BORON EFFECTS ON RED CLOVER SEED PRODUCTION AND QUALITY

N.P. Anderson, C.J. Garbacik, T.G. Chastain, and S. Elias

Introduction

Boron (B) is a critical micronutrient for many small-seeded legume crop species, including alfalfa and clovers grown for seed. Under mild to moderate B deficiency, legume growth and development may not be severely affected, but seed yield may be reduced (Mozafar, 1993). Boron is required for reproduction, and a deficiency adversely affects the formation of terminal growing points and flowering. When B is deficient, plants produce fewer flowers, and seed production may be inhibited due to inadequate pollination.

Red clover seed yields in western Oregon typically range from 500 to 1,200 lb/acre. Seed production is dependent on the formation of functional flowers, successful fertilization, and conditions suitable for seed development. Year-to-year yield variability is frequently attributed to annual differences in soil moisture availability and/or flower pollination.

Pollination studies showed that native western Oregon bumblebee species are abundant and play an important role in pollinating red clover flowers (Rao and Stephen, 2009). There is increasing evidence that illustrates the equally significant role that B plays in flower fertilization and increased seed yield in leguminous crops. Stigma receptivity and pollination are considered to be the processes most affected by B deficiency. Applications of B to clover have been reported to make flowers more attractive to pollinating insects by increasing nectar production and sugar content, thus improving flower fertilization (Eriksson, 1979). Subterranean clover research has indicated B concentration in plant tissue increased seed production more than did the presence of bees (Ben-Taamallah, 1987).

The total number of flowers produced by plants may also be increased by B fertilization. A foliar B application during early anthesis on alfalfa grown for seed increased seed yield 37% by increasing the number of pods produced. In addition, B applications significantly increased seed germination and seed vigor (Dordas, 2006).

Soils in western Oregon are commonly B deficient, containing less than 1 ppm B. Growers and crop advisors lack research-based agronomic information to assist in making management decisions regarding B fertilizer applications in red clover seed crops. The objectives of this two-year study were to (1) measure seed yield response to B application at different rates and timings and (2) determine the effect of B application on seed quality, including seed germination and seed vigor.

Materials and Methods

This study was initiated in the fall of 2011 at OSU's Hyslop Research Farm on a Woodburn silt loam soil with a pH of 6.2. The preplant soil test B level was 0.4 ppm across the trial, well below the recommended soil test level (1.0 ppm) for red clover seed production in western Oregon (Gardner et al., 2000). The experimental design was a randomized complete block with three replications. Individual plot size was 11 feet x 50 feet. Treatments applied in year 1 were repeated on the same plots in year 2. Soil samples from a 6-inch depth were collected from each individual plot prior to applying B treatments in year 2. In these samples, B levels ranged from 0.3 to 0.4 ppm across all treatments.

Grass and broadleaf weeds were managed with common herbicides registered for use on clover grown for seed in Oregon. In year 1, the trial was flail mowed in mid-May, and residue was left on the field. In year 2, the trial was flail mowed, and the residue was removed from the field. After regrowth, one insecticide application was made to all plots at bud emergence to manage aphids and other insect pests. Honeybee hives were placed near the study site after insecticide applications were complete.

Boron utilized for both foliage and soil application was a water-soluble sodium borate formulation (SprayBor®). Treatments were applied with a bicycle sprayer equipped with TeeJet XR 8003 nozzles at 20 psi applying a spray volume of 18.5 gpa.

Treatments evaluated in both years of the study included:

(1) Control (no B applied)
(2) 1 lb B/acre soil applied in the fall
(3) 2 lb B/acre soil applied in the fall
(4) 1 lb B/acre foliar applied at bud emergence in summer
(5) 1 lb B/acre soil applied in the fall plus 1 lb B/acre foliar applied at bud emergence in summer

Plots were sampled for total above-ground biomass and B tissue concentration at three timings: mid-June prior to foliar B applications, full bloom, and one to three days prior to swathing. Samples were taken from one-square-foot areas at three locations within each plot.

Seed was harvested with a small-plot swather (modified JD 2280) and a Hege 180 small-plot combine. Seed samples were then processed with a M2-B Clipper cleaner, and clean seed yield was determined. Seed weight was measured by counting two 1,000-seed subsamples from cleaned seed samples and determining the weight.

Seed quality analyses were conducted on clean seed samples from 2013 at the OSU seed lab. Seed viability was determined by standard germination tests. Seed vigor was ascertained by cold test and accelerated aging tests (AAT). Germination, hard seed, and viability percentages were recorded. All seed quality tests were conducted using the protocols of the Association of Official Seed Analysts (AOSA, 2012; AOSA, 2009).

Results and Discussion

Soil test analyses from both years indicate a B deficiency was present in the experimental red clover seed fields (data not shown). This deficiency could be corrected by application of B fertilizer. Boron fertilizer increased plant tissue B concentrations when applied to foliage in summer, while no increase in plant tissue B resulted from soil applications in the fall (Tables 1 and 2).

The observed increase in plant tissue B concentration from foliar applications in the summer did not influence seed yield, despite soil test results that suggested a B deficiency was present (Tables 1 and 2). In addition, no statistically significant differences in seed weight or percent cleanout were measured between B application

Table 1. Effect of rate and timing of B fertilizer treatment on seed yield and other characteristics of red clover seed crops in 2012.

B treatment[1]	Yield	Cleanout	Seed wt.	Jun 14 biomass[2]	Jul 14 biomass	Aug 14 biomass	Jun 14 tissue B	Jul 14 tissue B[2]	Aug 14 tissue B[2]
	(lb/a)	(%)	(mg)	---------- (g/ft^2) ----------			---------- (ppm) ----------		
Check	796	2.8	1.691	44.4 ab	153.1	121.0	27.8	22.6 a	23.7 a
Fall 1 lb/a	800	3.4	1.676	45.9 ab	134.3	114.3	29.0	19.3 a	22.8 a
Fall 2 lb/a	782	2.5	1.703	50.5 b	137.0	173.3	28.6	22.1 a	22.2 a
Summer 1 lb/a	725	2.9	1.751	39.7 a	159.0	150.5	27.7	37.4 b	37.0 b
Fall 1 lb/a + Summer 1 lb/a	797	3.4	1.717	51.6 b	145.9	131.2	27.4	52.6 c	37.7 b

[1]Summer applications were foliar applied at bud emergence. Fall applications were soil applied.
[2]Means followed by the same letter are not significantly different from each other at LSD (0.05).

Table 2. Effect of rate and timing of B fertilizer treatment on seed yield and other characteristics of red clover seed crops in 2013.

B treatment[1]	Yield	Cleanout	Seed wt.	Jun 14 biomass	Jul 14 biomass	Aug 14 biomass	Jun 14 tissue B	Jul 14 tissue B[2]	Aug 14 tissue B[3]
	(lb/a)	(%)	(mg)	---------- (g/ft^2) ----------			---------- (ppm) ----------		
Check	707	2.5	1.719	50.2	101.4	91.3	25.4	27.7 a	32.3 a
Fall 1 lb/a	661	2.6	1.783	59.7	102.4	97.6	26.0	24.7 a	25.9 a
Fall 2 lb/a	670	2.3	1.764	59.1	108.3	95.4	24.1	24.8 a	30.1 a
Summer 1 lb/a	636	2.5	1.744	58.4	107.2	94.3	24.7	65.3 b	35.2 ab
Fall 1 lb/a + Summer 1 lb/a	684	3.2	1.731	49.9	95.2	90.1	24.4	56.6 b	43.0 b

[1]Summer applications were foliar applied at bud emergence. Fall applications were soil applied.
[2]July 14 tissue B: Means followed by the same letter are not significantly different from each other at LSD (0.05).
[3]August 14 tissue B: Means followed by the same letter are not significantly different from each other at LSD (0.10).

Table 3. Effect of rate and timing of B fertilizer treatment on seed quality characteristics of red clover seed crops in 2013.[1]

	Germination test			Cold test			AAT
Treatment	Germ.	Hard seed	Total viable seed	Germ.	Hard seed	Total viable seed	Germ.
	(%)						
Check	69	26	95	75	20	95	48
Fall 1 lb/a	66	28	94	66	24	90	51
Fall 2 lb/a	70	24	94	74	17	91	54
Summer 1 lb/a	68	27	95	73	20	93	47
Fall 1 lb/a + Summer 1 lb/a	64	29	93	73	18	91	50

[1]No significant difference was found at LSD (0.05).

rates or application timing treatments. Some transient effects on total above-ground biomass were noted early in 2012, but these effects were not attributable to rate or timing of B fertilizer in either year.

There were no statistically significant differences among treatments in any of the seed quality analyses (Table 3). The B deficiency as determined by soil test analysis did not have any measurable effects on seed quality as measured by viability and vigor tests, and there were no seed quality responses of red clover seed to applied B fertilizers.

The results of this study suggest that red clover seed crops are not adversely affected by B soil test levels in the range of 0.3 to 0.4 ppm as previously thought and that the 1.0 ppm level for taking action to correct a B deficiency may need to be revised. Future work is warranted to better define the soil test level for B deficiency in red clover, as the seed crop was not sensitive to soil test levels as low as 0.3 ppm in the two years of this study. Results indicate that present recommendations for B fertilizer applications may not be economically beneficial in increasing red clover seed yield or improving seed quality in western Oregon.

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