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Boron toxicity in barley 1986 1987

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EXPERIMENTAL RESULTS

1986/87

BORON TOXICITY IN BARLEY

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CONTENTS

1. Boron Toxicity in cereals - 85 GL 3/4864 EX

Aim: To examine the inter and intraspecific variation in cereals to boron toxicity.

Location: Glasshouse, University of W.A.

Treatments: Cereals: barley varieties - Stirling
- Shannon
- cv. 3456
- cv. 1750

wheat varieties - Halberd
- Eradu

oat varieties - Mortlock

Boron: 6 levels - 0, 1, 2, 4, 8, 16 ppm B added to 3.5 kg pots of a Lancelin brown sand.

Results: sown: August 4
harvested: September 18

Table 1. Effect of adding boron to the soil on the growth stage, the dry weights of whole shoots, and on the degree of symptoms of boron toxicity in individual leaves of seven cereal varieties

Cereal	Variety	Boron added (ppm)	Zadoks growth stage	Dry weights of whole shoots (g/pot)	*Rating of leaf injury YEB	YEB +1	YEB +2	YEB +3	YEB +4
Barley	Stirling	0	18/23	10.64	1	3	3	3	3
		1	17.5/23	10.66	2	4	5	5	6
		2	17.5/22	9.20	3	4	6	6	7
		4	17/22	8.42	3	5	6	8	9
		8	17/22	7.10	3	5	7	8	10
		16	17/21	4.14	3	5	7	9	10
	Shannon	0	16.5/22	9.96	1	2	2	2	2
		1	16.5/22	9.38	3	4	4	4	4
		2	16.522	9.02	3	5	6	6	7
		4	16.5/21	8.40	3	6	7	8	9
		8	16.5/21	7.56	3	6	8	9	9
		16	16/21	4.94	3	6	8	9	10
	cv. 3456	0	17.5/23	10.57	2	3	3	3	3
		1	17.5/23	9.74	3	5	6	6	6
		2	17.5/22	9.24	4	6	8	8	9
		4	17/22	8.94	4	7	9	10	10
		8	17/22	7.84	5	7	9	10	10
		16	16.5/21	5.04	4	7	9	10	10

Table 1 continued...

Cereal	Variety	Boron added (ppm)	Zadoks growth stage	Dry weights of whole shoots (g/pot)	*Rating of leaf injury YEB	YEB +1	YEB +2	YEB +3	YEB +4
	cv. 1750	0	18/22	13.22	1	2	2	3	3
		1	18/22	13.52	1	2	3	4	4
		2	17.5/22	13.22	2	2	3	5	5
		4	18/22	13.85	2	3	4	6	6
		8	17.5/22	12.83	2	2	5	6	6
		16	17.5/21	8.60	2	2	5	7	7
Wheat	Halberd	0	18/22	13.39	1	1	1	1	4
		1	18/21	13.61	1	1	2	3	4
		2	18/21	12.62	1	2	3	4	4
		4	18/21	11.93	1	2	3	4	4
		8	17.5/21	10.39	2	3	4	4	5
		16	17/21	6.93	2	4	4	5	5
	Eradu	0	17.5/23	11.47	1	1	1	4	5
		1	17.5/23	11.39	1	2	4	5	6
		2	17.5/23	10.67	1	3	4	5	7
		4	17/22	7.71	2	4	6	8	9
		8	16.5/21	4.79	3	4	7	8	10
		16	16.5/20	2.24	3	5	8	10	10
Oats	Mortlock	0	18/25	11.79	1	1	1	1	2
		1	17.5/24	11.46	1	2	2	3	4
		2	17.5/24	11.68	1	2	3	4	5
		4	17/23	11.24	2	3	4	6	6
		8	17/22	9.19	2	4	5	6	7
		16	17/21	5.52	2	3	5	7	9

* Barley varieties - Appendix A
Wheat and oat varieties - Appendix B

Table 2. The [1]estimated critical concentrations of boron added to pots of soil that are toxic (90% of maximum dry weights of whole shoots) to the growth of seven cereal varieties, and the related critical ratings of leaf injury

Cereal	Variety	Critical toxic concentration of added boron (ppm)	[2]Rating of leaf injury on the primary tiller YEB	YEB +1	YEB +2	YEB +3
Barley	Stirling	1.2	2	4	5	6
	Shannon	2.0	3	5	6	6
	cv. 3456	1.4	3	6	7	8
	cv. 1750	9.0	2	2	5	6
Wheat	Halberd	3.2	1	2	3	4
	Eradu	2.2	1	3	5	6
Oats	Mortlock	5.0	2	4	5	6

1 From hand-drawn curves
2 Barley varieties - Appendix A
Wheat and oat varieties - Appendix B

Discussion of results

The tolerance of higher plants to elemental toxicities has been traditionally grouped into two classes; internal tolerance mechanisms where elements enter the symplasm but are subsequently rendered harmless; and exclusion mechanisms where tolerance is based on the plants ability to prevent entry of elements into the symplasm. In the field, variation in tolerance to boron toxicity will also be complicated by varietal differences in rooting habit and water use. It was therefore found necessary to return to the glasshouse to examine the intra- and interspecific variation in barley and other cereals to boron toxicity, and to attempt to identify any tolerance mechanisms observed. As chemical analyses of plant tissues are yet to be completed, only the first objective is currently attained.

Table 2 indicates that both intra- and interspecific variation exists in the tolerance of these cereal varieties to boron toxicity. As assessed by the estimated critical concentrations of boron added to the soil, a relative ranking of tolerance (from least to most) to boron toxicity for these seven varieties is: Stirling barley, cv. 3456 barley, Shannon barley, Eradu wheat, Halberd wheat, Mortlock oats, and cv. 1750 barley.

Traditionally, it has been thought that in tolerance to boron toxicity, barley was least tolerant, oats was most tolerant, and wheat was intermediate (Gupta, 1971). The results obtained here, however, indicate that intraspecific variation may be as large as interspecific variation in cereals in tolerance to boron toxicity. For example, the wheat variety Eradu appears to be as sensitive to boron toxicity as the barley variety Shannon, while the barley variety cv. 1750 is the most tolerant of the seven cereal varieties. This variety cv. 1750 was supplied by Dr R. Boyd from his collection of genetic material at the University of Western Australia's field station at Shenton Park. Credit is due to Dr Boyd for his selection of this variety from preliminary screenings for tolerance to boron toxicity in the sand culture tanks with controlled nutrient flow at Shenton Park. It is tempting to suggest, without evidence, that the high tolerance of this variety cv. 1750 is due to its Californian origin where high soil levels of boron are commonplace and natural selection resulted. Results of chemical analyses will indicate the mechanism for tolerance in this variety. Regardless of the mechanism, however, it is evident from the results obtained with the variety cv. 1750 that suitable genetic material exists for plant breeders to develop varieties of barley that will grow without the effects of boron toxicity on those soils with naturally high levels of boron in Western Australia.

The symptoms of dark necrotic spots and lesions that are associated with boron toxicity on the leaves of barley were not evident on the varieties of wheat and oats examined. Wheat and oats did display the symptom of "dirty white necrosis" that affected larger amounts of the leaf area from the tip and margins towards the leaf base as increasing additions of boron were made to the soil. As in barley, the symptoms of boron toxicity displayed by the varieties of wheat and oats were more marked on the older leaves.

Within the groups of cereals, the relationship between amount of leaf injury and reductions in plant growth were not consistent between varieties. Generally, those varieties more tolerant of boron toxicity (cv. 1750 barley, and Halberd wheat) had lower critical ratings of injury to the four youngest emerged blades on their primary tillers than those varieties less tolerant to boron toxicity (cv. 3456 barley, and Eradu wheat respectively).

Intraspecific Variation in Barley to Boron Toxicity - 86 SG 22 & 86 SG 31 /4864 EX

Aim: To investigate the intraspecific variation to boron toxicity in a range of commercial barley varieties.

Method: The varieties of barley were grown on a soil with naturally high levels of boron and were sampled during growth for ratings of leaf injury due to boron and analysed for boron concentrations within tissues. In order to make an assessment of the effects of boron toxicity on plant growth and grain yield, the trial was replicated at a near-by site on a soil with low (non-toxic) levels of boron. This endeavoured to provide a "standard yield reference" of these varieties of barley grown in this area under this season's conditions to which the relative yields of the barley grown with toxic levels of boron could be compared.

Location:

1. Salmon Gums Research Station (86 SG 22)
2. Graham's lease block - Salmon Gums (86 SG 31)

Soils:

1. Kumarl soil: a grey-brown calcareous earth with naturally high levels of boron.
2. Circle Valley sand: a grey sand with low levels of boron over a grey-brown clay.

Results:

86 SG 22: sown - May 29
- barley 48 kg/ha
- superphosphate 112 kg/ha

harvested - November 18

86 SG 31: sown - May 30
- barley 48 kg/ha
- Agras No. 1 108 kg/ha

harvested - November 18

Table 3. A comparison of grain yields of a range of barley varieties grown on soils low (Circle Valley sand) and moderately high (Kumarl clay) in boron

Barley variety	Circle Valley sand grain yield (t/ha)	(% av)	Kumarl clay grain yield (t/ha)	(% av)	Δ (%)
Beecher	1.41	88	3.53	98	+10
Clipper	1.57	98	3.41	95	-3
Dampier	1.48	92	3.35	93	+1
Forrest	1.41	88	3.07	86	-2
Grimmett	1.57	98	3.47	97	-1
O'Connor	2.03	126	4.00	111	-15
Schooner	1.52	95	3.38	94	-1
Shannon	1.12	70	3.10	86	+16
Stirling	1.64	102	3.39	94	-8
Triumph	1.63	102	3.66	102	0
WI 2584	1.78	111	4.16	116	+5
286	1.62	101	4.02	112	+11
311	1.68	105	3.68	102	-3
313	1.83	114	3.61	101	-13
323	1.59	99	3.91	109	+10
329	1.81	113	3.70	103	-10

Table 4. Ratings of symptoms of boron toxicity on a range of barley varieties grown at Salmon Gums

Soil type	Barley variety	Cartwright field ratings	Laboratory ratings of leaf injury on the primary tiller: Zadoks stage	YEB	YEB +1	YEB +2	YEB +3
Kumarl	Beecher	1	61	2	2	2	2
	Clipper	2	55	2	3	3	3
	Dampier	1	59	2	2	3	2
	Forrest	1-2	59	2	3	3	3
	Grimmett	2	55	2	3	3	3
	O'Connor	1-2	57	2	2	3	3
	Schooner	1-2	53	2	2	3	3
	Shannon	1-2	43	2	2	2	3
	Stirling	3	59	3	5	6	5
	Triumph	1-2	55	2	2	3	3
	WI2584	1-2	53	2	2	3	3
	286	1-2	61	2	3	2	2
	311	2-3	51	2	2	3	4
	313	2-3	52	2	3	4	4
	323	2	58	2	3	3	3
	329	1-2	59	2	2	3	3
Circle Valley	Stirling	2	59	2	2	3	3
	311	1-2	47	2	2	2	2

Sampled September 24

Results indicate

1. The degree of boron toxicity that occurred in the varieties of barley grown on this Kumarl soil was not as marked as intended. The ratings of symptoms of leaf injury were low on most varieties, making differentation between varieties in tolerance to boron toxicity difficult.

2. The variety Stirling continued to show its susceptibility to boron toxicity by displaying the highest (yet still moderate) ratings of leaf injury. The varieties 311 and 313 displayed the next highest ratings of leaf injury.

3. The relative grain yields of these three "susceptible" varieties decreased when grown on the soil with moderately high levels of boron (Kumarl). However, the relative grain yields of O'Connor and 329 (varieties with low ratings of leaf injury), were also decreased.

4. The relative grain yields of the varieties Beecher, Shannon, WI 2584, 286 and 323 increased when grown on the soil with moderately high levels of boron (Kumarl). These varieties had low ratings of leaf injury.

5. The highest yielding variety on the Circle Valley sand was O'Connor, while WI 2584, 286 and O'Connor yielded the best on the Kumarl clay. The variety WI 2584 is rated high yielding and tolerant to boron toxicity in South Australia.

Intraspecific Variation in Barley to Boron Toxicity - 86 SG 26/EDO 14-KY

This is a trial established by Kevin Young (Esperance) to study the phenological development, and its effect on yield, of a range of barley cultivars at four times of planting. Located on a heavy Kumarl soil at the Salmon Gums Research Station, symptoms of boron toxicity became markedly evident. The primary tillers of the barley varieties were consequently sampled (September 24), and rated for symptoms of boron toxicity in the laboratory.

Table 5. Ratings of symptoms of boron toxicity on the leaves from the primary tillers of a range of barley varieties grown on a soil with high levels of boron

Barley variety	Planting date	Zadoks stage	YEB	YEB +1	YEB +2	YEB +3
Stirling	27/5	32	1	3	5	6
	12/6	51	2	4	6	7
	23/6	55	3	5	6	7
	7/7	61	7	7	8	9
313	23/6	43	2	4	6	7
323	23/6	55	2	4	5	4
395	23/6	41	1	3	4	4
WI 2584	23/6	47	1	2	4	5
Short Wocus	23/6	35	1	3	3	3
Ketch	23/6	59	4	5	7	7
Triumph	23/6	45	1	3	5	6
F8H	23/6	31	2	4	5	5
HB 885/Grampercorn	23/6	33	2	4	5	5

Results indicate

1. Symptoms of boron toxicity were evident on all of these barley varieties with diverse genetic lines.

2. Stirling, together with Ketch (a commercial South Australian variety) appeared the least tolerant of the varieties to leaf injury from boron toxicity.

3. Short Wocus, an American 6-row variety, appeared the most tolerant.

4. The variety 323, a possible replacement for Stirling in Western Australia had lower ratings of leaf injury than Stirling.

5. The South Australian variety WI 2584 is rated as high yielding and tolerant to boron toxicity in that state. On this heavy Kumarl soil, its ratings of leaf injury were lower than most other varieties, but still marked.

6. Grown under the same conditions of soil boron supply, the ratings of leaf injury from boron toxicity increased as the variety Stirling developed.

Intraspecific Variation in Wheat to Boron Toxicity - 86 SG 24 & 86 SG 32 /4864 EX

Aim: To investigate the intraspecific variation to boron toxicity in a range of commercial wheat varieties.

Method: As with the investigation of barley, (86 SG 22 & 86 SG 31) these varieties of wheat were grown on a soil with naturally high levels of boron, with the trial replicated at a near-by site on a soil with low (non-toxic) levels of boron. This second trial endeavoured to provide a "standard yield reference" to the varieties of wheat grown in this area under this season's conditions to which the relative yields of the wheat grown with toxic levels of boron could be compared.

Location:

1. 86 SG 24 was adjacent to 86 SG 22 on the Salmon Gums Research Station.
2. 86 SG 32 was adjacent to 86 SG 31 on Graham's leaves block at Salmon Gums.

Soils:

1. Kumarl soil: a grey-brown calcareous earth with naturally high levels of boron.
2. Circle Valley sand: a grey sand with low levels of boron over a grey-brown clay.

Results:

86 SG 24: sown - May 29th
- wheat 48 kg/ha
- superphosphate 112 kg/ha

harvested - November 28

86 SG 32: sown - May 30
- wheat 48 kg/ha
- Agras No. 1 108 kg/ha

harvested - December 9

Table 6. A comparison of grain yields of a range of wheat varieties grown on soils low (Circle Valley sand) and moderately high (Kumarl clay) in boron

Wheat variety	Circle valley sand grain yield		Kumarl clay grain yield		Δ (%)
	(t/ha)	(% av.)	(t/ha)	(% av/)	
Aroona	1.33	119	3.78	106	-13
Cranbrook	1.13	101	3.79	106	+5
Eradu	1.16	104	3.67	102	-2
Gutha	1.13	101	3.34	93	-8
Halberd	1.09	97	3.64	102	+5
Kulin	1.03	92	3.62	101	+9
Millewa	1.16	104	3.72	104	0
Spear	1.04	93	3.86	108	+15
Warigal	0.95	85	3.25	91	+6
Wialki	1.09	97	3.21	90	-7
562	1.20	107	3.53	98	-9

Table 7. *Ratings of necrosis and chlorosis of leaves from the primary tillers of a range of wheat varieties grown at Salmon Gums

Soil type	Wheat variety	Zadoks growth stage	YEB	YEB +1	YEB +2	YEB +3
Kumarl	Aroona	61	2	3	4	7
	Cranbrook	57	2	3	4	6
	Eradu	6-	2	3	4	7
	Gutha	6-	2	3	5	9
	Halberd	53	2	2	5	8
	Kulin	6-	2	2	4	7
	Millewa	54	2	3	4	6
	Spear	53	2	2	3	6
	Warigal	51	2	2	3	5
	Wialki	61	2	2	4	8
	562	59	2	3	4	8
Circle Valley	Eradu	6-	2	4	5	7
	Halberd	47	2	3	5	8

Sampled September 24 and rated in the laboratory.
* see Appendix B

Table 8. Concentrations of boron on the Youngest Emerged Blades of a range of wheat varieties grown on a soil with moderately high levels of boron (Kumarl clay)

Variety of wheat	Concentration of boron in YEB T1	T2
Aroona	12	24
Cranbrook	12	35
Eradu	12	46
Gutha	15	50
Halberd	8	20
Kulin	11	35
Millewa	11	25
Spear	9	13
Warigal	11	19
Wialki	14	31
562	14	33

T1 - August 6, Feekes stage 5 to 6; Zadoks 15 to 16/21
T2 - September 24, Feekes stage 10 to 11; Zadoks 45 to 55

Table 9. The relative yields of wheat and barley grown on soils with low (Circle Valley sand) and moderately high (Kumarl clay) levels of boron

Cereal	Circle valley grain yield (t/ha)	Kumarl grain yield (t/ha)	Δ (%)
[1]Barley	1.61	3.59	223
[2]Wheat	1.12	3.58	319

1 average yields of 16 varieties
2 average yields of 11 varieties

Results indicate

1. These trials were sited adjacent to the trials examining intraspecific variation in barley in tolerance to boron toxicity (86 SG 22 and 86 SG 31). Consequently, the degree of boron toxicity on the Kumarl soil was not as marked as intended.

2. The symptoms of dark necrotic spots and lesions that are associated with boron toxicity in barley were not evident on the leaves of the varieties of wheat examined. A system was developed during a glasshouse experiment (see Appendix B) to rate the symptoms of necrosis and chlorosis that occur on the leaves of wheat with boron toxicity. These symptoms, however, are not specific, and cannot be used alone to identify boron toxicity in the field. Indeed, the ratings of leaf injury on the leaves of the varieties Halberd and Eradu grown on the Kumarl soil were no higher than those grown on the Circle Valley sand.

3. The varieties with the lowest ratings of leaf necrosis and chlorosis, Spear and Warigal, also had the lowest concentrations of boron in their youngest emerged blades. The relative grain yields of these varieties also increased when grown on the Kumarl soil, with Spear being the top yielding variety. The relative grain yield of Halberd, another variety with low concentrations of boron in the YEB, also increased on the Kumarl soil.

4. The relative grain yield of Gutha, the variety with the highest concentration of boron in the YEB, decreased when grown on the Kumarl soil.

5. Contrary to the above trends, however, the relative grain yield of Aroona, with moderately low concentrations of boron in the YEB, decreased when grown on the Kumarl soil.

6. The concentrations of boron in the YEB increased in all varieties as they developed.

Survey of Boron Toxicity in Stirling Barley in Western Australia

Aim — To determine the distribution of soils in the south-west of Western Australia with naturally high levels of boron toxic to the growth of barley.

Method: — A survey of Stirling barley crops grown through-out the south-west of the state, collecting matching samples of plant tissue (from booting to anthesis stages) and soil (to depth).

The survey required a large area (Yuna to Salmon Gums; Albany to Bullfinch) to be covered in a few weeks. It was, therefore, fortunate that Stirling could be identified from other barley varieties while driving by the nature of its reddish awns.

Matching plant and soil samples, yet to be analysed, were taken from 47 sites. The location and topsoil description were recorded for another 56 Stirling barley crops were no symptoms of boron toxicity were evident.

Table 10. Location, soil type, and rating of symptoms for Stirling barley crops affected by boron toxicity

No.	Location	Soil type (0-80 cm)	Zadoks growth stage	YEB	YEB +1	YEB +2	YEB +3
1	West. Yuna	Red clay	85	9	7	7	-
2	South Mullewa	Brown clay	57	7	7	6	6
3	North Carnamah	Red-brown clay	85	9	9	9	-
4	North Arrino	Brown loam over gravelly brown clay	85	8	7	6	-
5	West Arrino	Brown sandy loam over gravelly clay	83	6	6	5	4
6	East Moora	Grey clay	85	5	6	5	-
7	West Nangeenan	Red brown loam over mottled clay	73	9	9	9	9
8	North Nangeenan	Brown loam over mottled clay	87	10	9	10	-
9	West Bodallin	Red brown loamy clay over mottled clay	83	10	10	10	9
10	North Bodallin	Red brown loam over mottled clay	83	7	6	5	4

Table 10 continued...

No.	Location	Soil type (0-80 cm)	Zadoks growth stage	YEB	YEB +1	YEB +2	YEB +3
11	North Bodallin	Brown loamy sand over gritty yellow-brown clay	83	9	9	9	9
12	North Narembeen	Grey-brown sandy loam over gravelly brown loamy clay	87	10	9	9	-
13	East Bilbarin	Brown loam over rocky broken auger	87	9	7	6	-
14	South Bruce Rock	Red brown loamy clay over mottled clay	85	10	9	8	-
15	South Kellerberrin	Grey sandy loam over gritty grey clay	87	10	10	10	-
16	East Quairading	Grey sandy loam over mottled grey clay	85	9	8	7	-
17	West Meckering	Grey sand (saltpan)	85	9	9	9	-
18	South Dowerin	Brown gravelly loam over mottled red-brown clay	87	10	8	8	-
19	North Tammin	Brown sandy loam over mottled yellow-brown clay	87	8	7	6	-
20	East Cowcowing	Grey-brown sandy loam over brown sandy clay	87	10	10	10	-
21	North Cowcowing	Brown loamy clay	91	9	8	8	-
22	South Piawaning	Grey sandy loam over clay	83	8	7	6	-
23	Wongan Hills R.S.	Grey sandy loam over mottled grey-brown clay	87	10	9	9	-
24	Wongan Hills R.S.	Grey sandy loam over red and yellow clay	91	1	1	1	1
25	South Wongan Hills	Grey sand over yellow sand (saltpan)	81	10	10	10	-
26	West Tincurrin	Grey brown gravelly sand over gritty yellow-brown clay	85	10	8	7	-

Table 10 continued...

No.	Location	Soil type (0-80 cm)	Zadoks growth stage	YEB	YEB +1	YEB +2	YEB +3
27	North Lake Grace	Brown sandy loam over mottled brown clay	91	10	10	10	-
28	North Buniche	Fluffy grey-brown loam with white mottling	87	10	10	8	-
29	West Newdegate	Grey sand over yellow-grey sandy clay	87	8	9	8	-
30	East Newdegate	Fluffy grey loam over yellow-grey loamy clay	87	10	10	10	9
31	East Newdegate	Grey sandy loam over yellow-brown clay	87	10	10	10	9
32	West Lake Comm	Grey sandy loam over grey sandy clay	83	8	8	8	-
33	East Lake King	Grey sand over grey-yellow sandy clay	85	9	8	8	-
34	North Ravensthorpe	Brown loam over creamy brown clay	87	8	8	6	-
35	North Ravensthorpe	Red clay	87	8	7	6	-
36	West Ravensthorpe	Red-brown clay	85	10	10	10	9
37	South Jerramungup	Grey-black gritty sand over grey-yellow to white clay	85	7	7	6	-
38	South Dumbleyung	Brown gravelly sandy loam over yellow-white clay	85	6	6	5	4
39	East Nyabing	Grey-brown sandy loam over yellow-brown clay	85	9	9	7	-
40	North Ongerup	Grey gritty sandy loam over grey-white clay	85	9	8	7	7
41	West Ongerup	Grey sandy loam over yellow-brown clay	85	10	10	10	9
42	East Gnowangerup	Grey-brown sandy loam over grey-yellow clay	85	9	9	7	5
43	South Borden	Grey sandy clay over grey mottled clay	85	9	10	8	8

Table 10 continued...

No.	Location	Soil type (0-80 cm)	Zadoks growth stage	YEB	YEB +1	YEB +2	YEB +3
44	West Boxwood Hill	Grey-brown sandy loam over yellow-brown clay	83	9	9	9	8
45	East Kendenup	Grey-brown gravelly sandy loam over grey-yellow clay	87	1	1	1	1
46	South Qualeup	Grey sandy loam over grey-brown loamy clay	81	1	1	1	1
47	Salmon Gums R.S.	Grey sand over grey-brown clay	61	3	3	3	2

Table 11. Location and topsoil description of sites inspected where no symptoms of boron toxicity were found on Stirling barley

No.	Location	Top soil description
1	South Pindar	Yellow-brown sandy loam
2	East Nabawa	Red-brown sand
3	Chapman Valley R.S.	Red-brown sand
4	East Yuna	Red sand
5	Daisy Downs R.S.	Red sand
6	South Mullewa	Red-brown loam
7	North Three Springs	Red sandy loam
8	East Corrigin	Brown sandy loam
9	South Greenhills	Red-brown sandy loam
10	North Beverley	Brown gravelly sandy loam
11	North Beverley	Brown gravelly sandy loam
12	East Wongan Hills	Grey sand
13	North Ballidu	Brown gravelly sandy loam
14	North Miling	Grey gravelly sand
15	South Wongan Hills	Brown loam
16	South Toodyay	Brown gravelly sandy loam
17	West Dale	Brown gravelly sandy loam
18	South Brookton	Brown gravelly sandy loam
19	South Moorumbine	Brown loam
20	East Pingelly	Brown sandy loam
21	East Popanyinning	Grey-brown sandy loam
22	East Popanyinning	Grey-brown sand
23	South Kulin	Brown gravelly loam
24	Newdegate R.S.	Grey-brown gravelly sand
25	South Lake King	Grey sand

Table 11 continued...

No.	Location	Top soil description
26	South Jerramungup	Hard-setting grey sandy loam
27	South Dumbleyung	Brown sandy loam
28	West Nyabing	Brown gravelly sandy loam
29	South Pingrup	Grey-Brown loam
30	North Gnowangerup	Hard setting grey sandy loam
31	North Woodanilling	Grey sand
32	North Arthur River	Grey gritty sand
33	South Williams	Grey-brown sandy loam
34	Arthur River	Brown gravelly sand
35	East Arthur East	Brown gravelly sand
36	North Kojonup	Brown sandy loam
37	North Cranbrook	Grey-brown gritty sandy loam
38	East Woogenellup	Grey-brown gravelly loam
39	East Woogenellup	Grey-brown gravelly sandy loam
40	South Borden	Brown sand
41	South Borden	Brown sandy loam
42	West Wellstead	Grey-brown sandy loam
43	East Kendenup	Brown gravelly sand
44	West Kendenup	Brown gravelly sand
45	East Frankland	Brown gravelly-rocky sand
46	East Rocky Gully	Brown gravelly sandy loam
47	East Rocky Gully	Brown gravelly sand
48	South Mayanup	Brown gravelly sandy loam
49	South Kulikup	Grey-brown loam
50	north Qualeup	Brown gravelly sandy loam
51	North Qualeup	Brown gritty sand
52	South Moodiarup	Grey-brown gritty sand
53	South Duranillin	Brown gravelly sand
54	East Bowelling	Brown gravelly loam
55	West Bowelling	Brown gravelly sandy loam
56	South Bowelling	Grey-brown gravelly sand

Results and observations

1. Symptoms of boron toxicity on crops of Stirling barley were found over a large proportion of the medium to low rainfall barley growing areas from Yuna to Salmon Gums. These crops occurred on a range of heavy or sand over clay soil types.

2. Symptoms of boron toxicity were generally patchy in crops grown on sand over clay soil types, while the most affected crops of Stirling barley occurred on the red-brown clays in the eastern and south-eastern sections of the south-west land division. These soils often had white mottling in their subsoils.

3. Crops of Stirling barley west of the Great Southern Railway Line grew free from the symptoms of boron toxicity. The soil types of this high rainfall region are predominantly gravelly sands and loams.

85NO64 Tl (Mn) Whole tops August 20, 1985
ppm

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	24.25	28.00	31.50
	High	29.50	34.75	39.50
S/A	Low	23.00	31.25	33.75
	High	33.00	46.00	54.00
$NaNO_3$	Low	20.00	28.75	27.75
	High	17.00	24.50	29.00

85NO64 Tl (Mn) Uptake August 20, 1985
(g/ha)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	10.50	11.03	12.93
	High	10.05	13.20	13.60
S/A	Low	8.83	12.10	11.10
	High	11.53	17.60	20.08
$NaNO_3$	Low	5.48	9.43	8.52
	High	4.35	6.85	8.03

85NO64 Tl (N) Whole tops August 20, 1985
%db

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	3.87	4.00	3.95
	High	4.15	3.95	4.13
S/A	Low	3.87	3.75	3.80
	High	4.17	4.22	4.07
$NaNO_3$	Low	4.15	4.02	4.05
	High	4.17	4.05	4.12

85N064 T1 (N) Uptake August 20, 1985
(g/ha)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	16.70	15.93	16.33
	High	14.12	14.97	14.20
S/A	Low	14.67	14.45	12.53
	High	14.60	16.08	15.03
$NaNO_3$	Low	11.40	12.88	12.32
	High	10.77	11.35	11.43

85N064 D.M.'s T1 October 7, 1985
(kg/ha)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	4,076	4,012	4,145
	High	3,921	4,385	4,485
S/A	Low	4,098	4,667	3,982
	High	4,021	4,997	4,006
$NaNO_3$	Low	3,592	3,982	3,556
	High	3,146	3,571	4,312

85N064 T2 (Mn) Whole tops October 7, 1985
(ppm)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	6.78	6.88	6.82
	High	6.93	7.00	8.22
S/A	Low	6.70	6.88	7.40
	High	6.43	8.45	7.60
$NaNO_3$	Low	5.93	6.85	6.47
	High	6.40	6.15	7.40

85NO64 T2 Mn Uptake October 7, 1985
(g/ha)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	27.63	27.57	28.35
	High	27.43	30.72	37.35
S/A	Low	27.35	32.15	29.77
	High	26.05	42.78	30.65
$NaNO_3$	Low	21.37	27.75	23.05
	High	20.50	22.10	31.90

85NO64 Grain Mn November 27, 1985
(ppm)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	7.42	9.55	8.22
	High	9.62	9.60	10.88
S/A	Low	8.95	8.90	9.52
	High	8.35	9.88	11.25
$NaNO_3$	Low	7.90	8.05	9.27
	High	7.27	7.30	9.13

85NO64 - Grain yields (kg/ha)

Nitrogen Source and rate		Rate of $MnSo_4$ (kg/ha) 0	15	22.5
DAP	Low	1,815	1,760	1,690
	High	1,760	1,905	1,965
S/A	Low	1,810	1,840	1,835
	High	1,770	1,720	2,000
$NaNO_3$	Low	1,660	1,570	1,775
	High	1,550	1,660	1,950

85NO65 - YEB's Tl August 22, 1985
(Mn) ppm

Fertilizer	Mn (kg/ha)	(Mn) ppm
Agras No. 1 180	0	29.7
	15	46.3
	30	71.3
	60	116.7
	15	45.7
	30	69.0
	0	26.3
Super 180	0	15.0
Super 180 + Urea 68.5	0	23.7

85NO65 - YEB's T2 October 9, 1985
(Mn) ppm

Fertilizer	Mn (kg/ha)	(Mn) ppm
Agras No. 1 180	0	13.33
	15	16.33
	30	17.67
	60	19.33
	15	15.67
	30	17.33
	0	15.67
Super 180	0	11.33
Super 180 + Urea 68.5	0	12.17

85NO65 - D.M.'s Tl August 21, 1985
(kg/ha)

Fertilizer	Mn	Dry matter (kg/ha)
Agras No. 1 180	0	291
	15	391
	30	464
	60	363
	15	351
	30	363
	0	343
Super 180	0	225
Super 180 + Urea 68.5	0	298

85NO65 - T1 Whole tops (Mn) ppm August 21, 1985
Mn Uptake (g/ha)

Fertilizer	Mn	(Mn)	Mn Uptake
Agras No. 1 180	0	29.0	8.4
	15	48.7	18.4
	30	72.0	31.5
	60	111.0	41.2
	15	47.0	16.7
	30	65.7	24.3
	0	25.3	9.2
Super 180	0	13.7	3.2
Super 180 + Urea 68.5	0	21.7	7.8

85NO65 - T1 Whole tops (N) %db August 21, 1985
N Uptake (g/ha)

Fertilizer	Mn	(N)	N Uptake
Agras No. 1 180	0	4.43	12.80
	15	4.20	16.40
	30	4.17	19.17
	60	4.07	14.70
	15	4.27	14.80
	30	4.37	15.80
	0	4.10	14.03
Super 180	0	4.20	9.37
Super 180 + Urea 68.5	0	4.23	12.47

85NO65 - D.M.'s T2 October 9, 1985
(kg/ha)

Fertilizer	Mn	Dry matter (kg/ha)
Agras No. 1 180	0	3,031
	15	4,396
	30	3,793
	60	3,848
	15	3,239
	30	3,384
	0	3,457
Super 180	0	2,250
Super 180 + Urea 68.5	0	3,262

85NO65 - T2 Whole tops (Mn) ppm October 9, 1985
Mn Uptake (g/ha)

Fertilizer	Mn	(Mn)	Mn Uptake
Agras No. 1 180	0	8.47	25.8
	15	9.90	44.1
	30	10.17	36.5
	60	14.00	55.3
	15	7.40	12.8
	30	8.70	28.1
	0	8.67	29.0
Super 180	0	5.43	12.5
Super 180 + Urea 68.5	0	6.63	23.8

85NO65 - T2 Whole tops (N) %db October 9, 1985
N Uptake (g/ha)

Fertilizer	Mn	(N)	N Uptake
Agras No. 1 180	0	1.33	40.7
	15	1.27	54.9
	30	1.23	46.2
	60	1.27	48.8
	15	1.27	40.7
	30	1.33	45.0
	0	1.20	41.2
Super 180	0	1.37	31.0
Super 180 + Urea 68.5	0	1.47	45.6

85NO65 - Grain Mn Concn. (ppm)

Fertilizer	Mn	Grain Mn (ppm)
Agras No. 1 180	0	7.93
	15	9.50
	30	11.40
	60	12.67
	15	9.93
	30	10.87
	0	7.87
Super 180	0	5.27
Super 180 + Urea 68.5	0	7.03

85NO65 - Grain Mn Concn. (ppm)

Fertilizer	Mn	Grain Mn (ppm)
Agras No. 1 180	0	1,409
	15	1,435
	30	1,511
	60	1,493
Super 150	0	880
Super 150 + Urea 68.5	0	1,200

85NO66 YEB's T1 August 22, 1985
(Mn) ppm

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	11.0	15.5	17.0
50	15.75	21.0	20.75
100	16.75	22.25	24.0
150	19.0	26.5	25.25
200	24.75	32.75	32.75

85NO66 YEB's T2 October 9, 1985
(Mn) ppm

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	8.17	10.77	10.40
50	9.93	10.28	10.38
100	10.88	11.75	12.00
150	12.50	14.00	13.50
200	13.50	16.25	15.75

85NO66 D.B.'s Tl August 21, 1985
(kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	137.2	160.7	128.2
50	144.7	194.7	173.0
100	184.0	167.8	159.9
150	163.8	172.0	166.6
200	177.2	157.2	208.9

85NO66 Tl Whole Tops (Mn) ppm August 21, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	8.50	13.50	17.75
50	12.25	18.00	20.25
100	13.25	21.25	25.25
150	17.25	24.25	29.00
200	20.25	31.50	33.25

85NO66 Tl Whole Tops Mn uptake August 21, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	1.20	2.25	2.25
50	1.80	3.50	3.62
100	2.48	3.45	4.02
150	2.85	4.23	4.75
200	3.57	5.05	6.93

85NO66 T1 Whole Tops (N) %db August 21, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	4.97	4.77	4.75
50	5.00	4.75	4.55
100	4.65	4.72	4.52
150	4.72	4.77	4.55
200	4.67	4.67	4.72

85NO66 T1 Whole Tops (N) uptake August 21, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	6.88	7.65	6.10
50	7.25	9.27	7.87
100	8.65	7.95	7.22
150	7.78	8.20	7.62
200	8.38	7.35	9.90

85NO66 D.M.'s T2 August 21, 1985
(kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	1,573	2,099	2,061
50	1,854	2,545	2,373
100	2,434	2,501	2,267
150	2,239	2,192	2,322
200	2,346	2,754	2,985

85NO66 T2 Whole Tops (Mn) October 8, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	5.60	5.75	5.60
50	5.50	6.28	6.75
100	6.70	7.15	6.40
150	7.10	6.85	7.97
200	6.70	8.45	8.55

85NO66 T2 Whole Tops Mn uptake August 21, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	8.85	12.48	11.65
50	10.30	16.23	16.47
100	16.35	18.25	14.50
150	15.70	15.52	18.67
200	15.68	23.38	25.67

85NO66 Grain Mn concn. November 27, 1985
(ppm)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	5.10	6.45	5.45
50	4.97	5.35	5.50
100	6.02	6.92	6.82
150	6.57	7.25	7.58
200	7.00	8.45	9.23

85NO66 Grain yields (kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	825	1,125	1,070
50	1,185	1,275	1,165
100	1,410	1,350	1,420
150	1,455	1,480	1,490
200	1,415	1,540	1,555

85NO67 YEB's T1 August 22, 1985
(Mn) ppm

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	19.67	18.67	24.00
50	24.33	23.67	25.33
100	26.00	27.00	30.00
150	26.00	31.00	35.67
200	32.67	32.00	39.00

85NO67 YEB's T2 October 7, 1985
(Mn) ppm

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	14.33	14.33	16.33
50	16.33	14.67	15.00
100	16.00	14.00	15.33
150	14.67	16.00	15.00
200	16.33	16.00	17.67

85NO67 D.M.'s T1 July 23, 1985
(kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSO_4$ (kg/ha) 0	7.5	15
0	198.3	187.3	213.5
50	226.4	218.8	225.6
100	265.9	234.3	238.0
150	197.1	227.3	229.6
200	231.3	200.3	201.3

85NO67 T1 Whole tops (Mn) ppm July 23, 1985

Rate of S/A (kg/ha)	Rate of $MnSO_4$ (kg/ha) 0	7.5	15
0	19.33	23.00	25.00
50	28.67	24.00	24.33
100	28.67	34.67	40.00
150	30.67	36.00	44.67
200	34.33	34.00	50.33

85NO67 T1 Whole tops Mn uptake July 23, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSO_4$ (kg/ha) 0	7.5	15
0	3.83	4.27	5.33
50	6.57	5.23	5.53
100	7.77	8.03	9.53
150	6.03	8.20	10.27
200	8.07	7.00	9.93

85NO67 T1 Whole tops (N) %db July 23, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	3.93	3.97	4.03
50	3.83	3.87	3.77
100	3.83	4.10	3.83
150	3.83	3.87	4.00
200	3.87	3.97	4.20

85NO67 T1 Whole tops (N) uptake July 23, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	7.80	7.43	8.53
50	8.63	8.37	8.53
100	10.07	9.47	9.17
150	7.57	8.73	9.10
200	9.03	7.93	8.33

85NO67 D.M.'s T2 October 7, 1985
(kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	2,603	3,116	3,340
50	3,602	3,321	3,391
100	3,358	3,458	3,108
150	3,561	3,869	3,447
200	4,003	3,560	3,835

85NO67 T2 Whole tops (Mn) ppm October 7, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	6.53	6.17	7.60
50	6.93	6.37	6.70
100	6.53	7.50	8.30
150	7.67	9.27	8.17
200	9.23	7.63	10.17

85NO67 T2 Whole tops Mn uptake October 7, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	16.97	19.30	25.70
50	24.80	21.37	22.70
100	21.90	25.97	25.47
150	27.20	35.83	28.20
200	37.13	27.13	39.23

85NO67 T2 Whole tops (N) %db October 7, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	1.47	1.47	1.47
50	1.33	1.33	1.33
100	1.43	1.33	1.33
150	1.47	1.37	1.33
200	1.33	1.33	1.47

85NO67 T2 Whole tops N uptake October 7, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	38.3	45.2	48.8
50	48.4	44.9	45.1
100	47.4	46.2	41.5
150	51.8	53.0	45.9
200	53.5	48.1	55.9

85NO67 T2 Whole tops P uptake October 7, 1985
(g/ha)
*(P) all equal to 0.1

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	3.47	4.17	4.37
50	4.47	4.10	4.07
100	4.17	4.17	3.53
150	4.63	4.80	3.93
200	4.53	4.13	5.13

85NO67 T2 Whole tops 9k0 %db October 7, 1985

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	1.73	1.77	1.77
50	1.60	1.70	1.57
100	1.73	1.63	1.57
150	1.73	1.60	1.60
200	1.57	1.53	1.73

85NO67 T2 Whole tops K uptake October 7, 1985
(g/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	43.9	55.0	59.0
50	57.9	56.5	54.0
100	57.1	56.5	48.6
150	61.7	62.7	54.7
200	63.5	54.5	66.4

85NO67 Grain Mn Concn November 27, 1985
(ppm)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	6.27	6.60	7.80
50	8.37	6.70	7.70
100	8.10	8.37	9.43
150	9.10	10.13	9.17
200	10.40	10.27	11.00

85NO67 Grain yields (kg/ha)

Rate of S/A (kg/ha)	Rate of $MnSo_4$ (kg/ha) 0	7.5	15
0	1,587	1,507	1,580
50	1,827	1,753	1,707
100	1,647	1,700	1,687
150	1,820	1,880	1,887
200	1,827	1,880	1,847

85NO68 YEB's T1 August 22, 1985
(Mn) ppm

	0 Mn	20 Mn
Millewa	16.75	26.25
Gamenya	17.25	22.75
Bodallin	18.00	28.25
Canna	18.25	26.75
Jacup	17.50	22.00
Cranbrook	20.25	27.75
Eradu	13.25	20.75
Aroona	17.75	26.50
Tincurrin	19.00	25.25

85NO68 YEB's T2 October 9, 1985
(Mn) ppm

	0 Mn	20 Mn
Millewa	12.72	16.50
Gamenya	10.67	13.75
Bodallin	14.50	17.50
Canna	12.50	14.00
Jacup	12.25	13.50
Cranbrook	14.00	17.75
Eradu	8.50	12.25
Aroona	13.00	13.75
Tincurrin	12.00	14.75

85NO68 D.M.'s T1 August 21, 1985
(kg/ha)

	0 Mn	20 Mn
Millewa	203.6	241.4
Gamenya	253.7	243.1
Bodallin	172.2	211.5
Canna	271.0	248.7
Jacup	217.4	256.3
Cranbrook	230.8	231.7
Eradu	239.6	224.4
Aroona	253.1	293.2
Tincurrin	210.3	225.3

85NO68 Tl Whole tops (N) %db August 21, 1985
N uptake (g/ha)

	0 Mn		20 Mn	
Millewa	4.49	9.13	4.45	10.74
Gamenya	4.52	11.44	4.45	10.79
Bodallin	4.51	7.74	4.45	9.44
Canna	4.27	11.53	4.23	10.50
Jacup	4.58	9.90	4.51	11.54
Cranbrook	4.26	9.76	4.26	9.84
Eradu	4.29	10.20	3.87	8.65
Aroona	4.50	11.40	4.45	13.04
Tincurrin	4.07	8.57	3.96	8.95

85NO68 Tl Whole tops (P) %db August 21, 1985
P uptake (g/ha)

	0 Mn		20 Mn	
Millewa	0.30	0.61	0.28	0.68
Gamenya	0.32	0.81	0.29	0.71
Bodallin	0.29	0.51	0.29	0.62
Canna	0.29	0.78	0.27	0.67
Jacup	0.30	0.66	0.28	0.73
Cranbrook	0.30	0.68	0.30	0.69
Eradu	0.29	0.69	0.24	0.54
Aroona	0.28	0.72	0.27	0.79
Tincurrin	0.30	0.63	0.27	0.62

85NO68 Tl Whole tops (K) %db August 21, 1985
K uptake (g/ha)

	0 Mn		20 Mn	
Millewa	4.78	9.72	4.60	11.14
Gamenya	5.29	13.39	4.95	12.06
Bodallin	5.10	8.79	4.87	10.35
Canna	4.83	13.06	4.75	11.82
Jacup	4.82	10.35	4.67	11.97
Cranbrook	4.98	11.47	4.72	10.88
Eradu	4.96	11.78	4.20	9.44
Aroona	4.95	12.61	4.74	13.91
Tincurrin	5.12	10.75	4.86	10.98

85NO68 T1 Whole tops (Cu) ppm August 21, 1985
Cu uptake (g/ha)

	0 Mn		20 Mn	
Millewa	1.95	0.38	1.67	0.41
Gamenya	1.92	0.49	1.72	0.42
Bodallin	2.22	0.37	1.72	0.36
Canna	1.62	0.44	1.92	0.47
Jacup	2.10	0.46	1.85	0.47
Cranbrook	2.30	0.51	2.17	0.50
Eradu	1.95	0.46	1.62	0.34
Aroona	1.90	0.47	1.67	0.49
Tincurrin	1.92	0.41	2.00	0.46

85NO68 T1 Whole tops (K) %db August 21, 1985
K uptake (g/ha)

	0 Mn		20 Mn	
Millewa	17.0	3.50	36.5	8.63
Gamenya	17.0	4.33	31.5	7.50
Bodallin	18.0	3.11	36.0	7.55
Canna	17.7	4.81	26.7	6.57
Jacup	17.7	3.98	26.5	6.82
Cranbrook	19.5	4.60	33.7	8.05
Eradu	15.0	3.63	31.7	7.13
Aroona	18.5	4.66	34.7	10.17
Tincurrin	21.5	4.46	29.5	6.60

85NO68 T1 Whole tops (Zn) ppm August 21, 1985
Zn uptake (g/ha)

	0 Mn		20 Mn	
Millewa	15.5	3.17	16.2	3.89
Gamenya	16.5	4.18	15.5	3.79
Bodallin	16.2	2.83	16.2	3.43
Canna	16.0	4.32	16.0	3.95
Jacup	16.5	3.62	15.7	4.04
Cranbrook	18.5	4.25	17.2	4.02
Eradu	15.2	3.65	14.2	3.18
Aroona	18.0	4.57	16.5	4.85
Tincurrin	17.5	3.68	16.2	3.66

85NO68 D.M.'s T2 October 8, 1985
(kg/ha)

	0 Mn	20 Mn
Millewa	1,605	2,353
Gamenya	1,882	2,215
Bodallin	2,196	2,343
Canna	3,101	2,240
Jacup	2,131	2,854
Cranbrook	2,559	2,828
Eradu	2,509	2,579
Aroona	2,476	3,079
Tincurrin	1,945	2,739

85NO68 T1 Whole tops (N) %db October 8, 1985
N uptake (g/ha)

	0 Mn		20 Mn	
Millewa	1.60	25.7	1.47	34.8
Gamenya	1.62	30.5	1.37	30.4
Bodallin	1.52	32.8	1.40	33.3
Canna	1.45	44.9	1.37	30.8
Jacup	1.65	34.9	1.52	43.2
Cranbrook	1.41	35.9	1.30	36.7
Eradu	1.57	39.3	1.37	35.9
Aroona	1.42	35.1	1.47	45.4
Tincurrin	1.40	27.4	1.30	35.7

85NO68 T2 Whole tops (P) %db October 8, 1985
P uptake (g/ha)

	0 Mn		20 Mn	
Millewa	0.15	2.32	0.10	3.07
Gamenya	0.17	2.90	0.10	2.72
Bodallin	0.12	3.07	0.12	3.20
Canna	0.10	4.07	0.10	2.75
Jacup	0.15	3.05	0.10	3.67
Cranbrook	0.13	3.48	0.10	3.65
Eradu	0.15	3.68	0.10	3.27
Aroona	0.10	3.15	0.10	4.02
Tincurrin	0.10	2.65	0.10	3.47

85NO68 T2 Whole tops (K) %db October 8, 1985
K uptake (g/ha)

	0 Mn		20 Mn	
Millewa	2.07	32.8	1.85	43.9
Gamenya	2.05	38.7	1.65	36.4
Bodallin	1.92	42.4	1.87	43.8
Canna	1.72	54.4	1.70	38.1
Jacup	2.10	43.8	1.97	56.3
Cranbrook	2.01	49.1	1.82	50.2
Eradu	1.90	48.0	1.57	40.7
Aroona	1.80	44.7	2.00	61.6
Tincurrin	2.00	38.8	1.82	50.8

85NO68 T2 Whole tops (Cu) ppm October 8, 1985
Cu uptake (g/ha)

	0 Mn		20 Mn	
Millewa	1.32	2.07	1.00	2.35
Gamenya	1.17	2.22	0.85	1.95
Bodallin	1.15	2.50	1.02	2.43
Canna	1.10	3.57	1.22	2.75
Jacup	1.27	2.80	1.05	3.05
Cranbrook	1.17	2.86	1.20	3.55
Eradu	1.20	3.35	0.97	2.65
Aroona	0.90	2.27	1.10	3.30
Tincurrin	1.07	2.00	0.92	2.70

85NO68 T2 Whole tops (Mn) ppm October 8, 1985
Mn uptake (g/ha)

	0 Mn		20 Mn	
Millewa	7.90	12.85	10.00	24.05
Gamenya	7.27	13.83	9.50	20.83
Bodallin	7.60	16.95	8.60	20.05
Canna	6.76	20.63	7.47	16.75
Jacup	7.15	15.53	8.00	22.63
Cranbrook	7.18	18.55	9.67	27.40
Eradu	5.37	14.13	10.22	25.92
Aroona	7.47	17.92	14.47	41.22
Tincurrin	7.70	14.40	9.80	27.22

85NO68 T2 Whole tops (Zn) ppm October 8, 1985
Zn uptake (g/ha)

	0 Mn		20 Mn	
Millewa	12.75	20.67	11.25	26.67
Gamenya	13.50	25.32	10.75	24.10
Bodallin	13.25	28.85	11.25	26.50
Canna	11.00	34.55	10.50	23.57
Jacup	11.75	25.08	10.75	30.42
Cranbrook	10.90	26.91	10.25	29.00
Eradu	11.50	29.73	11.00	28.52
Aroona	10.75	26.25	12.25	38.00
Tincurrin	12.00	23.32	10.20	28.22

85NO68 Grain Mn Conc November 27, 1985
ppm

	0 Mn	20 Mn
Millewa	7.13	9.08
Gamenya	6.60	9.80
Bodallin	9.00	9.98
Canna	8.27	9.95
Jacup	7.78	8.58
Cranbrook	8.58	9.95
Eradu	5.60	7.83
Aroona	8.33	8.85
Tincurrin	6.10	8.23

85NO68 Grain yield (kg/ha)

	0 Mn	20 Mn
Millewa	885	895
Gamenya	890	1,030
Bodallin	1,000	1,090
Canna	1,075	1,159
Jacup	850	740
Cranbrook	1,005	1,235
Eradu	720	870
Aroona	1,025	1,220
Tincurrin	1,150	1,217

85NO69 YEB's T1 August 22, 1985
(Mn) ppm

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	15.33	14.00	-
Super + Urea + $MnSO_4$ 15	21.67	20.33	-
Agras 180	19.67	19.33	-
Agras 180 + $MnSO_4$ 15	28.00	27.00	-

85NO69 YEB's T2 September 10, 1985
(Mn) ppm

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	11.67	12.00	11.00
Super + Urea + $MnSO_4$ 15	15.33	16.67	14.00
Agras 180	13.67	14.33	15.67
Agras 180 + $MnSO_4$ 15	20.67	19.00	21.00

85NO69 YEB's T3 October 9, 1985
(Mn) ppm

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	12.7	10.8	69.0
Super + Urea + $MnSO_4$ 15	15.3	12.7	47.7
Agras 180	11.7	11.5	52.0
Agras 180 + $MnSO_4$ 15	14.0	18.0	58.3

85NO69 D.M.'s T1 August 27, 1985
(kg/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	177.7	181.0	-
Super + Urea + $MnSO_4$ 15	190.0	214.0	-
Agras 180	208.3	220.0	-
Agras 180 + $MnSO_4$ 15	201.7	187.7	-

85NO69 T1 Whole tops (Mn) ppm August 27, 1985
(Mn) uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	16.0	30.3	-
	2.84	5.50	
Super + Urea + $MnSO_4$ 15	21.7	41.0	-
	41.7	8.83	
Agras 180	19.7	30.7	-
	4.17	6.75	
Agras 180 + $MnSO_4$ 15	36.7	48.3	-
	7.69	9.57	

85NO69 D.M.'s T2 October 9, 1985
(kg/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	455	525	409
Super + Urea + $MnSO_4$ 15	431	521	510
Agras 180	526	514	625
Agras 180 + $MnSO_4$ 15	475	505	485

85NO69 T2 Whole tops (Mn) ppm October 9, 1985
(Mn) uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	10.1	11.5	10.0
	4.6	6.1	4.3
Super + Urea + $MnSO_4$ 15	13.0	13.3	10.1
	5.7	6.9	5.1
Agras 180	10.9	10.5	12.0
	5.9	5.5	7.5
Agras 180 + $MnSO_4$ 15	19.0	20.0	19.7
	9.1	10.2	9.5

85NO69 T2 Whole tops (K) %db October 9, 1985
K uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	3.29 15.0	3.50 18.2	3.21 12.9
Super + Urea + $MnSO_4$ 15	2.93 12.5	2.76 14.4	3.31 16.9
Agras 180	3.19 16.7	3.21 16.4	2.79 17.5
Agras 180 + $MnSO_4$ 15	2.95 13.8	2.68 13.6	2.97 14.4

85NO69 T2 Whole tops (P) %db October 9, 1985
P uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	.23 1.04	.24 1.23	.23 0.94
Super + Urea + $MnSO_4$ 15	.21 0.89	.21 1.11	.22 1.13
Agras 180	.23 1.21	.22 1.14	.23 1.41
Agras 180 + $MnSO_4$ 15	.22 1.05	.20 1.01	.21 1.02

85NO69 T2 Whole tops (N) %db October 9, 1985
N uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	3.12 14.3	3.22 16.8	3.05 12.4
Super + Urea + $MnSO_4$ 15	2.92 12.3	2.95 15.4	2.97 15.1
Agras 180	3.13 16.5	2.95 15.0	3.06 19.0
Agras 180 + $MnSO_4$ 15	3.15 14.8	2.86 14.5	2.98 14.4

85NO69 D.M.'s T3 (kg/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
	1,367	1.111	1,247
Super 150 + Urea 68.5	1,674	1,166	1,475
Super + Urea + $MnSO_4$ 15	1,338	1,734	1,593
Agras 180	1,763	1,660	1,789
Agras 180 + $MnSO_4$ 15	1,397	1,738	1,852

85NO69 T3 Whole tops (Mn) ppm
N uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	5.80	7.63	24.67
	9.5	8.8	37.0
Super + Urea + $MnSO_4$ 15	8.63	7.87	22.00
	10.9	13.5	34.9
Agras 180	7.30	6.47	24.33
	12.9	10.8	44.2
Agras 180 + $MnSO_4$ 15	8.20	8.97	18.33
	11.3	15.3	34.3

85NO69 T3 Whole tops (K) %db
K uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	1.67	1.74	1.46
	27.65	20.20	21.39
Super + Urea + $MnSO_4$ 15	1.38	1.34	1.45
	18.83	23.25	23.28
Agras 180	1.48	1.46	1.29
	25.99	24.28	23.05
Agras 180 + $MnSO_4$ 15	1.36	1.36	1.38
	19.06	23.67	25.61

85NO69 T3 Whole tops (P) %db
P uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	0.16	0.16	0.14
	2.76	1.90	1.99
Super + Urea + $MnSO_4$ 15	0.14	0.15	0.13
	1.82	2.63	2.09
Agras 180	0.15	0.14	0.14
	2.65	2.31	2.52
Agras 180 + $MnSO_4$ 15	0.13	0.14	0.13
	1.82	2.37	2.31

85NO69 T3 Whole tops (N) %db
N uptake (g/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	1.65	1.73	1.46
	27.51	20.18	21.24
Super + Urea + $MnSO_4$ 15	1.47	1.49	1.42
	19.43	26.36	22.73
Agras 180	1.53	1.43	1.40
	26.93	23.73	25.00
Agras 180 + $MnSO_4$ 15	1.39	1.42	1.36
	19.45	24.60	25.07

85NO69 Grain Mn Concn. November 27, 1985
(ppm)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	5.43	5.13	5.97
Super + Urea + $MnSO_4$ 15	6.47	6.73	6.80
Agras 180	6.33	5.70	7.33
Agras 180 + $MnSO_4$ 15	7.53	9.63	8.47

85NO69 Grain yield (kg/ha)

Fertilizer	Mn Sprays (4 kg/ha) 0	1	2
Super 150 + Urea 68.5	480	390	610
Super + Urea + $MnSO_4$ 15	610	640	580
Agras 180	760	660	960
Agras 180 + $MnSO_4$ 15	720	800	710