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Influence of nitrogen and sulfur application on camelina performance under dryland conditions

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ABSTRACT

There has been recent interest in camelina (*Camelina sativa* L.) because of its potential as a low-cost feedstock for biofuels and hence the need to optimize its production. We hypothesized that nutrient requirements under dryland environments with low and highly variable precipitation will depend on year and timely seeding. This study aimed at determining (a) the effects of nitrogen (N) and sulfur (S) application on the growth, yield, seed protein and oil content of spring-type camelina for the environmental conditions of northern Wyoming, USA, and (b) N and S requirement when camelina is seeded late. Four N levels (0, 28, 56, and 112 kg ha^{-1}) and two S levels (0 and 25 kg ha^{-1}) were studied. Sulfur had no significant effects on the measured responses. For trials established on May 13, 2013 and April 11, 2014, there was a general increase in plant height, seed yield, protein content, and protein yield with N application. Nitrogen application resulted in 31% seed yield increase but decreased oil content by 2.7% relative to the unfertilized control. As such, biodiesel that could be produced increased with N application. When seeded in May 24, 2014, N application caused a significant increase in the plant height, seed yield, harvest index and estimated biodiesel, but had no effect on the oil and protein content. The application of N showed a quadratic response to seed yield in all the trials. In general, applying N rate beyond 56 kg ha^{-1} did not result in significant increase in seed yield for trials established in May 13, 2013 and April 11, 2014, and 28 kg ha^{-1} for the trial established in May 24, 2014.

1. Introduction

Camelina (*Camelina sativa* L.) is an oilseed belonging to the family Brassicaceae. There has been recent interest in camelina because of its potential as a low-cost feedstock for biofuels and hence the need to optimize its production. According to Baligar et al. (2001), many agricultural soils of the world are deficient in one or more of the essential plant nutrients to support plant growth and thus inorganic sources of fertilizers have been used by producers to achieve desirable crop yields. Camelina, however, is reported to have low nutritional requirements for nitrogen (N), phosphorus (P), potassium (K), and sulfur (S), and is also able to produce moderate yields on poorer soils than most oilseed crops (Wojtkowiak et al., 2009).

Studies have reported different effects of N on camelina. Depending on the residual soil nutrients in Eastern Canada, Urbaniak et al. (2008) recommended optimum N application rate of 60 kg N ha^{-1} for Truro, Nova Scotia and 80 kg ha^{-1} for Harrington, Prince Edward Island. Jiang et al. (2013) also reported optimum N rates of 120–160 kg ha^{-1} for the Maritime Provinces of Eastern Canada. In a multi-location camelina fertility trial at Oregon, applying N rates beyond 17 kg ha^{-1} at Pendleton, 90 kg ha^{-1} at Moscow/Pullman, and 45 kg ha^{-1} at Corvallis did not result in any significant increase in the seed yield (Wysocki et al., 2013). The authors reported no response of camelina to N application at Lind, OR. Average annual rainfall at Lind (242 mm) and Pendleton

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Table 1
Pre-seeding soil characteristics at the experimental site, Wyarno, Sheridan, WY.

Studies	pH	Organic matter %	Soluble salts mmhos cm^{-1}	CEC mg 100 g^{-1}	NO_3 kg ha^{-1}	P mg kg^{-1}	K	SO_4^{2-}	Ca	Mg	Na	Fe	Mn	Zn	Cu
May 2013	7.2	2.2	1.26	25.8	5.0	14.0	272	5.0	2985	1203	22.8	20.9	17.9	0.38	1.6
April, 2014	7.7	2.2	0.79	21.7	5.6	18.3	299	2.5	3590	351	16.0	14.2	1.6	0.38	0.6
May 2014	7.1	2.4	0.72	24.7	4.7	19.0	286	4.6	2588	1109	13.4	11.2	2.1	0.42	0.8

Soil was sampled from 0–15 cm depth and soil fertility analysis performed using standard procedures.

(444 mm) compares well with that in northern Wyoming, suggesting that camelina N requirement might be considerably low for dryer environments. However, the response of camelina to low N rates in the above study may be due to higher pre-plant soil N test levels at the experimental site. For instance, soil test N content averaged 70 kg N ha^{-1} at Lind, 102 kg N ha^{-1} at Pendleton, 76 kg N ha^{-1} at Moscow/Pullman, and 71 kg N ha^{-1} at Corvallis (Wysocki et al., 2013). In a controlled environment study, Pan et al. (2011) observed optimum N rates of 100 kg ha^{-1} under low water availability (−0.065–−0.130 MPa of soil water potential) and 150 kg ha^{-1} when the soil was maintained at field capacity throughout the study.

Sulfur (S) is also an essential plant nutrient but it is required in relatively smaller amounts compared to N. Its limitations can result in decreased seed yields and quality. According to Rausch and Wachter (2005), sufficient S nutrition is vital for plant health and resistance to pathogens. Sulfur deficiency can inhibit plants use of N efficiently and vice versa. In addition, high N can create S deficiency which can reduce yield because N increases the utilization of S in most crops (Jamal et al., 2010). Elemental S is a common source of S fertilizer used in crop production. When applied, elemental S needs to be oxidized to sulfate (SO_4^{2-}) which is the primary available source of S to plants (Chapman, 1989; Germida and Janzen 1993; Nevell and Wainwright, 1987). There are conflicting reports on camelina response to S application. Whereas Jiang et al. (2013) found significant N and S interaction effects on camelina seed yield, protein content, protein yield, oil content, monounsaturated fatty acid (MUFA), and polyunsaturated fatty acid (PUFA), Solis et al. (2013) found no effects of S on camelina. Solis et al. (2013) compared 0 and 40 kg S ha^{-1} which was higher than the S rates (0 and 25) studied by Jiang et al. (2013).

The discrepancy in camelina response to N and S from the above studies demonstrates the need to determine site specific N and S requirements for camelina production. The amount of rainfall in northern Wyoming is low and its distribution is very variable. Average annual rainfall amount for the past 30 years ranges from 217 to 513 mm and majority of the rain was received from April through July (NOAA-NCDC, 2014). Studies conducted at Wyarno, near Sheridan, WY showed that moisture use of camelina increased with early seeding and translates into greater yields compared to late seeding (Sintim et al., 2014 unpublished results). In northern Wyoming and similar environments in the Great Plains, early seeding can be delayed because of low temperatures and wet field conditions. Since nutrient uptake and assimilation by crops are dependent on moisture availability (Pan et al., 2011), we hypothesized that nutrient requirements under dryland environments with low and highly variable precipitation will depend on year and timely seeding. The objectives of this study were to determine (a) the effects of N and S application on the growth, yield, seed protein and oil content of spring-type camelina for the environmental conditions of northern Wyoming, USA, and (b) N and S requirement when camelina is seeded late.

2. Materials and methods

2.1. Experimental site

A field experiment was conducted at the University of Wyoming's Sheridan Research & Extension Center (ShREC), at the Wyarno site, near Sheridan, WY (44°48'48"N, 106°46'26", 1154 m above sea level) in 2013 and in 2014 growing seasons. The soil at the experimental site was a Wyarno series (fine, smectitic, mesic Ustic Haplargids), characterized as very deep well drained, 0–6% slope, clay loam (31% sand, 36% silt, and 33% clay) (USDA-NRCS, 2007). The initial soil characteristics are given in Table 1. Soil samples were collected from top 0 to 15 cm of the soil profile; air dried and sieved through 2 mm sieves. The processed samples were shipped to the Olsen Agricultural Laboratory, McCook, NE for soil fertility analysis. Briefly, soil pH and soluble salts were analyzed using 1:1 saturated paste soil extract methods described by Watson and Brown (1998) and Whitney (1998a), respectively; Nitrate–N was determined after extracting the soil in 2 M KCL (Gelderman and Beegle, 1998); sodium bicarbonate method for P (Frank et al., 1998); Mehlich 3 extractant procedure for K, calcium (Ca), magnesium (Mg), and sodium (Na) (Warncke and Brown, 1998); monocalcium phosphate extraction procedure described by Combs et al. (1998) for SO_4^{2-}; diethylenetriaminepentaacetic acid extraction method for zinc (Zn), iron (Fe), manganese (Mn), and cupper (Cu) (Whitney, 1998b); and boron was determined using the hot-water extractable boron procedure described by Watson (1998).

The average rainfall distribution during the two years of the experiment deviated slightly from normal (30-year average; Table 2). Total rainfall in April, May and July was greater in 2013 than in 2014, and vice versa for June and August. In general, total rainfall during the summer months (June to August) in both years were slightly higher than normal. Mean temperature and total growing degree days in 2013 and 2014 compared well to normal year except for August where they differed slightly (Table 2).

Table 2
Total monthly rainfall, mean temperature, and growing degree days in April through August at Wyarno, Sheridan, WY in 2013 and 2014.

Month	Total rainfall (mm)			Mean temperature (°C)			Total growing degree days[a]		
	2013	2014	Normal[b]	2013	2014	Normal[b]	2013	2014	Normal[b]
April	51.9	22.6	33.3	−0.70	5.9	6.30	113	175	182
May	90.8	58.6	65.5	10.2	11.7	11.5	455	431	407
June	84.9	99.9	62.2	17.0	16.0	16.8	680	583	678
July	25.6	9.60	30.4	22.6	21.1	21.5	997	946	957
August	3.2	14.5	16.7	22.7	20.0	20.4	1012	862	906

[a] Growing degree days were estimated using 5 °C base temperature.
[b] Normal refers to 30-year average.