Adapting Management of Nitrogen Sources and Weeds in Flax Systems of Central Iowa

By Stefan R. Gailans and Mary H. Wiedenhoeft

Expansion of flax into the Midwestern U.S. has created a gap in regionalized knowledge on N source and weed management for this crop. Recent experiments in central Iowa found good responses across selected N sources, but results varied between the two very distinct growing seasons. Composted manure had the largest impact on reducing harvest index relative to other N sources in the initial year, but not the following, more challenging growing season. Weed competition had the most pronounced effect on flax yields compared to the effects of N source and rate. Weed biomass also increased with N rate, emphasizing the need for effective weed management in flax production systems.

Production of flax (*Linum usitatissimum* L.) has increased in North America over the past decade, due to markets driven by the recognition of the potential health benefits of including flax seed in the human diet. Knowledge of appropriate conventional and organic production practices for production in the Midwest, U.S. is lacking, as much of the research in North America originates in North Dakota, Manitoba, Saskatchewan and Alberta on the Northern Great Plains. Midwestern research is necessary to develop N recommendations for flax growers in this region. Additionally, adequate management of weeds is of particular concern for growers of flax due to its lack of competitiveness (Franzen, 2004).

Researchers evaluated the response of flax to three N sources applied at three N rates in the presence and absence of weed competition. This study occurred in 2007 and 2008 at the Iowa State University Agronomy and Agricultural Engineering Farm located near Ames in central Iowa. In both years, the experiment took place in fields planted to soybeans the previous year. Composted swine manure, fresh liquid manure, and urea were surface applied by hand to plots at 0, 30, 60, and 90 lb N/A and immediately incorporated into the soil. Nutrient analyses and applied rates of compost and manure are provided in **Table 1**. Each N source x rate combination was replicated four times. Flax was drilled into plots at 8-inch row spacings at 50 lb/A accompanied by red clover (*Trifolium pratense* L.) broadcasted at 15 lb/A. Flax was underseeded with red clover to mimic a common management strategy used for production of small grains. Plots were split into randomized subplots that either contained uncontrolled weeds ('weedy') or were weed-free. Throughout the growing season, weeds were removed by hand as needed from weed-free subplots. At flax seed maturity in late July, aboveground shoot material of flax, red clover, and weeds was hand-harvested at the soil surface from four randomly located 1 ft^2 areas in each subplot. The linolenic acid (omega-3 fatty acid) concentration of seed oil was assessed upon harvest.

Table 1. Nutrient analyses of composted swine manure and liquid swine manure and the amount applied to meet target N rates in 2007 and 2008. Ames, Iowa.

	Nutrient analysis			Target N rate, lb N/A		
	Total N	Total C	Moisture	30	60	90
Compost	-------- % --------			ton/A		
2007	2	19	31	7	14	21
2008	2	34	77	12	25	37
Manure	lb/1,000 gal		%	gal/A		
2007	28	-	98	1,053	2,000	3,053
2008	26	-	96	1,158	2,316	3,474

Amount of compost and manure applied was based on the availability of 10% of the total N in the compost and 98% of the total N in the manure.

Abbreviations and notes: N = nitrogen.

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Impact of Weed Competition and N on Flax

In both 2007 and 2008, flax seed yield was significantly reduced by weed competition regardless of N source or rate applied. In 2007, mean seed yield was 709 and 995 lb/A under weedy and weed-free conditions, respectively. In 2008, mean seed yields under weedy conditions were 197 lb/A compared to 385 lb/A under weed-free conditions. Nitrogen source was not a factor in either year. Under weed-free conditions, seed yield responded to N rate in 2007 and 2008 (**Figure 1**). Regardless of N source, seed yield response to each incremental increase in N rate under weed-free conditions was linear ($p = 0.05$) with greatest yields occurring at the 90 lb N/A rate. Under weedy conditions, maximal seed yields were observed at the 60 lb N/A rate in 2007 and no response to N rate was

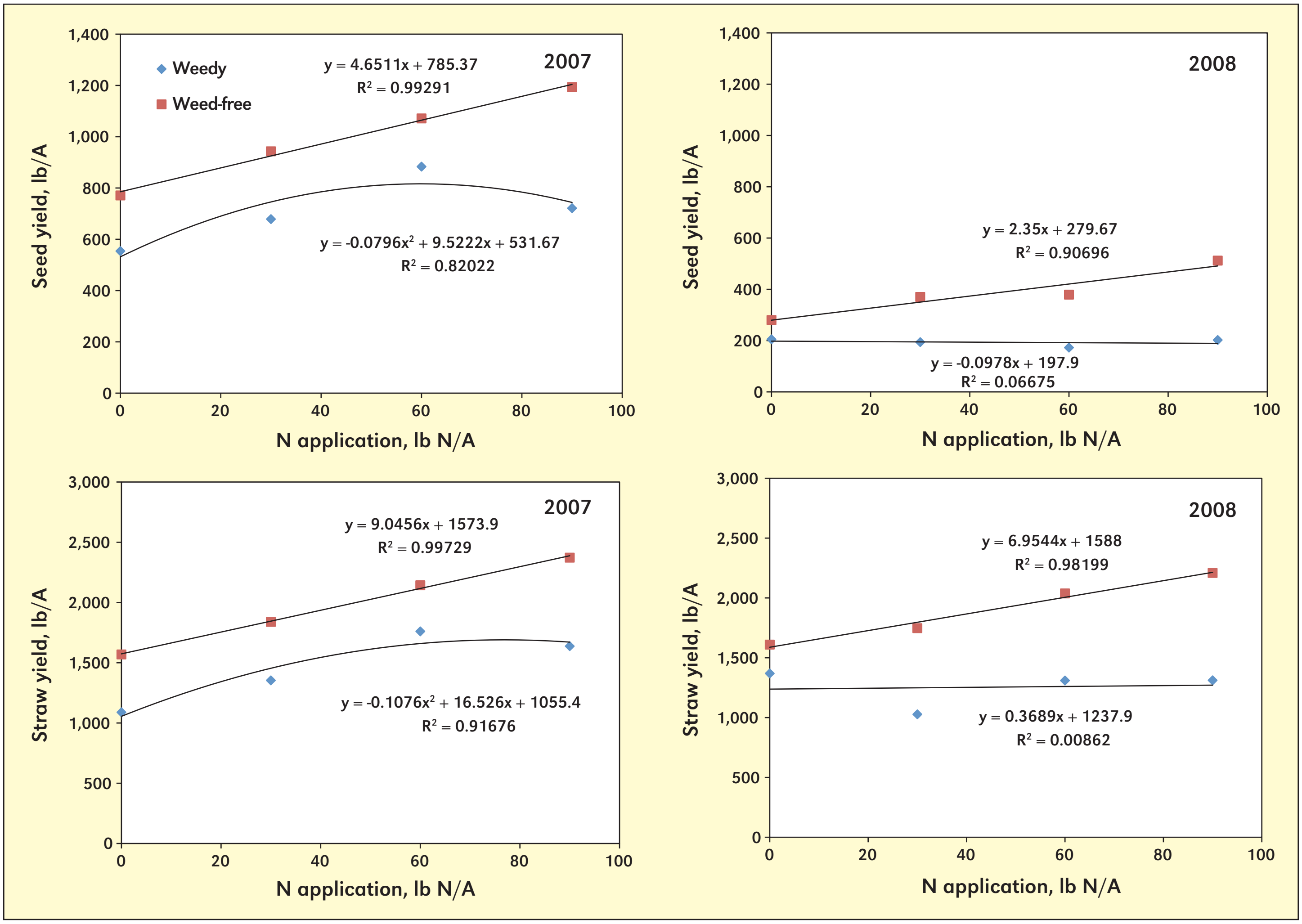

Figure 1. Flax seed yield (top) and straw yield (bottom) as affected by N rate under weedy and weed-free conditions in 2007 and 2008 in Ames, IA.

detected in 2008.

In 2007, linolenic acid content of seed oil was affected by N source and rate, but not weed competition (**Table 2**). Compost resulted in the lowest linolenic acid content and N rate decreased linolenic acid content in a linear fashion (p = 0.0001). In 2008, linolenic acid content was affected by the three-way interaction of N source x N rate x weed competition (**Table 2**). Under weedy conditions, increasing N as compost (p = 0.0001) and urea (p = 0.0023) resulted in a negative linear response. Under weed-free conditions, only increasing N as compost resulted in a negative linear response (p = 0.0429).

Table 2. Linolenic acid concentration of flax seed oil as affected by weeds, N source, and N rate in 2007 and 2008. Ames Iowa.

		2007				2008			
		N rate, lb N/A				N rate, lb N/A			
		0	30	60	90	0	30	60	90
Weeds	N source	%							
Weedy	Compost	50.7	49.9	47.3	45.1	51.4	52.0	51.5	44.8
Weedy	Manure	50.7	51.2	50.7	49.7	51.4	51.0	49.0	49.0
Weedy	Urea	50.7	49.6	49.4	47.6	51.4	52.0	47.1	44.3
Weed-free	Compost	50.9	50.4	49.6	49.2	53.0	51.7	52.6	51.9
Weed-free	Manure	50.9	50.9	51.0	50.6	53.0	53.0	52.3	51.7
Weed-free	Urea	50.9	50.4	50.0	49.6	53.0	53.1	51.8	51.7

Source of variation	2007 p value	2008 p value
Weeds (W)	0.1906	0.0034
N source (S)	0.0001	0.2301
N rate (R)	0.0001	0.0001
W x S	0.0811	0.0800
W x R	0.1008	0.0011
S x R	0.1935	0.0416
W x S x R	0.7256	0.0143

As with seed yield, flax straw yield was significantly reduced by weed competition across N sources and rates in both years. In 2007, mean straw yields under weedy conditions were 1,460 lb/A compared to 1,981 lb/A under weed-free conditions. In 2008, mean straw yields under weedy conditions were 1,255 lb/A compared to 1,901 lb/A under weed-free conditions. Regardless of weed competition and across N rate, straw yield was consistently greater with compost compared to other N sources in 2007. No differences among N sources was observed in 2008. In 2007, straw yield response to N rate was linear (p = 0.001) under weed-free conditions and quadratic (p = 0.0001) under weedy conditions (**Figure 1**). In 2008, straw yield response to N rate was linear (p = 0.001) under weed-free conditions while no response to N rate was observed under weedy conditions.

In 2007 only, harvest index (the ratio of seed yield to the sum of seed and straw yield) was least when compost was applied (data not shown). While seed yield responded to each of the N sources equally, compost tended to have a disproportionate effect on straw yields. Despite the increase in straw yields with compost application, lodging of flax plants was not observed in these plots.

Table 3. Weed biomass in weedy subplots as affected by N source and N rate in 2007 and 2008. Ames Iowa.

	2007				2008			
	N rate, lb N/A				N rate, lb N/A			
	0	30	60	90	0	30	60	90
N source	lb/A							
Compost	4,050	5,560	6,750	12,280	3,940	3,300	4,040	7,610
Manure	4,050	4,580	4,200	4,480	3,940	5,310	6,370	7,030
Urea	4,050	4,770	5,160	4,520	3,940	5,600	5,850	6,830
Source of variation	p value							
N source (S)	0.0002				0.2530			
N rate (R)	0.0160				0.0057			
S x R	0.0082				0.4622			

The late planting date (May 1st), above-normal precipitation, and very wet field conditions in 2008 relative to 2007 likely contributed to the reduction in flax seed yield in 2008. Significant seed yield reductions have been attributed to delaying planting at sites in Ontario (Sheppard and Bates, 1988), North Dakota (Thompson et al., 1988), and southern Saskatchewan (Lafond et al., 2008). With later plantings, vegetative growth of flax can be maintained due to an increased vegetative growth rate, but to the detriment of flower development period and seed yield (Dybing and Grady, 1994). Dybing (1964) attributed the negative effect of N on linolenic acid to the favoring of vegetative growth, which was also observed in the present study. We observed straw yield to increase with N in both years and at the same time reported a decrease in linolenic acid concentration.

Impact of N Source and N rate on Weeds

Common lambsquarters (*Chenopodium album* L.), common waterhemp (*Amaranthus rudis* Sauer), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), and giant foxtail (*Setaria faberi* Herrm.) were the most prevalent weed species contributing to weed biomass in both years in the subplots that contained ambient weeds. Weed biomass increased with N applied as compost in 2007 and applied as any of the N sources in 2008 (**Table 3**). Previous research has found composted swine manure to increase biomass of common waterhemp in corn and soybean production systems in Iowa (Liebman et al., 2004; Menalled et al., 2004). Furthermore, increasing applied N was found to preferentially favor wild buckwheat (*Polygonum volvulus* L.) growth and subsequent flax yield reduction in a direct competition study (Gruenhagen and Nalewaja, 1969). This points to the importance of weed management in flax production systems.

Summary

Clearly, weed competition was the most important factor affecting flax performance. As flax seed and straw yield tended to be superior under weed-free conditions, the importance of sufficient weed control strategies in flax production is apparent. Without weed competition, the applied N is more available to flax, which improves yield potential. Producers should select fields with a history of low weed pressure when growing flax, especially if organic production is considered as regulations would prohibit chemical weed management. Moreover, producers should exercise caution when applying N to flax, as N was found to unfavorably benefit weed competition. Applying N as compost tended to result in the greatest amount of weed biomass. It is possible that more N in the compost was plant available than anticipated resulting in greater weed growth. Nitrogen did have an effect on flax as seed and straw yield increased with N in 2007, but only under weed-free conditions in 2008. Linolenic acid (omega-3 fatty acid) concentration of seed oil, however, was reduced by N and regardless of weed competition. Late seeding and prolonged moist field conditions in 2008 contributed to lower yields and the general lessened response to N source and N rate that year. BC

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