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# Boron toxicity in barley.

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EXPERIMENTAL RESULTS

1985/86

BORON TOXICITY IN BARLEY

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PLANT RESEARCH DIVISION

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1. BORON TOXICITY IN BARLEY 85Me55/4864 EX

Aim

To investigate the intraspecific variation through time of symptoms of Boron toxicity and Boron levels in different plant tissues of barley.

Location

A. Parkhouse, Yelbeni.

Results

Sown - June 10th

Harvested - November 13th

Basals	-	Agras No 1.	114 kg/ha
		Grain	45 kg/ha

Table 1. LABORATORY RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING TILLERING

Variety	Zadoks Growth Stage	Cartwright Rating Boron Toxicity	Leaf Ratings					
			N.G.	YEB	YEB + 1	YEB + 2	YEB + 3	O.L.
Wheat:								
Aroona	15.2/2.2	1.0	1	1	2	2	2	2
Barley:								
Beecher	15.1/2.2	1.2	1	2	2	2	3	3
Clipper	15.4/2.2	2.3	1	2	4	5	5	5
Dampier	15.7/2.2	2.3	1	2	4	4	5	5
Forrest	15.2/2.2	1.9	1	2	3	3	4	4
Grimmett	15.2/2.2	2.7	1	3	5	6	6	7
O'Connor	15.2/2.1	2.2	1	2	3	4	5	5
Schooner	15.1/2.2	2.1	1	2	3	4	4	5
Shannon	15.1/2.2	2.2	1	2	4	5	5	5
Stirling	15.5/2.2	2.8	1	3	5	6	6	6

Sampled August 21st; Feekes 4.

Table 2. FIELD RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING RIPENING

Variety	Zadoks Growth Stage	Cartwright Boron Toxicity Rating
Wheat:		
Aroona	7	0
Barley:		
Beecher	7	4
Clipper	6	4
Dampier	7	4
Forrest	7	4/5
Grimmett	6	4/5
O'Connor	6	3/4
Schooner	6	4
Shannon	5	3/4
Stirling	7	5

Rated October 17th; Feekes 13

Table 3: DRY MATTER PRODUCTION (kg/ha) DURING RIPENING AND FINAL GRAIN YIELDS (kg/ha) OF WHEAT AND BARLEY VARIETIES

Variety	*Dry Matter Production	Grain Yield
Wheat:		
Aroona	1310	581
Barley:		
Beecher	920	229
Clipper	1110	152
Dampier	1370	269
Forrest	920	200
Grimmett	1270	165
O'Connor	940	115
Schooner	1140	213
Shannon	430	86
Stirling	1470	156

\* October 17th

Table 4. LABORATORY RATINGS OF BORON TOXICITY SYMPTOMS IN THE PRIMARY TILLERS OF WHEAT AND BARLEY DURING RIPENING

Variety	Zadoks Growth Stage	Cartwright Rating Primary Tiller	Leaf Ratings			
			YEB	YEB + 1	YEB + 2	YEB + 3
Wheat:						
Aroona	7	0	1	1	1	1
Barley:						
Beecher	7	5	9	8	9	9
Clipper	6	5	10	9	9	10
Dampier	7	5	9	9	10	10
Forrest	7	5	8	8	9	9
Grimmett	6	5	9	9	9	9
O'Connor	6	4/5	8	8	8	8
Schooner	6	5	10	9	9	9
Shannon	5	4	6	6	6	6
Stirling	7	5	10	9	10	10

Sampled October 17th

Table 5. BARLEY GRAIN YIELDS EXPRESSED AS A PERCENTAGE OF STIRLING AND COMPARED TO DEPARTMENT OF AGRICULTURE RESULTS FOR THE L3 ZONE

Barley Variety	Barley Yield		L3 Results
	(kg/ha)	(% Stirling)	
Beecher	229	147	96
Clipper	152	97	90
Dampier	269	172	-
Forrest	200	128	92
Grimmett	165	106	-
O'Connor	115	74	103
Schooner	213	136	-
Shannon	86	55	-
Stirling	156	100	100

L3 Zone recommendations (all sowings) :

Manufacturing grade - Stirling  
 Feed grade - O'Connor  
 Stirling (alternative)

Results indicate

1. Grain yields were low due to conditions of drought, with wheat far outyielding the barley varieties.
2. Wheat showed none of the spotting symptoms associated with Boron toxicity in barley.
3. Symptoms of Boron toxicity were evident in all barley varieties during tillering, with Beecher showing the least and Stirling and Grimmett the most symptoms.
4. Symptoms of Boron toxicity increased within plants on older leaves.
5. Symptoms of Boron toxicity became more marked during barley growth. A field assessment during ripening indicated that together with Forrest, Stirling and Grimmett showed the most symptoms, with Shannon and O'Connor showing the least. The variety Beecher, which showed the least symptoms during tillering, now joined Clipper, Dampier and Schooner with a mid-rating of 4 during ripening.
6. A laboratory assessment of the degree of symptom expression on the primary tillers alone indicated more marked symptoms than barley plants as a whole. Shannon expressed the least symptoms, followed by O'Connor. All other varieties showed near-maximum symptoms.
7. A glasshouse experiment (85GL2) would indicate that with the degree of symptoms expressed, all the varieties of barley would have yield restricted by Boron toxicity at this site.



2.

BORON TOXICITY IN BARLEY 85SG29/4864 EX

Aim

To investigate the intraspecific variation through time of symptoms of Boron toxicity and Boron levels in different plant tissues of barley.

Location

Salmon Gums Research Station.

Soil

Grey-brown calcareous earth.  
(medium Kumarl soil)

Results

Sown - July 18th

Harvested - December 3rd

Table 6. RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING TILLERING.

Variety	Zadoks Growth Stage	Cartwright Boron Toxicity Rating
Wheat:		
Aroona	16.3/2.4	0
Barley:		
Beecher	16.5/2.7	0
Clipper	15.6/2.9	1
Dampier	17.3/2.6	2
Forrest	17.7/2.5	1
Grimmett	17.5/2.6	1
O'Connor	17.7/2.6	1
Schooner	16.8/2.6	1
Shannon	17.8/2.7	0
Stirling	17.3/2.6	1

Rated September 12th; Feekes 5

Table 7. FIELD RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING HEADING

Variety	Zadoks Growth Stage	Cartwright Boron Toxicity Rating
Wheat:		
Aroona	6-	0
Barley:		
Beecher	6-	3
Clipper	57	3/4
Dampier	57	3/4
Forrest	59	4
Grimmett	57	3
O'Connor	55	2/3
Schooner	55	3
Shannon	49	2
Stirling	59	4

Rated October 24th

Table 8. LABORATORY RATINGS OF BORON TOXICITY SYMPTOMS IN THE PRIMARY TILLERS OF WHEAT AND BARLEY, DURING HEADING.

Variety	Zadoks Growth Stage	Cartwright Rating Primary Tiller	Leaf Ratings			
			YEB	YEB + 1	YEB + 2	YEB + 3
Wheat:						
Aroona	6-	0	2	2	2	2
Barley:						
Beecher	6-	3	5	5	5	6
Clipper	57	3	6	5	6	6
Dampier	6-	3	5	6	6	6
Forrest	6-	3/4	6	7	7	6
Grimmett	57	3/4	6	6	7	7
O'Connor	57	3	5	5	5	6
Schooner	57	3/4	7	6	6	6
Shannon	49	2	2	3	4	5
Stirling	6-	4	7	7	7	7

Sampled October 24th

Table 9: DRY MATTER PRODUCTION (t/ha) DURING HEADING AND FINAL GRAIN YIELDS (t/ha) OF WHEAT AND BARLEY VARIETIES

Variety	*Dry Matter Production	Grain Yield
Wheat:		
Aroona	3.98	1.38
Barley:		
Beecher	4.68	1.83
Clipper	5.83	2.13
Dampier	4.47	1.70
Forrest	4.06	1.63
Grimmett	4.41	1.54
O'Connor	4.84	1.71
Schooner	4.97	2.23
Shannon	4.91	1.03
Stirling	3.87	1.57

\* October 24th

Results indicate

1. A good season at Salmon Gums resulted in high yields, and with the exception of the late maturing variety Shannon, all the barley varieties outyielded wheat.
2. Wheat showed none of the spotting symptoms associated with Boron toxicity in barley.

3. During tillering, the varieties Beecher and Shannon were free of symptoms, with all other varieties expressing a low degree of Boron toxicity symptoms.
4. Symptoms of Boron toxicity became more marked during barley growth. A field assessment during heading indicated that followed by O'Connor, Shannon showed the least symptoms, with the new varieties of Forrest and Stirling showing the most symptoms. The variety Beecher, which was free of symptoms during tillering, now joined Grimmett and Schooner with a mid-rating of 3 during heading.
5. A laboratory assessment of the degree of symptom expression on the primary tillers alone during heading confirmed that Shannon expressed the least and Stirling the most symptoms.
6. Symptoms of Boron toxicity increased with age of leaves on the primary tiller.

3.

BORON TOXICITY IN BARLEY 85SG33/4864 EX

Aim

To investigate the intraspecific variation through time of symptoms of Boron toxicity and Boron levels in different plant tissues of barley.

Location

Salmon Gums Research Station

Soil

Grey-brown calcareous earth  
(heavy Kumarl soil)

Results

Sown - July 18th

Harvested - December 3rd

Table 10. GRAIN YIELDS (t/ha) OF BARLEY VARIETIES

VARIETY	GRAIN YIELD
Beecher	2.15
Clipper	2.37
Dampier	2.17
Forrest	1.93
Grimmett	2.21
O'Connor	2.23
Schooner	2.75
Shannon	1.34
Stirling	2.00

Table 11. RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING TILLERING

Variety	Zadoks Growth Stage	Cartwright Boron Toxicity Rating
Wheat:		
Aroona	17.4/2.5	0
Barley:		
Beecher	17.1/2.7/3.1	0
Clipper	17.7/2.6	1
Dampier	18.6/2.7/3.1	2
Forrest	17.5/2.7	0
Grimmett	18.6/2.7/3.1	1/2
O'Connor	16.8/2.5/3.1	1
Schooner	17.6/2.6	1
Shannon	17.8/2.8	0
Stirling	17.6/2.8	1

Rated September 12th; Feekes 5

Table 12. FIELD RATINGS OF BORON TOXICITY SYMPTOMS IN WHEAT AND BARLEY DURING HEADING

Variety	Zadoks Growth Stage	Cartwright Boron Toxicity Rating
Wheat:		
Aroona	6-	0
Barley:		
Beecher	6-	3
Clipper	57	3/4
Dampier	57	3/4
Forrest	59	3/4
Grimmett	57	3
O'Connor	55	2/3
Schooner	55	3
Shannon	49	2
Stirling	57	3/4

Rated October 24th

Table 13. AVERAGE BORON TOXICITY SYMPTOMS DURING HEADING AND AVERAGE BARLEY GRAIN YIELDS FROM 85SG29 and 85SG33; WITH YIELDS EXPRESSED AS A PERCENTAGE OF STIRLING AND COMPARED TO DEPARTMENT OF AGRICULTURE RESULTS FOR THE L5 ZONE

Barley Variety	Cartwright Rating	Average Barley yield		L5 Results
		(t/ha)	% Stirling	
Beecher	3	1.99	111	100
Clipper	3/4	2.25	126	93
Dampier	3/4	1.94	108	-
Forrest	4	1.78	100	92
Grimmett	3	1.88	105	-
O'Connor	2/3	1.97	110	106
Schooner	3	2.49	139	-
Shannon	2	1.18	66	-
Stirling	4	1.78	100	100

L5 Zone recommendations (all sowings) :

- Manufacturing grade - Stirling
- Feed grade - O'Connor
- Stirling (alternative)

Results indicate

1. On this heavier Kumarl soil at Salmon Gums, the intraspecific variation in barley to Boron toxicity and its development with plant growth generally reflected the results in 85SG29.
2. The results in Table 13 indicate that although they were high yielding, the new varieties of Stirling and Forrest did not yield as well as some of the more established varieties which expressed a lesser amount of symptoms of Boron toxicity.



4. SAMPLING TECHNIQUES FOR BORON TOXICITY IN BARLEY 85GL2/4864EX

Aims

- i. To reproduce the symptoms of Boron toxicity in barley in the glasshouse.
- ii. To relate degree of severity of symptoms to reduction in yield of barley and to the concentration of Boron in different barley plant tissues.
- iii. To monitor the levels of Boron in plant tissues during plant growth and to establish the plant tissue most sensitive to change in Boron supply.

Location

Glasshouses, University of Western Australia.

Treatments

Soil : Lancelin brown sand

Barley : Stirling - has shown susceptibility to Boron toxicity in the field.

Boron : Six levels - 0, 0.5, 1, 2, 4 and 8 ppm  
Boron in 3.5 kg soil/pot

Sampling : 3 times

- I. Harvest 1 - 5 leaf stage
- II. Harvest 2 - flag leaf stage
- III. Harvest 3 - maturity

Results

Sown - June 7 : D1  
Harvest 1 - July 11 : D35

Necrotic leaf removal - D 46, 50, 57, 64, 71, 78, 85.

Harvest 2 - August 30 : D85  
Harvest 3 - November 5 : D152

Table 14. THE EFFECT OF BORON APPLICATIONS ON THE DRY WEIGHTS OF BARLEY TOPS, AND DEGREE OF SYMPTOMS OF BORON TOXICITY IN INDIVIDUAL LEAVES OF STIRLING BARLEY AT THE FIVE LEAF STAGE - HARVEST 1

Boron (ppm)	Dry weight Barley tops (g/pot)	LEAF RATINGS				
		YEB	YEB + 1	YEB + 2	YEB + 3	O.L.
0	3.52	1	1	1	1	1
0.5	3.74	1	1	2	1	2
1	3.46	2	3	3	4	4
2	3.86	2	4	5	7	6
4	2.95	2	4	5	8	8
8	2.29	2	4	4	8	9

Table 15. THE EFFECT OF BORON APPLICATIONS ON THE DRY WEIGHTS OF BARLEY TOPS AND ROOTS, AND DEGREE OF SYMPTOMS OF BORON TOXICITY IN THE TOPS AND IN THE INDIVIDUAL LEAVES OF THE PRIMARY TILLER OF STIRLING BARLEY AT THE BOOT STAGE - HARVEST 2.

Boron (ppm)	Dry weight (g/pot)		Cartwright Rating Tops	LEAF RATING				
	Tops	Roots		YEB	YEB + 1	YEB + 2	YEB + 3	YEB + 4
0	27.6	9.42	3	1	3	3	5	6
0.5	27.4	9.42	3	3	4	4	6	7
1	26.4	8.76	4	3	4	5	7	9
2	24.2	6.95	4	3	5	6	8	9
4	22.5	5.41	4	4	6	8	9	10
8	19.7	3.96	5	6	7	9	9	10

Table 16. THE EFFECT OF BORON APPLICATIONS ON THE GRAIN YIELD AND TOTAL DRY WEIGHT OF TOPS; ON THE NUMBER LODGED AND TOTAL NUMBER OF TILLERS; ON THE NUMBER OF HEADS; AND ON THE HEIGHT OF THE PRIMARY TILLER OF STIRLING BARLEY AT MATURITY - HARVEST 3.

Boron (ppm)	Grain Yield (g/pot)	Total Dry weight of tops (g/pot)	Total Number Tillers	Number Lodged Tillers	Number Heads	Height Primary Tiller (cm)
0	11.46	42.4	30	0	26	65
0.5	10.14	39.6	31	0	26	66
1	10.98	39.8	28	1	25	68
2	9.92	36.3	30	7	26	69
4	9.55	34.5	27	19	24	74
8	7.28	31.7	27	25	22	73

Table 17. THE EFFECT OF BORON APPLICATIONS ON THE PERCENTAGE OF THE TOTAL LEAF AREA COVERED WITH BLACK SPOTS AND LESIONS FOR INDIVIDUAL LEAVES ON THE PRIMARY TILLER OF STIRLING BARLEY AT MATURITY - HARVEST 3.

Boron (ppm)	Percentage of leaf area affected				
	YEB	YEB + 1	YEB + 2	YEB + 3	YEB + 4
0	2	2	2	3	5
0.5	5	3	2	7	10
1	5	7	5	10	12
2	20	20	15	20	15
4	60	75	30	40	20
8	75	75	50	25	20

Table 18. THE EFFECT OF BORON APPLICATIONS ON THE LENGTH AND MAXIMUM WIDTH (mm) OF INDIVIDUAL LEAVES ON THE PRIMARY TILLER OF STIRLING BARLEY AT MATURITY - HARVEST 3.

Boron (ppm)	YEB		YEB + 1		YEB + 2		YEB + 3		YEB + 4	
	Length	Width	Length	Width	Length	Width	Length	Width	Length	Width
0	80	4	170	6	210	7	270	8	310	7
	(250)		(800)		(1152)		(1696)		(1704)	
0.5	100	4	150	8	180	7	220	7	270	6
	(313)		(941)		(988)		(1210)		(1272)	
1	90	5	150	8	190	7	240	7	280	6
	(353)		(941)		(1044)		(1320)		(1319)	
2	110	5	180	6	210	9	230	10	260	8
	(431)		(847)		(1484)		(1806)		(1634)	
4	110	6	170	9	200	10	260	8	280	10
	(517)		(1200)		(1570)		(1429)		(2199)	
8	120	8	190	11	230	11	280	9	280	8
	(752)		(1638)		(1987)		(1979)		(1759)	

( ) - estimated area  
 =  $\pi/4$  (length x width) mm<sup>2</sup>

Table 19. THE EFFECT OF BORON APPLICATIONS ON THE WEIGHT (g/6 POTS) AND NUMBER OF NECROTIC LEAVES REMOVED AT INTERVALS BETWEEN THE FIVE LEAF AND BOOT STAGES OF STIRLING BARLEY - HARVEST 1 to 2.

Day	Boron applied (ppm)						
	0	0.5	1	2	4	8	
46	- weight	0.03	0.11	0.26	0.75	1.06	0.82
	- number	6	19	35	81	97	78
50	- weight	0.24	0.52	0.48	0.64	1.76	1.02
	- number	35	58	51	39	74	45
57	- weight	0.54	0.75	0.95	2.30	3.76	2.82
	- number	73	68	68	99	114	92
64	- weight	3.16	4.73	6.71	12.66	11.92	8.42
	- number	185	224	253	343	262	189
71	- weight	4.11	5.33	7.24	4.77	3.60	4.09
	- number	171	198	185	106	73	73
78	- weight	3.27	3.64	3.34	2.02	2.72	3.86
	- number	104	105	80	45	54	66
85	- weight	2.46	2.46	2.18	2.42	2.61	3.90
	- number	66	60	52	50	46	54

Table 20. THE EFFECT OF BORON APPLICATIONS ON THE CUMULATIVE WEIGHT (g/6 POTS) AND WEIGHT INDEX (\*) OF NECROTIC LEAVES REMOVED AT INTERVALS BETWEEN THE FIVE LEAF AND BOOT STAGES OF STIRLING BARLEY - HARVEST 1 to 2.

Day	Weight Removed Leaves	Boron applied (ppm)					
		0	0.5	1	2	4	8
46	- cum.	0.03	0.11	0.26	0.75	1.06	0.82
	- index	0.1	0.3	0.8	2.2	3.8	3.7
50	- cum.	0.27	0.63	0.75	1.38	2.83	1.83
	- index	0.7	1.5	2.0	3.4	8.7	7.1
57	- cum.	0.81	1.38	1.70	3.68	6.58	4.65
	- index	1.6	2.6	3.3	7.0	15.0	13.1
64	- cum.	3.97	6.11	8.41	16.34	18.50	13.07
	- index	5.8	8.5	12.4	23.9	32.1	27.2
71	- cum.	8.08	11.44	15.64	21.11	22.10	17.16
	- index	8.8	11.3	17.4	24.4	29.0	26.7
78	- cum.	11.35	15.08	18.98	23.14	24.82	21.03
	- index	9.3	12.0	15.8	20.3	24.3	24.0
85	- cum.	13.81	17.54	21.16	25.56	27.43	24.92
	- index	8.3	10.7	13.4	17.6	20.3	21.1

\* Weight index is the cumulative leaf weight as a percentage of the estimated dry weight of barley tops at the time of leaf removal :

weight index = cumulative leaf weight (g/6 pots)

$$\frac{\text{cumulative leaf weight (g/6 pots)}}{6 \times \text{estimated dry weight barley tops (g/pot)}} \times 100\%$$

where dry weights of barley tops were estimated from logarithmic growth curves fitted from D35 to D85 - Harvest 1 to 2 :

Day	Boron applied (ppm)					
	0	0.5	1	2	4	8
35	3.52	3.74	3.46	3.86	2.95	2.29
46	5.5	5.8	5.4	5.8	4.6	3.7
50	6.5	6.8	6.4	6.7	5.4	4.3
57	8.7	9.0	8.6	8.7	7.3	5.9
64	11.5	12.0	11.3	11.4	9.6	8.0
71	15.3	16.8	15.0	14.4	12.7	10.7
78	20.3	20.9	20.0	19.0	17.0	14.6
85	27.6	27.4	26.4	24.2	22.5	19.7

Table 21. SUMMARY : THE EFFECT OF BORON APPLICATIONS ON THE WEIGHTS OF BARLEY TOPS (% MAXIMUM) AT THE FIVE-LEAF, BOOT, AND MATURITY STAGES, ON THE WEIGHTS OF BARLEY ROOTS (% MAXIMUM) AT THE BOOT STAGE, AND ON THE GRAIN YIELD (% MAXIMUM).

Boron Applied (ppm)	Five-leaf Stage Tops	Boot Stage		Maturity	
		Tops	Roots	Tops	Grain
0	91	100	100	100	100
0.5	97	99	100	93	88
1	90	96	93	94	96
2	100	88	73	86	86
4	76	82	57	81	83
8	59	71	42	74	64

Table 22. SUMMARY AT HARVEST 2 : THE EFFECT OF BORON APPLICATIONS ON THE WEIGHTS (% MAXIMUM) OF BARLEY TOPS AND ROOTS, ON THE DEGREE OF SYMPTOMS OF BORON TOXICITY FOR TOPS AND LEAVES, AND ON THE TOP WEIGHT THAT IS FULLY NECROTIC LEAVES (%).

Boron Applied (ppm)	Tops Weight (% max.)	Roots Weight (% max.)	Cartwright Rating For Tops	* Leaf Rating	Fully Necrotic Leaves (% Tops Weight)
0	100	100	3	4	8
0.5	99	100	3	5	11
1	96	93	4	6	13
2	88	73	4	6	18
4	82	57	4	7	20
8	71	42	5	8	21

\* Average for leaves YEB to YEB + 4 on primary tiller

Table 23. SUMMARY AT HARVEST 3 : THE EFFECT OF BORON APPLICATIONS ON THE WEIGHTS (% MAXIMUM) OF BARLEY TOPS AND GRAIN, ON LODGING OF TILLERS (% TOTAL), AND ON THE LEAF AREA OF THE PRIMARY TILLER COVERED WITH BLACK SPOTS AND LESIONS.

Boron Applied (ppm)	Tops Weight (% max.)	Grain Weight (% max.)	Tillers Lodged (% total)	* Leaf Area Black (%)
0	100	100	0	2
0.5	93	88	0	6
1	94	96	4	8
2	86	86	23	17
4	81	83	70	39
8	75	64	92	45

\* Is the percentage of the area of the YEB to YEB + 4 on the primary tiller covered with black spots and lesions.

Results indicate

Increased applications of Boron resulted in increased spotting and necrosis of barley (cv. Stirling) leaves. These symptoms due to Boron excess were markedly expressed before plant growth was reduced. Further plant uptake of Boron progressively increased the severity of symptoms, the rate of leaf senescence, and the lodging of tillers, and reduced grain yield. Root growth was markedly more reduced than shoot growth.

Upon completion of chemical analyses, critical levels in plant tissues where Boron is toxic to plant growth will be established.

#### APPENDIX A

The Cartwright rating system for Boron toxicity in barley just prior to anthesis :

- 0 - No symptoms.
- 1 - Tips of oldest leaves necrotic, but youngest leaves completely unaffected.
- 2 - Small brown lesions occur on oldest leaves.
- 3 - Brown lesions with yellow haloes more numerous, and most fully expanded leaves affected.
- 4 - Many dead leaves, and approximately half the expanded leaf area chlorotic in some degree, and with necrotic blotches formed from coalesced lesions.
- 5 - Blotches and lesions widespread on stems, leaves and awns.

#### APPENDIX B

A rating system, adapted from Kluge and Podlesak (1985), for Boron toxicity in individual leaves of barley :

- 1 - No visual damage.
- 2 - Dirty white necrosis of leaf tip.
- 3 - Dirty white necrosis and brown spot necrosis of leaf tip.
- 5 - Brown point and area necrosis, mainly on the leaf margin of upper 1/3 of leaf, with approximately 1 cm of leaf tip necrotic.
- 7 - Brown point and area necrosis of about 2/3 of leaf area with only the leaf base free. About top 1/3 of leaf is dirty white necrotic.
- 9 - Strongly developed brown point and area necrosis of whole leaf. About 1/2 of leaf area from tip downwards is dirty white necrotic.
- 10 - Strongly developed brown point and area necrosis of whole leaf. Whole leaf to base is dirty white necrotic.