GRAINS RESEARCH ORGANISATIONS WORLDWIDE
Three articles from the Encyclopedia of Grain Science

The three articles in this report were written by John Skerritt for the Encyclopedia of Grain Science, edited by C.W. Wrigley, H. Corke and C.F. Walker, to be published in 2004 by Elsevier Science, Oxford, UK. These few articles were selected as being of special relevance to staff of the Value-Added Wheat CRC, but it is anticipated that much more of the information in the encyclopedia will provide valuable background to cereal-research scientists.

The range of topics in the encyclopedia is indicated by the list of titles below. The encyclopedia consists of about 170 articles, each being about 5,000 words long, plus figures and tables. This three-year project is scheduled to be completed in May, 2004, with the publication of the encyclopedia in three volumes, plus electronic access.

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GRAINS-RESEARCH ORGANISATIONS WORLD-WIDE

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Part A.
Major Public-Sector Grain-Science Organisations
(Government And University)
in North America And Europe

Introduction
This chapter describes the activities of some of the major research institutes in Europe and North America in the area of grain science. There is a deliberate bias towards provision of more detailed information on institutions in English-speaking countries, reflecting the main readership of this article. Compared with the long history of cultivation of grains (many thousands of years) use of research principles to address constraints is a comparatively recent approach. Agricultural societies were established in the UK, France and Germany in the mid-1800s (for example, The Royal Agricultural Society of England (1839); La Société des Agricultrues de France (1850); Deutsche Landwirtschafts-Gesellschaft (1885)) and by the mid-late 19th century agriculture experiment stations were appearing in Europe and North America (Pardey and Beintema, 2001). The tradition of Government-funded grains research is longest established in Europe and North America, although similar initiatives also were started in the late 19th century in a number of European colonies.

A number of trends are identified, including the move towards formation of networks between research institutes as well as the shift in focus of several grain R&D institutions from a largely production focus to an emphasis on environmental issues such as water use efficiency and sustainability of farming systems. Other consistent trends include the greater importance of levies from grain-growers in supporting research a number of countries (for example, since 1959 in France), and the increase in commercial involvement in grain breeding and biotechnology. Government funding bodies have also shown a greater interest in assessing the impacts of research that they fund, including carrying out more economic analysis of projects - research is increasingly viewed as an investment rather than as "grants". The most significant trend in terms of research intensity is the very significant growth over the last couple of decades in the level of grains R&D carried out by the private sector. Most publicly-funded agricultural research in North America and Europe is concentrated in the US, France and Germany, with the UK and Canada having smaller roles. There is also a much greater proportion of agricultural (including grains) research carried out in Universities in Europe and North America compared with developing countries, where it is overwhelmingly within government-funded research institutes (Pardey and Beintema, 2001). Grains R&D carried out by commercial and industry organisations is reviewed in a separate chapter.
USA

The USA has very large private sector (seed companies, milling, baking, brewing and oilseed processing companies, and biotechnology companies) and government investments in grains R&D. A wide range of temperate grain crops are targeted - especially wheat, barley, maize, oilseeds and pulses (and also sub-tropical rice), with most resources dedicated to maize and wheat research. Both state and federal governments invest in agricultural research, with the federal investment being slightly higher.

The ARS (Agricultural Research Service; www.nps.ars.usda.gov) is the principal in-house research agency of the (National) US Department of Agriculture (USDA), and together with the "Land Grant" Universities form the main research centres for grains research. In the past there has been comparatively limited interaction and coordination between different USDA centres carrying out grains research, although the development of a "national program" structure by USDA-ARS in recent years has increased the amount of coordination. Most of the grains research activities are within the "Crop Production, Product Value and Safety" cluster of programs. Some of the major objectives of USDA grains research include:

- crop improvement; integrated crop production systems
- crop protection and quarantine
- crop genetic resources, genomics and genetic improvement
- fundamental research on plant productivity and quality and plant-pathogen interactions
- quality maintenance postharvest, environmentally friendly and efficient processing and value-added products, including the use of grain crops as biofuels.

Some USDA centres are free-standing multidisciplinary USDA research centres while others are co-located on University campuses. Many centres have the mandate to carry out research directed at the particular agro-ecological zone in which the institute is based. For example, wheat is grown in many parts of the US, but there are different quality types suited for different locations - soft red winter wheat in the Midwest, Virginia and North Carolina; Hard White and some Hard Red Winter Wheat in Pacific Northwest, Hard Red Winter varieties in the Great Plains, from Texas to Montana on the Canadian border, and Spring varieties in northern central states such as Minnesota, North and South Dakota and Montana - and appropriate located USDA centres develop germplasm and agronomy packages for the different types of varieties. Some of the major USDA centres carrying out grains research, shown in alphabetical order of location, are based in:

- Aberdeen, ID: Small grains and potato germplasm research
- Albany, CA (Western Regional Research Center, www.pw.usda.gov): genomics and gene discovery; Crop Improvement/Utilization; Plant mycotoxins
- Ames, IA: Corn insects and crop genetics
- Beltsville, MD: (Beltsville Agricultural Research Center, www.barc.usda.gov) Sustainable Agricultural Systems Laboratory; Instrumentation and Sensing Laboratory; National Germplasm Resources Laboratory; Soybean Genomics and Improvement Laboratory
- College Station, TX: (Southern Plains Agricultural Research Center, www.sparc.usda.gov): Crop germplasm and insect pest research.
- Columbia, MO: Plant Genetics Research
- Corvalis, OR: Forage seed and genetics research
- Fargo, ND: (Red River Valley Agricultural Research Center), Cereal Crops Research, Wheat quality
- Fort Collins, CO: National Center for Genetic Resources Preservation
- Ithaca, NY: Plant Genetic Resources, Plant protection research
• Lane, OK: (Southern Central Agricultural Research Laboratory) Genetics and production research
• Lincoln, NE: Wheat, sorghum and forage research
• Lubbock, TX: Cropping Systems Research Laboratory
• Madison, WI: Cereal Crops Research
• Manhattan, KS: (Grain Marketing and Production Research Center, www.usgmr1.ksu.edu) - biochemical and structural aspects of grain quality; stored grains entomology; fungal diseases; plant physiology of cereals
• Peoria, IL: (National Center for Agricultural Utilization Research, www.ncaur.usda.gov) Cereal products and Food Science Research; Plant polymer research; mycotoxin research; new crops processing research
• Raleigh, NC: Soybean and Nitrogen Fixation Research, Basic plant science
• Shafter, CA: Western Integrated Cropping Systems Research
• Stillwater, OK: Plant Science and Water Conservation Research
• Stoneville, MS: Crop Genetics and Production Research
• Stuttgart, AR: Dale Bumpers National Rice Research Center
• Tifton, GA: Crop Genetics and Breeding Research, Crop Protection and Management Research
• Urbana, IL: Soybean/maize germplasm, pathology and genetics research
• Wooster, OH: Soft Wheat Quality Research, Corn and soybean research
• Wyndmoor, PA: Crop conversion science and engineering

USDA also has a (smaller) Economic Research Service (www.ers.usda.gov), which carries out research and communication activities in many areas relevant to grains, including farm-level risk management, commodity outlook research and research on marketing and production sustainability. The USDA Federal Grain Inspection Service (www.usda.gov/gipsa/tech-servsup) has a technical centre in Kansas City, MO, which validates equipment and methods for grains analysis.

The "Land Grant" college system was established in 1862 under the Morrill Act, in the same year that USDA was established - the name derives from the fact that the colleges were originally endowed by grants of public lands in the expanding western United States. The 1887 Hatch Act established the agricultural experiment station system to enable these colleges to undertake research, and the 1914 Smith-Lever Act established the Cooperative Extension system. This unique system has the advantages of linking state government R&D and extension activities to University research. At the federal level, land grant University programs are supported through the USDA Cooperative Research, Education and Extension Service (www.reeusda.gov). Universities have anywhere from a few to over a dozen discrete experiment stations at different locations in their state, again often corresponding to different agro-ecological zones, but also allowing researchers to carry out a local outreach function. Usually a significant proportion of the researchers - maybe half - are located on the main University campus and the rest throughout the state. There is usually a balance of applied grains research on constraints to productivity in the particular state and a proportion directed towards more fundamental research. Cooperative Extension systems from Land Grant universities have a state development mandate and often involve location of farm advisors in counties throughout the state. Virtually all US states have one (and in some cases, two) land-grant Universities, and about half of them have strong grains research activities, usually across several departments rather than in a single program.

A summary of some of the main US Universities that carry out grains research is provided in Table 1. Land Grant Universities are usually predominantly state-funded, but with significant federal funding as well.
### Table 1. Some United States Universities undertaking significant grains research

<table>
<thead>
<tr>
<th>University (website)</th>
<th>Grains Research Emphasis</th>
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<tbody>
<tr>
<td><strong>Colorado State University</strong>, Fort Collins, CO</td>
<td>Genomics, biotechnology, dryland farming systems, wheat breeding, precision agriculture</td>
</tr>
<tr>
<td>College of Agr. Sci. (<a href="http://www.agsci.colostate.edu">www.agsci.colostate.edu</a>)</td>
<td></td>
</tr>
<tr>
<td><strong>Cornell University</strong>, Ithaca, NY</td>
<td>Genetics, biotechnology, basic plant science, maize breeding, seed science, cereal</td>
</tr>
<tr>
<td>College of Agr. and Life Sci. (<a href="http://www.cals.cornell.edu">www.cals.cornell.edu</a>)</td>
<td>pathology, cereal product rheology</td>
</tr>
<tr>
<td><strong>Iowa State University</strong>, Ames, IA (<a href="http://www.eg.iastate.edu">www.eg.iastate.edu</a>)</td>
<td></td>
</tr>
<tr>
<td><strong>Kansas State University</strong>, Manhattan, KS (<a href="http://www.oznet.ksu.edu">www.oznet.ksu.edu</a>)</td>
<td>Corn and soybean breeding, non-food crop products, corn quality, basic plant sciences,</td>
</tr>
<tr>
<td><strong>Michigan State University</strong>, East Lansing MI (<a href="http://www.maes.msu.edu">www.maes.msu.edu</a>)</td>
<td>crop genomics, seed technology</td>
</tr>
<tr>
<td><strong>Montana State University</strong>, Bozeman, MT (<a href="http://www.montana.edu/agriculture">www.montana.edu/agriculture</a>)</td>
<td>Wheat, soybean and sorghum breeding; Cereal (wheat, corn, sorghum, millet) agronomy and</td>
</tr>
<tr>
<td>College of Agr.</td>
<td>physiology, entomology, cereal chemistry, milling and baking, livestock feeds</td>
</tr>
<tr>
<td><strong>North Carolina State University</strong>, Raleigh, NC (<a href="http://www.cals.ncsu.edu">www.cals.ncsu.edu</a>)</td>
<td></td>
</tr>
<tr>
<td><strong>North Dakota State University</strong>, Fargo, ND (<a href="http://www.ag.ndsu.nodak.edu">www.ag.ndsu.nodak.edu</a>)</td>
<td></td>
</tr>
<tr>
<td>College of Agr., Food Systems and Nat. Res.</td>
<td>Basic research on wheat quality and processing; milling; pasta production; brewing;</td>
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<tr>
<td></td>
<td>farming systems, pathology and entomology</td>
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<tr>
<td>Institution</td>
<td>Focus Areas</td>
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<td>-----------------------------------------------------------------------------</td>
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<tr>
<td><strong>Oklahoma State University, Stillwater</strong></td>
<td>Baking, grain protein chemistry, oilseed chemistry, plant diseases</td>
</tr>
<tr>
<td>Div. of Agr. Sci. and Nat. Res.</td>
<td>(www1.dasnr.okstate.edu)</td>
</tr>
<tr>
<td><strong>Ohio State University, Columbus, OH</strong></td>
<td>Maize production systems, cereal and oilseed quality, soft red winter wheat</td>
</tr>
<tr>
<td>Ohio Agr. R&amp;D Center (<a href="http://www.oardc.ohio-state.edu">www.oardc.ohio-state.edu</a>)</td>
<td>and soybean agronomy and breeding, soy protein functionality</td>
</tr>
<tr>
<td><strong>Pennsylvania State University, Univ. Park, PA</strong></td>
<td>Starch chemistry, entomology</td>
</tr>
<tr>
<td>College of Agr. Sci. (research.cas.pse.edu)</td>
<td></td>
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<tr>
<td><strong>Purdue University, West Lafayette, IN</strong></td>
<td>Plant stress physiology, biotechnology, integrated pest management,</td>
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<tr>
<td>(<a href="http://www.agriculture.purdue.edu/arp">www.agriculture.purdue.edu/arp</a>)</td>
<td>precision agriculture, new grain products, carbohydrate research</td>
</tr>
<tr>
<td><strong>Rutgers University, New Brunswick, NJ</strong></td>
<td>Cereal processing, plant biotechnology</td>
</tr>
<tr>
<td>Center for Adv. Food Tech. (foodsci.rutgers.edu/caft)</td>
<td></td>
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<tr>
<td>NJ Agr. Experiment Station (<a href="http://www.cook.rutgers.edu">www.cook.rutgers.edu</a>)</td>
<td></td>
</tr>
<tr>
<td><strong>Texas A&amp;M University, College Station, TX</strong></td>
<td>Precision agriculture, farming systems, plant genomics, grain food</td>
</tr>
<tr>
<td>(agresearch.tamu.edu; agrprogram.tamu.edu)</td>
<td>processing</td>
</tr>
<tr>
<td><strong>University of Arkansas, Fayetteville, AR</strong></td>
<td>Rice, wheat, oat and soybean breeding; agronomy and physiology, rice</td>
</tr>
<tr>
<td>Dale Bumpers College of Agr. Food and Life Sci.</td>
<td>processing</td>
</tr>
<tr>
<td>(<a href="http://www.uark.edu/admin/aes">www.uark.edu/admin/aes</a>)</td>
<td></td>
</tr>
<tr>
<td><strong>University of California, Davis</strong></td>
<td>Genetic resources conservation, genetics of cereals and legumes, agronomy,</td>
</tr>
<tr>
<td>College of Agr. and Environ. Sci</td>
<td>wheat breeding, entomology, plant pathology, rice breeding (with California</td>
</tr>
<tr>
<td>(ucanr.org; caes.ucdavis.edu)</td>
<td>Rice Exp. Station and USDA)</td>
</tr>
</tbody>
</table>
University of Illinois, Urbana-Champaign, IL (web.aces.uiuc.edu)
Maize and soybean breeding and agronomy, cereal diseases, starch chemistry

University of Idaho, Aberdeen, Moscow College of Agr. and Life Sci. (www.ag.uidaho.edu)
Grains breeding and agronomy (wheat, oilseeds, peas,

University of Minnesota, St Paul, MN Colleges of Agr., Food and Environ. Sci (www.maes.umn.edu)
Cereal structure, wheat and barley breeding and pathology, soybean diseases, precision agriculture, cereal food processing

University of Missouri, Columbia, MO College of Agr., Food and Nat. Res. (cafrn.missouri.edu)
Tillage, soybean, sorghum and corn cropping systems and soybean breeding, Basic grain science, maize genome mapping (Donald Danforth Center, St Louis, MO)

University of Nebraska, Lincoln, NE Institute of Agr. Natural Res. (www.ard.unl.edu)
Processing of grain starches, cereal breeding, genomics

Washington State University, Pullman, WA College of Agr. and Home Econ. (www.cahe.wsu.edu)
Grain crops breeding and genetics, pathology/entomology, soil science, processing
Canada
The Canadian Grains Commission (www.grainscanada.gc.ca) in Winnipeg, Manitoba regulates grain handling and establishes and maintains grain quality standards for Canada. Its Grain Research Laboratory has emphasized understanding the genetic, environmental, structural and biochemical basis on end-use quality of major Canadian grains, including bread and durum wheat, barley, oilseeds and pulses (peas, lentils, chickpeas and beans). There is a special focus on analytical methods and processing technologies. The Canadian International Grains Institute, also in Winnipeg (www.cigi.ca) has a technical training and information dissemination role.

Agriculture and Agri-Food Canada (res2.agr.gc.ca) carries out grains research at several of its 19 research centers across the country. Cereal research is carried out mainly at the Winnipeg (Manitoba) Cereal Research Centre (res2.agr.ca/winnipeg) emphasizes the development of bread and durum wheat and oat varieties for the prairies, with research strengths in genetics, biotechnology, plant pathology, cereal chemistry and quality evaluation. There are also active research groups on grain and oilseed storage and insect pests of stored commodities. The Eastern Cereal and Oilseed Research Centre (Ottawa, Ontario) (res2.agr.ca/ecore) develops new varieties of wheat, barley, corn, oats and soybeans along with crop protection and management systems. Wheat breeding is also carried out at the Semi-arid Prairie Agricultural Research Centre (Swift Current, Saskatchewan) and the Lethbridge Research Centre (Kamloops, Alberta) there is an emphasis on disease and disease resistance as well as agronomy. The Brandon Research Centre (Brandon, Manitoba) is the main site of barley breeding, while the Lacombe Research Centre (Lacombe, Alberta) carries out oat varietal improvement.

The Saskatoon Research Centre (Saskatoon, Saskatchewan) is the main centre of breeding programs for canola and mustard and conserves many of the grains genetic resources of Canada. Some canola breeding also takes place at the Lacombe Research Centre, while the Greenhouse and processing crops research centre also carries out soybean breeding. Agronomy research for grains production is Soils and Crops Research and Development Centre (Sainte-Foy, Quebec) and the Crops and Livestock research centre (Charlottetown, Prince Edward Island), the Brandon Research centre and the Semi-arid Prairies Agricultural Research Centre.

Several Universities carry out grains research in Canada, and in some cases individual Departments and staff interact closely with Agriculture Canada scientists. These include:

• University of Manitoba, Winnipeg, through its Faculty of Agricultural and Food Sciences (www.umanitoba.ca/faculties/afs/research.html) carries out research on canola and wheat breeding and postharvest technology, grain storage technology, cereal chemistry and baking technology, pulse food science, functional foods, cereal agronomy including precision agriculture.

• University of Saskatchewan, Saskatoon, through its college of Agriculture (www.ag.usask.ca) has an emphasis on wheat, barley, oat, canola and legume (lentil, pea, dry bean and chickpea) breeding and agronomy, plant genetic engineering and molecular marker development and malting and brewing science.

• University of Alberta, Edmonton, through its Department of Agricultural, Food and Nutritional Science (www.afns.ualberta.ca) grain and oilseed crops for Western Canada breeding, disease resistance and agronomy and livestock feed utilization.

• University of Guelph, Guelph, Ontario, through its Department of Plant Agriculture (www.plant.uoguelph.ca) emphasizes grain crops breeding (soybean, barley, wheat and canola), agronomy, pathology and genome mapping.
- McGill University, Quebec, Ontario, through its Faculty of Agricultural and Environmental Sciences (www.mcgill.ca/macdonald), with basic plant science, biotechnology and some grains food processing research.

The National Research Council (NRC) Plant Biotechnology Institute in Saskatoon (www.nrc.ca) carries our basic research in genomics and proteomics, and has a special interest in the modification of oil composition and of agronomic traits of oilseeds, as well as cereal and legume molecular marker and transformation technology. Some individual provinces also have agencies that carry out applied agriculture and food research.

**Mexico**

In Mexico, maize is main grain crop but the national program played an important role in semi-dwarf wheat breeding ahead of the establishment of CIMMYT. Most federal government agricultural research is carried out by INIFAP, the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias; some of the state Governments have small grains research activities. There is also significant activity within the higher education/science and technology ministries (CONACYT, Consejo Nacional de Ciencia y Tecnología), with grains research being carried out in several of their regional centres (CAID, CIATEJ, CIBNOR and ECO SUR). Postgraduate colleges within the Universities managed under the agriculture secretariat (SAGAR) along with the agronomy faculties in Autonomous universities in different Mexican states are also active. Mexico is home to a number of national seed companies (maize, sorghum, wheat), along with subsidiaries of foreign (especially US) seed companies and these carry out some variety trials and agronomy work.

**Europe**

In Western Europe, yields of most major cereals are high, and it is clear that there has been a shift away from research on increasing production to an emphasis on environmentally-friendly production, along with research on:

- quality and processing technologies, including value-addition and non-food uses of grains
- food safety, nutrition and health - with grains the main emphasis is on mycotoxins, nutraceuticals, dietary fiber, and allergies and intolerances
- traceability - eg of GM cereals
- breeding, genomics and diagnostic technologies.

**United Kingdom**

Of United Kingdom government institutes, the Biotechnology and Biological Sciences Research Council (BBSRC, www.bbsrc.ac.uk) has several of its 8 institutes which have some emphasis on research on grains

- John Innes Centre, Norwich (www.jic.bbsrc.ac.uk) - starches, plant biotechnology, fundamental biology of cereals and brassica crops
- Institute of Food Technology, Norwich (www.ift.bbsrc.ac.uk) - basic food science, including research on grain foods ingredients stricture, protein functionality in breadmaking quality and on allergenicity;
- Silsoe Research Institute;
- Institute for Arable Crops Research (recently renamed Rothamsted Research after consolidation of the Rothamsted and Long Ashton sites; www.iacr.bbsrc.ac.uk/iacr). The institute has an emphasis on grain crop performance and improvement, disease management, invertebrate pests and weeds of grain crops and crop-environment interactions;
Under the former Ministry of Agriculture, Fisheries and Food (now known as the Department for Environment, Food and Rural Affairs) there is direct responsibility for the Central Science Laboratory in York (www.csl.gov.uk). The Laboratory has an emphasis on food safety and quality, pest and disease management in crops and chemical residues. The Department also carries out some research on sustainability of grain-based farming systems in the UK. There is a separate Department of Agriculture for Scotland, with two relevant institutes, the Rowett Research Institute (food processing, nutrition, biotechnology) and the Scottish Crop Research Institute (www.scri.sari.ac.uk; cereal quality and nutrition, cereal and brassica breeding, plant pathology).

Major British Universities carrying out research in grain science include:
- University of Reading (www.apd.rdg.ac.uk) has research programs on agriculture-environment interactions, crop protection, crop breeding and agronomy, seed science, farming systems and cereal chemistry;
- University of Nottingham, Sutton Bonington (www.nottingham.ac.uk) has programs in basic plant sciences, agriculture and food sciences, including agronomy of temperate and tropical cereals and research on grain crop abiotic field stress;
- University of Bristol, Long Ashton
- University of East Anglia, Norwich (www.uea.ac.uk) carries our research on cereal molecular biology;
- Heriot-Watt University, Edinburgh, Scotland
- University of Plymouth, Devon
- University of Leeds, Procter Dept of Food Science
- University of Manchester Institute of Science and Technology (UMIST)'s Satake Centre for Grain Process Engineering (www.cc.umist.ac.uk)
- University of Wales, Centre for Arid Zone studies
- Queen's University Belfast (www.qub.ac.uk/afs). The School of Agriculture and Food Science - plant pathology, grain crop physiology, aflatoxins, oat quality

The Home-Grown Cereals Authority (www.hgea.co.uk) is an organisation funded on grower levies to support research, provide market information and extension information for British grain farmers.

France
In France, INRA, the Institut National de la Recherche Agronomique is the main government research organisation in agriculture and grains research. INRA has a large centre in Nantes emphasising agriculture and food processing (www.nantes.inra.fr/public/anglais). There is an emphasis on cereal food and nutritional quality and non-food uses, with a strong emphasis on processing technologies and basic protein and starch molecular sciences related to cereals. At INRA Montpellier, there is also research on processing technology, grain crop production systems, plant protection and genetic resource conservation as well as more basic studies on grain crop development. CIRAD (Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement, www.cirad.fr) is a foreign-aid organisation that carries out research both within France and in developing countries. CIRAD has strong programs covering production and postharvest technology of rice, maize and tropical grain legumes, research on soil and water management for crop production and strong molecular marker/biotechnology programs. Auvergne is a partnership involving private companies such as Groupe Limagrain (www.limagrain.com) and public organisations such as INRA, and have established a cereal genotyping laboratory to form a link between breeding and genomic research. Several French Universities have Ecole Nationale Superieure Agronomique - for example in Paris-Grignon, (the Institut National Agronomique INA-PG),
in Montpellier, Rennes, Nancy and Toulouse. ARVALIS Institut du végétal (www.arvalisinstitutduvegetal.fr) is responsible for Applied Research on cereals, maize, pulses, potato and forage crops. The activities of this Technical Institute, which is run and financed by farmers, include sustainable cropping systems, precision farming, remote sensing, satellite images, biotechnology, farm economics, quality assurance, safety quality, traceability, human food, animal feed, and technology transfer. CETIOM (www.cetiom.fr) is responsible for similar topics on oil crops.

**Germany**

In Germany, The Federal Ministry of Food, Agriculture and Forestry has several relevant institutes - the federal institute for Grain, Potato and Lipid Research (BAGKF, Detmold), the Federal research Centre for Plant Breeding (BAZ), the Federal research Institute for Nutrition (BFE) and the Institute of Agricultural Engineering (ATB, Potsdam-Bornim). There is also an institute for Plant Genetics and Crop Plant Research (IPK, Gatersleben). At least two of the Max Planck institutes carry out grains research - the Institute of Plant Breeding in Cologne and the Institute of Molecular Plant Physiology in Golm. Many of the German states have research agencies or centres in agriculture and several of these carry out grains research, sometimes in conjunction with Universities. Universities carrying out grains research include Humboldt University, Technical University of Berlin, Technical University of Munich, and the Universities of Bonn, Goettingen, Hohemheim, Kassel, Kiel, Rostock and Paderborn.

**Ireland**

In Ireland, the Irish Agriculture and Food Development Authority (TEAGASC) has nine research centres, the Oak Park Research Centre emphasises grain crops, especially aiming for more efficient production systems for cereals, grain lupins and oilseed rape. There is a strong emphasis on the management of fungal and viral diseases of cereal crops. The main University for production research on grain crops is University College Dublin (www.ucd.ie), while University College Cork (www.ucc.ie) emphasises grains processing research.

**Switzerland**

In Switzerland, the major Government grains research institutes are the Federal Office of Agriculture Research station for Plant Production and Research station for agroecology and agriculture, while in the University sector the Swiss Federal University for Technology in Zurich carries out most of the applied grains sciences research.

**Greece**

The NAGREF (National Agricultural Research Foundation), Cereal Institute Thessaloniki, Greece (www.nagref.gr) is the Greek Government research institute charged with cereal breeding and cereal food product development. However, the Ministry of Agriculture has a separate Research Service with a network of institutes in different parts of the country. At least three Universities carry out some grains work - Agricultural University of Athens, Aristotle University of Thessaloniki and the Mediterranean Agronomic Institute at Chania.

**Hungary**

In Hungary, the Ministry of Agriculture and Rural Development manages the Central Food Research Institute (KEKI) and the Agricultural Biotechnology Center (MBK), as well as the Cereal Research Institute in Szeged. The Hungarian Academy of Science has several institutes relevant to grain science - the Agricultural Research Institute, the Research
Institute for Soil Science and Agricultural Chemistry, and the Plant Protection Institute. Most relevant Universities are the Technical University of Budapest (grains processing), the Universities of Agricultural Science at Godollo, Debrecen and Pannon.

**Austria**
In Austria, the Federal Ministry of Agriculture and Forestry has research institutes for general Agriculture as well as an Institute of Cereal Processing. Applied Soil Science and Agricultural Engineering, while there is a University of Agriculture, Forestry and Natural Resources in Vienna. In the Czech Republic, relevant Ministry of Agriculture research institutes include the Food Research Institute, Research Institute of Crop Production, Research Institute for Soil and Water Conservation and Research institute of Agricultural Engineering. There are semi-commercial institutes responsible for cereals (Kromeriz Ltd), Oilseed crops (Oseva Ltd) and brewing and malting. Two Universities - Mendel University of Agriculture and Forestry and Chezch University of Agriculture are relevant to grains research.

**The Netherlands**
In the Netherlands, several institutes within the Government Department of Agricultural research (DLO) carry out grains research - including the Agrotechnological Research Institute (ATO, cereal chemistry and processing), Plant Research International, and Applied Plant Research Institute (PPO). Wageningen Agricultural University is the main University research centre for grains research.

**Belgium**
In Belgium, there are relevant Government Agricultural Research Centres in Gent and Gembloux (www.crugx.fgov.be), while at least four Universities carry out some aspects of grains production and processing research - Ghent, Leuven Catholic University, Gembloux and Louvain-la-Neuve.

**Italy**
The Italian Government Ministry of Agriculture and Forestry has several Research Institutes covering grains research, including the Research Institutes for Cereals (ISC), Industrial Crops, Plant Nutrition, Plant Pathology and Food and Nutrition (IMRAN). The National Research Council (CNR) has a separate system of research institutes, and some of these also carry out grains research. Many major states in Italy host Universities which have agriculture faculties, and most of these carry out at least some grains research - Turin, Milan, Padua, Udine, Bologna, Piacenza, Florence, Pisa, Ascoli, Perugia, Viterbo, Naples, Bari, Potenza, Reggio Calabria, Catania, Palermo, and Sassari.

**Sweden**
In Sweden, the Government Swedish Institute for Food Research and the Swedish Institute for Food and Biotechnology (SIK, a joint industry/ government body) carry out grains processing research. Production research and basic scientific investigations within Universities include the Swedish University of Agricultural Sciences at Svalov and Lund University.

**Norway**
Three main institutes in Norway carry out grains research: within the Government Ministry of Agriculture, there is the State Agricultural Research Station (SFL); while MATFORSK,
the Norwegian Food Research Institute is a nonprofit organisation; and the Agricultural University of Norway at Aas.

**Finland**
In Finland, the Ministry of Agriculture and Forestry has the Agricultural research Centre of Finland and Plant Breeding Institute, while VTT Biotecnology in Espoo (www.vtt.fi/bol/) carries out cereal technology research in close collaboration with industry. The University of Helsinki is the main higher education centre dealing with grains research.

**Denmark**
In Denmark, The Ministry of Food, Agriculture and Fisheries has Institutes in Agricultural Sciences and Agricultural Engineering. The Royal Veterinary and Agricultural University also carries out grains research. Activities related to the Carlsberg laboratory are described elsewhere.

**Spain**
In Spain, the Ministry of Agriculture, Fisheries and Food has the National Institute of Agricultural and Food Technology (INIA), while the Madrid Polytechnic University has a large agriculture faculty.

**Portugal**
There is also an INIA in Portugal, while agricultural research is performed at the Technical Universities of Lisbon, the Universidade de Tras-os-Montes e Alto Douro and Universidade dos Acores.

**Russia**
In Russia, the Russian Academy of Agricultural Sciences comprises about 200 institutes. These include both "All-Russia Research Institutes" - for example those carrying out entomology research related to grains include Plant Quarantine (Bykovo), Plant Protection (St Petersburg), Biological Plant protection (Ekaterinburg) and Regional Research institutes in former republics. The latter often cover a range of agricultural disciplines and some have an almost 100 year history; many have significant grain breeding and seed distribution programs. Three of the All-Russian Research Institutes most relevant to grains are the Institute of Legumes and Groat Crops (Streletskoye), Institute of Sorghum and Cereals (Zemograd) and The N.I. Vavilov Institute of Plant Industry. The latter Institute, based in St Petersburg, but with a number of experimental stations throughout Russia (www.vir.nw.ru) is the main internationally-renowned Russian institute emphasising the conservation and study of plant genetic resources, including of grain crops. Most states have State Agrarian Universities, and there are a small number of specialist agrarian academies including Moscow Agricultural Academy.

**Former Soviet Republics**
After separation from Russia in 1991, National Agricultural Research Systems developed in most of the former soviet republics using the institutional assets left by the former USSR; several of these have a strong crops emphasis although resources for research are very limited and it has been difficult (and often undesirable) to maintain the staff numbers and infrastructure left behind. They have had to develop their priority setting to match specific requirements of their agroecological zone and changed policy/ economic environment including a greater emphasis on markets.
Further reading
www.asti.cgiar.org Agricultural Science and Technology Indicators (for various developed
and developing countries)


Part B.
Grain-Science Organisations
in Asia/Pacific, Central/South America,
and Africa/ Middle East

Introduction
This chapter describes the activities of some of the major research institutes active in grain
science in regions other than North America and Europe. These countries vary significantly
in their state of development, and correspondingly in the development of their grains
research capacity. Furthermore, grains research in some countries such as China has
advanced so much over the last 20 years that in some areas, such as biotechnology and the
development of hybrid rice, world leading R&D is carried out. The National Agricultural
Research Systems (NARS) of countries such as China, India and Brazil are now among the
largest internationally and thus make an increasing input to international grain science
efforts. On the other hand, capacity for grains research (and agricultural research in general)
has fallen in many African countries. There is a special effort to review relevant
International Agricultural Research Centres. While attempts are made to review
organisations that carry out grains research world-wide, there is a deliberate bias towards
provision of more detailed information on institutions in English-speaking countries,
reflecting the main readership of this article. This chapter focuses on Government and public
sector research institutes; private sector research is reviewed in the next chapter.

Many of the trends in North America and Europe are reflected in both the developed
and developing countries in these regions. In Australia especially, there has been a move
towards formation of networks between research institutes. Other trends in Australia include
the greater importance of levies from grain-growers in supporting research a number of
countries, and the increase in commercial involvement in grain breeding and biotechnology.
More broadly across each of the regions reviewed is a shift in focus of many of the grain
R&D institutions from a largely production focus to an emphasis on environmental issues
such as water use efficiency and sustainability of farming systems. For the developing
countries that benefited from the higher-yielding varieties of the “Green Revolution”,
sustaining the gains through more efficient use of water and prevention of erosion,
waterlogging, salinity and acidification is now critical. Also critical is research on grain
quality and addressing market requirements, as grain production in several of these countries
struggles to compete with subsidised European and US agriculture.
The International Agricultural Research Centres
The CGIAR system (Consultative Group for International Agricultural Research) is a non-profit network of 16 semi-autonomous R&D centres, supported by the World Bank and a range of national Governments, usually through their overseas development assistance programs. Several of the centres have a grain science focus, including the first two centres that were established in the early 1960’s, IRRI (International Rice Research Institute, www.irri.org) and CIMMYT (Centro Internacional para Mejoramiento del Maíz y Trigo, the International Maize and Wheat Centre). CIMMYT (www.cimmyt.org) is based in Mexico, but has programs in Latin America, Africa, Asia, Central Asia and West Asia and North Africa. Other CGIAR centres with a strong grains focus include ICRISAT (International Crops Research Institute for the Semi-Arid Tropics in Patancheru, India; sorghum, pearl millet, chickpea, pigeon pea and peanut) and ICARDA (International Center for Agricultural Research in the Dry Areas in Aleppo, Syria; barley, wheat, lentil, faba bean, chickpea, forage legumes).

Three centres carry out rice improvement. IRRI, centred at Los Banos, Philippines is the main one, and its work aims to help poor farmers in developing countries grow increased yields of rice using less water, less labour and fewer chemical inputs. The semi-dwarf rice varieties and management packages developed by IRRI were central to the successes of the Green Revolution in the 1960s and 1970s. IRRI has a focus on Asia while two other centres undertake rice breeding and management in Latin America and Carribean (CIAT, International Center for Tropical Agriculture in Cali, Colombia, www.ciat.cgiar.org) and West Africa (WARDA, Western Africa Rice Development Association, Bouaké, Côte de Ivoire, www.warda.cgiar.org).

The CGIAR centres have traditional strengths in germplasm development, providing much of the germplasm for development of the modern varieties now utilised throughout the developing world (as well as in some developed countries such as Australia). To support germplasm development, centres have strengths in agronomy, quality assessment, biotechnology, pathology, natural resource management and economics. Conservation of genetic resources is an important part of the centres’ mandates. At CIMMYT, wheat and maize breeding (agronomy and quality evaluation programs) are backed up by programs in economics, natural resource management and biotechnology. ICRISAT (www.icrisat.org) has a geographical emphasis on South Asia and Sub-Saharan Africa, and its research addresses water scarcity through natural resource management research (rainwater conservation and utilisation) and plant breeding to improve water use efficiency and drought tolerance. ICARDA (www.icarda.cgiar.org) has a geographical emphasis on Central West Asia and Northern Africa, but its germplasm is utilised world-wide. ICARDA focuses on agriculture in tropical dry areas, while ICRISAT emphasises temperate and subtropical dry areas. It also has an emphasis on water-soil management in integrated farming systems for low-rainfall areas. IITA, the International Institute of Tropical Agriculture (www.iita.org) with headquarters in Ibadan, Nigeria focuses on germplasm (including several grains - cowpea, maize and soybean), pest management and crop-based farming systems for smallholder farmers of Sub-Saharan Africa.

Some work on processing quality is carried out by the centres, but very little work on grain storage and other postharvest technologies. While germplasm development is still the main focus, there has been an increased involvement in recent years in natural resource management, farming systems research and in understanding social, policy and economic constraints. There is a level of tension within the CGIAR system as a whole on the appropriate balance of such activities, given that there have been few additional funding resources in real terms over the last decade.
Major public-sector grain-science organisations (Government and University)

Asia-Pacific

Australia

There are three main public sector providers in grains research in Australia - State Departments, CSIRO (National Government) and Universities. State Departments are the main research providers - the National Government Department, Agriculture, Fisheries and Forestry Australia (AFFA), does not conduct laboratory or field research in agriculture. In the last 10-15 years there has been a shift in emphasis of many State Departments from an overwhelming emphasis on production agriculture towards sustainable production. Nonetheless, the states remain particularly strong in crop improvement and agronomy, and in soil science and farming systems research. A summary is provided in Table 1. An increasing proportion of extension services, formerly provided by the States, are now provided to farmers on a commercial basis by these Departments or by the private sector.

Some of the Divisions of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), a national Government authority, conduct research in grains production and processing, including:

- Plant Industry - genomics of grains including wheat and rice; barley genetic engineering; wheat starch composition; breeding of winter wheats and oilseeds; physiology, agronomy and adaptation of cereal crops, soybean, mungbean; sustainable crop-pasture systems; Mediterranean cropping systems; cereal chemistry and rapid testing methods;
- Entomology - stored grains research (sgrl.csiro.au);
- Food Science Australia - extrusion cooking; mycotoxin contaminants;
- Land and Water - sustainable use of soil and water resources in grain cropping;
- Sustainable Ecosystems - rodent pests of cereal crops; predictive understanding of biophysical and ecological processes.

BRI Australia Ltd (www.bri.com.au) is an independent non-Government grains research organisation. Areas of research expertise include Milling, Near-Infrared Reflectance technology, baking science and technology and Asian wheat foods (noodles and steamed breads). AWB Ltd's (www.agrifood.com.au, formerly The Australian Wheat Board) R&D laboratory, Agrifood Ltd, has an emphasis on testing services, although some research on nutrition, milling and wheat products is carried out.

There are about twenty tertiary institutions that teach and research aspects of agriculture, horticulture, forestry, fisheries and natural resource management. Relevant grains research is carried out at several Universities. This includes:

- University of Adelaide (www.sciences.adelaide.edu.au/faculty/schools/ag_wine.html) - bread and durum wheat and barley breeding, molecular markers, cereal root diseases, cereal pathology, biotechnology, weed management, malting and brewing biochemistry
- University of Sydney (www.agric.usyd.edu.au) - breeding for rust resistance in barley and wheat; wheat, oat, rye breeding for processing quality; cereal diseases; cereal genomics; precision agriculture; soil science; crop modelling
- University of Melbourne, through its Joint Centre for Crop Innovation (www.jcci.unimelb.edu.au) associated with the School of Land and Food (www.landfood.unimelb.edu.au) emphasises research to underpin the sustainability of temperate grain crop production, with emphasis on variety development, agronomy and farming systems and protection of natural resources.
- University of New England (sciences.une.edu.au/srsag) - agronomy and soil science, plant nutrition, crop protection, weed science, integrated pest management.
<table>
<thead>
<tr>
<th>Department (website)</th>
<th>Grains Research Emphasis</th>
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<tr>
<td>NSW Agriculture (<a href="http://www.agric.nsw.gov.au">www.agric.nsw.gov.au</a>)</td>
<td>bread, biscuit and durum wheat breeding; malting barley breeding; oat breeding rice breeding, nutrition, pests and quality assessment cereal, canola and pulse agronomy and disease management; crop-pasture rotations chickpea, faba bean, field peas, canola, lupins with enhanced yield and disease resistance</td>
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<tr>
<td>Department of Primary Industries Agriculture Victoria (<a href="http://www.nre.vic.gov.au">www.nre.vic.gov.au</a>)</td>
<td>dryland cropping; sustainable cereal/pasture-based farming systems cereal molecular marker development milling wheat, malting barley, pulse and oilseed brassica breeding pulse agronomy, pathology and processing</td>
</tr>
<tr>
<td>Queensland Dept of Primary Industries (<a href="http://www.dpi.qld.gov.au">www.dpi.qld.gov.au</a>)</td>
<td>wheat and oat breeding and quality assessment malting barley breeding and barley biochemistry tropical maize improvement; sorghum breeding and pest management soybean and peanut breeding and agronomy subtropical grain farming systems; new grain crops (pearl millet, guar and adzuki beans) integration of cropping systems and climate models grain storage technologies</td>
</tr>
<tr>
<td>South Australian R&amp;D Institute (SARDI) (<a href="http://www.sardi.sa.gov.au">www.sardi.sa.gov.au</a>)</td>
<td>bread and durum wheat, triticale, oat and malting barley improvement chickpea and lentil improvement biotechnology in cereal crop improvement cereal chemistry and quality assessment cereal, pulse and oilseed pathology and disease diagnostics soil-borne root diseases and abiotic constraints to productivity agronomy, tillage practices, climate risk management</td>
</tr>
</tbody>
</table>
Dept of Agriculture, Western Australia (www.agric.wa.gov.au)
- wheat and barley breeding and agronomy for Mediterranean environments
- cereal- pasture farming systems
- canola and field pea
- grain storage and protection
- cereal chemistry and Asian products
- pulse pathology

Dept of Primary Ind., Water and Environment, Tasmania (www.dpiwe.tas.gov.au)
- cool temperate cereal breeding and selection
- brassica oilseed variety assessment
- assessment of soybean and broadbean varieties

- agronomy of irrigated maize, peanuts, sesame and rice production
• University of Queensland (www.aghort.uq.edu.au) - production and postharvest handling of cereals, grain legumes and oilseeds; weed management; plant protection; molecular biology; sustainable grains production systems.

• University of Western Australia (www.fnas.uwa.edu.au) - grain crop science and molecular genetics.

  Smaller University research efforts are based at:

• Charles Sturt University (www.csu.edu.au/faculty/sciagr/sag) - agronomy, irrigation, fertiliser management of grain crops, plant pathology.

• Curtin University Muresk Institute (www.curtin.edu.au/curtin.muresk/research.htm) - agronomy, precision agriculture.

• Murdoch University (www.sabc.murdoch.edu.au/SABC) - molecular markers for barley and wheat, grain legume genome mapping, transgenics, diseases and viruses.

• Southern Cross University (www.scu.edu.au/research/cpcg) - cereal genotyping technology; genes delivering cereal processing and health benefits.

• University of New South Wales (www.chem.unsw.edu.au) - grain storage engineering.

• University of South Australia (www.unisa.edu.au) - agricultural machinery research and design.

• University of Southern Queensland (www.usq.edu.au/faculty/science/decpts/biophyssci/CREBhome.htm) - plant-pathogen interactions, cereal genetic engineering, marker-assisted breeding, canola breeding.

• University of Tasmania (www.scieng.utas.edu.au/agsci/research/asp) - cereals, grain legumes and oilseeds as break and rotation crops.

Over the last 10-15 years, there has been a significantly increased emphasis on establishment of more formal links between research organisations. This has been driven to a significant extent by the advent of the Cooperative Research Centres (CRC) program and encouragement by funding providers such as the Grains R&D Corporations (RDCs). A special feature of the Australian research landscape is Cooperative Research Centres (CRCs). This program, funded by the Government, was launched in 1990 to strengthen collaborative linkages between industry, research organisations, Universities and Government agencies. CRCs cover all areas of science and technology, but several of the centres relate to grain production and processing. As of January 2003, these include:

• CRC for Value-Added Wheat (qwrcr.webbit.com.au), following on from the Quality Wheat CRC, focuses on the development of wheat varieties, agronomic management, new approaches for the assessment of wheat quality, and improved wheat processing quality;

• CRC for Innovative Grain Food Products, to commence in July 2003, emphasises high value functional grain foods;

• The CRC for Sustainable Rice Production (www.ricecrc.org) emphasises increased production efficiency, development of value-added products and improved management of soil and water resources;

• The CRC for Molecular Plant Breeding (www.molecularplantbreeding.com) emphasises the identification and utilisation of molecular markers in cereal and pasture grass breeding.

• The CRC for Weed Management Systems (www.weeds.crc.org.au, emphasises non-chemical management of weeds, including in cereal-based farming systems)

• CLIMA (Centre for Legumes in Mediterranean Agriculture, www.clima.uwa.edu.au) emphasises research on the role of grain and annual pasture legumes in the Mediterranean climate of SW Western Australia. Research strengths include breeding, germplasm assessment, pests and diseases, molecular biology and crop physiology of legumes.
The Rural R&D Corporations, of which the Grains R&D Corporation is the relevant one for grains research, facilitate and manage funding for research and assist in communicating its results. They are generally funded on the basis of the Government matching, dollar-for-dollar, industry R&D levies up to a maximum of 0.5% of the industry’s gross value of production (GVP). Until the early-mid 1990s, most RDCs saw themselves as “reactive” funding bodies that selected a limited number of projects for funding from a larger number of competitive proposals. Managers from most RDCs now play a much greater role in determining research priorities in consultation with particular industries, and are being involved in project design and negotiating research partnerships. In grains, funding mechanisms have provided strong encouragement for different laboratories working on particular diseases and breeding targets within a given agro-ecological zone to collaborate more closely and formally.

Much of Australia’s plant breeding is still done in the public sector although in many cases private sector seed companies now license the varieties developed from the research and distribute and market the seed to farmers. Increased commercialisation of plant breeding and development of national breeding networks for major grains are recent developments and have reduced research duplication.

New Zealand
The main New Zealand organisation undertaking grains research is the NZ Institute of Crop and Food Research (www.crop.ori.nz). It is one of nine Government-owned research institutes. It has a strong emphasis on grain crop improvement as well as basic cereal science and baking technology. Universities with research interests in grains include Massey University (Palmerston North, sciences.massey.ac.nz) includes a research emphasis on food science and engineering. Lincoln University (Christchurch, www.lincoln.ac.nz) carried our research on grain foods composition, crop agronomy, seed science and technology and some biotechnology. Although wheat is also the major cereal, the cereals growing environment is very different from that in Australia, requiring rather different varietal characteristics.

Japan
In Japan, much of the grains research is carried out in institutes managed under the Agriculture, Forestry and Fisheries Research Council of the Ministry. Crops (including grains) research is carried out in a series of regional institutes in Hokkaido, Tohoku, Hokuriku, Chugoku, Shikoku and Kyushu, and grains nutrition at the National Food Research Institute in Tsukuba. Major Universities with agriculture faculties include Tokyo University of Agriculture and Technology, Tohoku, Kyoto, Kyushu, Hokkaido, Kagoshima, Yamaguchi, Tottori and Nagoya. Several Universities carry out research in grains processing.

Korea
The Korean Rural Development Administration (home.rda.go.kr/emg) of the Ministry of Agriculture and Forestry has a series of National Research Institutes, including the National Crops Research Institute, National Institute of Agricultural Science and technology (with relevant work on crop protection and agroecology), National Institute of Agricultural Biotechnology, National Rural Nutrition Institute and nine provincial agricultural and extension institutes. Under the Ministry of Science and technology, the Korea Food Research Institute (www.kri.re.kr) and the Korea Research Institute of Bioscience and Biotechnology (web.kribb.re.kr). Grains research is strongly rice-focused, but with an increasing environmental protection and biotechnology emphasis. Major Universities with Agriculture faculties include the National Agricultural College, Chungbuk, Chungnam. Seoul National University, Gyeongsang, Kyungpook, Wonkwang and Dongguk.
China

China has one of the largest National Agricultural Research Systems in the world, and in recent years the Government has placed a high priority on developing research capacity and infrastructure. Because of the large range of production environments, research on both temperate and tropical grains is important, and some institutes perform world-leading grains research, for example in the development of high-yielding rice varieties, rice functional genomics and transgenic crops. In recent years, the Chinese Government has been making investments in R&D that are huge by any standards; the physical infrastructure and equipment have significantly improved, and there has been a move to retain or attract back eminent scientists. There is an increasing shift in emphasis in China from research aimed at increasing grain production to increasing quality and ensuring that production is environmentally sustainable, especially in view of the increasing pressure on water resources for agriculture in China.

Grains research is carried out in five main types of organisations. The Chinese Academy of Agricultural Sciences (CAAS; www.caas.net.cn) governed by the Ministry of Agriculture is the national academy with the largest number of grains research projects. It also can confer postgraduate degrees. 16 of its 38 institutes carry out grains science, including the Institute of Crop Germplasm Resources, Beijing; Institute of Crop Breeding and Cultivation, Beijing; Institute of Plant Protection, Beijing; Institute of Biological Control, Beijing; Biotechnology Research Center, Beijing; Institute of Food Research, Beijing; Institute of Soils and Fertilizers, Beijing; Institute of Agricultural Mechanisation, Nanjing; China National Rice Research Institute, Hangzhou; Agro-Environment Protection Institute, Tianjin; Institute of Oil Crops, Wuhan. Main thrusts are crop breeding, germplasm conservation, development of biotechnology tools, natural resource management and protection (with a recent emphasis on water-saving agriculture for arid and semi-arid regions), integrated pest management and agricultural mechanisation to improve efficiency.

The Chinese Academy of Sciences (CAS, english.cas.ac.cn) also carries out some research relating to Grains, including at the Institute of Botany and Institute of Genetics (Beijing, basic plant biology and biotechnology), Institute of Zoology (Beijing, pest management), Institute for Soil Research (Nanjing), National Centre for Genetic Research, Shanghai (rice genomics), Chengdu Institute of Biology (cereal breeding); Institute of Soil and Water Conservation, Yangling (agronomy), NW Plateau Institute of Biology, Qinghai (crop assessment) and Shijiazhuang Institute of Agricultural Modernization, Hebei (farming systems for the North China plain).

Provincial Academies of Agricultural Science are increasing in resources. Those with strengths in strategic or applied grains include Jiangsu, Sichuan, Guangdong, Fujian, Henan (for wheat), Shandong, Liaoning, and Gansu. The Beijing Food Research Institute carries out some cereals processing research, while the State Administration of Grain Reserves also carries out grain storage research, including through the Grain Storage Research Institute in Chengdu. The four strongest universities in terms of agricultural science are China Agricultural University (Beijing), Nanjing Agricultural University, Zhejiang University and Huazhong Agricultural University. Other agricultural Universities carrying out grains research are South China Agricultural University (Guangzhou), Shenyang Agricultural University, Central China Agricultural University (Wuhan), South-West Agricultural University (Chongqing) and North-West Agricultural University (Yangling). The Botany department at the University of Hong Kong (www.hku.hk/botany/research.html) carries our basic research on rice grain structure, maize breeding and processing research on wheat, oats and soybeans.
India
India has one of the largest NARS in the world, and a traditional strength in grains sciences. ICAR has almost 30,000 staff, including 7000 research scientists. Most grains research is done within the Indian Council for Agricultural Research Institutes (www.icar.org.in). Of its 46 Central Research Institutes, most of the grains research institutes are within the Crop Science Division. Major thrusts include development of grain varieties resistant/tolerant to a range of abiotic and biotic stresses, hybrid technology, application of molecular techniques, plant genetic resources conservation, farming systems research. The main ICAR institutes carrying out grains research include:
- **Indi an Agricultural Research Institute**, New Delhi (emphasis on more strategic research)
- **Central Rice Research Institute**, Cuttack, Orissa
- **Indian Institute of Pulses Research**, Kanpur, Uttar Pradesh
- **National Bureau of Plant Genetic Resources**, New Delhi
- **National Research Centre for Groundnut**, Junaghar, Gujarat
- **National Research Centre for Rapeseed Mustard**, Bharatpur, Rajasthan
- **National Research Centre on Sorghum**, Hyderabad, Andhra Pradesh
- **National Research Centre on Soybean**, Indore, Madhya Pradesh
- **National Centre for Integrated Pest Management**, New Delhi
- **National Research Centre for DNA fingerprinting**, New Delhi
- **National Research Centre on Plant Biotechnology**, New Delhi

Several smaller project directorates covering biological control, oilseeds, rice, wheat and maize. In addition All-India Coordinated Research projects attempt to link institutes; current coordinated projects cover all major (and most minor) cereal, oilseed and pulse crops, as well as specific pests such as white grubs and rodents. An even bigger resource is the 29 State Agricultural Universities (SAUs), which fall under the ICAR. They employ almost 26,000 scientists in teaching, research and extension roles. Some of the SAUs with strong grains research programs include Acharya NG Ranga AU (Andhra Pradesh), CCS Haryana AU, GB Pant AU (Uttar Pradesh), Punjab Agricultural University and Tamil Nadu AU. The Council for Scientific and Industrial Research CSIR has a set of national institutes in different areas of science and technology. The Central Food Technological Research Institute (CFTRI, Mysore) has a department which researches cereal (especially wheat) milling, baking and biochemistry.

Indonesia
The major Indonesian Government agricultural research and development agency is IAARD (Indonesian Agency for Agricultural research and development). Research Institutes working on grains within the Central Research Institute for Food Crops are the Rice Research Institute, Sukamandi, Java; Research Institute for Maize and Other Cereals, Makassar, Sulawesi; Research Institute for Legume and Tuber Crops, Malang, Java and a Research station for (rice) tungro disease. New Research Institutes for Biotechnology and genetic resources and for Postharvest Technology have recently been established. Adaptive research is carried out by Assessment Institutes for Agricultural technology (under IAARD, but located in each province). Major agricultural Universities include Bogor Agricultural University (IPB), Gadjah Mada University (Yogyakarta), Hassanuddin University (Makassar), University of Mataram (Lombok) and Universitas Sam Ratulangi (Manado).

The Philippines
Under the Philippines Department of Agriculture (DA), there is a national rice research centre (PhilRice in Munoz, Luzon; www.philrice.gov.ph) addressing both research and technology
dissemination, and the Bureaus of Plant Industry, Soil and Water Management and Postharvest Research and Extension. The last of these is based at Munoz (on the Central Luzon State University campus) and has two main research emphases - grain storage and processing of high-value crops such as potato, cashew, coffee and beans. There are also Regional Integrated Agricultural Research Centres - there is one organisation in each of the 15 Regions, but some have 2-3 research stations, and several focus on grain crops. The strongest University in grains research is the University of Philippines at Los Banos (www.uplb.edu.ph), which has specialised Institutes of Plant Breeding and of Farming Systems Research.

There are also a number of Universities in regions with strengths in agriculture, and the Universities have a far greater share of research capacity than DA. These include Benguet, Central Luzon State, Visayas State College of Agriculture, Don Mariano Marcos State U, Central Mindanao and Southern Mindanao, but there are several others with some strengths in agriculture (Mindanao State, Bicol, Central Visayas State). Some of the Universities have regional research and development centres involving the Federal Departments of Agriculture and of Environment and Natural Resources, and some of the state Universities also have quite good extension/outreach systems.

**Thailand**

The Thailand Department of Agriculture (DOA, www.doa.go.th) of the Ministry of Agricultural and Cooperatives is responsible for crop research while the Department of Agricultural Extension (DOAE) is responsible for transfer of technology to farmers. While there are experiment stations in every region of the country, most research is carried out in Bangkok. DOA has technical divisions covering Agricultural Chemistry, Agricultural Engineering, Plant Pathology and Microbiology, Entomology and Zoology, Soil Science, Botany and Weed Science, and Agricultural Toxic Substances (pesticides), and specialist Rice and Field Crops institutes (there is reasonable research capacity in maize and legumes research). The Land Development Department (www.ldd.go.th) conducts research in relation to land improvement and soil and water conservation. Grains postharvest technology is carried out within the Thailand Institute of Scientific and Technological Research (TISTR, www.tistr.or.th) in Bangkok. One of the three research centres with National Science and Technology Development Agency (www.nstda.or.th) is Genetic Engineering and Biotechnology (BIOTECH). Kasetsart (www.ku.ac.th) in Bangkok, Khon Kaen (www.kku.ac.th), Chiang Mai (www.cmu.ac.th) and Prince of Songkla Universities (Hat Yai, www.psu.ac.th), and King Mongkut's Institute of Technology in Bangkok (www.kmutt.ac.th) are all involved in grains research, the latter having a special focus on grains postharvest technology.

**Malaysia**

In Malaysia, the Rice and Industrial Crops Research Centre of the Malaysian Agricultural Research and Development Institute (MARDI, www.mardi.my) researches rice, maize and groundnuts as well as several non-grain crops. The most relevant activity is development of high quality rice varieties with disease resistance and accompanying agronomy. The Food Technology research centre does work on the development of rice-based snacks and other food products. The major University carrying our grains science research is University Putra Malaysia (www.agri.upm.edu.my).

**Pakistan**

The Pakistan Agricultural Research Council, PARC (www.parc.gov.pk) coordinates much of the Government Agricultural R&D effort. The main institute, the National Agricultural
Research Centre as Islamabad has several sections relevant to grains research, covering soil fertility, sorghum and millet, farm machinery, water resources, agricultural biotechnology, vertebrate pests, crop diseases, crop production, land resources, plant genetic resources, and seed sciences. There is separate tropical agricultural research centre at Karachi, four arid zone research centres in different regions of Pakistan. There are several agricultural Universities in Pakistan which carry out grains research, the largest being the Pakistan Agricultural University at Faisalabad. Sindh Agricultural University, the University of Arid Agriculture (Rawalpindi), the Northwest Frontier Agricultural University (Peshawar) are all smaller, but with a similar range of activities. The Ministry of Science and technology manages the Pakistan Council of Scientific and Industrial Research which carries out grains postharvest research. There is also a separate National Institute for Biotechnology and Genetic Engineering (Faisalabad) (www.nibge.org).

Vietnam
Most grains research in Vietnam is conducted under the Ministry of Agriculture and Rural Development (MARD; www.agroviet.gov.vn). Other relevant Ministries are Education and Training (University sector); Science, Technology and Environment (MOSTE), which has some excellent crop biotechnology and plant protection research facilities and the Ministry of Industry (which has an Oil Plant Research Institute (with the mandate for peanut, soybean, sunflower and sesame). While most institutes are located in either Hanoi or Ho Chi Minh City, many maintain “research centres” in more remote locations.

The key MARD institutes in grains science are the National Institute for Plant Protection, National Institute for Soils and Fertilizers, Post–Harvest Technology Institute, Vietnam Agricultural Science Institute, Institute of Agricultural Genetics and the Cu Long Delta Rice Research Institute. The Department of Plant Protection of MARD is also becoming an important applied research organisation. The main Universities with research interests in grain science include Hanoi Agricultural University, Hanoi University of Science (also known as Hanoi College of Sciences), University of Agriculture and Forestry (Ho Chi Minh City) and Can Tho University; the two southern universities are the best equipped.

Central and South America
Brazil
Brazil has a well-developed NARS, with many centres falling under EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria; Brazil Agricultural Research Corporation), a specialised science agency of the Agriculture Ministry. Brazil has the largest NARS of any Central or South American country, followed by Mexico; Brazil also has an advanced University system. There are separate EMBRAPA institutes relating to Genetic Resources and Biotechnology (CENARGEN), Rice and Beans (CNPAF), Corn and Sorghum (CNPMS), Soils (CNPS), Soybean (CNPSO), Wheat (CNPT), Temperate Climate Agricultural Research (CPACT), Temperate rice and Agriindustry food technology (CTAA). Many of the Brazilian states have state "research corporations" that carry out grain crop assessment. There are also a non-profit centre for Wheat Experimentation and Research (FUNDACEP) and the Rice Institute of the Rio Grande (IRGA). Several Universities carry out grains research - the Federal Universities of Goias, Lavras, Paraiba, Pelotas, Rio Grande do Sul, Rural do Rio de Janeiro, Santa Catarina, Sao Carlos, Santa Maria, Vicosa and Brasilia as well as several state Universities - Santa Catarina State, Paulista, Campinas, Sul de Santa and Sao Paulo. Some Brazilian companies, such as Agroceres, Durafiora, Mogiana and Braskalb carry out breeding and agronomy research to support seed distribution businesses.
Argentina
The Argentine Government Instituto Nacional de Tecnología Agropecuaria (INTA) is under the agriculture Ministry, but there are a large number of programs and centres relevant to grains research under CONICET, which is under the Culture and Education Ministry. This includes centres for maize (CIG), plant protection (CIPEN), rice and biotechnology (IMBIV), postharvest technology (INSIBIO and INTECH) and semi-arid crops (CERZOS). Several National Universities have agronomy science faculties - Buenos Aires, Buenos Aires Province, Catamarca, Comahue, Cordoba, Cuyo, Entre Ríos, Jujuy, La Pampa, La Plata, Litoral, Lomas de Zamora, Mar del Plata, Noreste, Rio Cuarto, Rosario, Santiago del Estero, de Sur, de Salta, Tucuman, and de Formosa.

Chile
The Chilean Ministry of Agriculture has an Instituto de Investigaciones Agropecuarias (INIA) which includes some grains research. There are also Agronomy Departments at several Universities - Austral, Concepcion, Frontera, Serena, Magallanes, Talca, Tarapaca and Universidad de Chile, Universidad Iberoamericana de Ciencias as well as the Catholic Universities - Temuco, Valparaíso and Maule.

Colombia
In Colombia, the main Government crops research agency is CORPOICA; under the Asociacion Nacional de Acuicultores (ACUANAL) there are research groups working on wheat, barley, maize, sorghum and rice. Apart from the campuses of the National University, other Universities with agronomy faculties include Cordoba and Tolima. The main research agency in the Ecuador agriculture ministry is INIAP (Instituto Nacional Autonomo de Investigaciones Agropecuarias); universities in most regional centres have small agronomy departments.

Information about grains research in the Carribean can be found in Roseboom et al. (2001).

Africa and the Middle East
South Africa
South Africa has the best-developed NARS of the African countries, and reasonable research capacity in maize (the main grain crop), sorghum and some experience in wheat and barley. The Agricultural Research Council (www.arc.agric.za) is the main agricultural research structure, and has a series of research institutes several carrying out grains research - these include the Institutes for Agricultural Engineering, Range and Forage, Industrial Crops, Plant Protection, Grain Crops Institute and Soil, Climate and Water. The Nine Provincial Departments also carry out selection and agronomy research, including those in Eastern Cape (Dohue), Free State (Glen), Natal (Cedara) and Elnsburg. There are some well-resourced grains research programs at the University of Pretoria, Natal, Free State and Stellenbosch. "Traditionally Black" Universities are increasing in strength, and several emphasise agriculture, including University of Fort Hare, University of the North and Venda. In the last decade, there has been a significant shift in research emphasis in South Africa to accommodate the needs of the wider population, rather than just white commercial agriculture, to include emerging farmers and subsistence farmers in former homelands.

Zimbabwe
In Zimbabwe, most crops research is carried out by the Department of Research and Specialist services in the Ministry of Lands, Agriculture and Water Development, with the
University of Zimbabwe maintaining reasonable strength. Some of the grains IARCs, such as CIMMYT and ICRISAT have maintained successful in-country programs in Zimbabwe, too.

Kenya
The Kenya Agricultural Research Institute (KARI, www.kari.org) is comparatively strong in crops and livestock; overall the Kenyan government agricultural research system is the second strongest in Africa, next to that of the Republic of South Africa. In the grains area, mandate crops include cereals (wheat, maize, sorghum, millets and rice) and grain legumes (dry beans, cowpeas, mungbeans, pigeon pea, chickpeas and Dolichos) with efforts ranging from plant breeding for adaptation to different agro-ecological zones and stress resistances, agronomy, postharvest technology and cooking quality. Almost all Kenyan grain production is rain-fed. The maize breeding and seed distribution program has probably been the most extensive. The breeding and postharvest research is backed up by a soil and water management research program. Some grains research is carried out at various Universities (Egerton, Moi, University of Eastern Africa and University of Nairobi).

Ethiopia
The Ethiopian Agricultural Research Organisation (EARO) has national centres emphasising maize, plant protection, soils and agricultural mechanisation as well as a number of centres in regional areas. Crops research is carried out at Alemaya University and Mekele Universities.

Nigeria
In Nigeria, the Ministry of Agriculture has a series of research institutes; several of these, including the National Cereals Research Institute, Lake Chad research Institute and the Institute for Agricultural research. Postharvest technology is carried out under the Ministry of Industry at the National Stored Products Research Institute. Universities with relevant research programs include the University of Ibadan, University of Nigeria, Obafemi Awolowo and Maiduguri.

Zambia
In Zambia, the Soils and Crops research Branch of the Ministry of Agriculture, Food and Fisheries and the University of Zambia are the main grains research providers.

Tanzania
In Tanzania, it is the Directorate of Research and Development of the Ministry of Agriculture and Food Security.

Ghana
In Ghana, the Crops Research Institute of the Council for Scientific and Industrial Research, along with the University of Ghana and the University of Science and Technology are the crops research providers.

Sudan
In Sudan, the major grains research organisations are the Agricultural Research Corporation (within the Ministry of Agriculture and Forestry) and the Universities of Khartoum and Gczira.

Israel
The Israel National Agricultural research System is reasonably well-resourced, within the Agricultural Research organisation (www.agri.gov.il) several institutes are relevant to grains
research, including the Institutes for Field and Garden Crops (IFGC); Plant Protection; and Soil, Water and Environmental Services. The IFGC has a particular emphasis on wheat breeding to overcome drought and disease stress and heat tolerance in wheat and sorghum. There are also peanut breeding and rhizobiology programs. Universities carrying out grains research include the Technicon, Israel Institute of Technology (Haifa) and the Ben-Gurion University of Negev.

**Egypt**

Egypt also has a very large government agricultural research system, within the Agricultural Research Center (ARC), within the Ministry of Agriculture and Land Reclamation. In ARC, there are separate Institutes for field crops, plant protection, plant pathology, food technology (bread and pasta research), agricultural genetic engineering and soil, water and environment research. There are programs on wheat, barley, maize, rice, sorghum, legumes and oil crops. Universities with agriculture faculties include Alexandria, Cairo, Ain Shams, Al Azhar, Suez Canal, Zagagig, Assuit, Mansoura, Minia, Menoufa, tanta and South Valley. Further information on grains research in other West Asia and North African countries is provided in Casas et al (1999).

**Further reading**


www.asti.cgiar.org Agricultural Science and Technology Indicators (for various developed and developing countries)

**Part C. Global Trends and the Commercial Sector**

**Introduction**

This chapter sets out to synthesise some of the recent trends in the subject matter and institutional organisation of grains research internationally. Among these trends include a greater emphasis on demand-driven rather than science-driven research. Accompanying this is greater involvement of industry and farmer groups in setting research priorities, and in some cases, farmer groups are setting up and managing their own research trials. While ex ante economic impact assessment studies have shown that very significant returns on research investments have come from germplasm development (Alston et al., 1999), there is an increasing emphasis in grains research on topics such as production sustainability, crop-livestock systems, systems modelling, and use of techniques from molecular and information sciences. Priority-setting processes and funding agencies have also encouraged greater collaboration between disciplines and between research institutes, and it is now the norm for grains researchers to be part of large networks. The private sector has greater involvement in
agricultural R&D than ever before, particularly in developed countries, and in the case of grains research, especially involving linkages between seed business and biotechnology/life science concerns. Pardey and Beintema (2001) have calculated that since the mid-1990s, in developed countries expenditure from the private sector in agricultural research have exceeded public expenditure.

**GRAINS RESEARCH IN THE COMMERCIAL SECTOR**

**Grain-processing companies**
Most of the research carried out by these companies is applied in nature, aimed to support their flour milling and bakery products businesses (including breakfast cereals), but some carry out more basic research and their staff contribute to industry research conferences and the scientific literature. Major US examples include the ConAgra Grain Processing Company (www.conagramilling.com) in Omaha, NE, General Mills (www.gennills.com), Kellogg Company (www.kelloggs.com) in Battle Creek, MI and Nabisco, New Jersey. Nabisco Research carries out some rather fundamental studies on dough rheology and physical properties. Riceland Foods (www.riceland.com, Stuttgart, AR, USA) and Riviana Foods (Houston, TX) are two very large manufacturers of rice- and soya-based food ingredients, and carry out some applied research to support their markets. The National Starch and Chemical Company, Bridgewater, NJ (www.nationalstarch.com) focuses on cereal starch-based polymers and carries out a significant research program including work on new adhesives, specialty food starches and biodegradable packaging materials. Cargill (www.cargill.com) has wheat flour milling and maize wet-milling divisions provides grains-based feeds for livestock and through Cargill Health and Food Technology has an emphasis on nutraceuticals research, especially developing products derived from soy. Other companies with an interest in research in soy products as nutraceuticals include DuPont Protein Technologies, St Louis, MO (www.solaex.com); Central Soya Company, Fort Wayne IN (www.centralsoya.com); Schouten USA, Minneapolis, MN (www.soylife.com)

In Japan, two large milling companies, Nisshin Flour Milling (www.nisshin.com) and Nippon Flour (www.nippon.co.jp) have played an important role over the last few decades in increasing the consumption of wheat in the Japanese diet. They also carry out a significant amount of research. In the UK, Rank Hovis and ADM Milling, Associated British Foods (www.abf.co.uk), Allied Bakeries and British bakeries are among the largest milling and baking companies, and they conduct some in-house research and technology development. Barilla in Italy (www.barilla.com) has a large cereal products research centre in Italy, while in Australia, Goodman Fielder (www.goodmanfielder.com.au), Weston Foods (www.westonmilling.com.au) and Penford starches (www.starchaust.com.au) have active technology development programs. Other companies within the oilseed crushing and animal feeds industry also have applied research programs.

**Baking Industry Associations**
Industry associations are also an important provider of research and technical services in the grains industry. In the UK, the Campden and Chorleywood Food Research Association, Chipping Campden, is a membership-based organisation that provides research and consultancy services for cereal processing companies (www.campden.co.uk). The RHM Technology centre in High Wycombe, Bucks, UK, is part of the RHM (Rank Hovis McDougall) group and apart from carrying out cereal (especially wheat) food science and technology analytical and food technology research for the group, the centre carries out research and development for other commercial and government clients. Leatherhead Food International (www.leatherheadfood.com) started as a UK food industry association, but has
evolved into an independent provider of food research and market information. In France, ARVALIS Institut du végétal, a farmers’ organisation, carries out research on grain to satisfy the demands of markets and consumers (www.arvalisinstitutduvegetal.fr). The American Institute of Baking, in Manhattan, KS, USA was founded by the North American baking industry to transfer the results of research to this industry in the US and internationally. Emphases include cereal science and baking technology, nutrition and food safety.

BRI Australia Ltd (formerly the Bread Research Institute) (www.bri.com.au) is an independent Australian organisation supported by industry membership fees and competitive Government and industry research grants. It carries out applied research in flour milling, baking and Asian foods. The Japan Institute of Baking Technology (www.jibt.com) in Tokyo has a similar role.

**Seed and Grain Biotechnology Companies**

In a large number of cases, these two sectors have merged over the last decade. A brief description of some of the largest multi-national companies is in Table 1. Many of the companies commenced as agrochemical suppliers, but the development of transgenic, herbicide-resistant grain crops meant that it was a logical approach to market the seed and agrochemical as a package. Several of the companies have an obvious leadership role in agrochemical development and in the development of transgenic crops, but the merger of many of the enterprises with seed companies (important so that the results of the development of the transgenics can link to delivery) also means that the companies has strength in breeding and agronomy. Most genetic engineering has been on maize, cotton, soybean and canola, and targeting herbicide resistance and insecticidal activity through incorporation of genes for *Bacillus thuringiensis* toxin. For example, Monsanto Company’s products (www.monsanto.com, St Louis, MO) include herbicide resistant soybeans, canola and corn and insect-protected corn. A wider range of traits and crops such as wheat, as well as output traits relating to processing quality is now being targeted. For example, Syngenta is currently developing a transgenic Fusarium head blight-resistant wheat. The companies also have broader genomics and gene discovery programs. Syngenta, Basel Switzerland through its Torrey Mesa research Institute in California, have published a rice genome analysis and made the information publicly available.

Research and development budgets of several of the companies run into several hundreds of millions of US dollars, comparable with government agricultural R&D budgets for some medium-sized developed countries.

**Brewing companies**

These form the second largest group of industry companies carrying out grains research. The largest brewing industry research organisation is BRI (Brewing Research International), in Nutfield, UK (www.brewingresearch.co.uk). They carry out research on behalf of member breweries world-wide on aspects of food safety, barley and malt quality, fermentation and beer quality. In addition, a number of the major brewery companies have significant in-house R&D activities, such as the giant US brewer, Anheuser-Busch, the European Brewer, Interbrew (www.interbrew.com), and Tepral (Strasbourg, France, www.tepral-fr.com) as well as smaller brewing companies worldwide. Applied research on barley and malt composition and quality is carried out.
Table 1. Major international life sciences and seed companies carrying out grain research

<table>
<thead>
<tr>
<th>Company/ Locations</th>
<th>Product/ Technology R&amp;D Emphasis</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monsanto Company</strong></td>
<td>agrochemicals, seeds, genomics</td>
<td><a href="http://www.monsanto.com">www.monsanto.com</a></td>
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<tr>
<td>St Louis, MO, USA</td>
<td></td>
<td></td>
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<tr>
<td><strong>Agracetus (part of Monsanto)</strong></td>
<td>crop plant transformation, therapeutic protein expression in plants <a href="http://www.agracetus.com">www.agracetus.com</a></td>
<td></td>
</tr>
<tr>
<td>Middletown, WI, USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pioneer Hi-Bred</strong></td>
<td>seeds, grain additives</td>
<td><a href="http://www.pioneer.com">www.pioneer.com</a></td>
</tr>
<tr>
<td>(a Du Pont Company)</td>
<td>- emphasis on crop management, precision farming</td>
<td></td>
</tr>
<tr>
<td>Des Moines, IA, USA</td>
<td>- grain seeds, especially hybrid maize (also millet, rice, sorghum, wheat)</td>
<td></td>
</tr>
<tr>
<td><strong>BASF</strong></td>
<td>crop protection products</td>
<td><a href="http://www.basf.de/en">www.basf.de/en</a>; <a href="http://www.basf.com">www.basf.com</a></td>
</tr>
<tr>
<td>Limburgerhof, Germany</td>
<td>transgenic crops with stress tolerance, high oil content and pathogen tolerance</td>
<td></td>
</tr>
<tr>
<td>Raleigh, NC, USA</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bayer Crop Science</strong></td>
<td>crop protection</td>
<td><a href="http://www.bayercropscience.com">www.bayercropscience.com</a></td>
</tr>
<tr>
<td>Akeno and Yuki, Japan</td>
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<td>Frankfurt, Germany</td>
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<tr>
<td>Kansas City, MO, USA</td>
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<tr>
<td>Lyon, France</td>
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<td></td>
</tr>
<tr>
<td><strong>Syngenta</strong></td>
<td>crop protection, seeds, crop genetics</td>
<td><a href="http://www.syngenta.com">www.syngenta.com</a></td>
</tr>
<tr>
<td>Basel and Stein, Switzerland</td>
<td>genomics, marker-assisted breeding</td>
<td></td>
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<tr>
<td>Jealott’s Hill, UK</td>
<td>BT corn, transgenic fungal disease resistance in wheat, glyphosate-tolerant soybeans</td>
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</tr>
<tr>
<td>Research Triangle Park, USA</td>
<td>transgenic maize with improved starch quality</td>
<td></td>
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<tr>
<td>Toulouse, France</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Products/Activities</td>
<td>Website</td>
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</tr>
<tr>
<td><strong>Dow Agrosciences</strong></td>
<td>Plant genetics and biotechnology; agrochemicals engineered canola with different oil composition; BT corn; maize hybrids, sorghum, soybeans, sunflowers</td>
<td><a href="http://www.dowagro.com">www.dowagro.com</a> <a href="http://www.mycogen.com">www.mycogen.com</a></td>
</tr>
<tr>
<td><strong>Groupe Limagrain (Biogenma)</strong></td>
<td>Cereal seeds; plant genome analysis; maize, wheat, rapeseed, sunflower, soybean, barley, peas baking technology</td>
<td><a href="http://www.limagrain.com">www.limagrain.com</a></td>
</tr>
</tbody>
</table>
The research activities of Carlsberg Brewers (www.carlsberg.com) spread much further than malting and brewing. Since the establishment of research laboratories in 1876, Carlsberg have made major contributions to fundamental chemistry and such as the development of the Kjeldahl protein analytical method. There are now three affiliated research centres located near the Carlsberg brewery site in Copenhagen, Denmark. The first, the Carlsberg Research Center, emphasises both basic and applied research on grain protein and carbohydrates and their reactions during brewing, and biochemical studies on amino acid transport, protein folding seed germination and yeast physiology. The second, Carlsberg Research Laboratory emphasises barley breeding, genetics, microbiology and plant biotechnology. Recently, a third laboratory, Carlsberg Biosektor has been established, covering a range of biotechnologies designed for commercialisation.

MAJOR TRENDS AMONG GRAINS RESEARCH ORGANISATIONS

Increased planning and collaboration
Over the last 10-20 years, much of the nature of management of grains research has changed from how it was organised and managed for most of the 20th century. There has been a greater degree of planning and an increased degree of focus in the programs of many research organisations. Much of the increased focus has been on market needs - it is hard to criticise the important influence this should have on breeding programs and grains chemistry and processing research. Greater linkages between research on grain production and marketing is important so that the research facilitates farmers producing for particular market specification, as opposed to research to underpin increased production of grain as a bulk commodity. A less ad hoc approach in the activities carried by Government research organisations has to an extent been forced on them by funding agencies - research centres have often moved from being provided with guaranteed government allocations to being dependent on competitive funding. Research planning exercises have been in favour in a number of commercial and government organisations across the globe. It is unclear to what extent individual creativity has been affected by these trends - certainly there may be less scope for curiosity-driven grains research.

An overarching trend has been the greater level of cooperation between research organisations; funding networks such as those established by the EC and Australian Government CRC system have facilitated this trend, as well as organisational changes in major government departments such as US Department of Agriculture. However, it is probably still true to state that US grain research appears less well coordinated at a national level - although locally, the close interactions between a number of USDA-ARS facilities and land grant Universities is very productive. The increased importance of networks in many areas of science is a response to the increased cost of carrying out research plus an increasing realisation that problems are multidimensional and are best addressed through multidisciplinary approaches. Certainly there has also been pressure from Governments and funding bodies for research providers to network more, in part to avoid duplication of research and also to ensure that particular sub-projects are carried out by the most qualified group.

In the developing world, development banks such as the World Bank and Asian Development Bank have funded reform programs that encourage rationalisation in the number of research providers as well as greater coordination. Scientist-to-scientist collaboration across institutional and national boundaries has been greatly facilitated by the communications revolution - the ability to email large amounts of data and draft manuscripts for immediate receipt has totally changed the possibilities for collaboration compared with only a decade ago. Globalisation in industry - both through development of alliances between
commercial research providers in different countries, and increased emphasis on grains breeding for export markets have also become more important forces. Markets are becoming more differentiated so there is an increased emphasis on grain quality - both as a target for breeding efforts, additional to yield and disease resistance - and on research aimed at improving the understanding of the genetic, chemical and structural factors underpinning grain quality - is apparent.

**Changes in research subject matter**

Grains agronomy programs have had to develop a stronger research emphasis on sustainability of production in recent years, responding to a shift in community values as well as serious scientific concerns about the long-term impact of some grain farming practices. Concerns about effects of irrigation, salinity, acidification (especially with certain legume crops), loss of soil and of soil structure have led to an increase in research on reduced tillage, water conservation and weed control, and maintenance of soil fertility. Indeed, the major factor underpinning sustainable agriculture has been the ability to feed the world’s increasing population through enhanced yields, and with the exception of a few communities, grains, especially cereals are the central element of almost diets. Over the last 50 years, there has not been a significant increase in the area of land available for agriculture, although it is true that with the expansion of irrigation systems and with new varieties and increased fertiliser use in the middle of the 20th century there was an expansion of grain growing areas. Over the last decade the expansion of irrigated areas has ceased and so production increases must come from increases in yield. Therefore the key contributor to sustainability in grains production will continue to be productivity increases are important for both developing and developed country farmers, as the terms of trade for farmers continue to become poorer. An even greater challenge to developing countries is how North American and European Governments shield their grain farmers from market realities through subsidies.

Livestock are becoming a very significant consumer of grains worldwide; the trend is especially noticeable in developing countries, where meat consumption has increased significantly since 1980 and 1990, from a low base. Many of these animals are now grain-fed, so research has had to underpin the increased importance of grains for feed rather than food applications. This research is also driven by increased intensification of monogastric animal production, including in developing countries. In many countries, farmers are not solely grain growers or cattle or sheep farmers, but manage a mixed enterprise. There has been a more active development of systems-based research to address their needs.

**Institutional trends**

Another major change in the nature of agricultural research in the last 2 decades, particularly in the US and Europe, has been the shift in balance of research to a greatly increased role of the private sector. In some parts of the world, such as Europe, there has been a long history of significant plant breeding efforts being carried out by industry, in others, such as Australia, with the exception of hybrid cereals, almost all plant breeding was formerly carried out by Government and Universities. Different countries also have different patterns of involvement of Universities in breeding, although in the process of training breeders some Universities have developed significant breeding programs or in other cases have been the mainstay of breeding efforts for a region or country. Several factors, some of which are interdependent, have given rise to greater commercial involvement in grains breeding, including increased importance of plant breeders’ rights, development and application of biotechnology in grain science, shrinkage of government support for agricultural research and the increased importance of intellectual property protection. In some cases privatisation of former public
sector plant breeding institutes has taken place, such as PBI in the UK (once Plant Breeding Institute, now Plant Breeding International).

The other industry that has become more involved in grains research are farmers themselves. Farmer-driven groups now often have a key role in identifying research priorities as well as being a vehicle for dissemination of research results - farmers groups directly manage on-farm adaptive research trials on technologies such as rotations, weed control and reduced tillage. Realising that both small and large farms are often diversified enterprises, grains research has a much greater emphasis on farming systems than in previous year. The influence of farmers is important in fitting grains research into a wider farming systems context. Organisations that use farmers' levies to fund research such as the Home-Grown Cereals Authority in the UK or the Australian Grains Research and Development Corporation (www.grdc.com.au) have also been instrumental in encouraging greater farmer involvement.

Most grains science is done within institutional structures which have evolved from a range of historical situations, rather than having been developed with a consideration of whether the institutional structures fit the needs of the 21 century. In many state or provincial-based Departments, there is a linkage of cereal breeding and cereal chemistry, and the scientists involved carry out a service function as well as independent research - often creating a tension between the time spent on the two, but with the advantage that the research objectives are informed by genuine industry problems. There are few broad grain science institutions in the world (i.e. those that cover all of cereals, legumes and oilseeds). Instead, there may be research clusters within University agronomy or agriculture faculties, or grains researchers within plant science or crops research organisations. It is more usual for post-harvest technology institutions or grain storage laboratories to address the breadth of cereal and other grains on the basis that storage and handling of grains as durable commodities has common research challenges. Some institutes cover several cereals, although usually with a focus on those relevant for their country or targeted group. For example wheat and barley are sometimes studied together. Some of the equipment and techniques are common, while other specialised - for example while Falling Number is used as a measure of postharvest sprouting for both wheat and barley, dough rheology testing is specific to wheat. Specialised University grain science departments are found in a small number of US Universities. Arguments for this model are the critical mass of researchers and ability of students to training in aspects from grains breeding to post-harvest technology, on the other hand, such Departments can lack linkages to discovery science and to a broader range of disciplines in agriculture and science.

One of the lessons of modern molecular biology is that techniques such as those in functional genomics are often readily transferable between grains, other crops, microorganisms and animals. The high degree of synteny tells us that gene structure and function is conserved across cereals, and many physiological and biochemical processes similar, meaning that it is often simple to move research between different grain crops. There are no definitive answers to the issue of an optimal institutional structure for grains research other than to assume that earlier structures need not necessarily fit more important than ever for breeders, agronomists, crop protection scientists and researchers of processing quality to interact.

Further reading