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Camelina: Seed yield response to applied nitrogen and sulfur

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ABSTRACT

Camelina (*Camelina sativa* L. Crantz) has received worldwide attention in recent years as a biofuel crop and as a broadleaf option in cereal-based cropping systems. The objective of our 3-year study was to determine camelina seed yield and nitrogen use efficiency (NUE) as affected by six applied nitrogen (N) rates at four rainfed sites in the Pacific Northwest (PNW) of the United States. An N + sulfur (S) variable was also included. Seed oil content as affected by applied N and S was also evaluated in 2010. The four sites and their average annual crop-year precipitation during the 3 years were Lind, WA (228 mm); Pendleton, OR (421 mm); Moscow/Pullman, ID (695 mm); and Corvallis, OR (1085). The majority of precipitation occurs in the winter and summers are comparatively dry. Camelina responded differently to applied N among sites based upon precipitation and available soil N. Seed yield did not respond to N rate treatments at Lind, presumably due to sufficient soil residual N and limited precipitation. Seed yield increased with applied N at Pendleton, Moscow/Pullman, and Corvallis. Optimum applied N rates ranged from 0 to 90 kg ha^{-1} depending on annual precipitation and soil available N. Maximum seed yield increases attributable to applied N ranged from 19% at Pendleton to 93% at Moscow/Pullman. Camelina NUE was greatest at Moscow/Pullman although it decreased gradually with increasing applied N rates at all sites. Lind, Pendleton, and Corvallis had the same decrease in NUE of -0.06 kg seed for each additional kg of available N. Camelina did not respond to applied S at any site. Seed oil content was not affected by applied N or S. Based upon the results of this study, camelina requires about 12 kg N ha^{-1} per 100 kg of expected seed yield.

1. Introduction

There has been much recent interest in the oilseed camelina as a low greenhouse-gas-emission biofuel crop, and especially as a feedstock for jet aviation fuel (Shonnard et al., 2010). Camelina is an annual plant with small seed (700,000 seed kg^{-1}) that has been cultivated in Europe for centuries. Camelina has a short growing season, requiring only 85–100 days from emergence to maturity when planted in the spring. Plants grow from seedlings to rosettes to mature plants reaching 0.5–1.0 m in height. Leaves are 50–75 mm in length, arrow-shaped and pointed with smooth edges. Stems are branched and bear seedpods 5–6 mm in diameter. The growth stages of camelina have been described in detail by Martinelli and Galasso (2011). Seed contains 32–43% oil that is an excellent feedstock for biodiesel, aviation fuel, or other liquid fuel (Moser, 2010). Camelina is a good potential fit for rainfed crop rotations of the PNW because it is more drought tolerant, less susceptible to freezing in the seedling stage, and has fewer insect pests compared to rapeseed (*Brassica napus*) or pulse crops (Henderson et al., 2004). Camelina has potential as a broadleaf crop option over the large cereal-based cropping region of the inland PNW. A desirable feature of camelina is the ability to be sown on frozen soil (frost seeding) with limited or no tillage (Robinson, 1987; Putnam et al., 1993).

Camelina has several unique agronomic features, including adaptability to marginal soils, short growth cycle and, if compared to rapeseed, a greater resistance of siliques to dehiscence. Gesch and Cermak (2011) found camelina to be a viable winter-sown crop in the northern corn belt of the USA. Camelina is productive under a wide range of plant stands (McVay and Khan, 2011). In addition, camelina is resistant to diseases such leaf spot (*Alternaria brassicae*) (Browne et al., 1991; Sharma et al., 2002) and insect pests (Henderson et al., 2004). Together these characteristics highlight the agronomic potential of this species and serve in promoting camelina as a suitable candidate for sustainable cropping systems.

Camelina was grown on a limited basis in the northern Great Plains of the USA in recent years with 8100 ha planted in 2010 (NASS, 2012). Camelina production has been limited but increasing

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in the PNW. Research-based information is lacking to provide basic agronomic recommendations for this crop. Schillinger et al. (2012) demonstrated that seed yield response of camelina to planting date varied across four diverse sites in the PNW. Recommended N and S application rates for camelina production in the PNW are unknown because of the lack of previous studies and the varied crop production environments in the region, although a few such studies have been conducted elsewhere in the USA (Putnam et al., 1993; McVay and Lamb, 2008; Jackson, 2008). Based on limited research in Montana, McVay and Lamb (2008) suggested that N management for camelina should follow recommendations for canola (*B. napus* L.). Recommendations for canola in the PNW are predicated on the expected yield of the crop, N requirement, soil available N, and cropping history (Wysocki et al., 2007a). Following N, sulfur is the most limiting element in the PNW and oilseed crops are known to have greater S requirements than cereals.

Rainfed cropping in the PNW can be divided into at least four distinct rainfed agricultural production zones that vary widely in precipitation, elevation, soil conditions and temperature (Douglas et al., 1990; Schillinger et al., 2006). In the PNW, camelina will most likely be grown following a cereal crop. It is anticipated that camelina can be grown to both diversify and intensify (less summer fallow) rainfed cereal-based cropping systems. To grow camelina successfully in the region will require crop performance information from a wide range of environments. The objective of our study was to assess the impact of N and S fertility on camelina seed yields across four diverse rainfed cropping zones of the PNW. Individually each site in this study is representative of from 0.2 to 1.5 million cultivated hectares. Information from this study on N and S fertility management for camelina has broad application in the PNW and other Mediterranean climates around the world.

2. Materials and methods

2.1. Locations

Nitrogen and S fertility studies were conducted during the 2008, 2009, and 2010 crop years at four sites. Lind, Pendleton, and Moscow/Pullman are located in the inland region east of the Cascade Mountains and Corvallis is located in the Willamette Valley of western Oregon (Fig. 1). Environmental conditions vary widely among the four locations. Soil type, average annual precipitation, elevation and growing degree-days (GDD) for all sites are shown in Table 1. Moscow/Pullman and Pullman represent the same cropping environment. In 2008 and 2009, the experiment was conducted near Moscow and in 2010 near Pullman, 14 km apart (Fig. 1), and have the same soil type.

Growing degree days (Table 1) are reported from January 1 to August 1 because camelina is a spring crop that will have matured by the end of July. Average long-term annual precipitation among sites ranges from 242 to 1085 mm, elevation ranges from 70 to 809 m, and GDD from 1109 to 1524. Of the three locations east of the Cascade Mountains, Moscow/Pullman is the coolest (fewest GDD) and receives the most precipitation. Precipitation is sufficient for continuous annual cropping (no fallow) and a common crop rotation is winter wheat (*Triticum aestivum* L.)-spring cereal-spring pulse. Lind is by far the driest of the four sites and has about the same cumulative GDD as Corvallis, though the seasonal distribution is different. Winter wheat-summer fallow is the customary crop rotation at Lind and is in a wide geographic area that receives less than 350 mm annual precipitation. Pendleton has the greatest GDD and receives 80% more annual precipitation than Lind. Crop rotation options at Pendleton are varied and include winter wheat-summer fallow, winter wheat-spring crop-summer fallow, and winter wheat-spring pea (*Pisum sativum* L.). Corvallis is at a low elevation in the Willamette Valley, receives high precipitation, and has a more moderate climate than sites east of the Cascades. Numerous annual and perennial crops are successfully and profitably produced at Corvallis. Grass seed is the major crop in the Willamette Valley with wheat as secondary crop in rainfed production. Vegetable and other high-value crops are also important where irrigation is available.

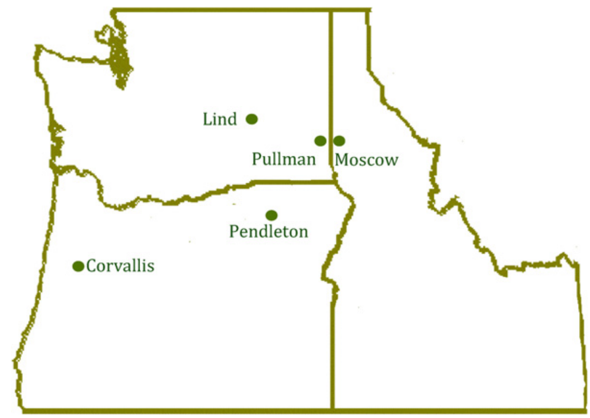

Fig. 1. Study site locations.

2.2. Overview of experiment

Annual precipitation at the four locations ranged from 174 to 1168 mm during the study period (Table 2). Nitrogen and S rates were evaluated based upon expected yield at each respective study site. Based on earlier work, yields were expected to range from 500 to 2200 kg ha^{-1} depending on annual precipitation (Guy and Lauver, 2007; Wysocki and Sirovatka, 2008). Treatments consisted of six incremental N rates with and without applied S (Table 3). Because of lower yield potential, S was applied at two N rates at Lind and at one N rate at Pendleton. Fertilizer rates were identical for

Table 1
Characteristics of study locations.

Location	Lat./Long./Elevation (m)	Soil classification	Average annual precipitation (mm)	Average GDD (5C base) January 1–August 1 1980–2010
Lind, WA	47°0′ 6.72″ N, 118°33′ 52.08″ W, 497	Shano silt loam (coarse-silty, mixed, superactive, mesic Xeric Haplocambids)	242	1428
Pendleton, OR	45°43′ 12.42″ N, 118°37′ 22.19″ W, 455	Walla Walla silt loam (coarse-silty, mixed, superactive, mesic Typic Haploxerolls)	444	1524
Moscow ID/Pullman WA	46°43′ 28.07″ N, 116°57′ 11.09″ W, 809	Palouse silt loam (fine-silty, mixed, superactive, mesic Pachic Ultic Haploxerolls)	695	1109
Corvallis, OR	44°37′ 30.26″ N, 123°12′ 54.39″ W, 70	Willamette silt loam (fine-silty, mixed, superactive, mesic Pachic Ultic Argixerolls)	1085	1424