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MONTANA FERTILIZER eFACTS

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Lentil Yield and Nitrogen Fixation Response to Inoculant and Fertilizer

Kaleb Baber[1], Sydney Atencio[2], Perry Miller[1], Clain Jones[1], Chengci Chen[1], Bill Franck[1], Simon Fordyce[1], Patrick Carr[1], Peggy Lamb[1], Michael Ostlie[3], John Rickertsen[3], Maryse Bourgault[4], and Samuel Koeshall[1]

[1]Montana State University; [2]Willow Innovations, Inc.; [3]North Dakota State University; [4]University of Saskatchewan

INTRODUCTION

Lentil production has grown dramatically in the northern Great Plains over the past 20 years. In Montana and North Dakota, planted acreage of lentil has increased from 67,000 in 2000 to 585,000 in 2022 (USDA-NASS, 2022). Interestingly, only limited research has been conducted on effects of inoculation and fertility management practices on lentil production in the region. Lentil is capable of biological nitrogen (N) fixation, a process in which rhizobia bacteria in legume root nodules convert N gas into N that is available for plant uptake. This makes lentil an attractive option for producers wanting to decrease fertilizer N inputs in their operations. However, little is known about the effects of starter fertilizer or inoculant on lentil N fixation or yield. The objectives of this study were to (1) quantify lentil yield and N fixation responses to rhizobial inoculation with granular vs peat powder, seed-coat inoculant formulation, and (2) determine if potassium (K), sulfur (S), or foliar-applied micronutrients enhance lentil yield and N fixation.

METHODS

We conducted lentil yield field trials at four sites in Montana (Bozeman, Havre, Moccasin, Sidney) and three sites in North Dakota (Carrington, Hettinger, Minot) from 2019 through 2021 for a total of 20 site years (Carrington was abandoned in 2020 due to poor emergence). The amount of N fixed by lentil was measured at two of the Montana sites (Bozeman, Havre) using the ^{15}N natural abundance method (Shearer and Kohl 1986), with flax serving as the non-N fixing reference crop. Nitrogen fixation data are not reported for Havre in 2020 due to

Table 1. Inoculant type and fertilizer sources for lentil fertility treatments.

Treatment	Fertilizer Grade
Control	--
Granular	--
Peat powder	--
Granular+K	0-0-60
Peat powder+K	0-0-60
Granular+K+S	0-0-50-17
Peat powder+K+S	0-0-50-17
Granular+K+S+Micros	0-0-50-17 + *Micro1000*[a]

[a]AgroLiquid (St. John, MI), applied at 1 qt/acre near first flower for < 0.025 lb/acre each of B, Ca, Co, Cu, Fe, Mg, Mn, Mo, Ni and Zn

Table 2. Range of pre-plant soil characteristics from 2019 to 2021 by site. All characteristics were measured in the top 6 inches except for nitrate-N, which was measured to 3 feet.

Site	Organic Matter (%)	pH	Nitrate-N (lb/acre)	Olsen P (ppm)	Exchangeable K (ppm)	Sulfate-S (ppm)
Bozeman	2.5 – 2.8	7.0 – 7.9	16 – 54	9 – 19	334 – 414	2.1 – 2.6
Havre	1.2 – 2.4	6.5 – 8.3	40 – 233	11 – 31	308 – 390	2.7 – 17.8
Moccasin	3.5 – 4.2	7.2 – 7.6	15 – 50	11 – 30	243 – 320	2.4 – 10.5
Sidney	2.3 – 2.5	6.8 – 7.3	10 – 49	16 – 23	214 – 242	3.9 – 4.1
Carrington	3.2 – 3.8	7.6 – 7.7	26 – 54	9 – 10	132 – 155	5.6 – 5.8
Hettinger	2.5 – 3.1	5.7 – 6.4	37 – 108	19 – 28	407 – 470	4.2 – 6.9
Minot	2.6 – 3.3	6.1 – 6.7	11 – 61	11 – 17	257 – 616	1.6 – 131

high and variable soil nitrate-N levels that lowered confidence in the results. Each trial consisted of eight treatments of different inoculant (granular and seed-coat peat powder) and fertilizer (12.5 lb K_2O/acre, 5 lb S/acre, and micronutrients) combinations (Table 1). Potash was used in the K only treatments. Potassium sulfate rather than ammonium sulfate fertilizer was used in all K+S treatments because the N in ammonium sulfate could confound the N-fixing ability of the inoculants in those treatments. Both S sources are expected to produce similar crop responses.

Avondale lentil, a medium green variety, was seeded into no-till crop stubble following wheat or barley each year. Field soils were sampled in spring and measured for soil organic matter, pH, nitrate-N, Olsen P, exchangeable K, and sulfate-S (Table 2). At Bozeman and Havre, aboveground lentil and flax biomass were sampled when lentil was at early to late pod-fill to determine the amount of N fixed. In 2020 at Bozeman, S concentrations of aboveground lentil biomass from the +K and +K+S treatments were measured. Lentil seed was harvested with a combine and yield determined at 12% moisture. Additional methods are in Miller et al (2022) and Baber et al (2022).

Table 3. Frequency of treatment effects on yield among 20 site-years and mean lentil yield response (lb/acre) for each comparison. (Ctrl = Control, Inoc = Inoculated, Gran = Granular, PP = Peat powder)

	Ctrl < Inoc	Ctrl = Inoc	Ctrl > Inoc
Frequency	6	14	0
Control	1531	1538	--
Inoculant	1875	1571	--
	Gran < PP	**Gran = PP**	**Gran > PP**
Frequency	2	15	3
Granular	1619	1547	2261
Peat powder	1726	1552	1821
	K < No K	**K = No K**	**K > No K**
Frequency	1	18	1
K	2183	1648	1336
No K	2388	1645	1252
	S < No S	**S = No S**	**S > No S**
Frequency	0	16	4
S	--	1555	2266
No S	--	1569	2011

RESULTS

Yield

Inoculation increased lentil yield in 30% of site-years by an average of 344 lb/acre and did not decrease yield in any site-year (Table 3). Yield response to inoculation was not explained by whether a field had a lentil or pea crop in the last 10 years, meaning inoculation increased yield in some fields that had a lentil or pea crop history (Bozeman 2019, Moccasin 2020) and some that did not (Sidney 2019, Hettinger 2020, Havre 2021). Yield was different between inoculant types in 5 of 20 site-years. Peat powder inoculant produced higher yields than granular inoculant twice, by an average of 107 lb/acre, while granular inoculant resulted in higher yields than peat powder inoculant in three site-years, by an average of 440 lb/acre.

Potassium fertilizer increased yield in one site-year, decreased yield in one site-year, and had no impact in other site-years. Soil exchangeable K across site-years was occasionally below the critical level of 250 ppm, but when it was, there was no consistent response to K fertilizer. Sulfur fertilizer increased lentil yield in 4 of 20 site-years, by an average of 255 lb/acre , and did not reduce yield in any site-year. Yield response to S fertilizer was not correlated with soil sulfate-S levels. Soil sulfate-S was relatively low each year at Bozeman (< 5 ppm in top 6 inches), yet yields only increased with S fertilization in 2020. However, because of the several positive yield responses observed and the low cost of applying 5 lb S/acre, S fertilization is likely a good decision for many lentil producers. No effect was observed from micronutrient application.

Figure 1. Lentil at Bozeman in 2020 was noticeably greener with S (right) than without S (left).

Nitrogen Fixation

Inoculation increased N fixed by lentil in 40% of the site-years (Havre 2019 and 2021) by an average of 14 lb N/acre. The N fixation response was accompanied by a yield response in both years. Neither inoculant type nor K fertilizer influenced N fixed in any site-year. Sulfur fertilizer increased N fixed in one of five site-years (Bozeman, 2020) by 30 lb N/acre when soil sulfate-S was relatively low, there was moderate drought, and plants showed obvious symptoms of S deficiency (Figure 1). Notably, the amount of N fixed continued to increase up through the highest observed shoot S concentration, while N removed in seed plateaued around shoot S concentrations of 0.09% (Figure 2). This indicates that an S fertilizer application may be justified even when a seed yield response does not occur, since more N is contained in lentil residue and hence producers may be able to decrease N fertilizer the following year. Organic producers who rely more upon legume cover crops for their N fertility could especially benefit from increased N contained in crop residue.

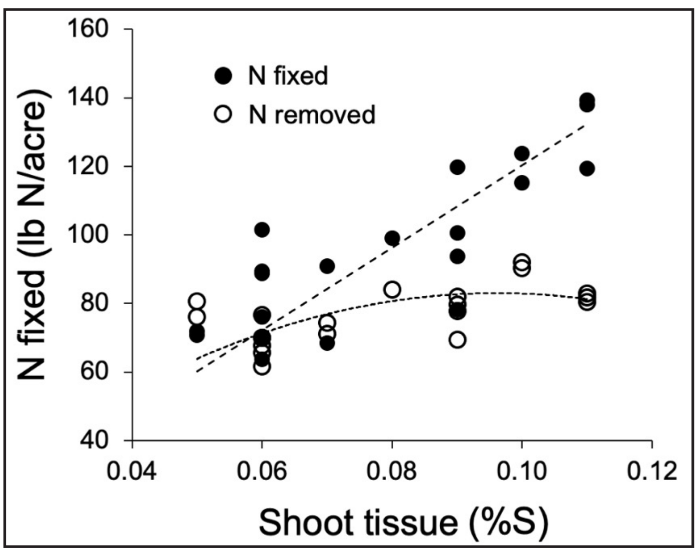

Figure 2. N fixed consistently increased with shoot tissue S concentration, while N removed by lentil grain plateaued near 0.09% S at Bozeman (2020). Lentil fertilized with S resulted in shoot tissue S concentrations above 0.08%, while unfertilized lentil tissue was always less than 0.08% S. The difference between N fixed and N removed is the net benefit of N to the soil from aboveground residue.

FERTILIZER FACTS

- Inoculation and S fertilizer are two practices that can increase lentil yield and N fixation.
- Lentil response to inoculation was not impacted by field lentil or pea crop history in this study, but other research suggests it can impact nodulation success. Inoculation is likely worth the cost since nodulation failure risks an insufficient N supply.
- Inoculant type did not affect amounts of N fixed, and neither granular nor peat powder inoculant consistently resulted in higher yields.
- Lentil response to S fertilizer was inconsistent and not explained by soil sulfate-S levels, but some positive responses to relatively inexpensive S applications likely make S fertilizer cost-effective for many producers. Strip trials with ammonium sulfate or gypsum can assess potential for benefit.

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