The Effect of Nitrogen Rate on Field Pennycress Seed Yield and Oil Content

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ABSTRACT

Field pennycress (*Thlaspi arvense* L.) is a new potential oilseed crop that is currently being evaluated as a domestic source of biodiesel fuel. The research based information about pennycress nitrogen requirements will help producers apply optimal nitrogen rate and minimize production costs. Therefore, this study was initiated to evaluate the effect of nitrogen fertilization rate on pennycress seed and biomass yield and oil content.

A growth chamber experiment was conducted on the spring annual pennycress breeding line 'Spring-32' from Montana, with five nitrogen rates ranging from 25 to 125 lbs. of nitrogen per acre. In addition, the effect of nine nitrogen fertilization treatments on yield and oil content of the winter breeding line 'W-12' was evaluated in a field experiment.

The greatest seed and biomass yields of 0.32 and 0.48 g per plant respectively, were achieved with 50 lbs. of nitrogen per acre in a growth chamber environment. Greater nitrogen rates did not result in further seed and biomass yields increasing. A rate of 50 lbs. of nitrogen also resulted in the greatest pods number per plant. The greatest seed number per plant was achieved with 75 lbs. of nitrogen per acre. Height of the plants that received the rate of 25 lbs. of nitrogen per acre was higher than that of non-fertilized control but did not differ from height achieved with increased nitrogen rates. In the field study, the greatest seed yield of 793 lbs. per acre respectively was achieved with amount of 50 lbs. of N per acre when one half of nitrogen was applied in the fall and another half in the spring. Greater fertilizer rates of 75 and 100 lbs. of nitrogen per acre applied in fall did not result in greater seed yield. Nitrogen fertilization rates had no effect on the oil content in the seed in both studies.

Our results indicate that the optimal nitrogen rate in pennycress production is likely 50 lbs. of nitrogen per acre when fertilizer application is divided on fall and spring. This information will be further evaluated in the field experiments with pennycress populations from different geographical regions.

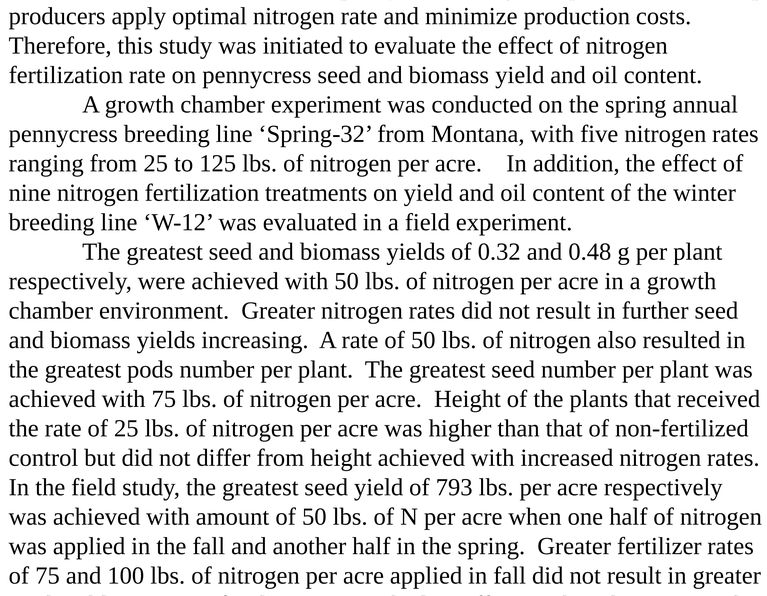

Figure 1. The stage of flowering of field pennycress spring breeding line 'Spring-32' in the growth chamber nitrogen rate evaluation study.

INTRODUCTION

Field pennycress (*Thlaspi arvense* L.) is a new potential oilseed crop that is currently being evaluated as a domestic source of biodiesel fuel. Pennycress belongs to *Brassicaceae* family and grows as a common weed throughout temperate climate in North America. The seed contains between 20-36 wt % of oil with high contents of erucic, linoleic and other unsaturated fatty acids (Moser et al., 2009). This oil profile enables production of biodiesel with a high cetane number and excellent low temperature properties.

Nitrogen is one of the most expensive agricultural inputs in oilseed production (Gan et al., 2008). Literature indicates that important oilseed crops from the *Brassicaceae* family, like rapeseed and canola, have high demands for nitrogen (Balint at al., 2008; Gan et al., 2008). Currently, no information is available on the response of pennycress to nitrogen and other nutrients. Producers need information on pennycress nitrogen requirements to apply optimal nitrogen rate and minimize production costs.

A growth chamber and the field experiment were consequently initiated to evaluate the effect of nitrogen fertilization rate on pennycress seed and biomass yield, yield components, and seed oil content and constituents.

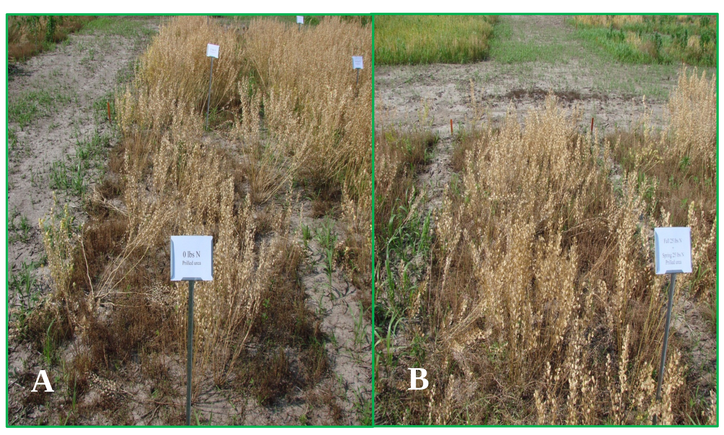

Figure 2. Pennycress field plots, (A) non-fertilized control (O N), (B) field plot treated with 50 lbs. of nitrogen per acre split on fall and spring application (25 NF + 25 NS). Photo taken on June 14, 2011.

Table 1. Mean values of field pennycress seed and biomass yield, stand, tillering, height, total oil content and content of oleic, linolenic, and erucic acid obtained with nine fertilization treatments in the field experiment.

Trait / Fertilization treatment	Seed yield (lbs./acre)	Biomass yield (lbs./acre)	Stand density (plants/acre)	Number of tillers per plant	Plant height (cm) ns#	Total oil content (%, dry weight basis) ns	C18:1d9 Oleic acid content (%) ns	C18:3d9 Linolenic acid content (%)	C22:1 Erucic acid content (%) ns
0 N*	313.1 c	1,175.8 c	13,403 c	11.5 b	78.3	34	9	21.5 b	37.2
25 N	531.7 bc	2,041.0 bc	22,450 bc	15.5 a	86.5	34.5	9.1	21.7 b	36.7
50 N	557.3 bc	2,212.0 bc	34,345 abc	15.5 a	82.5	34.8	9.1	21.6 b	36.8
75 N	810.3 ab	3,307.5 ab	42,219 abc	14.0 ab	86.3	34.6	9	21.8 b	37
100 N	994.9 a	4,151.8 a	62,156 a	16.8 a	85.5	34.6	9	21.8 b	36.6
25 NF + 25 NS	793.0 ab	3,035.3 ab	28,649 bc	14.3 ab	88.3	34.3	9.1	21.7 b	36.8
50 NF + 25 NS	611.5 bc	2,480.6 bc	44,230 abc	15.0 a	85.8	34.8	9	22.2 a	36.5
25 N + 10 S	547.4 bc	2,184.1 bc	30,659 bc	15.5 a	88.5	36.2	8.9	21.6 b	36.6
50 N + 10 S	840.7 ab	3,474.9 ab	49,591 ab	14.3 ab	85.8	34	9	21.7 b	36.8

* , N: nitrogen rate (lbs./acre); NF: nitrogen rate applied in fall; NS: nitrogen rate applied in spring; S: sulfur rate applied.
# , Within columns, means followed by the same letters are not significantly different at 0.05 probability level. ns: not significant.

MATERIALS AND METHODS

Growth chamber experiment:

A growth chamber experiment was conducted on the non-dormant spring pennycress breeding line 'Spring-32' from Montana (Figure 1). Growth chamber conditions were set on 18 hour photoperiod (7.9 μE/m^2/sec) with day and night temperatures of 24°C and 20°C, respectively. The pennycress seed was planted for germination into seeding trays filled with germination medium. After germination, five replicate uniform seedlings for each nitrogen treatment were transplanted into individual 7.5 cm square pots. Nitrogen treatments comprised of non-fertilized control and five nitrogen rates representing a range from 25 to 125 lbs. of nitrogen per acre. The source of nitrogen was granulated urea fertilizer (46-0-0). Fertilizer was hand applied at the time of seedlings transplanting. Plants were watered by wicking system throughout the experiment. Plants were hand harvested approximately 60 days after transplanting at the time of full maturity.

Field experiment:

A field study was conducted at the Western Illinois University Agricultural Research Farm in Macomb, IL. The dormant winter pennycress breeding line 'W-12' was planted at a rate of 4 lbs. of seeds per acre in September of 2010. The experiment was laid out as a completely randomized design with four replicates. Nitrogen fertilization comprised of non-fertilized control and eight different treatments (Figure 2). Treatments included: fall application of 25, 50, 75 and 100 lbs. of nitrogen per acre (25 N, 50 N, 75 N, and 100 N); fall application of 25 and 50 lbs. of nitrogen per acre with application of 25 lbs. of nitrogen in spring (25 NF + 25 NS and 50 NF + 25 NS) and fall application of 25 and 50 lbs. of nitrogen combined with 10 lbs. of sulphur per acre (25 N + 10 S and 50 N + 10 S). The source of sulfur was Disper-Sul (90%). All plots were hand harvested in June of 2011. Seed and biomass yields were assessed after drying the plant material and seed.

Oil and data analysis:

Total oil content was determined by nondestructive pulsed NMR (Bruker Minispec PC 120, 180-mm absolute probehead) on whole pennycress seed. Medium-chain triglycerides were extracted and derivatized into fatty acid methyl esters for gas chromatography analysis. The fatty acid methyl esters were analyzed using an Agilent 6890 gas chromatograph with a flame ionization detector. Analysis of variance (ANOVA) was performed with SAS software. Levels of statistically significant factors were compared with Student Newman Keuls (SNK) method for multiple comparisons.

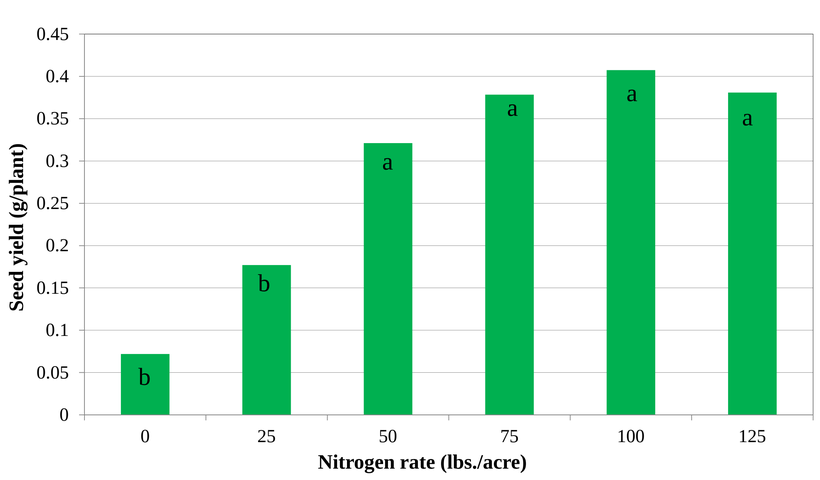

Figure 3. The effect of nitrogen fertilizer rate on pennycress seed yield in a growth chamber experiment. Yield values marked with the same letter are not significantly different at 0.05 probability level.

RESULTS

Growth chamber experiment:

Nitrogen fertilizer rate was a significant factor influencing pennycress seed and biomass yield, pods and seeds number per plant as well as final height of the plants. Nitrogen fertilization had no effect on total oil content in pennycress seed. Seed and biomass yields increased as fertilizer rate was increased from 0 to 50 lbs. of nitrogen per acre (Figure 3). Further nitrogen rate increasing did not contribute to greater seed and biomass yield. Likewise, the number of pods and seeds per plant increased as nitrogen rate increased to 50 and 75 lbs. per acre respectively. Nitrogen rate of 25 lbs. per acre increased plant height relative to non-fertilized control; nitrogen rates greater than 25 lbs. of nitrogen per acre did not result in further height increase.

Field experiment:

Nitrogen fertilization had a significant effect on pennycress seed and biomass yield, tillering, and plant stand in the field. Nitrogen fertilization effect was not significant for plant height. Nitrogen rate of 50 lbs. per acre split on fall and spring application increased the seed and biomass yield as compared with non-fertilized control. The same yields were achieved with fall nitrogen of 75 and 100 lbs. per acre and with combination of 50 lbs. of nitrogen and 10 lbs. of sulphur. The nitrogen rate of 100 lbs. per acre and 50 lbs. of nitrogen combined with 10 lbs. of sulphur per acre were the only fertilization treatments that increased plant stand relative to non-fertilized control. There were no differences among fertilizer treatments regarding tiller number but some treatments produced more tillers than non-fertilized control. Nitrogen fertilization treatments had no effect on total oil, oleic and erucic content in pennycress seed. The significant effect of fertilization on linolenic acid content is a consequence that 50 NF +25 NS treatment resulted in slightly higher linolenic acid content as compared with other treatments.

CONCLUSIONS

The greatest pennycress seed yield in a growth chamber and the field experiment was achieved with a total nitrogen fertilizer rate of 50 lbs. per acre. In the field experiment, the greatest seed yield of 793 lbs. per acre was achieved when the nitrogen rate of 50 lbs. per acre was divided on fall and spring application. Seed yield increase obtained with 50 lbs. of nitrogen was 480 lbs. per acre or approximately 60 gallons of biodiesel. Nitrogen fertilization cost would likely be less than the profit obtained with such yield increase.

LITERATURE CITED

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