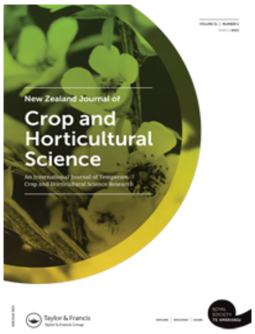

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Effect of boron application on seed production of New Zealand herbage legumes

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Abstract Six rates of boron (B) were applied to 2 white clovers (*Trifolium repens* L.), alsike clover (*Trifolium hybridum* L.), 3 red clovers (*Trifolium pratense* L.), and lucerne (*Medicago sativa* L.) in the glasshouse on a soil which was known to be low in available B. None of the 7 cultivars produced seed without added B, and red clovers also did not produce seed at low B rates. Maximum seed yields and the amount of B required to produce them were higher for red clovers and lucerne than for white and alsike clovers. The increase in seed yield of lucerne from B application was due entirely to an increase in the number of flowers formed and setting seed. In contrast, increases in white clover seed yields were due entirely to increases in the number of seeds per flower. For red clovers, increases in both the number of flowers and seeds per flower contributed to increased seed yields. It is concluded that B application may be beneficial in areas such as Marlborough and Canterbury for commercial herbage legume seed crops.

Keywords boron; seed yields; herbage legumes; white clovers; red clovers; lucerne

INTRODUCTION

Seed yields of herbage legumes, particularly red clover and lucerne, are low and variable in New Zealand (Lynch 1967; Clifford & Anderson 1980). Much of the variation has been attributed to genetic and climatic factors, the latter having some effect on both plants and their pollinators (Doull 1967; Clifford & Anderson 1980). Research has been concentrated on management practices to improve yields within these constraints, but one condition that has been overlooked is the need for adequate boron (B).

Large responses to B in seed yield have been reported on soils low in available B from North America and Europe for lucerne (Grizzard & Matthews 1942; Piland et al. 1944), white clover (Johnson & Wear 1967; Spooner & Huneycutt 1978), alsike clover (Montgomery 1951), and red clover (Agerberg & Roots 1962 quoted by Eriksson 1979). In this country, there has been only one report of work investigating the effect of B on legume seed production (Cullen 1968), but B had no effect probably because there was sufficient B in the soil to supply the crop's requirement.

The objective of this work was to determine whether seed production of New Zealand herbage legumes could be increased by B application.

MATERIALS AND METHODS

Soil

The soil used was a subsoil (15–30 cm) of Taupo sandy silt, a yellow-brown pumice soil (New Zealand Soil Bureau 1968) with pH 5.8 and 0.28 ppm hot water soluble B. Response to B in dry matter yield of white and red clovers and lucerne has been obtained in pots with this soil (Sherrell 1983a).

Trial procedure

Separate experiments with 'Grasslands Huia' and 'Grasslands Pitau' white clovers, alsike clover, 'Grasslands Hamua', 'Grasslands Turoa' and 'Grasslands Pawera' red clovers, and lucerne cv. Wairau were conducted in the glasshouse from September to March.

The soil, after sieving through a 6 mm screen, was placed in pots containing 1400 g oven dry soil as described previously (Sherrell & Saunders 1974). Basal solutions containing nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), sulphur (S), copper (Cu), zinc (Zn), and molybdenum (Mo) were applied to the surface and watered in. B treatments of 0 (B_1), 0.25 (B_2), 0.50 (B_3), 1.0 (B_4), 2.0 (B_5), and 4.0 (B_6) ppm (oven dry soil basis) were applied in borax solutions. These rates are equivalent to 0, 0.23, 0.46, 0.91, 1.8, and 3.6 kg B/ha. Each treatment was replicated 4 times.

Plants were thinned, when established, to 10 and 8 per pot for clovers and lucerne respectively. N was applied weekly at 35 mg N/pot in weeks 2–5 from planting and then at 70 mg N/pot. This treatment was applied as a precautionary measure against nodulation failure and to provide sufficient nitrogen to maintain the high rate of growth necessary for the expression

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Table 1 Effect of boron application on dry matter yield (g/pot) of herbage legumes at the preliminary cut.

Rate of B (ppm)	Huia	Pitau	Alsike	Hamua	Turoa	Pawera	Lucerne
	white clovers		clover		red clovers		cv. Wairau
0 (B_1)	10.9	10.7	14.0	14.9	12.8	14.5	9.8
0.25 (B_2)	11.4	10.6	13.4	13.1	13.0	13.8	11.7
0.50 (B_3)	10.8	10.3	12.8	13.3	12.6	14.0	11.0
1.0 (B_4)	9.4	10.4	13.3	13.7	12.3	14.5	11.3
2.0 (B_5)	9.4	10.5	12.6	13.3	12.3	14.6	10.1
4.0 (B_6)	7.2	7.1	10.4	12.8	8.7	13.3	11.4
LSD (5%)	1.7	1.5	2.0	2.4	1.6	1.4	7.1

of B deficiency. A preliminary cut was made when plants were making rapid vegetative growth at 10 or 11 weeks from planting, and dry matter yields were determined. After this cut, basal P, K, and Mg were reapplied. Plants were then grown to maturity with weekly additions (5) of N (70 mg/pot) until maximum vegetative growth was attained.

When plants were flowering fully, the clover cultivars were moved into a shade house and placed adjacent to a hive of honeybees (*Apis mellifera*). Lucerne was moved to a small semi-sealed glasshouse in which alfalfa leafcutter bees (*Megachile rotundata*) were released. After pollination, all cultivars were returned to the glasshouse and allowed to set seed.

Flowers on each pot were counted and were harvested when fully ripe, the harvesting period being spread over 4–6 weeks. When harvesting was complete, seed was rubbed out by hand and the weight and number of seed were determined. The weight of 100 seeds, and the number and weight of seeds per flower were calculated.

Statistical analysis

Some data were analysed after square root transformation. In these cases, the LSD is an approximate back-transformed value but all reported means are actual observed means. In cases where some treatments gave nil yields, the available data were analysed to determine differences between the other treatments.

RESULTS AND DISCUSSION

Growth and dry matter yield of preliminary cut

Visual B deficiency symptoms began to appear on B_1 treatments of all cultivars except alsike clover just before the plants were harvested, but B did not increase dry matter yield (Table 1). After the preliminary cut, B deficiency symptoms developed and vegetative growth was less at low rates of B on all cultivars. Symptoms appeared only at B_1 on alsike clover. For other cultivars, symptoms appeared on treatments up to B_3 but were more severe on B_1 and B_2.

This response pattern is consistent with previous work with this soil, in which there was also no response in dry matter yield of white and red clovers and lucerne in the first cut but there was in subsequent cuts (Sherrell 1983a). Although the soil was low in available B, there was sufficient for maximum growth of one cut.

B toxicity symptoms (white halo around leaf edges) appeared on B_6 treatment for all clover cultivars, but not lucerne, 2–3 weeks from planting. Symptoms were less severe on Hamua and Pawera red clovers and they lessened as growth progressed on these 2 cultivars. Symptoms persisted on white and alsike clovers and Turoa red clover, and there was a noticeable reduction in vegetative growth. Dry matter yields of these 4 cultivars were reduced at the preliminary cut, and the reduction in vegetative growth was observed to continue into the seed producing period, but was not measured because much of the vegetative material had died before seed was collected. The highest rate of B, when applied to the seed bed, was obviously detrimental to plant vigour although Hamua, Pawera, and lucerne appeared to show greater tolerance than the other cultivars.

Seed production

Seed yields of all cultivars were increased by B (Table 2). There was no significant seed yield from any of the cultivars without applied B, and red clovers also did not produce seed at B_2 and B_3. Maximum seed yields were obtained at B_4 for white and alsike clovers, but at B_5 and B_6 for red clovers and lucerne, i.e., at rates where no deficiency symptoms had occurred in the vegetative growth.

These effects indicate that red clovers and lucerne have similar B requirements for seed production, are more sensitive to low available B, and are more responsive than white clovers. These requirements are similar to the relative B requirements of the 3 species for vegetative growth (Sherrell 1983a). Alsike clover was the least sensitive of the cultivars tested.

There was a reduction in seed yield of some cultivars at B_6. It was in these same cultivars that dry matter yield reduction occurred in the preliminary cut, so it

Table 2 Effect of boron application on seed production of herbage legumes.

Rate of B (ppm)	Huia white clovers	Pitau white clovers	Alsike clover	Hamua red clovers	Turoa red clovers	Pawera red clovers	Lucerne cv. Wairau
			Total weight of seed (mg)				
0 (B_1)	0[1]	0	0	0	0	0	0
0.25 (B_2)	85	0[1]	217	0	0	0	98
0.50 (B_3)	388	285	252	280	0	0	213
1.0 (B_4)	830	466	490	1260	430	39	638
2.0 (B_5)	716	365	411	3680	1190	170	1640
4.0 (B_6)	498	330	209	4250	740	188	1710
LSD (5%)	282	289	268	1010	436	70	564
			Total number of seeds				
0 (B_1)	12[1]	0	0	0	0	0	0
0.25 (B_2)	154	28[1]	281	0	0	0	59
0.50 (B_3)	697	586	317	150	0	0	102
1.0 (B_4)	1370	1010	600	680	240	16	340
2.0 (B_5)	1390	769	483	1990	650	59	844
4.0 (B_6)	968	667	266	2340	411	62	938
LSD (5%)	471	232	322	597	254	26	297
			Weight/100 seeds (mg)				
0 (B_1)	57.5	-	-	-	-	-	-
0.25 (B_2)	58.0	60.3	78.5	-	-	-	168
0.50 (B_3)	53.5	51.5	79.8	183	-	-	213
1.0 (B_4)	55.0	46.8	82.0	183	177	243	183
2.0 (B_5)	50.5	47.5	85.0	186	185	291	195
4.0 (B_6)	51.3	49.3	77.3	185	181	304	181
LSD (5%)	7.6	8.9	40.7	23	33	25	25

[1]The few seed produced had insignificant weight.

is probable that the reductions in seed yield were due to there being less plant material from which seed could be produced, rather than an adverse effect of this rate of B on seed production *per se*.

B effects on the number of seeds were identical to those on total weight, but B had no effect on seed weight (size) (Table 2). Analysis of the other components of yield indicated a marked difference between lucerne and clovers. The number of lucerne flowers formed per pot was increased by B in the same way as total seed yield, but the number and weight of seeds per flower were unaffected (Table 3). In contrast, the number of white clover flowers was not altered by increasing B rates, and increase in seed yield was due entirely to increase in the number and weight of seeds per flower. This is consistent with findings of Johnson & Wear (1967) for white clover.

B is involved in flowering and the reproductive process. It is necessary for germination and growth of pollen (Whittington 1957) and it increases nectar production (Smith & Johnson 1969; Eriksson 1979), which in turn results in a higher number of visits from pollinating insects. The contrast between lucerne and white clovers in this work suggests that the effect of B in increasing lucerne seed yield was due to its promotion of flowering but that in white clovers it was due to increased pollination.

Both the number of flowers and number of seeds per flower of red clovers were increased by B. Some flowers were formed at B_2 and B_3 but they did not set seed. There was a similar but slightly lower number of flowers formed on Pawera as on the other 2 red clovers, but there were very few seeds so lack of pollination was probably the reason for the much lower seed yield of Pawera. Clifford & Anderson (1980) observed that short-tongued bumble bees are necessary for successful pollination of Pawera, and that honey bees are ineffective. A few bumble bees were observed visiting red clover flowers in the current work, but these were insufficient to fully pollinate Pawera. Honey bees are effective pollinators of Hamua and Turoa.

The results reported here indicate clearly the importance of B in increasing seed yields of New Zealand herbage legumes on soil low in available B. B deficiency occurs in lucerne in Marlborough and Canterbury (During 1955; Sherrell 1983b) where much of the legume seed is produced. Hence, some of the soils in these areas are marginal for B for vegetative growth of lucerne. Since the B requirement for seed production is higher than for vegetative growth (Shorrocks 1974), seed crops will probably suffer from lack of B. In fact, there have been instances of response to B or the need for B in lucerne seed

Table 3 Effect of boron application on flower formation and seed setting of herbage legumes.

Rate of B (ppm)	Huia white clovers	Pitau white clovers	Alsike clover	Hamua red clovers	Turoa red clovers	Pawera red clovers	Lucerne cv. Wairau
			Number of flowers formed/pot				
0 (B_1)	5	4	0	0	0	0	0
0.25 (B_2)	19	22	19	10	6	9	9
0.50 (B_3)	22	27	12	40	13	15	22
1.0 (B_4)	25	13	19	52	37	18	48
2.0 (B_5)	19	25	15	49	37	22	103
4.0 (B_6)	17	17	15	56	34	19	103
LSD (5%)	12	14	18	14	15	6	29
			Number of seeds/flower harvested				
0 (B_1)	3	0	–	–	–	–	–
0.25 (B_2)	9	1	16	0	0	0	7
0.50 (B_3)	30	21	28	4	0	0	4
1.0 (B_4)	55	69	42	13	7	1	7
2.0 (B_5)	75	39	47	41	20	3	9
4.0 (B_6)	54	43	36	42	12	4	9
LSD (5%)	18	32	26	10	9	2	6
			Weight of seed/flower harvested (mg)				
0 (B_1)	–	–	–	–	–	–	–
0.25 (B_2)	5.2	–	12.2	–	–	–	11.1
0.50 (B_3)	16.3	10.4	22.4	6.7	–	–	9.0
1.0 (B_4)	33.2	32.4	33.3	24.0	11.4	2.3	11.8
2.0 (B_5)	38.5	18.7	39.0	75.7	36.4	7.7	16.0
4.0 (B_6)	27.4	21.2	28.0	76.4	21.8	9.9	16.3
LSD (5%)	8.1	15.2	19.7	17.7	14.5	3.4	10.6

production in these areas (Stephen pers. comm.; Cresswell 1980), but B is not used widely. The work reported here has shown also that red clovers and lucerne have the same B requirement for seed production, so red clovers should also benefit from B application where soil B is low.

In addition to the benefit for commercial seed production, B may be useful in extending the lifespan of legume species, especially red clovers which depend on reseeding for longevity. There could be some benefit also to pastures where white clover is not persistent.

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