/4/BOW/NKT//CBRD/3/CBRD/5/FRET2/TUKURU//FRET2	CMSS06Y00605T-099TOPM-099Y-099ZTM-099Y-099M-11WGY-0B	116	11	4	1597.0	28.7	21.5
KACHU #1/4/CROC_1/AE.SQUARROSA (205)//BORL95/3/2*MILAN/5/KACHU	CMSS06Y00946T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	117	11	4	1584.8	28.7	21.4
SAUAL/3/ACHTAR*3//KANZ/KS85-8-4/4/SAUAL	CMSS06Y01171T-099TOPM-099Y-099ZTM-099Y-099M-8WGY-0B	118	11	4	1566.7	28.7	21.4
MUNAL #1	CGSS01B00054T-099Y-099M-099M-099Y-099M-13Y-0B	119	11	4	1584.8	28.7	21.4
BAJ #1/3/KIRITATI//ATTILA*2/PASTOR	CMSS07Y00288S-0B-099Y-099M-099Y-17M-0WGY	120	11	4	1584.8	28.7	21.4
MONS/ALDS//ALDANS/IAS58/3/SAFI-1/4/ZEMAMRA-1	ICW01.21120-6AP-9AP-0AP-0AP-7AP-0AP	121	11	4	1603.6	28.7	21.4
WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING	CMSS07Y00348S-0B-099Y-099M-099Y-19M-0WGY	122	11	4	1605.6	28.8	21.4
DORADE/KAPSW	ICW98.0120-3AP-0APS-030AP-10AP-5AP-0AP	123	11	4	1599.5	28.8	21.3

NAME_IDENTIFIER Pedigree AllYearsEntry Experiment SowingTime Yield TKW Screenings

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
HUBARA-8///MONS/ALDS//BOWS	ICW02.00099-11APTS-0AP-0AP-4AP-0AP	124	11	4	1573.1	28.6	21.5
QAFZAH-33/ICW84.0074-09AP-300L-1AP-300L-8AP-0L-0AP	ICW02.00423-3APTS-0AP-0AP-7AP-0AP	125	11	4	1599.4	28.9	21.5
SERI 82/SHUHAS//CM85295-0101TOPY-2M-0Y-0M-3Y-0M-0AP	ICW02.00478-3APTS-0AP-0AP-18AP-0AP	126	11	4	1584.8	28.8	21.4
ICW91.0145-4AP-0TS-2AP-0L-0AP/4/NAI60/HN7//SX/3/JUNS	ICW02.00493-7APTS-0AP-0AP-17AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	127	11	4	1598.5	28.7	21.6
ICW91.0145-4AP-0TS-2AP-0L-0AP/QAFZAH-33	ICW02.00495-11APTS-0AP-0AP-9AP-0AP	128	11	4	1576.1	28.9	21.3
KIRITATI/WBLL1//MESIA/3/KIRITATI/WBLL1	CMSS07Y00847T-099TOPM-099Y-099M-099Y-53M-0WGY	129	11	4	1567.6	28.8	21.4
NS732/HER//SAADA///SAADA	ICW00.0885-8AP-0AP-0AP-6APMOR-0APMOR-0AP	130	11	4	1572.3	28.6	21.4
FRNCLN*2/TECUE #1	CMSS07Y00941T-099TOPM-099Y-099M-099Y-11M-0WGY	131	11	4	1584.8	28.7	21.4
ACHTAR/IG 132176	MOROCCO F2-17 00/01-27AP-0AP-0AP-11APMOR-0APMOR-0AP	132	11	4	1578.6	28.7	21.5
ACHTAR/IG 132176	MOROCCO F2-17 00/01-47AP-0AP-0AP-9APMOR-0APMOR-0AP	133	11	4	1562.2	28.7	21.3
BT1735/ACHTAR//ASFOOR-1	ICW01.00164-0AP-2AP-0AP-0AP-8APMOR-0APMOR-0AP	134	11	4	1569.8	28.7	21.4
ESWYT99#18/ARRIHANE	MOROCCO F2-23 00/01-17AP-0AP-0AP-	135	11	4	1584.8	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
	17APMOR-0APMOR-0AP						
KACHU//WBLL1*2/BRAMBLING	CMSS07Y00124S-0B-099Y-099M-099NJ-099NJ-9WGY-0B	136	11	4	1571.5	28.7	21.4
CHAM4/SHUHA*2/6/SAKER/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW	ICW00.0634-6AP-0AP-0AP-13AP-0AP-0DZAP-0DZKULSINAP-0NJAP-0ALKAP	137	11	4	1565.3	28.7	21.3
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-2N-99N	138	11	4	1557.0	28.8	21.3
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-8N-99N	139	11	4	1543.1	28.9	21.3
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-4N-99N	140	11	4	1576.6	28.9	21.3
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-8N-99N	141	11	4	1584.1	28.8	21.3
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-14N-99N	142	11	4	1607.0	28.9	21.3
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-26N-99N	143	11	4	1591.6	28.7	21.3
DBW17//DBW17 / 18293 KC75	PBI09C047-BC-0C-19N-99N	144	11	4	1591.4	28.8	21.3
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-17N-99N	145	11	4	1586.4	28.7	21.3
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-8N-99N	146	11	4	1599.5	28.8	21.3
DBW17//DBW17 / 21758 KC75	PBI09C048-BC-0C-3N-99N	147	11	4	1601.1	28.8	21.3
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-7N-99N	148	11	4	1598.4	28.8	21.3
WAXWING*2/KIRITATI ///WAXWING*2/KIRITATI // 35891 M500281	PBI09C027-BC-0C-12N-99N	149	11	4	1584.1	28.8	21.3
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-13N-99N	150	11	4	1567.2	28.7	21.3
DBW16//DBW16 / 18293 KC75	PBI09C042-BC-0C-10N-99N	151	11	4	1580.8	28.5	21.3
SOKOLL//SOKOLL / 35888 M 500132	PBI09C009-BC-0C-27N-99N	152	11	4	1594.4	28.7	21.3

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PBW550//PBW550/18343 KC75	PBI09C036-BC-0C-2N-99N	153	11	4	1577.9	28.9	21.3
DBW16//DBW16 / 21758 KC75	PBI09C043-BC-0C-18N-99N	154	11	4	1578.4	28.8	21.4
KAUZ/PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-16AP-0AP	42	15	4	1558.2	28.7	21.4
KAUZ/PASTOR/3/ALTAR 84/AEGILOPS SQUARROSA (TAUS)//OPATA	ICW04.0121-3AP-0AP-0AP-1AP-0AP	43	15	4	1569.9	28.7	21.4
KARAWAN-1/TALLO3//JADIDA-2	ICW04.0146-1AP-0AP-0AP-9AP-0AP	44	15	4	1581.4	28.7	21.3
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-4AP-0AP-0AP-16AP-0AP	45	15	4	1634.3	28.7	21.3
SHUHA-4/FLORKWA-4//HUBARA-3	ICW04.0161-9AP-0AP-0AP-4AP-0AP	46	15	4	1614.0	28.7	21.4
HUBARA-3*2/SHUHA-4	ICW04.20024-17AP-0AP-0AP-0AP-6AP-0AP	47	15	4	1604.2	28.6	21.4
HUBARA-3*2/SHUHA-4	ICW04.20024-26AP-0AP-0AP-0AP-1AP-0AP	48	15	4	1542.6	28.7	21.4
HUBARA-3*2/SHUHA-4	ICW04.20024-47AP-0AP-0AP-0AP-5AP-0AP	49	15	4	1606.0	28.7	21.4
ATTILA-7/KATILA-12	ICW04.0054-1AP-0AP-0AP-3AP-0AP	50	15	4	1582.2	28.6	21.4
FLORKWA-2/6/SAKERS/5/RBS/ANZA/3/KVZ/HYS//YMH/TOB/4/BOWS/7/DAJAJ-6	ICW04.0169-4AP-0AP-0AP-7AP-0AP	51	15	4	1607.1	28.7	21.4
HUBARA-3*2/SHUHA-4	ICW04.20024-10AP-0AP-0AP-0AP-3AP-0AP	52	15	4	1596.0	28.6	21.4
HUBARA-3*2/SHUHA-4	ICW04.20024-9AP-0AP-0AP-0AP-9AP-0AP	53	15	4	1604.1	28.6	21.4
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-1AP-0AP-0AP-0AP-6AP-0AP	54	15	4	1593.2	28.6	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
PASTOR-2*2//ACSAD 685/ACSAD 639	ICW04.20124-5AP-0AP-0AP-0AP-1AP-0AP	55	15	4	1570.6	28.6	21.4
PASTOR-2/HUBARA-5	ICW04.0037-6AP-0AP-0AP-7AP-0AP	56	15	4	1590.4	28.6	21.4
HUBARA-15/CATBIRD//PASTOR-2	ICW04.20029-40AP-0AP-0AP-0AP-8AP-0AP	57	15	4	1606.9	28.7	21.3
HUBARA-1/3/MUNIA/CHTO//MILAN/4/GOUMRIA-8	ICW04.20121-14AP-0AP-0AP-0AP-2AP-0AP	58	15	4	1653.5	28.7	21.3
HUBARA-3/SHUHA-4//PASTOR-2	ICW04.20025-43AP-0AP-0AP-0AP-2AP-0AP	59	15	4	1632.2	28.7	21.4
KACHU//KIRITATI/2*TRCH	CMSS08Y00152S-099Y-099M-099NJ-099NJ-41WGY-0B	60	15	4	1555.2	28.7	21.4
PFAU/SERI.1B//AMAD/3/WAXWING/4/QUAIU #2	CMSS08Y00269S-099Y-099M-099NJ-9WGY-0B	61	15	4	1584.8	28.7	21.4
PFAU/SERI.1B//AMAD/3/WAXWING/4/ND643/2*WBLL1	CMSS08Y00274S-099Y-099M-099NJ-099NJ-12WGY-0B	62	15	4	1549.4	28.6	21.4
SAAR//INQALAB 91*2/KUKUNA/3/KIRITATI/2*TRCH	CMSS08Y00299S-099Y-099M-099NJ-099NJ-19WGY-0B	63	15	4	1592.6	28.7	21.4
VILLA JUAREZ F2009/DANPHE #1	CMSS08Y00415S-099Y-099M-099NJ-31WGY-0B	64	15	4	1584.8	28.7	21.4
WBLL1/KUKUNA//TACUPETO F2001/3/FRANCOLIN #1	CMSS08Y00447S-099Y-099M-099NJ-29WGY-0B	65	15	4	1584.8	28.7	21.4
WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08Y00477S-099Y-099M-099NJ-7WGY-0B	66	15	4	1618.6	28.6	21.4
QUAIU//2*BRBT1*2/KIRITATI	CMSS08Y00623T-099TOPM-099Y-099M-099NJ-099NJ-7WGY-0B	67	15	4	1566.4	28.8	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
MUU/FRNCLN//FRANCOLIN #1	CMSS08Y00728T-099TOPM-099Y-099M-099Y-20M-0WGY	68	15	4	1584.8	28.7	21.4
PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI*2/5/CHONTE	CMSS08Y00731T-099TOPM-099Y-099M-099Y-8M-0WGY	69	15	4	1597.3	28.7	21.4
TOBA97/PASTOR*2//KBIRD	CMSS08Y00760T-099TOPM-099Y-099M-099Y-11M-0WGY	70	15	4	1645.1	28.7	21.4
VILLA JUAREZ F2009//KIRITATI/2*TRCH/3/WBLL1*2/BRAMBLING	CMSS08Y00784T-099TOPM-099Y-099M-099NJ-099NJ-9WGY-0B	71	15	4	1585.8	28.8	21.4
FRNCLN/3/ND643//2*PRL/2*PASTOR/4/FRANCOLIN #1	CMSS08Y00896T-099TOPM-099Y-099M-099NJ-24WGY-0B	72	15	4	1584.8	28.7	21.4
FRNCLN/3/KIRITATI//HUW234+LR34/PRINIA/4/FRANCOLIN #1	CMSS08Y00900T-099TOPM-099Y-099M-099NJ-6WGY-0B	73	15	4	1584.8	28.7	21.4
PFAU/MILAN/4/VEE/TRAP#1//ANGRA/3/PASTOR/5/PRL/2*PASTOR/4/CHOIX/STAR/3/HE1/3*CNO79//2*SERI	CMSS08B00137S-099M-099NJ-099NJ-50WGY-0B	74	15	4	1584.8	28.7	21.4
MP4010/MUNAL #1	CMSS08B00576S-099M-099Y-14M-0WGY	75	15	4	1584.8	28.7	21.4
TRCH*2//ND643/2*WBLL1	CMSS08B00602T-099TOPY-099M-099NJ-099NJ-4WGY-0B	76	15	4	1588.9	28.6	21.4
QUAIU #1/5/KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/6/BECARD	CMSS08B00645T-099TOPY-099M-099NJ-099NJ-6WGY-0B	77	15	4	1584.8	28.7	21.4
QUAIU/BECARD//BECARD	CMSS08B00648T-099TOPY-099M-099NJ-2WGY-0B	78	15	4	1615.6	28.8	21.4
FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ/5/KIRITATI/2*TRCH/6/BAJ #1	CMSS08B00678T-099TOPY-099M-099NJ-099NJ-4WGY-0B	79	15	4	1584.8	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
KACHU*2/CHONTE	CMSS08B00714T-099TOPY-099M-099Y-22M-0WGY	80	15	4	1597.9	28.7	21.4
MILAN/S87230//BAV92/3/KIRITATI/2*TRCH/4/WHEAR/KRONSTAD F2004	CMSS08B00764T-099TOPY-099M-099NJ-26WGY-0B	81	15	4	1571.8	28.7	21.4
ND643/2*WBLL1//KIRITATI/2*TRCH/3/ND643/2*WBLL1	CMSS08B00772T-099TOPY-099M-099Y-21M-0WGY	82	15	4	1574.3	28.6	21.4
BECARD//KIRITATI/2*TRCH/3/BECARD	CMSS08B00888T-099TOPY-099M-099NJ-20WGY-0B	83	15	4	1549.5	28.8	21.4
FALCIN/AE.SQUARROSA (312)/3/THB/CEP7780//SHA4/LIRA/4/FRET2/5/MUU/6/MILAN/KAUZ//DHARWAR DRY/3/BAV92	CMSA08Y00099T-099B-050Y-040M-0NJ-0NJ-4Y-0B	84	15	4	1604.1	28.8	21.4
PASTOR/3/VEE#5//DOVE/BUC/4/DANPHE #1	CMSA08Y00613S-050Y-050ZTM-050Y-59BMX-010Y-0B	85	15	4	1584.8	28.7	21.4
GLADIUS/3/2*KA/NAC//TRCH	CMSA08M00007T-030(AWW5L7BO1HET)Y-040M-0NJ-4Y-0B	86	15	4	1617.2	28.7	21.3
RAC 1192/4/2*ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00008T-040Y-050ZTM-050Y-13ZTM-010Y-0B	87	15	4	1609.3	28.6	21.3
TC870344/GUI//TEMPORALERA M 87/AGR/3/2*WBLL1/4/ATTILA/PASTOR	CMSA08M00289S-040ZTM-050Y-40ZTM-010Y-0B	88	15	4	1622.6	28.6	21.4
VEE/MJI//2*TUI/3/PASTOR/4/BERKUT/11/CROC_1/AE.SQUARROSA (213)//PGO/10/ATTILA*2/9/KT/BAGE//FN/U/3/BZA/4/TRM/5/ALDAN	CMSA08M00364S-040ZTM-050Y-1ZTM-010Y-0B	89	15	4	1584.8	28.7	21.4

NAME_IDENTIFIER	Pedigree	AllYearsEntry	Experiment	SowingTime	Yield	TKW	Screenings
/6/SERI/7/VEE#10/8/OPATA							
SOKOLL/WBLL1/4/ATTILA/3/WEAVER*2/TSC//WEAVER	CMSA08M00393S-040ZTM-050Y-41ZTM-010Y-0B	90	15	4	1596.9	28.7	21.4
SOKOLL/3/PASTOR//HXL7573/2*BAU/4/PARUS/PASTOR	PTSA08M00046S-050ZTM-050Y-85ZTM-010Y-0B	91	15	4	1558.3	28.8	21.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH10	92	15	4	1563.3	28.7	21.3
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH63	93	15	4	1561.5	28.7	21.3
PBW550 /2/PBW550 / 18343 KC75	PBI09C039-BC-DH81	94	15	4	1581.9	28.7	21.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH17	95	15	4	1550.3	28.7	21.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH22	96	15	4	1555.1	28.7	21.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH21	97	15	4	1559.5	28.7	21.3
PBW550 /2/PBW550 / 18293 KC75	PBI09C038-BC-DH1	98	15	4	1533.3	28.7	21.3
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH56	99	15	4	1613.3	28.8	21.4
SOKOLL/2/SOKOLL / 35888 M 500132	PBI09C009-BC-DH16	100	15	4	1616.7	28.7	21.4