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Enhanced efficiency nitrogen fertilizer effect on camelina production under conventional and conservation tillage practices

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ABSTRACT

Camelina (*Camelina sativa*) is a promising biofuel feedstock to fill the fallow period in dryland wheat (*Triticum aestivum*) –fallow cropping system of the U.S Northern Great Plains (NGP). Responses of camelina to tillage system (conventional tillage [CT] and no-till [NT]), nitrogen (N) rate (0, 45, 90 kg ha^{-1}), and nitrogen source (urea and an enhanced efficiency nitrogen fertilizer [EENF] containing urease and nitrification inhibitors) were evaluated in a 2-yr (2013–2014) field experiment in a dryland farming system of central Montana. Grain yield, biomass, oil content, and oil yield of camelina displayed significant first-order effects of tillage, N rate, and N source when averaged across each of the other factors, but interaction effects were not significant. Camelina tended to yield greater in CT than NT by about 26%. Application of EENF significantly increased grain yield when compared with U, which was more pronounced under CT. Dose response of camelina grain yield, biomass, and grain protein to N rate in the range of 0 to 90 kg ha^{-1} was linear, whereas N fertilization showed a detrimental effect on oil accumulation in seeds. Although oil content declined in response to N application, oil yield (kg ha^{-1}), which is the most important criterion in seedoil derived biofeedstock, positively responded to N application. Our results clearly demonstrated the need for further research to optimize management strategies for successful camelina production under NT system. Our results also indicated the potential of EENF in enhancing the yield of camelina, especially under CT system. Irrespective of tillage system and source of N, application of 90 kg N ha^{-1} (minus soil mineral N) led to the highest yield of camelina in this environment, but yield gain in response to N application greater than 45 kg ha^{-1} was very small.

1. Introduction

Camelina has shown considerable agronomic and ecological potential to replace fallow in the wheat-fallow predominant cropping system in the U.S. NGP (McVay and Lamb, 2008; Chen et al., 2015). Our previous studies have shown that due to relatively high production cost and low yield of the crop, replacing fallow with camelina is not yet economically feasible in the NGP (Chen et al., 2015). It was shown that for farmers to adopt camelina in their cropping systems, higher yield and/or lower production cost is essential (Chen et al., 2015).

In our previous economic analyses, we showed that N has the biggest share of production costs in camelina production when N was applied at a rate of 75 kg ha^{-1} (Chen et al., 2015). Moreover, analysis of on-farm energy flow revealed that optimization of N fertilization has the highest priority to enhance energy use efficiency and reduce the energy footprint of camelina in this environment (Keshavarz-Afshar et al., 2015a; Keshavarz-Afshar and Chen, 2015). Since, excessive N applications are undesirable, from both economic and environmental standpoints (Spargo et al., 2008), improving N fertilization strategy is paramount to agronomic viability as well as environmental health.

Nitrogen fertilization greatly interacts with soil management, including tillage, in different ways (Halvorson et al., 2006; López-Bellido and López-Bellido, 2001). Generally, the crop's response to N in a dryland system depends greatly on moisture availability (Angás et al., 2006). Since tillage affects soil moisture, it is expected to influence crop's response to N as well. Moreover, tillage affects N dynamics in the soil through altering soil structure and aeration (Karlen et al., 1998), as well as soil organic matter and crop

Abbreviations: EENF, enhanced efficiency nitrogen fertilizer containing urease and nitrification inhibitors; CT, conventional tillage; NT, no-tillage; N, nitrogen; NGP, U.S. Northern Great Plains; NUE, nitrogen use efficiency; U, urea fertilizer; SU, SuperU.

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residue mineralization (Wienhold et al., 1999). Thus, it is expected that the response of a crop to N fertilizer varies from conventional tillage (CT) to no-till (NT). Extensive research have focused on the response of major agronomic crops to N fertilizer under NT vs. CT (Camara et al., 2003; Kelley and Sweeney, 2005; Rieger et al., 2008), whereas limited information exists regarding the response of camelina to N fertilization under different tillage systems. Rieger et al. (2008) reported that wheat grain yield was lower under NT compared to CT, which was not altered by application of N fertilizer. Halvorson et al. (1999) conducted a 12-year study to determine winter wheat response to tillage system and N fertilizer rate in a dryland system of the NGP. They reported wheat grain yield was greater under NT (2022 kg ha^{-1}) than that under CT (1801 kg ha^{-1}) and increasing N rate from 34 kg N ha^{-1} to 67 kg N ha^{-1} increased grain production from 1844 to 1953 kg ha^{-1}. They pointed out that maintaining crop residue on the soil surface in NT system trapped winter snow, which contributed to a higher yield of wheat in NT than in CT. Similarly, a lower yield of durum wheat under reduced tillage has been reported when no N fertilizer was applied, whereas application of 50 to 100 kg N ha^{-1} alleviated the deleterious effect of reduced tillage on crop yield (De Giorgio et al., 2004). In some other studies, identical responses of crops to N fertilizer rate have been documented, regardless of the tillage method (Riley, 1998).

In addition to the rate of N, source of N also plays an important role in N management. Urea is the principal source of N fertilizer worldwide. Previous studies in Montana have shown that N loss through ammonia (NH_3) volatilization can exceed 40% when urea is broadcasted on the soil surface (Engel et al., 2011). It has been reported that EENF containing urease inhibitors and/or nitrification inhibitors, have potential to mitigate N loss, mostly through lowering NH_3 volatilization and N_2O emission (Thapa et al., 2015; Zaman et al., 2008). Nevertheless, discrepancies have been reported with respect to the influence of EENF on crop yields; some researchers reported yield advantages (Dawar et al., 2012; Abalos et al., 2014; Kyveryga and Blackmer, 2014), whereas others found no effects (McKenzie et al., 2010; Franzen et al., 2011; Sistani et al., 2011; Thapa et al., 2015). Since the potential of NH_3 volatilization in central Montana is abundant, the likelihood to obtain positive influence of EENF on crop yield is high, which requires more research to determine.

In the current study, we aimed to determine the N-dose response of camelina under CT and NT in a dryland farming system of central Montana. We hypothesized that the optimum N rate for wheat-camelina rotation would be affected by tillage system. We also examined if replacing urea with an EENF could enhance camelina grain yield and oil production.

2. Materials and methods

2.1. Experimental site

Field trials (2013–2014) were conducted at the Central Agricultural Research Center (47° 03′ N, 109° 57′W; 1400 m elevation) near Moccasin, Montana. Long-term average monthly air temperature and precipitation, which were recorded at the experimental site as well as the monthly precipitation and average temperature during the study are presented in Fig. 1. The typical frost-free period in this location is 110 d.

Soil at the site is classified as a Judith clay loam (fine –loamy, carbonatic, frigid Typic Calciustolls) and its water holding capacity is limited by gravel content and shallow soil profile. Selected soil characteristics are shown in Table 1.

2.2. Experimental details

The experiment consisted of two tillage systems (CT and NT), three rates of nitrogen (0, 45, 90 kg N ha^{-1}), and two sources

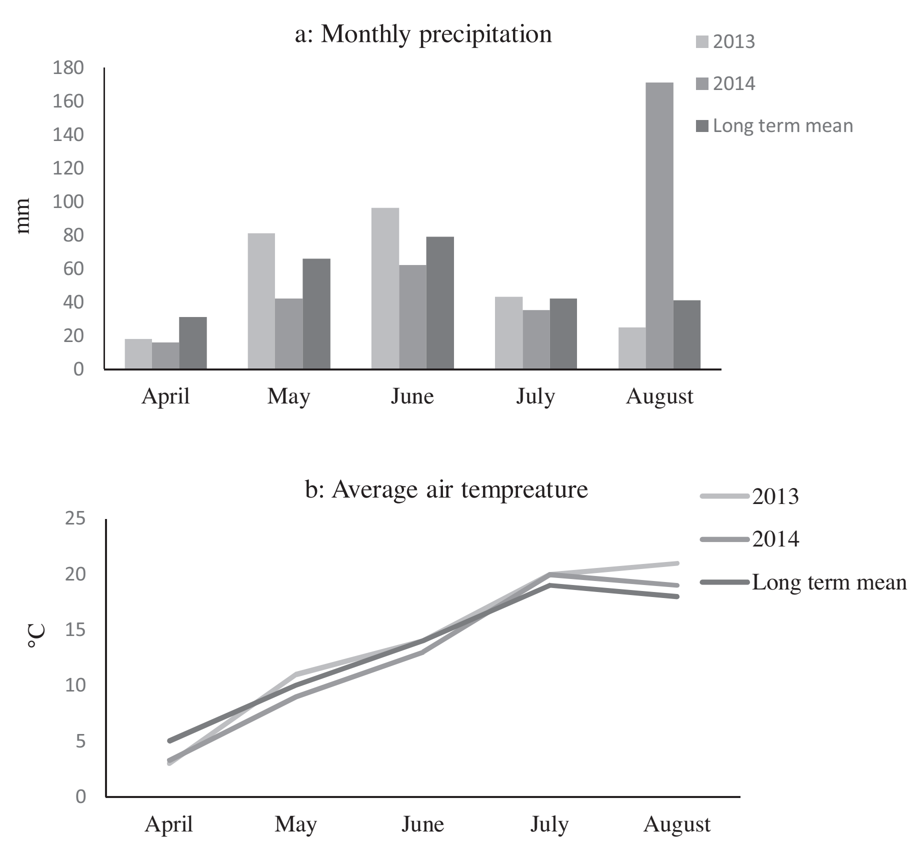

Fig. 1. Monthly precipitation (a) and average air temperature (b) along with their long-term averages in central Montana during the experiment.