AGRONOMIC EVALUATION OF CAMELINA GENOTYPES SELECTED FOR YIELD, OIL CONCENTRATION, AND NITROGEN USE EFFICIENCY

M. Etesami*, C. Chen**, W. Franck, S. Franck, and C. Lu
Eastern Agricultural Research Center, Montana State University, Sidney, MT
*Presenting author: maral.etesami@montana.edu.
**Corresponding author: cchen@montana.edu. (406) 433-2208

ABSTRACT

In recent years, camelina (*Camelina sativa* L.) has received global recognition for its role as a biofuel crop and multipurpose addition to cereal-based farming systems in the Northern Great Plains (NGP). The present study objected to investigative the differential responses of selected camelina varieties to nitrogen (N) and sulfur (S) inputs. Biomass, seed yield, seed oil concentration, and nitrogen use efficiency (NUE) of five varieties, variety 229, variety 35, variety 53, Suneson, and Check1, were investigated under five nitrogen (N) rates ranging from 33 to 168 kg ha^{-1} and two sulfur rates of 0 and 22 kg ha^{-1} in Sidney, Montana. Cultivars differed in stand count, plant height, biomass, yield, oil content, oil yield, and nitrogen uptake, and fertility treatment affected biomass, seed yield, oil concentration, and N uptake. Averaged over all N and S input levels, variety 229 had the highest and variety 35 had the lowest biomass yield, while Check1 had the highest and variety 35 had the lowest seed yield. Variety 229 also had the highest and variety 35 had the lowest oil concentration. Averaged over the cultivars, increasing the N rate resulted in increased camelina biomass and seed yield but decreased oil concentration. Contrast analysis showed inconsistent S effects at varying N rates. Based on the N response regression curves, the optimum N rate for the maximal seed yield was determined as 125 kg N ha^{-1} for variety 229 with 1894 kg ha^{-1} yield, 286 kg N ha^{-1} for variety 35 with 1470 kg ha^{-1} yield, 141 kg N ha^{-1} for variety 53 with 1957 kg ha^{-1} yield, 158 kg N ha^{-1} for Suneson with 1977 kg ha^{-1} yield, and 132 kg N ha^{-1} for Check1 with 2137 kg ha^{-1} yield. The NUE at the optimum N rate was 15.2, 5.1, 13.9, 12.5, and 16.2 kg seed per kg N for varieties 229, 35, 53, Suneson, and Check1, respectively. Results demonstrated that variety 229 and Check1 are the two superior cultivars with high yield, low optimal N input rate, and high NUE.

INTRODUCTION

Camelina has been successfully integrated into the cropping system in the northern Great Plains (NGP) of the United States bringing advantages of yield stability, further diversification, economic profitability, and correspondingly proceeding energy initiatives (Milliken et al., 2007). While it is regarded as a low-input crop, camelina responds significantly to nitrogen fertilizers, with a comparatively lesser impact from phosphorus and sulfur, as indicated by Solis et al. (2013). Application of 60 kg ha^{-1} N (Mohammad et al, 2016), 90–100 kg N ha^{-1} applied plus soil N (McVay and Lamb, 2008), and 90 kg ha^{-1} (Afshar et al., 2016) were reported for camelina grown in Montana to perceive the maximum grain yield and oil composition. Subsequently, sulfur fertilization is justified when nitrogen is supplied optimally (Mohammad et al, 2016). Kumari et al

(2015) recommended the application of 40 N kg ha^{-1} and 20 S kg ha^{-1} resulting in the highest grain yield and oil content. Apparently, the performance of camelina is shaped by a combination of genetic characteristics, ecological conditions, and agronomic practices, including fertilization (Jiang et al., 2014). The objective of the current study was to evaluate the differential responses of camelina genotypes to nitrogen and sulfur inputs and determine the optimum N input level and N use efficiency (NUE) of selected camelina varieties in Montana.

MATERIALS AND METHODS

Five camelina cultivars including Check 1, Suneson, variety 229, variety 53, and variety 35, were evaluated at the Eastern Agricultural Research Center Sidney, MT (47◦43′32″ N, 104◦9′5″ W) in 2023 under five incremental N rates of 33, 68, 100, 132, and 168 kg N ha^{-1} from urea (46% N) and two S levels at 0 and 22 kg S ha^{-1} from garden Gypsum (16% S) in a factorial randomized complete block design with four replicates. Stand count, plant height, and biomass weight were recorded at physiological maturity. Plants were harvested when seeds were completely matured (late July to early August) using a plot combine. After harvesting, sub-samples of seed were taken to measure the oil concentration using an MQC + benchtop NMR analyzer (Nuclear Magnetic Resonance, Oxford Instruments). The following oil yield was obtained by multiplying seed oil concentration in seed yield. To determine nitrogen uptake and nitrogen use efficiency, the grain nitrogen content was assessed using a Perkin Elmer CHNS/O Analyzer Model 2400. Seed N uptake and Nitrogen use efficiency (NUE) were computed by the following formulas:

N uptake = Seed N Content × Grain Yield

$$\text{NUE} = \frac{\text{Seed Yield}}{\text{N Supply}}$$ (Rathke et al., 2006)

Data was analyzed using SAS 9.4 software while the LSD test at 0.05 was employed to compare the means when significant differences were identified. The graphs were drawn using Excel 2010.

RESULTS AND DISCUSSION

The stand count varied among varieties, ranging from 70.1 plants m^{-2} in variety 35 to 149.7 plants m^{-2} in Check1. Plant height also differed significantly from 60.1 cm in variety 35 to 74.6 cm in variety 229. Stand count and plant height were not significantly affected by applying N and S combinations. Biomass was significantly affected by varieties ranging from 4351 kg ha^{-1} in variety 35 to 6463 kg ha^{-1} in variety 229. Additionally, 120N+20S and 150N+0S were identified as more effective in promoting biomass production, yielding 6463 kg ha^{-1} and 6322 kg ha^{-1}, respectively indicating a significant increase in biomass as N increased. Harvest index (HI) showed no significant variation in response to different varieties or fertilizer treatments, averaged at 26.9% (Table 1, Table 2).

Seed yield varied among varieties extending from 1153 kg ha^{-1} in varieties 35 to 2015 kg ha^{-1} in Check1. Moreover, yield varied with varying N and S rates. Averaged over all varieties, the maximum yield was obtained in 150N+20S (Table 2).

Nevertheless, variety 35 responded to N differently from other varieties demonstrating lower yield at all N levels (Figure 1 b). In addition, sulfur tended to further increase seed yield at higher N input level (Figure 1 a). The contrast analysis showed that sulfur did not increase the yield of camelina varieties at low N levels, which is in agreement with the insignificant effect of S on camelina yield documented by Solis et al. (2013); Wysocki et al. (2013); Sintim et al. (2015), by applying different sources of S including gypsum, ammonium sulfate, ammonium thiosulfate, and elemental S. From the N response regression curves, the optimum N rate was determined for each variety (Figure 2). The optimum N rate for the maximal seed yield was determined as 125 kg N ha^{-1} for variety 229 with 1894 kg ha^{-1} yield, 286 kg N ha^{-1} for variety 35 with 1470 kg ha^{-1} yield, 141 kg N ha^{-1} for variety 53 with 1957 kg ha^{-1} yield, 158 kg N ha^{-1} for Suneson with 1977 kg ha^{-1} yield, and 132 kg N ha^{-1} for Check1 with 2137 kg ha^{-1} yield.

Seed oil concentration was reduced with increasing N rate (Figure 3 a). However, camelina genotypes trended to respond differently to the increasing N rate (Figures 3b and d). Averaged over N and S levels, the minimum oil concentration was observed in variety 35 (35.53%) and the maximum was found in variety 229 (41.48%) Variety 53, Suneson, and Check1 exhibited comparable levels of oil concentrations (Table 2). Similarly, camelina oil content was reported at 300 g kg^{-1} (Obour et al., 2018), ranging from 28% to 41% in different sites and years according to Palvlista et al., (2016). The variations in yield and oil concentration led to differences in oil yield, yet the findings indicated that oil yield was more influenced by yield than by oil concentration. The lowest oil yield was observed in variety 35 while the maximum oil yield was found in Check1 (Table 2). Nitrogen uptake in the seed increased with higher nitrogen rates, reaching the maximum in 150N+20S. Among the varieties, Check1 and variety35 were identified as the most and least promising, respectively, for nitrogen uptake. Nitrogen Use Efficiency (NUE) was influenced by the interactions between variety and fertilizer, ranging from 15.1 kg seed per kg N in variety 35 to 26.5 kg seed per kg N in Check1. Additionally, NUE decreased with higher nitrogen rates. Contrast analysis showed an insignificant S effect on N uptake and NUE (Table 1, Table 2). From regression curves, the NUE at the optimum N rate was 15.2, 5.1, 13.9, 12.5, and 16.2 kg seed per kg N for varieties 229, 35, 53, Suneson, and Check1, respectively (Figure 2). Cultivars with higher NUE can contribute to reduced amount of nitrogen without decreasing grain yield. These findings align with a study by Mohammed et al. (2017) on camelina grown in Montana, revealing NUE ranging from 12.4 to 6.7 kg seed per kg N at nitrogen rates of 45 and 90 kg N ha^{-1}, respectively. Obeng et al (2021) showed that the maximum yield of camellia was obtained by applying 54 kg N ha^{-1} while sulfur fertilizer did not have any significant effect on grain yield and oil concentration.

In summary, different varieties exhibited significant variations in response to nitrogen availability, indicating that the optimal nitrogen level varies for each genotype to achieve maximum yield, oil content, and NUE. Results demonstrated that varieties 229 and Check1 are superior cultivars with high yield, low optimal N input rate, and high NUE.

REFERENCES

Mohammed, Y. A., Chen, C., Afshar, K. R., 2017. Nutrient requirements of Camelina for biodiesel feedstock in Central Montana. Agron. J. 109: 1– 8.

Obeng, E., Obour, A. K., Nelson, N. O., Ciampitti, I. A., Wang, D., 2021. Nitrogen and sulfur application effects on camelina seed yield, fatty acid composition, and nutrient removal. Can. J. Plant Sci. 101: 353– 365. dx.doi.org/10.1139/cjps-2020-0104.
Obour, A. K. Chen, C. Sintim, H. Y. McVay, K. Lamb, P. Obeng, E. Mohammed, Y. A. Khan, Q. Afshar, R. K. Zheljazkov, V. D., 2018. Camelina sativa as a fallow replacement crop in wheat-based crop production systems in the US Great Plains. Industrial crops and products. 111: 22- 29. http://dx.doi.org/10.1016/j.indcrop.2017.10.001.
Palvlista, A. D., Hergert, G. W., Margheim, J. M., Isbell, T. A., 2016. Growth of spring camelina (Camelina sativa) under deficit irrigation in western Nebraska. Ind. Crop Prod. 83: 118– 123.

Table 1. ANOVA analysis of camelina varieties at different N and S rates.

Source	Stand Count	Plant Height	Biomass	HI*	Seed Yield	Oil Content	Oil Yield	Seed N Uptake	NUE
V	***	***	***	ns	***	***	***	***	***
F	ns	ns	***	ns	***	***	***	***	***
V× F	ns	ns	ns	ns	ns	ns	ns	ns	***
LSD	16.74	1.86	355.57	1.65	103.6	0.36	40.37	5.19	1.68
CV	31.46	6.26	14.11	13.91	13.54	2.08	13.29	14.59	16.88
Mean	120.4	67.45	5702.27	26.92	1731.18	39.44	687.47	80.59	22.52

*Harvest Index

Table 2. Mean comparison of camelina affected by N and S.

Variety	Stand Count (Plants m^{-2})	Height (Cm)	Biomass (Kg ha^{-1})	HI (%)	Seed Yield (Kg ha^{-1})	Oil Content (%)	Oil Yield (Kg ha^{-1})	Seed N Uptake (Kg ha^{-1})
Check1	149.7^{a}	69.4^{b}	6043^{b}	27.8	2014.6^{a}	39.8^{c}	801^{a}	93.1^{a}
Suneson	139.2^{ab}	66.1^{c}	5492^{c}	27.8	1845.3^{b}	40.2^{b}	755^{b}	85.3^{b}
Variety	124.2^{bc}	67.1^{c}	6162^{ab}	26.3	1864.3^{b}	40.0^{bc}	742^{b}	86.1^{b}
Variety	110.2^{c}	74.6^{a}	6463^{a}	26.3	1811.5^{b}	41.8^{a}	727^{b}	79.6^{c}
Variety	79.1^{d}	60.1^{d}	4351^{d}	26.4	1152.8^{c}	35.5^{d}	413^{c}	58.8^{d}
F (N+S)								
30+0	113.6	66.6	4868^{f}	26.6	1526.3^{d}	40.6^{a}	625^{c}	68.2^{d}
30+20	120.7	66.6	5024^{ef}	27.1	1579.6^{d}	40.2^{ab}	639^{c}	71.3^{d}
60+0	124.1	66.8	5491de	27.6	1642.3^{cd}	40.0^{bc}	665^{bc}	74.7^{cd}
60+20	124.9	66.9	4884^{f}	27.1	1575.5^{d}	40.1^{ab}	638^{c}	70.6^{d}
90+0	132.7	69.0	5798^{bcd}	26.3	1773.5^{ab}	39.3^{d}	703^{ab}	82.2^{b}
90+20	129.5	67.2	5726^{cd}	26.2	1750.8^{bc}	39.5^{cd}	697^{ab}	81.9^{bc}
120+0	110.9	69.1	6301^{ab}	27.8	1845.6^{ab}	38.7^{e}	720^{ab}	88.1^{ab}
120+20	113.5	68.9	6463^{a}	26.7	1863.2^{ab}	38.7^{e}	725^{a}	88.2^{ab}
150+0	121.7	68.2	6322^{a}	26.7	1839.6^{ab}	38.6^{e}	714^{ab}	88.1^{ab}
150+20	112.8	66.3	6145^{abc}	27.1	1915.5^{a}	38.7^{e}	750^{a}	92.5^{a}

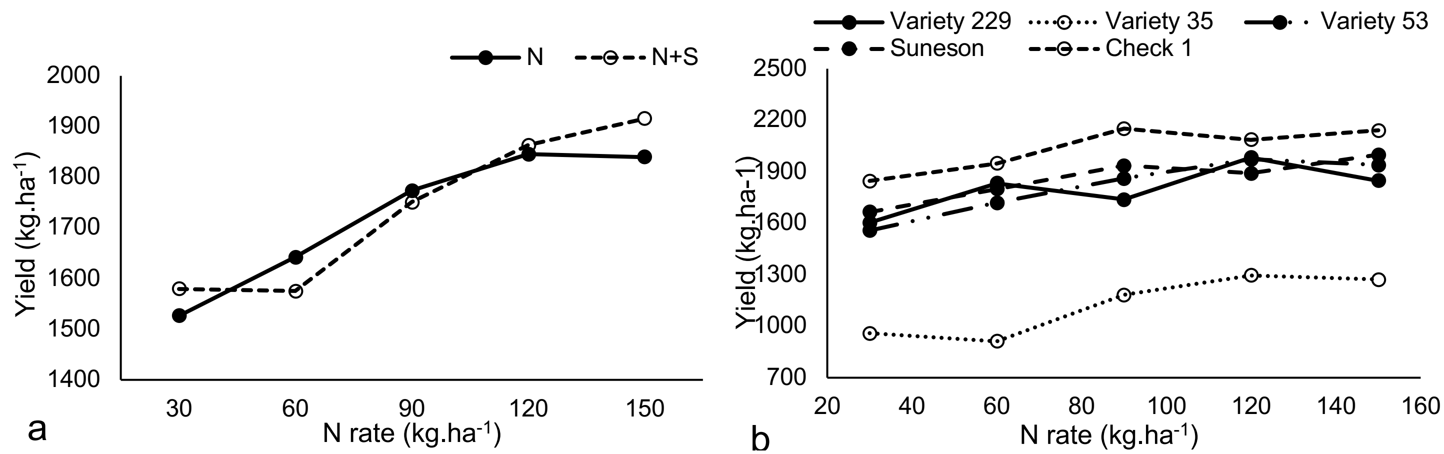

Figure1. Yield trends of different varieties of camelina affected by N and N+S.

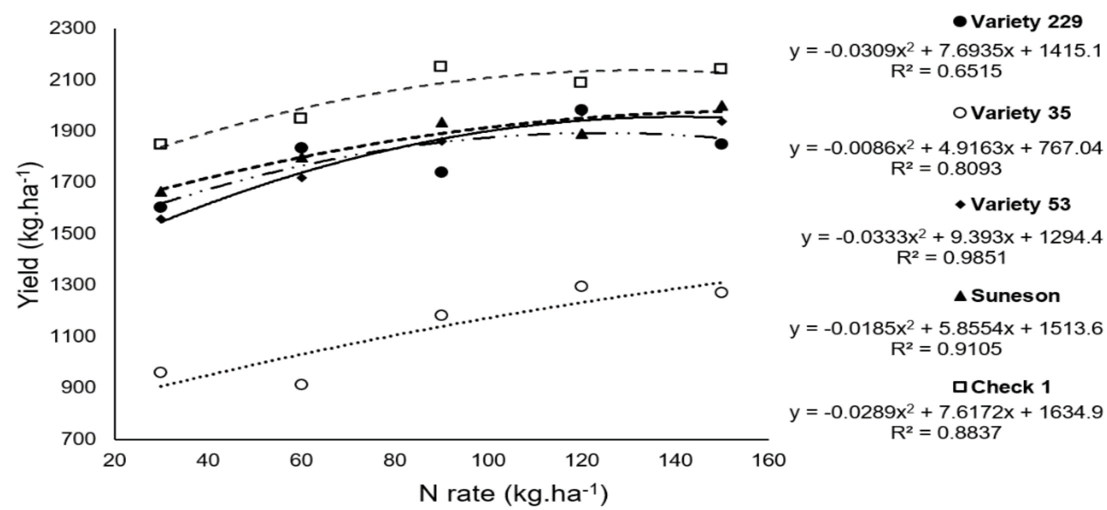

Figure 2. Regression response of camelina varieties to N rate.

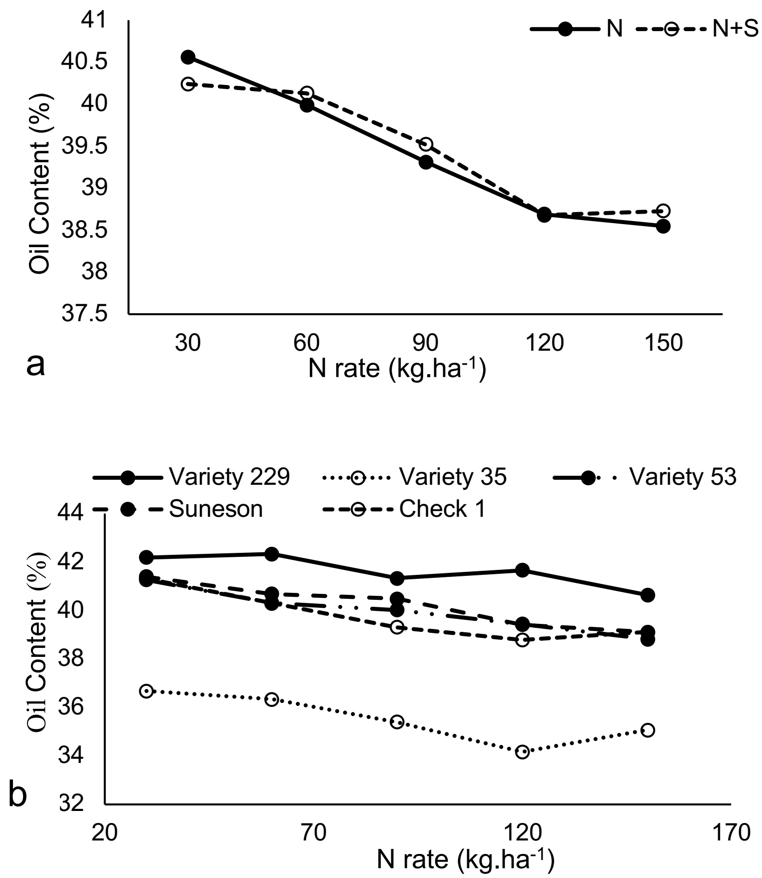

Figure 3. Oil concentration trends of different varieties of camelina affected by N and N+S.

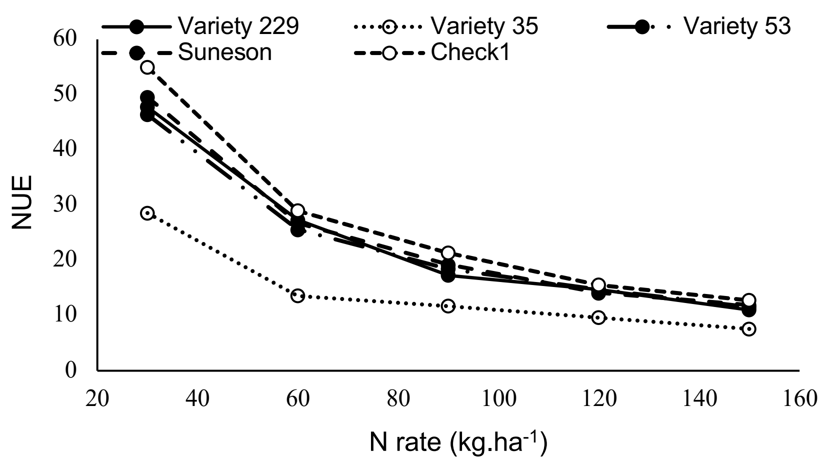

Figure 4. The interactive effects of Variety × Fertilizer on NUE.