EFFECTS OF APPLIED NITROGEN ON YELLOW MUSTARD SEED PRODUCTION IN THE WILLAMETTE VALLEY

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Introduction

Given recent legislative actions prohibiting production of *Brassica* spp. oilseed crops in much of the Willamette Valley, field crop producers are continuing their search for a productive crop to include in rotation with grass seed crops. Yellow mustard (*Sinapis alba* L.) is a promising, low-input, multipurpose crop that, although a member of the Brassica family, is taxonomically classified in the *Sinapis* genus and is therefore not restricted in the Willamette Valley. Yellow mustard is a distant relative of *Brassica* species vegetable seed crops, but will not hybridize with them (Vaughn, 1997; Brown et al., 2005).

Agriculturalists recognize the versatility that yellow mustard can offer as a green manure, condiment mustard (Vaughn, 1997), and oilseed crop (Brown et al., 2005), as well as its utility as a biopesticide (Beckie et al., 2008). Stemming from this newly realized potential comes the need for recommendations specific to yellow mustard production under Willamette Valley conditions, especially regarding nitrogen (N) fertilizer application rates. No agronomic guide highlighting recommended yellow mustard production practices for the high-rainfall environment of western Oregon is available. Additionally, no data addressing the effect of N fertilizer on yellow mustard plant physiology or the components of seed yield are available in the scientific literature. The objectives of this study were to quantify the effects of applied N on yellow mustard dry matter partitioning, seed yield, components of seed yield, and oil production characteristics.

Materials and Methods

Field trials were conducted in 2013 and 2014 at the OSU Hyslop Research Farm near Corvallis, OR, utilizing a randomized complete block design and four replications. The cultivar 'IdaGold' was utilized in this study because it is resistant to lodging, seed shatter, and a number of insect pests and diseases. A preplant application of K-Mag (0-0-22-11-22) and a postplant foliar application of Solubor were made to correct nutrient deficiencies identified in preplant soil analysis (sampled at 0–8 inches in depth). A preplant herbicide trifluralin (Treflan) was applied and incorporated each year to control weeds; however, no additional pesticides were utilized. Following seedbed preparation, mustard seed was planted at 18 lb/acre with a double-disk drill set in 6-inch rows on March 11, 2013 and March 13, 2014.

A tractor-mounted orbit-air fertilizer spreader was used to apply dry granular urea (46-0-0) at five rates: 0, 50, 100, 150, and 200 lb N/acre. Nitrogen application dates coincided with appearance of the first few true leaves (BBCH stages 11–13) on April 4, 2013 and April 18, 2014. Plant growth, development, and lodging rates were tracked weekly throughout the growing season. Vegetative measurements were conducted at the stem elongation (BBCH 30) and inflorescence emergence (BBCH 50) growth stages. At each stage, two adjacent 1-square-foot quadrats of yellow mustard vegetation were randomly cut and removed from each plot.

Immediately following collection, samples were weighed and plant number determined. Ten plants were then randomly selected from each observation and measured for height as well as total one-sided leaf area (measured with a LI-3100 leaf area meter), from which the leaf area index (LAI) was calculated. All biomass was returned to the individual observation sample bags, dried in an air-forced chamber at 158°F for 48 hours, and weighed.

The final biomass collection occurred when approximately 70% of siliques, commonly referred to as seed pods, were ripe (BBCH 87), on July 9, 2013 and July 7, 2014. Two adjacent 1-square-foot quadrat samples per plot were removed, weighed, dried, and then reweighed. Crop growth rate (CGR) was calculated as the change in plant dry weight over time. Ten random and representative plants were subsampled from each quadrat observation, and their plant height was quantified. These plants were also utilized to determine the components of seed yield (raceme/plant, siliques/plant, seeds/silique, and seed weight per raceme type).

Shortly after the final biomass sampling date, plots were swathed and left to dry for 7 to 12 days. The center swath (6 feet x 50 feet) from each plot was harvested and bagged with a plot combine on July 23, 2013 and July 28, 2014. The seed was cleaned and used to ascertain seed yield, seed weight, seed number/square foot, harvest index (ratio of seed yield to above-ground biomass), and nitrogen use efficiency (NUE) (ratio of seed yield to available N supply). The cleaned seed was further subsampled and utilized for measuring seed oil and protein concentrations via nuclear magnetic resonance spectroscopy. Oil yield was calculated as the product of seed yield and fractional seed oil concentration.

Analysis of variance (ANOVA) was conducted for data on a plot means basis for each year. Vegetative measurements were analyzed for each growth stage. Treatment means were separated by Fisher's protected LSD values at the 5% level of significance. Regression analysis was used to determine the relationship between seed yield components and seed yield.

Results and Discussion

Vegetative measurements

Applied N affected plant height at all developmental stages in 2013 and 2014, with the greatest increase in plant height occurring between stem elongation (BBCH 30) and inflorescence emergence (BBCH 50). Plants attained nearly full mature height during flowering when produced under dry conditions in 2013, but continued to grow under the wet conditions in 2014. Plant height is one of the main factors contributing to lodging, which is a potential problem for many crops produced in western Oregon. Lodging in yellow mustard was present only with the two highest N rates (150 and 200 lb N/acre) in 2013, and appeared to a lesser extent in 2014 (data not shown). In both years, lodging was not severe, and adverse impacts on seed yield or increased harvest difficulty were not observed.

There was a positive relationship in both years between above-ground biomass and applied N for all developmental stages. Plants in the control plots grew at all measurement timings; however, the control plants consistently accumulated the least biomass when compared to plants in the treatments receiving applied N. Overall, applied N stimulated above-ground biomass accumulation increases ranging from 16% to 169% in 2013 and from 27% to 150% in 2014.

Leaf area index (LAI) is an indicator of potential photosynthetic capacity of a crop canopy. Increased LAI at stem elongation and inflorescence emergence was observed with application of N in 2013; however, only rates greater than 100 lb N/acre produced LAI values greater than the control in 2014 (Table 1). Crop growth rate (CGR) was also influenced in both years by applied N, especially at rates greater than 150 lb N/acre in 2013 and greater than 100 lb N/acre in 2014 (Table 1). The CGR in 2013 was somewhat greater than in 2014, possibly resulting from more favorable growing conditions in 2013, as well as a short-term boron toxicity experienced early in 2014.

Table 1. Nitrogen fertilizer effects on yellow mustard leaf area index (LAI), crop growth rate (CGR), nitrogen use efficiency (NUE), and harvest index (HI), 2013 and 2014.[1]

		------- Leaf area index -------				
Year	Nitrogen	BBCH 30	BBCH 50	Crop growth rate	Nitrogen use efficiency[2]	Harvest index[3]
	(lb/a)			(lb/a/day)		
2013	0	1.4 b	1.8 c	132 b	79.6 a	0.15 a
	50	3.1 a	3.0 b	142 ab	23.2 b	0.15 a
	100	3.3 a	2.9 b	157 ab	13.4 c	0.12 a
	150	3.6 a	4.9 a	188 a	10.3 c	0.12 a
	200	3.7 a	5.1 a	190 a	10.6 c	0.15 a
2014	0	0.8 c	1.3 d	86 c	66.2 a	0.18 a
	50	1.3 bc	2.2 cd	110 bc	19.7 b	0.18 a
	100	1.7 ab	3.3 ab	156 ab	13.9 c	0.16 a
	150	2.1 a	4.3 b	181 a	10.6 c	0.16 a
	200	2.4 a	6.9 a	175 a	8.3 c	0.17 a

[1]Means within columns and years followed by the same letter are not significantly different by Fisher's protected LSD values (*P* = 0.05).
[2]Nitrogen use efficiency = ratio of seed yield to available N supply
[3]Harvest index = ratio of seed yield to above-ground biomass

Seed yield

Although precipitation during the 2 years was markedly different, seed yield responses to applied N were similar. A positive linear relationship between the rate of applied N and seed yield was found in both years (Figure 1). Average seed yields were 300 to 500 lb/acre lower in 2014 than 2013, with the exception of the 100 and 150 lb N/acre rate treatments (Table 2). Nevertheless, all applied N rates significantly increased seed yield over the control in both years. The 50 lb N/acre rate increased seed yield by 14% in 2013 and by 32% in 2014. Applications of 200 lb N/acre resulted in 68% and 86% greater seed yield than the control in 2013 and 2014, respectively.

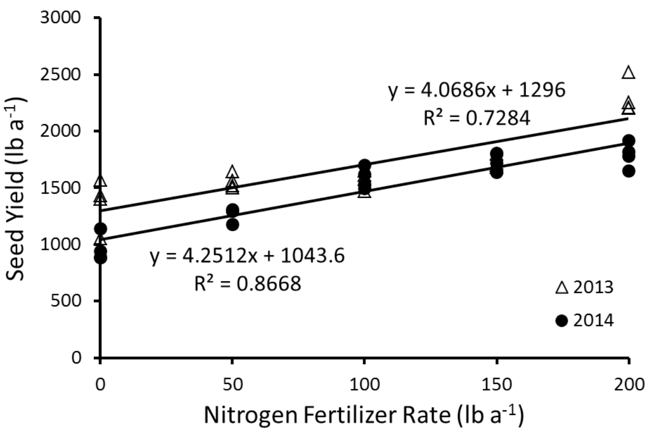

Figure 1. Applied nitrogen effects on yellow mustard seed yield, 2013 and 2014.

Harvest index and NUE

Harvest index (HI) provides a measure of how applied N might influence partitioning to seed in relation to total above-ground biomass production. Applied N did not affect HI in yellow mustard in either year (Table 1). Values for HI in yellow mustard in this study ranged from 0.12 to 0.18, which were less than those reported for other Brassica family members (Ferguson et al., 2016).

Nitrogen use efficiency (NUE) in yellow mustard was reduced by applications of N in both years (Table 1). The inverse relationship of NUE and N application rates results from changes in N uptake during plant growth and development. The average NUE of yellow mustard in this study, 27.5 and 10.8 in 2013 and 2014, respectively, is within the range of NUE values obtained for oilseed rape (12.0 to 27.0) (Wang et al., 2014).

Components of seed yield

Applied N affected all seed yield components in both years, with the exceptions of seed weight on primary (1°) branches in 2013 and seeds/silique on 1° branches in 2014. The number of racemes/plant was increased by applied N. The number of 1° branch racemes was increased with 200 lb N/acre in 2013 and with rates greater than 100 lb N/acre in 2014.

The numbers of siliques on the main stem and 1° branch racemes were increased with applied N in both years. Similar results were found in oilseed rape and winter canola (Wang et al., 2014). Siliques borne on the main

Table 2. Nitrogen fertilizer effects on yellow mustard seed yield, seed weight, and seed number, 2013 and 2014.[1]

Year	Nitrogen	Seed yield	Seed weight	Seed number
	(lb/a)	(lb/a)	(mg)	(seeds/ft^2)
2013	0	1,363 d	6.92 bc	2,060 c
	50	1,555 c	6.83 c	2,370 b
	100	1,576 bc	6.84 bc	2,400 b
	150	1,725 b	7.04 ab	2,550 b
	200	2,296 a	7.19 a	3,330 a
2014	0	961 d	5.94 c	1,680 c
	50	1,269 c	5.98 c	2,210 b
	100	1,586 b	5.99 c	2,760 a
	150	1,739 a	6.20 b	2,920 a
	200	1,789 a	6.48 a	2,880 a

[1]Means within columns and years followed by the same letter are not significantly different by Fisher's protected LSD values (*P* = 0.05).

stem and 1° branch racemes accounted for roughly 99% of the total silique production in both years. Main stem siliques accounted for 61% and 65% of the total siliques/plant in 2013 and 2014, respectively. Total production of siliques by the plant was greater in 2013 than in 2014 and is likely a contributor to seed yield differences observed between years.

Applied N increased the number of main stem seeds/silique in both years and 1° branch raceme seeds/silique in 2013, but not in 2014. These results are in contrast with reported effects of applied N in winter canola, where the number of seeds/silique was not affected by N application (Ferguson et al., 2016).

Seed number/square foot was increased with all rates of applied N in both years (Table 2). The greatest number of seeds/square foot was observed with 200 lb N/acre in 2013 and with rates greater than 100 lb N/acre in 2014. All N rates resulted in significantly more seeds/plant in 2013 when compared to the control.

Seed weight was increased by applied N with the 200 lb N/acre rate in 2013 and by rates greater than 150 lb N/acre in 2014 (Table 2). The weight of seed produced on the main stem in both years, as well as seed produced on 1° branch racemes in 2014, was incrementally increased with the rate of applied N (Figure 2). However, N had no influence on the weight of seed produced on 1° branch racemes in 2013. Applied N either reduced or had no effect on seed weight produced on main stem and 1° branch racemes in winter canola (Ferguson et al., 2016).

Seed yield was most strongly affected by seeds/square foot rather than by seed weight because variation in seed weight across applied N rates was much less than that observed for seeds/square foot. There was a strong linear relationship between seeds/square foot and seed yield (Figure 3), similar to that reported by Ferguson et al. (2016) in winter canola. Since seeds/plant was the most important characteristic in determining seed yield responses to applied N, the increased number of seeds most likely was a result of N-induced increases in siliques on main stem and 1° branch racemes.

<u>Seed oil and protein content and oil yield</u>

Seed protein content is a major consideration in many oilseed crops, yet is of less concern in yellow mustard production due to limited nutritional applications. Contrary to Kovács et al. (2006), who found that seed protein content in yellow mustard was positively influenced by increasing N fertilizer, seed protein content in this study did not vary from 24%, regardless of N rate (Table 3).

Generally, N fertilizer causes reductions in seed oil content; however, applied N inconsistently affected the oil content in yellow mustard seed in both 2013 and 2014. In this study, yellow mustard seeds averaged 27.3% and 27.5% oil in 2013 and 2014, respectively.

Applied N influenced yellow mustard oil yield, with all N rates increasing oil yield over the control in both years (Table 3). Overall, oil yields were greater in 2013 than in 2014, as a result of more favorable growing environment in 2013. Greatest oil yields were noted with the 200 lb N/acre rate in 2013 and rates greater

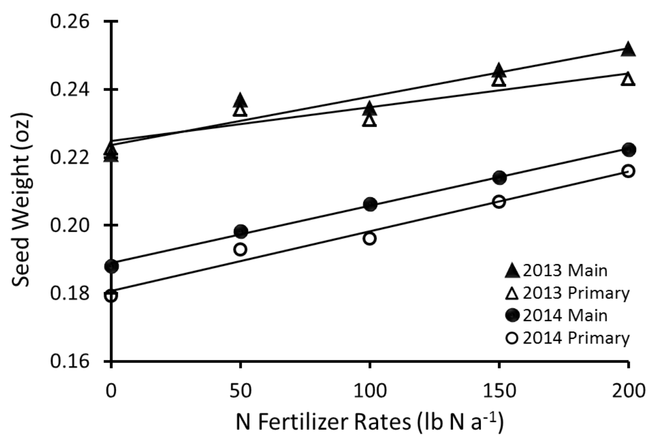

Figure 2. Applied nitrogen effects on yellow mustard main stem and primary seed weight, 2013 and 2014.

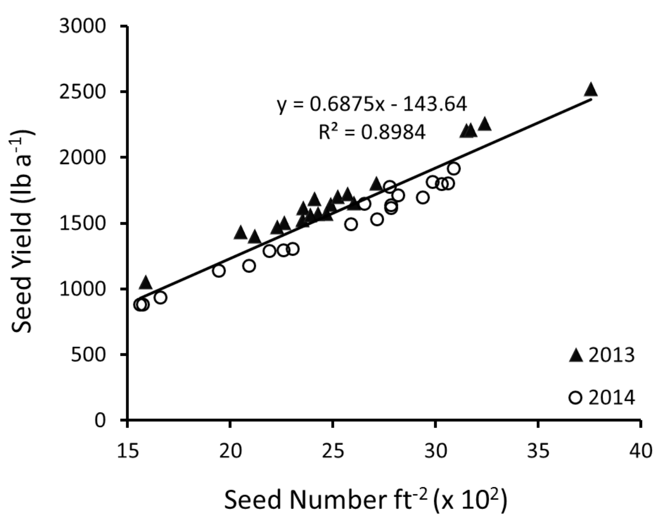

Figure 3. Relationship of yellow mustard seed yield and seed number/square foot, 2013 and 2014.

than 150 lb N/acre in 2014. Yellow mustard oil yields ranged from 271 lb to 604 lb oil/acre.

Conclusions

This study was initiated to provide the background information needed to establish N fertilizer recommendations for Willamette Valley produced yellow mustard. Applications of 150 to 200 lb N/acre supported the greatest seed and oil yields over the 2-year trial period and are recommended as the optimal N fertilizer application rate for 'IdaGold' yellow mustard cultivated under nonirrigated Willamette Valley growing conditions.

References

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Table 3. Applied nitrogen effects on seed protein, oil content, and oil yield in yellow mustard, 2013 and 2014.[1]

Year	Nitrogen	Seed protein content	Seed oil content	Oil yield
	(lb/a)	(%)	(%)	(lb/a)
2013	0	24.2 a	26.3 b	359 c
	50	23.9 a	28.4 a	442 b
	100	24.0 a	28.4 a	448 b
	150	24.2 a	27.0 b	466 b
	200	24.4 a	26.3 b	604 a
2014	0	24.3 a	28.1 ab	271 d
	50	24.2 a	28.7 a	364 c
	100	24.4 a	27.6 b	437 b
	150	24.6 a	26.8 c	466 a
	200	24.9 a	26.4 c	472 a

[1]Means within columns and years followed by the same letter are not significantly different by Fisher's protected LSD values ($P = 0.05$).