FLAX SEED YIELD AND QUALITY AS AFFECTED BY N AND P

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ABSTRACT

Flax (*Linum usitatissimum)* has the potential to become an important oilseed crop for bio-products and is well adapted to the cropping systems of Montana. Little information on the response of flax to N and P fertilization is available; consequently, nutrient management research was initiated in 2004 and 2005 at four locations each year. Nine treatments consisting of 0, 30, and 60 lbs N/acre in combination with 0, 15, and 30 lbs P_2O_5/acre were applied at planting in a factorial, RCB design. Average yields ranged from 425 to 1783 lbs seed/acre; six locations responded to N while only two responded to P fertilization. Average seed oil contents averaged between 40.2% and 42.2% and declined slightly at six locations as N levels increased. Phosphorus fertilization increased seed oil content slightly at the 2004 location that experienced the P yield response. Palmitic fatty acid levels averaged 3.3 to 5.1 % of the oil content, oleic averaged 15.5 to 17.1 %, linoleic 14.8 to 17.7%, linolenic 53.4 to 61.6% and stearic 2.7 to 3.4 %. Linoleic fatty acid levels were unaffected by N and P fertilization; however, palmitic levels declined with increasing N at one location and increasing P at another location. The most important fatty acid, linolenic, declined slightly with increasing N at three locations. Oleic fatty acid levels increased slightly with N fertilization at three locations in 2005.

INTRODUCTION

Biodiesel is expected to increase in consumption in the United States at a rate between 6-14% annually. Currently, the United States consumed 25 million gallons of biodiesel in 2003, and in 2005, consumption is slated to be 100 million gallons. This is expected to increase to 250 million gallons by 2007; however, the issue with biodiesel has been cost. Using canola as a base oil, production costs are expected to be $2.25-$2.60/gallon. Seventy-five percent of this cost is in the base oil ingredient. What is required is a crop with relatively low input costs which could reduce biodiesel production costs to approximately $1.15-$1.50/gallon. Flax has the potential to become a major source of oil for biodiesel because it is well adapted and offers a badly needed rotation crop for inclusion into the dominant, small grain cropping system.

Historically flax was an important crop in Montana. According to Montana Agricultural Statistics, the first reported harvested flaxseed acreage occurred in 1902 peaking at 515,000 acres in 1943. Flaxseed acreage gradually declined and no harvested acreage was reported from 1978 until 1998. Flaxseed acreage appeared again in 1999 and has steadily increased to 53,000 harvested acres in 2005. In Montana, flax nutrient management information is non-existent; therefore, fertilizer experiments were initiated with the following objectives: to evaluate seed yield, oil content, and oil quality response of flax to N and P fertilization in North Central Montana.

MATERIALS AND METHODS

Flax (variety indicated in site characteristics table) was planted in a RCB, factorial design with the following fertilizer treatments: 0, 30, and 60 lbs N/acre as urea applied broadcast or in a band to the side and above the seed while planting and 0, 15, and 30 lbs P_2O_5/acre as triple super phosphate applied with the seed. In addition all plots received 25 lbs/acre of K_2O as KCL applied with urea. Plots were planted in 2004 at Sunburst and Cut Bank locations in 2005 with a six-row, 12-inch spaced planter. The other locations were planted with a 5-row, 10-inch spaced planter with a Conserv-a-pac opener that placed N fertilizer above and to the side of the seed. Plot length was 25 feet. All locations, except WTARC, were planted no-till into previously fallowed land or following barley. Soil test results and site characteristics are shown in Tables 1 and 2.

Table 1. Soil test results by location. Western Triangle Ag. Research Center, Conrad, MT. 2004-2005.

Test	Cut Bank		Joplin		Sunburst		WTARC	
	2004	2005	2004	2005	2004	2005	2004	2005
pH	9.1	8.4	8.0	8.2	8.1	6.5	8.6	8.3
O.M. (%)	1.9	2.2	1.3	1.5	1.9	3.7	2.4	2.2
P (ppm)	4.5	7.4	18.9	10	40.2	27.5	16.4	12.1
K (ppm)	228	343	366	326	436	568	246	290
NO_3-N (0-3', lb/ac)	92	39	57	70	97.6	28	81	58
SO_4-S (0-3', lb/ac)	129	531	2089	1476	2827	153	820	5521

Table 2. Site characteristics by location. Western Triangle Ag. Research Center, Conrad, MT. 2004-2005.

Character	Cut Bank	Joplin	Sunburst	WTARC
2004				
Variety	Pembina	Golden	Pembina	Pembina
Planting Date	April 30	May 3	April 26	April 13
Harvest Date	Sept 16	Sept. 8	Sept. 8	Sept.2
Previous Crop	Chem. Fall.	Chem. Fall.	Barley	Fallow
2005				
Variety	York	Neche	Carter	Omega
Planting Date	April 25	April 19	May 3	April 26
Harvest Date		Sept. 1	Sept. 8	Sept. 2
Previous Crop	Chem. Fall.	Chem. Fall.	Barley	Fallow

RESULTS AND DISCUSSION

Seed yield results of the N responsive sites are presented in Figure 1. The Cut Bank and Sunburst locations in 2004 had excessive variability and high soil N levels and are not shown. Average yields ranged from 425 to 1243 lbs seed/acre in 2004 and 792 to 1527 in

2005. As shown in Table 3 only two locations responded to P; however, the Sunburst location had a significant N x P interaction that is shown in Figure 2.

Average seed oil contents (Table 5) ranged from 40.2 to 42.2 %. Seed oil concentration declinced slightly at six locations as N levels increased. In 2004 P fertilization increased seed oil content slightly at WTARC but did not affect seed oil concentration at the remaining locations.

Fatty acid composition data are summarized in Table 4. In 2004 palmitic fatty acid levels averaged 3.3 to 3.8 % of the oil content, oleic averaged 15.5 to 17 %, linoleic 14.8 to 17.7 %, and linolenic 53.8 to 61.6 %. Oleic and linoleic fatty acid content were unaffected by N and P fertilization; however, palmitic levels declined with increasing N at WTARC and increasing P at Cut Bank. The most important fatty acid, linolenic declined slightly with increasing N at Joplin but was unaffected by P at all locations and by N at WTARC and Cut Bank. There were no significant N and P interactions at any location.

In 2005 palmitic fatty acid levels averaged 4.8 to 5.1 % of the oil content, oleic averaged 15.5 to 17 %, stearic 2.7 to 3.4 %, linoleic 16.2 to 17.2 %, and linolenic 53.4 to 61.2 %. Palmitic and linoleic fatty acid content were unaffected by N fertilization; however, oleic levels increased with increasing N at Joplin, Sunburst, and WTARC. Stearic increased significantly at Sunburst with increasing N, and linolenic declined slightly with increasing N at Joplin and Sunburst. Phosphorus had no affect on any of the fatty acids; however, there was one significant N and P interaction with linoleic fatty acid at Cut Bank.

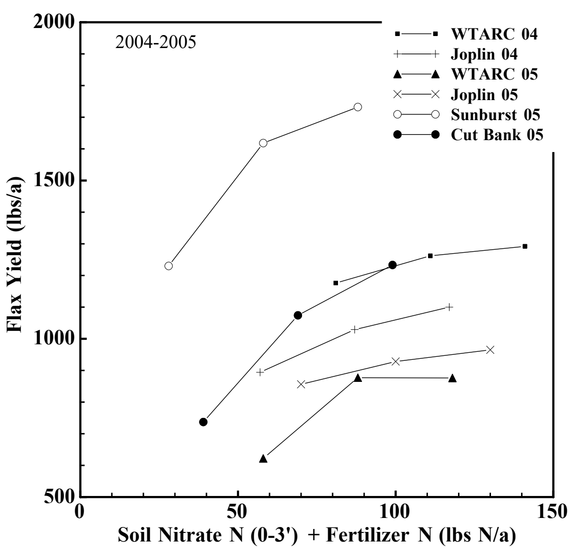

Figure 1. Effect of N on flax seed yield.
Western Triangle Ag. Res. Ctr., Conrad, MT

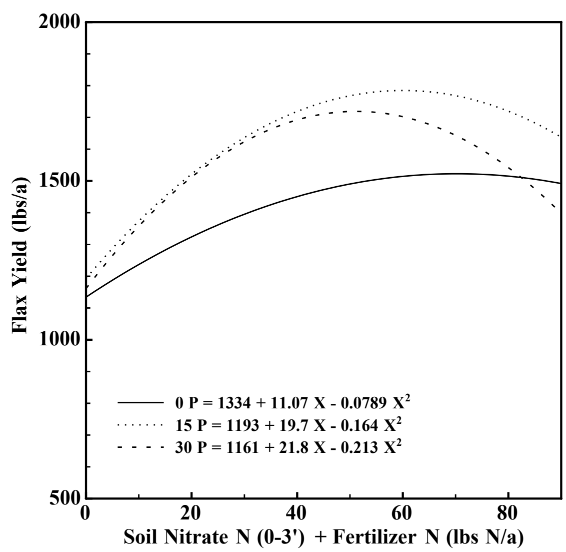

Figure 2. Effect of N and P on flax seed yield. Sunburst Site.
Western Triangle Ag. Res. Ctr., Conrad, MT. 2005.

Table 3. Effect of phosphorus on seed yield of flax. Western Triangle Ag. Research Center, Conrad. 2004-2005.

P_2O_5 Rate	Year - Location							
	2004				2005			
	Cut Bank	Joplin	Sunburst	WTARC	Cut Bank	Joplin	Sunburst	WTARC
------lbs/acre------								
0	723 a	1002 a	440 a	1214 a	999 a	869 a	1548 a	840 a
15	730 a	999 a	433 a	1291 b	1018 a	942 b	1537 a	764 a
30	702 a	1023 a	402 a	1226 ab	1027 a	938 b	1495 a	771 a
p values of linear and quadratic contrasts and interaction, and summary statistics								
Linear	0.678	0.576	0.089	0.736	0.385	0.031	0.086	0.496
Quadratic	0.694	0.679	0.536	0.027	0.857	0.146	0.549	0.636
Interaction	0.674	0.711	0.897	0.392	0.142	0.955	0.029	0.133
Mean	718	1008	425	1243	1015	916	1527	792
CV (%)	17.3	9.0	12.3	6.8	7.8	8.1	4.8	31.1

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 4. Average flax fatty acid content. Western Triangle Ag. Research Center, Conrad, MT. 2004-2005.

Fatty Acid	Location						
	2004			2005			
	Cut Bank	Joplin	WTARC	Cut Bank	Joplin	Sunburst	WTARC
	------% of Oil Content ------						
Oleic	15.5	17.7	17.0	14.2	17.3[1]	16.6[1]	21.1[1]
Palmitic	3.3[2]	3.5	3.5[1]	4.9	5.0	5.1	4.8
Linoleic	14.8	15.4	17.7	16.2	16.3	17.2	17.0
Linolenic	61.6	59.2[1]	53.8	61.2	57.5[1]	57.9[1]	53.4
Stearic	ND	ND	ND	3.4	3.4	2.7[1]	3.4
ND = Not Determined; [1]N Response; [2]P Response							

Table 5 . Effect of nitrogen and phosphorus on the oil content of flax. Western Triangle Ag. Research Center, Conrad. 2004 - 2005.

Treatment $N – P_2O_5$	Year - Location						
	2004			2005			
	Cut Bank	Joplin	WTARC	Cut Bank	Joplin	Sunburst	WTARC
lbs/acre	---------------------------------------%---------------------------------------						
Nitrogen Summary							
0	40.8 a	42.6 a	42.4 a	40.5 a	41.6 a	41.2 a	40.4 a
30	40.4 b	41.9 b	42.2 a	40.5 a	41.0 ab	41.2 b	40.2 a
60	40.4 b	41.7 b	42.1 a	40.6 a	40.6 b	40.6 b	40.1 a
Linear contrast p-value	0.0286	0.001	0.043	0.732	0.006	0.001	0.093
Quad. contrast p-value	0.288	0.038	0.573	0.843	0.771	0.022	0.692
Phosphorus Summary							
0	40.6 a	41.9 a	42.0 a	40.3 a	41.1 a	41.1 a	40.3 a
15	40.6 a	42.0 a	42.4 a	40.6 a	41.1 a	41.0 a	40.2 a
30	40.4 a	42.2 a	42.2 a	40.7 a	41.0 a	40.9 a	40.2 a
Linear contrast p-value	0.480	0.136	0.205	0.179	0.757	0.298	0.479
Quad. contrast p-value	0.646	0.971	0.062	0.693	0.812	0.744	0.497
Summary Statistics							
Interaction p-value	0.911	0.510	0.622	0.862	0.600	0.482	0.964
Mean	40.5	42.0	42.2	40.5	41.1	41.0	40.2
CV (%)	1.1	0.8	0.93	1.5	1.9	0.9	1.1

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

SUMMARY

Nitrogen generally lowers oil content and has an impact on oil composition at specific locations. Also N usually decreases saturated fats and increases mono- and poly-unsaturated fatty acids. This may be due to a delayed maturity as mono- and poly-unsaturated fatty acids are generated from saturated fats.

Biodiesel composition can be affected by soil fertility under specific conditions. Poly-unsaturated oils have been regarded as not being beneficial and have been cited to produce varnish and corrosion of rubber. However, these effects are generally unfounded unless the fuel has become oxidized. The higher levels of poly-unsaturated fats do lower the pour point of the fuel which would be beneficial during cold weather.

REFERENCES

Montana Agricultural Statistics. 1902-2005. www.nass.usda.gov/mt/crops/flxsdayp.htm.