Chapter 3
Background to the bract browning problem

3.1 Introduction

3.1.1 Background to symptoms, timing and cause of bract browning

Bract browning of waratahs has been described as a 'major component in poor bloom quality' (Burnett and Nixon, 1990), however, symptoms of the disorder, the timing of its occurrence, details of susceptible cultivars and the proportion of the crop affected have not been investigated in detail. The symptoms of bract browning include a red-brown discolouration attributed to wind burn (Nixon, 1997), scorching (Burnett and Nixon, 1990) and necrosis (Dennis, 1991).

Reported triggers for bract browning include strong sunlight, particularly after early morning frost; water deficit stress; heat stress; high winds; and physical damage (Worrall, 1983 and 1994; Burnett and Nixon, 1990; Offord; 1996; Nixon, 1997). However, the effect of these environmental factors has not been quantified and the physiological cause of browning is unknown. The appearance, timing and severity of bract browning require further characterisation, with subsequent experimentation to assess the effects of particular environmental factors. In particular, the severity of the disorder needs to be quantified to objectively assess whether experimental treatments reduce bract browning.

3.1.2 Describing the severity of physiological browning disorders

In horticultural crops including cut flowers, the visual appearance of the end product such as waratah flowers, is paramount. Domestic and export consumers demand high quality cut flowers, particularly in Japanese and European markets where the industry is highly competitive (Wills *et al.*, 1998; B. Gollnow, personal communication). However, quality assessments are highly subjective (Wills *et al.*, 1998), therefore, more objective indicators of browning are recommended. Dennis (1991) used a simple scoring system to assess bract browning ("a disorder of unknown cause resulting in necrosis") in two new waratah cultivars. According to the scale of Dennis (1991), 1 = no damage, 3 = 25% of bract length affected and 5 = 50% of length affected. Scores and counts have also been used to assess the severity of browning disorders in other crops. For example, Wissemeier *et al.* (2000) measured poinsettia margins affected by bract necrosis with a ruler, and presented the data as affected bract margins (mm) per shoot, while Jenni (2001a) developed parameters to describe brown bead in broccoli including disease severity, based on the number of brown florets, and the proportion of crop affected.

The aim of this chapter is to provide a background to the bract browning disorder using (1) dissected waratah buds from eight commercial growers throughout NSW during 2001; and (2) market surveys, to determine the proportion of the crop affected by browning and provide further information on the symptoms and timing of bract browning. Anecdotal evidence from commercial waratah grower's experience of the bract browning disorder is presented in Appendix A1, sourced from NSW Waratah Industry Network surveys collated by the author.

3.2 Development of bract browning

3.2.1 Aim

The aim of this survey was to describe the severity and timing of bract browning in four affected cultivars, by collecting buds from eight commercial waratah growers on the North, Central and South Coast of NSW. Descriptions of bract types and maturity scales were also developed during the course of the experiment.

3.2.2 Method

Eight growers from the far North Coast to the South Coast of NSW (Table 3.1) sent three buds for dissection every month from March to harvest. Latitude and longitude for the location of each grower was sourced from the Australian Government Gazetteer website, using Town and Locality data (Geoscience Australia, 2004). Cultivars susceptible to bract browning were targeted for dissection based on the results of grower surveys (Appendix A1). Cultivars included 'Fire and Brimstone', 'Cardinal' and 'Wirrimbirra White', as well as 'Speciosissima No. 1' from one grower. Several growers of seedling waratahs also sent buds, but measurements are only presented for the same plant measured at different times, to remove genetic variation as a factor influencing development.

Table 3.1: Location and waratah cultivar details of commercial waratah growers in NSW who participated in bract browning development surveys in 2001.

Grow-er	Region	Town	Post-code	Latitude (dd mm)	Longitude (dd mm)	Cultivars
1	Central Coast	Mangrove Mountain	2250	33 17	151 11	Fire and Brimstone
2	Far North Coast	Ulmarra	2462	29 37	153 02	Fire and Brimstone
3	North Coast	Beechwood	2446	31 25	152 40	Fire and Brimstone Cardinal
4	North Coast	Wauchope	2446	31 27	152 44	Fire and Brimstone Cardinal
5	North Coast	Wauchope	2446	31 27	152 44	Fire and Brimstone Cardinal
6	Blue Mountains	Bilpin	2758	33 29	150 31	Speciosissima No.1
7	South Coast	Woollamia	2540	35 00	150 38	Wirrimbirra White
8	Blue Mountains	Bilpin	2758	33 29	150 31	Wirrimbirra White

Growers were asked to pick three buds of the same cultivar from the same area on their property each month. Buds were then packed in a padded Express Post bag and sent to the University of Sydney for dissection in the lab within one to two days of picking. On each bud, the diameter of the bud (or at maturity, the diameter of the bract circle) and flower head diameter were measured, a score assigned for the severity of bract browning. Initially, 0 = no browning, 1 = light bract browning, and 5 = very severe browning, bud ruined for future sale. The position of the browning was noted. From late May, a more quantitative scale was developed to describe bract browning (Figure 3.1).

Buds (Figure 3.2) were then dissected, with bracts removed in order from most to least exposed (Figure 3.3). Bracts were then placed on a flat surface and digital or film photographs were taken for one to three buds from each grower in each month. The number of exposed bracts (whole, part or tips exposed) and the number of bracts enclosed by outer bracts were recorded, and the number of bracts with browning in each of these categories was counted. The area of all exposed and all enclosed bracts was also measured using a Leaf Area Meter (Delta-T devices, Cambridge, UK) in March/April and July/August for some samples.

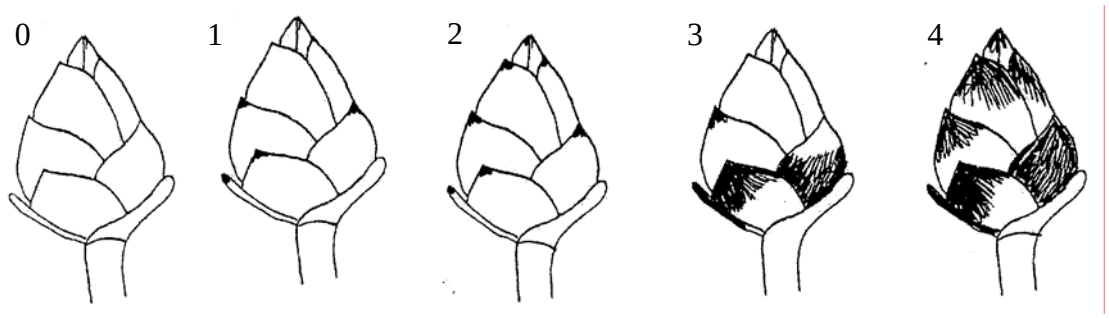

Figure 3.1: Scores for describing severity of bract browning in waratah buds. 0 indicates no browning on any bracts; 1 and 2 indicate up to 10% browning on up to half or more than half of the bracts, respectively; and 3 and 4 indicate more than 10% browning on up to half or more than half of the bracts, respectively.

Later in the season, bracts were classified as:

- Basal: scale-like or leaf-like, smaller than a 20c piece, often senescing towards flower maturity (Figure 3.4)
- Outer: mostly exposed, protecting the inner bracts (Figures 3.4 and 3.5)
- Inner: mostly enclosed until the bud begins to open (Figure 3.5)

The number of bracts exposed, and the number of those bracts with browning, was difficult to interpret towards flower maturity because previously enclosed bracts were exposed and some basal bracts had fallen off. Therefore, a retrospective assessment was made using digital and film photographs of the number of basal, outer and inner bracts, and the number in each category with browning. The number of bracts in each category (basal, outer and inner) was averaged between March and May, before senescence of basal bracts impacted on measurements (Table 3.2).

The stages of bud development were also described (after Khoo *et al.,* 1997) as tight bud (TB) (Figure 3.2 and 3.6a), juvenile open bud (JO) (Figure 3.6b) and mature flower (MF) (Figure 3.5 and 3.6c). Commercial flower maturity was judged to occur when the perianth on several florets had split and the anthers were exposed (stage c in Figure 3.7).

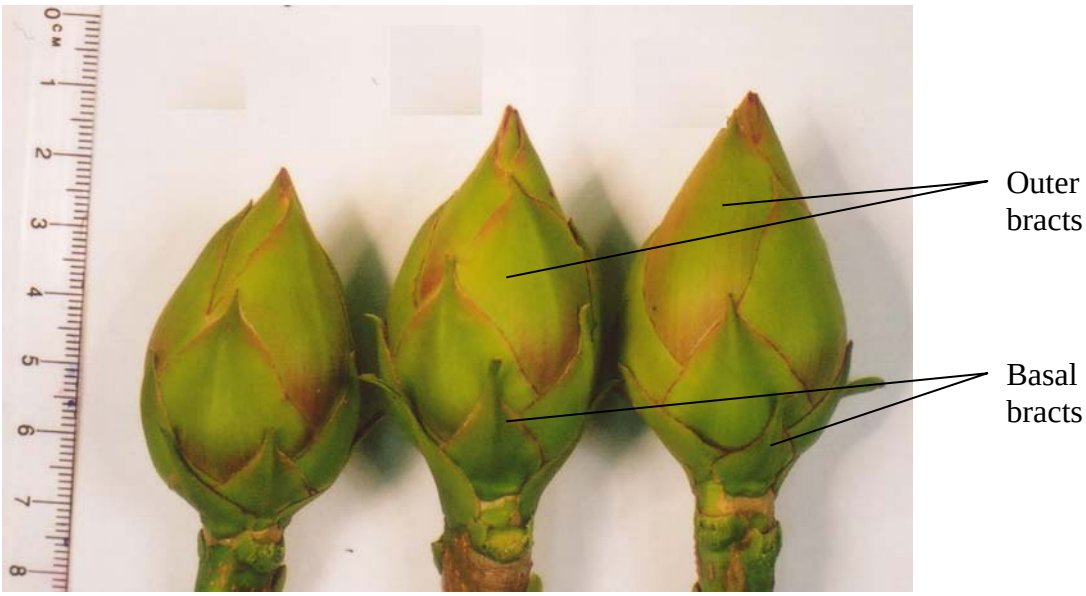

Figure 3.2: Tight bud (TB) stage of 'Fire and Brimstone' waratahs from grower 1 on Central Coast of NSW on 29th July 2001, showing basal and outer bracts.

Figure 3.3: Dissected tight bud (TB) stage of 'Fire and Brimstone' waratah bud 2 from grower 1 on the Central Coast of NSW on 29th July 2001. Bracts 1-7 are basal, bracts 8-18 are outer and bracts 18-39 are inner. Bract types are separated by vertical line.

Figure 3.4: Basal view of 'Fire and Brimstone' waratah at mature flower (MF) stage. Flower was from grower 1 on the Central Coast of NSW on 27th September 2001, showing senescing basal bracts and outer bracts.

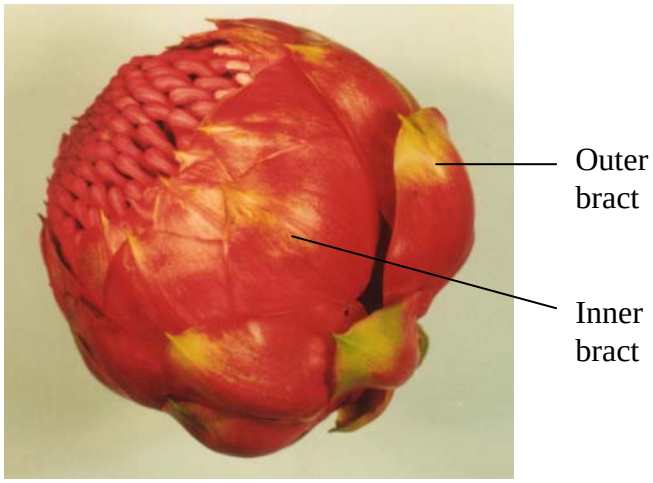

Figure 3.5: Lateral view of 'Fire and Brimstone' waratah at mature flower (MF) stage. Flower was from grower 1 on the Central Coast of NSW on 27th September 2001, showing inner and outer bracts.

Figure 3.6a-c: Tight bud (TB), juvenile open bud (JO), and mature flower (MF) stages of 'Wirrimbirra White' waratah inflorescences in full sun from grower 7 on the South Coast of NSW 2003.

a = bud
b = corolla split underside
c = perianth tips rolled back
d = flower open showing ovary
style
stigma
e = anthers in the perianth tips

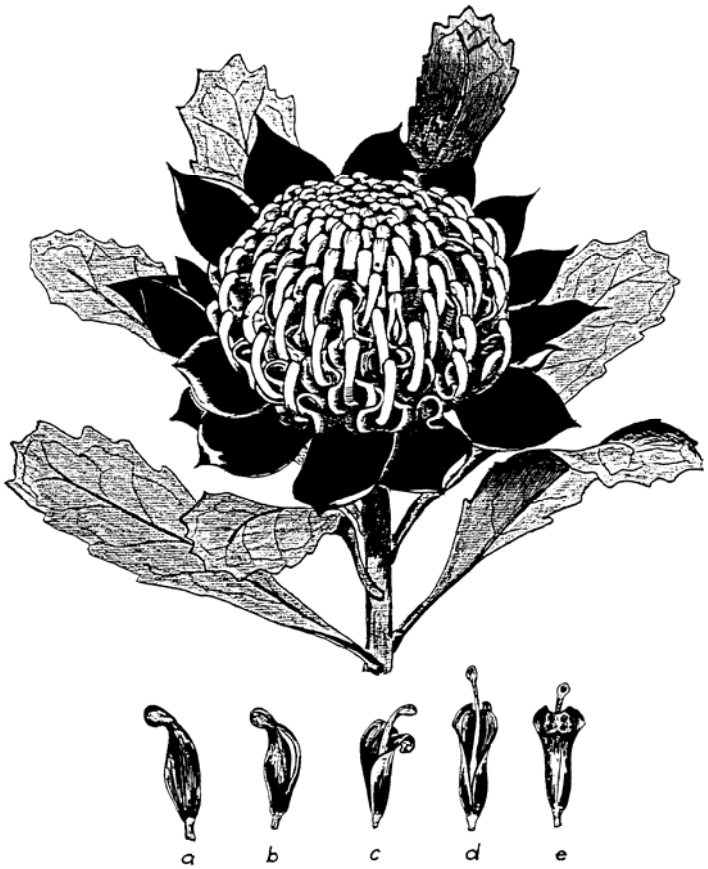

Figure 3.7: NSW Waratah (*Telopea speciosissima*) inflorescence, showing stages of flower opening (a-e) (Nixon, 1997).

3.2.3 Results

Results are presented for the cultivars ‘Cardinal’, ‘Fire and Brimstone’ and ‘Wirrimbirra White’ grown on several properties.

The waratah inflorescence expanded rapidly from August to October (Figure 3.8), coinciding with significant increases in the area of outer bracts (Figure 3.9). Expansion of inner bracts was not as rapid between March/April and July/August, with some bract areas decreasing due to measurement of smaller buds in July/August (Figure 3.10). However, observations from the same seedling waratah show that inner bracts expanded rapidly between August and October (average of 16 cm^2 to 227 cm^2, respectively).

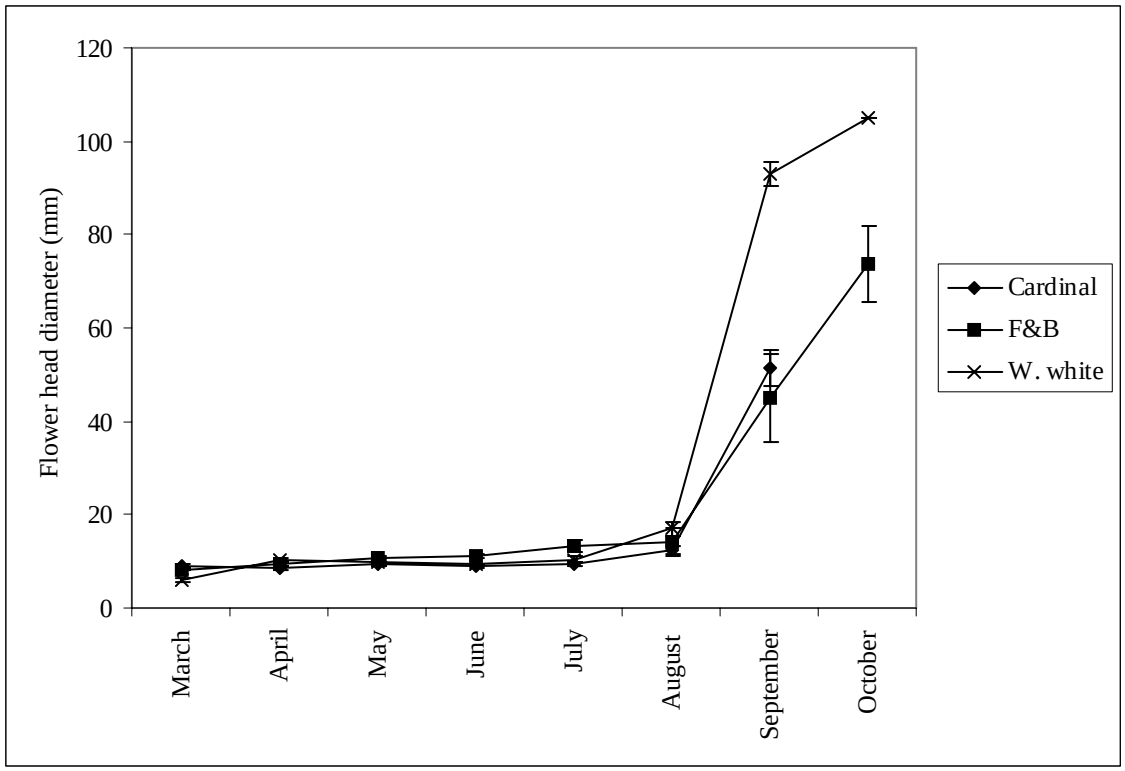

Figure 3.8: Mean waratah flower head diameter (± SE) from March-October in cultivars ‘Cardinal’, ‘Fire and Brimstone (F&B)’ and ‘Wirrimbirra White’. n = 3 buds from 2-3 growers for each cultivar in each month.

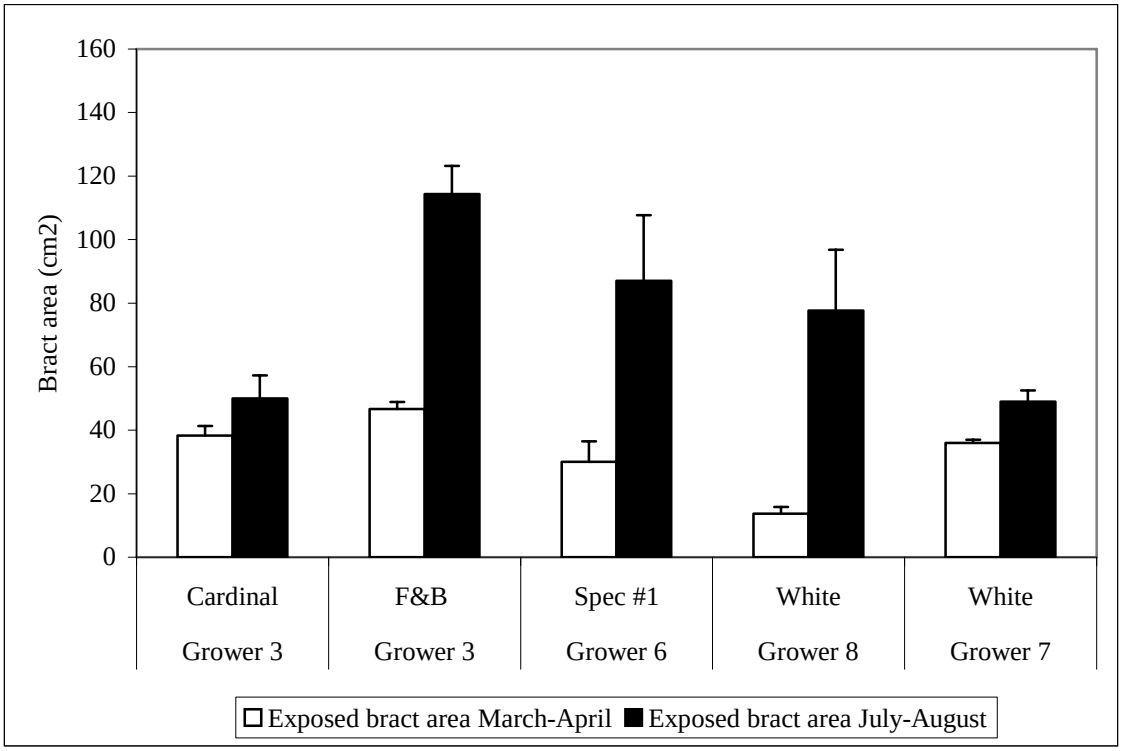

Figure 3.9: Mean total area (cm^2) of exposed bracts (+ SE) for 'Fire and Brimstone' (F&B), 'Cardinal', 'Speciosissima No.1' (Spec.#1) and 'Wirrimbirra White' (White) waratahs from different growers in March/April and July/August. n = 3 buds.

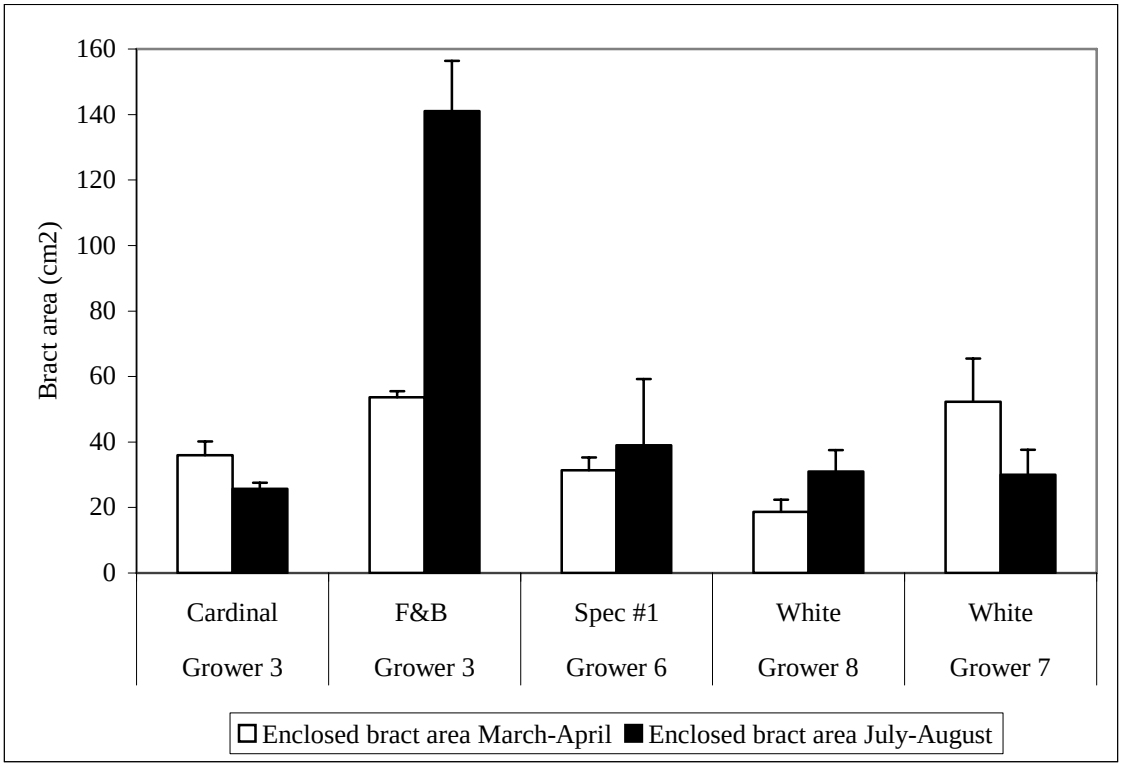

Figure 3.10: Mean total area (cm^2) of enclosed bracts (+ SE) for 'Fire and Brimstone', 'Cardinal', 'Speciosissima No.1' and 'Wirrimbirra White' (white) waratahs from different growers in March/April and July/August. n = 3 buds.

Retrospective assessments revealed that the number of outer bracts with more than 10% browning increased from March to October, with the most significant increases from August to October in 'Fire and Brimstone' and 'Wirrimbirra White' cultivars (Figure 3.11). The number of inner bracts with browning was initially very low (between 0 - 1 bracts affected), although this increased significantly between August and October (Figure 3.12). The retrospective assessments of browning corroborate the initial scores given to whole buds (Figure 3.13). Scores were initially very low, from 0 - 1 in March, and remained relatively low with an average of 2 or less up to June, indicating less than 10% browning. Browning then increased, to affect more than 10% of bracts, with scores of 3 - 4 at flower maturity (Figure 3.13). A decrease in browning, for example, on 'Speciosissima No. 1' buds from July to August, may occur because bracts senesce after browning. It may also occur because the three buds sampled at each date do not adequately represent the total population of flowers. Therefore, buds sampled at each time may have more or less browning than the average bud in that population.

Table 3.2: Mean, minimum and maximum number of basal, outer and inner bracts for inflorescences of 'Cardinal', 'Fire and Brimstone', 'Speciosissima No.1' and 'Wirrimbirra White' waratah cultivars from commercial growers between March and May 2001. n = 3 buds from 1-3 growers of each cultivar in each month, except for 'Speciosissima No.1' (not measured in April).

	Number of basal bracts			Number of outer bracts			Number of inner bracts		
Cultivar	Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.
Cardinal	7	5	9	7	5	7	17	14	20
Fire and Brimstone	7	4	11	7	5	9	27	19	36
Speciosissima No.1	5	4	6	7	6	8	13	12	15
Wirrimbirra White	6	5	7	5	4	6	16	12	19

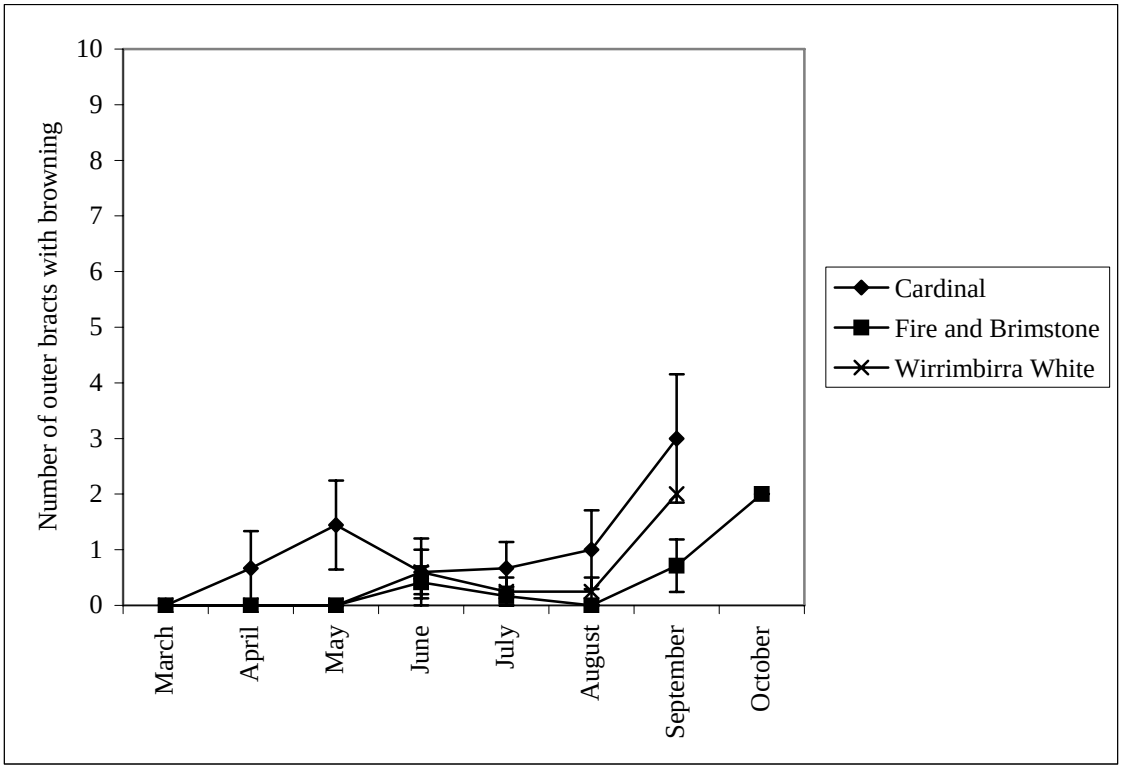

Figure 3.11: Mean number of outer bracts with >10% browning (± SE) from March to October in 'Cardinal', 'Fire and Brimstone' and 'Wirrimbirra White' waratah cultivars. n =3 buds from each of 2-3 growers in each month.

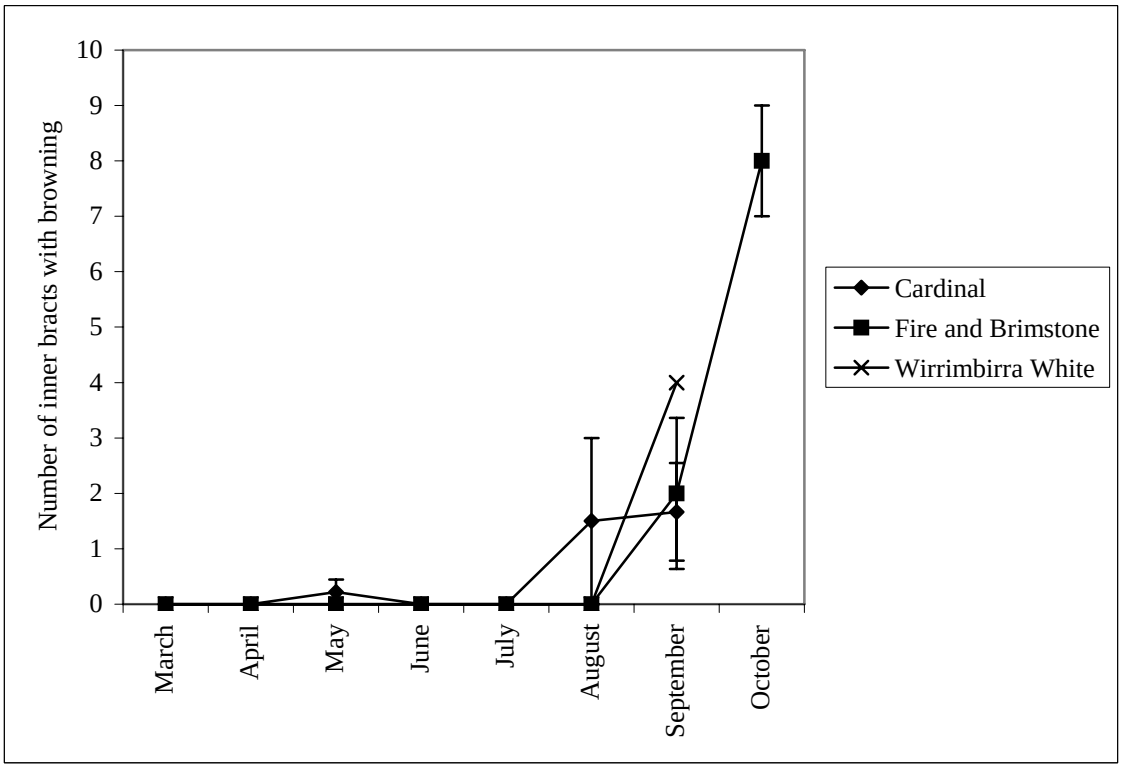

Figure 3.12: Mean number of inner bracts with >10% browning (± SE) from March to October in 'Cardinal', 'Fire and Brimstone' and 'Wirrimbirra White' waratah cultivars. n =3 buds from each of 2-3 growers in each month.

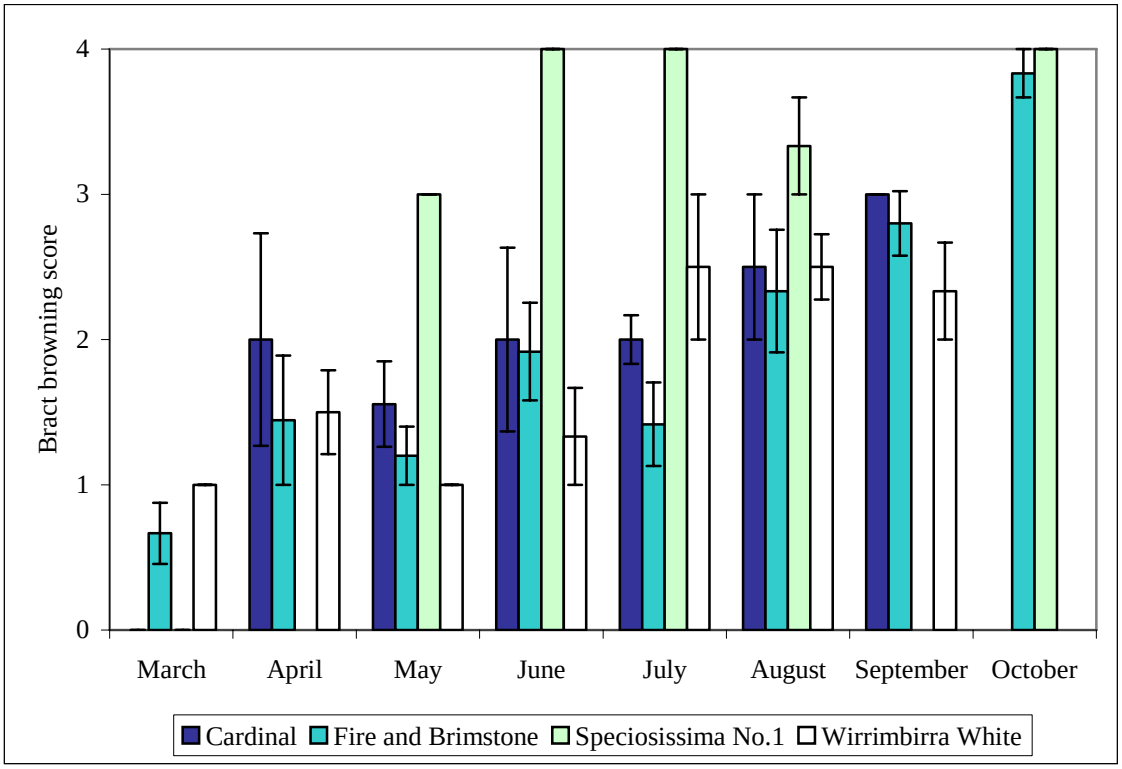

Figure 3.13: Mean score for severity of bract browning (± SE) for 'Cardinal', 'Fire and Brimstone', 'Speciosissima No.1' and 'Wirrimbirra White' waratah buds from March to October 2001. From March-May, score of 0 = no burn, 1 = light bract burn, 5 = very severe burn, bud ruined for future sale. From late May, a more quantitative scale was introduced with 0 indicating no burn on any bracts; 1 and 2 indicating up to 10% burn on up to half or more than half of the bracts, respectively; and 3 and 4 indicating more than 10% burn on up to half or more than half of the bracts, respectively. n = 3 buds from each of 2-3 growers in each month, except for 'Speciosissima No.1' grown on one site only.

Browning tended to occur primarily on bract tips (Figure 3.6c), accounting for 75% of observations, and to a lesser extent on other bract margins (10%) or in patches (10%). Browning of whole bracts generally affected senescing basal and outer bracts towards flower maturity, accounting for 25% of observations (Figure 3.4). Browning could occur in more than one region, so total occurrences of browning of tips, margins, patches and whole bracts were greater than 100%. On some bracts, v-shaped exposed areas were differently pigmented compared to enclosed areas (Figure 3.14a). These exposed areas seemed particularly vulnerable to browning and necrosis, while adjacent areas covered by outer bracts showed no evidence of browning (Fig. 3.14b and c). Several growers noted that browning was more prevalent on the N or NE side of the bud

(F. Allatt and J. Anderson, personal communication), although this effect may be site-specific.

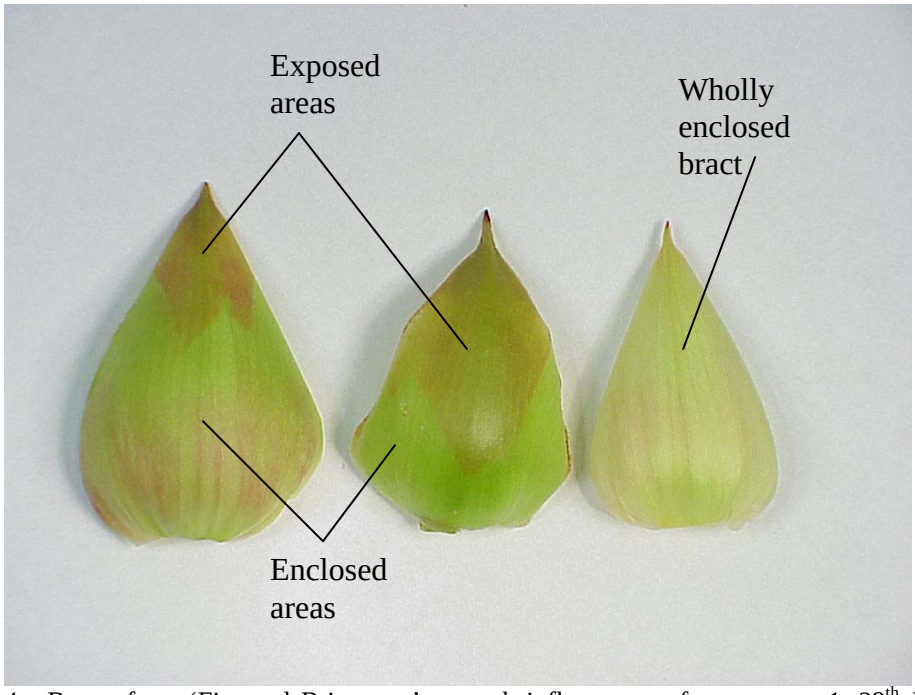

Figure 3.14a: Bracts from 'Fire and Brimstone' waratah inflorescence from grower 1, 29th July 2001, showing different pigmentation of exposed and enclosed areas on bracts.

Figure 3.14b: Waratah from Sydney Flower Markets in 2001, showing distinct margin between exposed and enclosed areas on bracts.

Figure 3.14c: Waratah from Sydney Flower Markets in 2001, showing browning and necrosis of exposed areas on bracts.

Pest and disease problems also resulted in bract browning, and the causal agent was generally readily identified. Pests included bud borer (*Xylorycta luteotactella*) caterpillars (Figure 3.15a-c) and mealy bug (Figure 3.16), while diseases resulted in decaying flower heads.

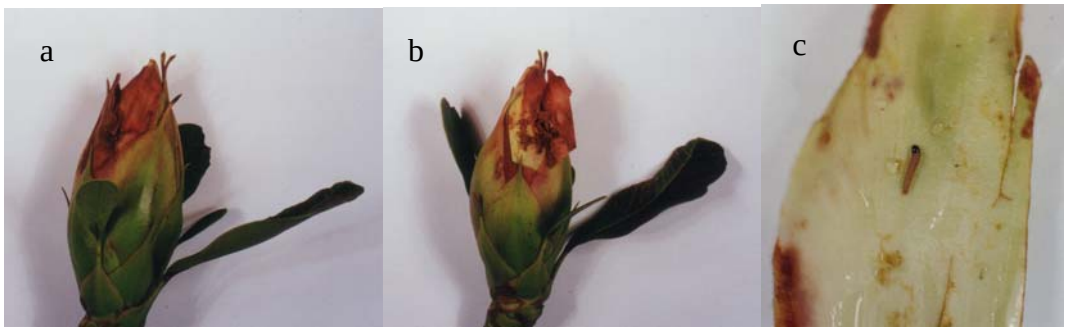

Figure 3.15a-c: Waratah bud from Mount Annan with 'borer' (Macadamia twig girdler, *Xylorycta luteotactella*) in July 2002.

Figure 3.16: Waratah bud at Mount Annan with mealy bug (July 2002).

3.3 Market surveys

3.3.1 Aim

The aim of this survey was to estimate the proportion of crop for sale that was affected by browning in 2001, by assessing the proportion of waratah flowers with browning at the Sydney Flower Markets.

3.3.2 Method

Bract browning incidence was assessed at the Sydney Flowers Markets at Flemington over three consecutive Fridays in October 2001, that is, during the peak waratah season. At the market, waratahs from various growers and locations were displayed for sale in buckets. At each stand selling waratahs, the number of waratah flowers per bucket, and the number of those flowers with more than 10% browning on any bracts was counted. The average percentage of flowers affected was calculated for fifty nine buckets of red and twelve buckets of white waratahs, giving a total of 817 and 130 flowers of each colour, respectively. The effect of browning on the market price of waratahs was also discussed with agents at the markets.

3.3.3 Results

Proportion of waratahs for sale with bract browning

Browning affected 62% of red waratahs and 68% of white waratahs for sale at the Sydney markets over three weeks. Many flowers had significantly more than 10% browning.

These results are indicative of waratahs for sale on the market floor at 5am, and do not include waratahs pre-ordered or exported, which are likely to be higher quality (C.

Scott, personal communication) or waratahs not harvested due to browning or other faults, which are likely to be lower quality (B. Gollnow, personal communication).

Effect of bract browning on waratah prices

Waratah grower, wholesaler and exporter Craig Scott reported in 2001 that waratahs without browning could be sold for $4.50 to $5.00 per stem, while those with moderate bract burn, affecting 25% of bracts, sold for $3.50 and those with severe bract burn for $2.50 per stem. 'Fire and Brimstone' waratahs grown in a commercial plantation under shade cloth in 2003 had no browning and were sold for $7.00 - $9.00 per stem (C. Scott, personal communication). In the Sydney Flower Markets however, many agents were more concerned with stem length than bract browning, with long stems sold for $3.50 - $5.00 each in 2001.

3.4 Discussion

3.4.1 Bract browning of waratahs in the cut - flower market

The extensive planting of waratahs in the five years prior to 2003 (Gollnow *et al.,* 2003), and the high incidence of browning in the markets (section 3.3) indicate that the cost of lost production due bract browning is likely to increase in the future. Bract browning has been tolerated in the market in the past, as most waratah blooms were affected (Burnett and Nixon, 1990). This high incidence of browning may be a reflection of the greater number of waratahs harvested from natural populations under license prior to widespread cultivation of waratahs.

As selection and cultivation of waratahs continues, there is a need to identify cultivars resistant to bract browning. Although new cultivars may have excellent size, shape or

colour, the high incidence of browning in some cultivars (Appendix A1) may limit their acceptance by growers and consumers. While the local market continues to accept bract browning to some extent, this may be due to the "patriotic fervour" associated with the waratah as the NSW floral emblem (Gollnow *et al.,* 2003). Bract browning is not likely to be tolerated in international markets, where products need to be free of blemishes (Gollnow *et al.,* 2003).

3.4.2 Potential causes of bract browning

Waratah crop management practices are highly variable, particularly in terms of the protection and light environment provided within a plantation (Appendix A1). This reflects the relatively short history of waratah cultivation and research, as well as the fact that many growers are new to horticulture and refine their crop management through experience over time (B. Gollnow, personal communication). However, surveys of commercial waratah growers (Appendix A1) suggest common causes for the bract browning disorder. These causes corroborate reports in the literature and include exposure to strong sunlight, high temperatures and wind.

Dissection of waratah buds (section 3.2) confirms growers' observations that browning generally occurs in the six to eight weeks prior to harvest (Appendix A1), coinciding with rapid flower and bract expansion. The position and timing of browning suggest light damage (photoinhibition) or localised calcium deficiency may cause bract browning in waratahs.

Within a flower head, bract browning was generally observed in exposed tissues, rather than enclosed tissues protected by outer bracts (section 3.2). These results suggest that

exposure to light may increase bract browning, and protection from high light intensities may reduce bract browning. Light damage resulting in photoinhibition and browning causes problems in other crops, such as blackleaf of grapevine leaves (Lang *et al.,* 1998) and bleaching and necrosis of floral tissue of *Dendrobium* orchids (He *et al.,* 1998). The increased browning on the north or northeast side of the waratah bud parallels the increased risk of photoinhibition observed in the northern hemisphere on south facing leaves of *Heteromeles arbutifolia* (Valladares and Pearcy, 1999).

However, the rapid growth of waratah bracts and the location of bract browning, primarily in bract tips, also suggest a localised calcium deficiency. Other disorders attributed to localised calcium deficiency include tipburn in lettuce, which tends to occur on the most rapidly expanding leaf parts (Collier and Huntington, 1983) and poinsettia bract necrosis, which occurs on bract margins (McAvoy and Bible, 1996).

The role of localised calcium deficiency as a potential cause of bract browning is investigated in chapter 4, and the role of the light environment in bract browning development is examined from chapter 5 onwards.