A FLAX PRODUCTION SYSTEMS ANALYSIS

J. J. Hammond

Crop production as a science deals with both the theoretical and applied aspects of growing plants. It is a correlating science, concerned with bringing together principles developed in specialized areas.

Maximum production cannot be realized for any crop without an understanding and application of principles developed in soil science, plant pathology, entomology, weed science and the general area of botany. Practical systems of soil management and utilization are needed to realize maximum profit per unit area. Plant pathology and entomology provide essential information to control diseases and insects. Weed science gives an understanding and methods to control the largest crop enemy, weeds. Botany is concerned with plant growth and the function of the living plant.

Yield obtained from a given area is a function of many factors. Certainly, non-controllable climatic factors are very important in the resulting yield. However, a number of controllable factors also can be very influential in the final yield.

We are concerned in this article with controllable factors affecting seed yield of flax. Ten areas of research will be discussed. To make suggestions as to what is limiting yield, a brief economical analysis is attempted. An order of events in flax production is followed rather than an order of importance.

Selection of Field

Flax can be grown profitably in all crop rotations. For best yields, careful planning is needed. As with other crops commonly grown in the flax growing region of the North Central States, flax yields have been higher following fallow than nonfallow if weeds are controlled (Table 1). From the crop rotation standpoint it is of interest that wheat and barley yield more following flax than when following wheat (11).

Flax, unlike other cash crops in the North Central States, is not grown on the most productive soils, nor is it grown on the most weed-free areas. Independent of crop rotation, it is very important to select a field that is fertile and relatively free of weeds. Flax is a poor competitor, and careful planning is needed to minimize yield losses from weed competition.

Table 1. Yield of wheat, barley and flax following fallow, wheat or flax.[1]

Crop Evaluated	Yield (lbs/A) following		
	fallow	wheat	flax
Wheat	1694	1212	1250
Barley	2130	1799	1897
Flax	554	416	351

[1]After Gerrie et al (11)

Fertilizer

Average crops of flax remove about 27 pounds of nitrogen, whereas wheat and barley remove about 45 pounds (7). Flax removes only one-half to three-fourths as much phosphorus and potassium as does wheat or barley. Since flax is relatively high in protein and oil rather than carbohydrates, the nutrients required to produce one pound of flax seed is greater than required to produce a pound of wheat or barley seed (Table 2).

Table 2. Pounds per acre and per pound of seed of major elements removed by average production of wheat, barley and flax.[1]

Crop	Nitrogen (lbs)	Phosphorus (lbs)	Potassium (lbs)
Wheat	46(.0299)[2]	6(.0040)	7(.0048)
Barley	44(.0242)	6(.0035)	10(.0052)
Flax	27(.0444)	3(.0052)	5(.0080)

[1]After Clagett et al (7)
[2]Values in parentheses are pounds of nutrients per pound of seed.

Even though flax as a crop has a low fertility requirement, experiments clearly indicate that flax will respond to fertilizer, particularly nitrogen (Figure 1). Applications of 20 pounds of nitrogen per acre increased yields about 10 per cent (13, 16). Experiments (13, 16) indicate little effect (or perhaps negative effect) with application of phosphorus (Figure 2).

Dr. Hammond is assistant professor, Department of Agronomy.

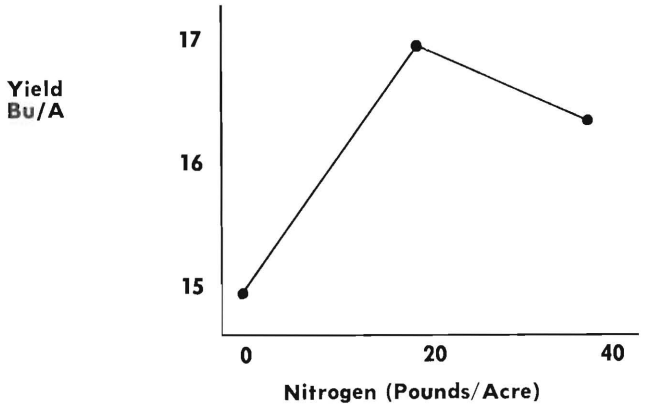

Figure 1. Effect of nitrogen on flax yield in North Dakota (from Zubriski (16) and Sckerl (13).

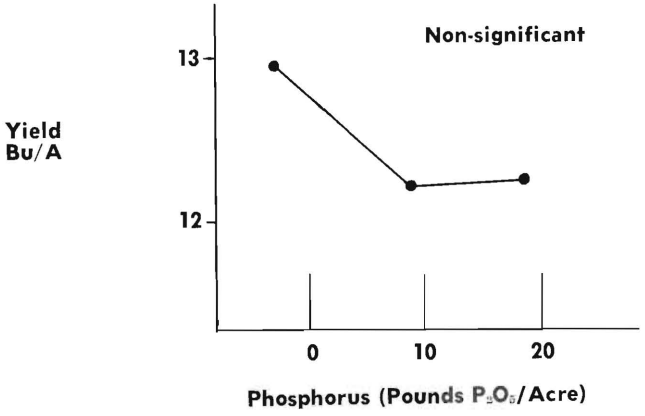

Figure 2. Effect of phosphorus on flax yields in North Dakota (from Zubriski (16) and Sckerl (13).

Some minor elements, particularly zinc, have increased yields nearly 20 per cent (6). In each experiment reported, some zinc increased yield ranging from ½-bushel per acre to nearly double yields (10 bu/A) in one experiment (Table 3).

Table 3. Effect of zinc on flax yields in North Dakota.[1]

No zinc	17.2 bu/A
Zinc added	20.5 bu/A

[1]Zubriski data cited by Chesnin (6).

For flax, as with most crops, the balance of fertilizer is critical. In one experiment reported at the Flax Institute (3), yields were reduced by one-half with application of phosphorus. However, with the addition of zinc and phosphorus, yields were markedly increased (Table 4).

Early research involving flax fertilization often failed to consider fertilizer placement in relation to the seed, possibly explaining the lack of response. Experiments comparing fertilizer placement clearly

Table 4. Effect of fertilizer balance on flax yields in Texas.[1]

Application	Yield (Bu/A)
None	14
P_2O_5 (25 lbs/A)	7
P_2O_5 + 1% spray $ZnSO^4$	15
P_2O_5 + 3 lbs/A $ZnSO^4$	20
P_2O_5 + 1.3 lbs/A Zn Edta	25

[1]After Anderson & Reyes (3)

indicate an advantage of placement separate from the seed (Table 5). Placement of fertilizer (particularly nitrogen) with the seed reduced yields from one to three bushels per acre. On the average, a 15 per cent increase in yield was realized by placement separate from the seed (13, 16).

Table 5. Effect of fertilizer placement of flax yields in North Dakota.[1]

With seed	16.4 bu/A
Separate	18.7 bu/A

[1]After Zubriski (16) and Sckerl (13)

In general, flax responds when grown on fertile soils. A combination of soil test and cropping history should be followed in the flax fertility program. High rates of fertilizer should not be placed in contact with the seed. Growing flax on fertile soil enhances the need for weed control since weeds also grow better on fertile soil.

Weed Control

Numerous studies have shown reduction in yield as a result of weed infestation. To grow a good crop, weeds must be controlled since flax is a poor competitor. Many of the production practices are designed to minimize weed problems. Early fall working of the field for spring planting of flax stimulates fall germination of weed seeds. However, the use of chemical weed control frequently is needed for adequate control.

A number of selective chemicals are available for weed control in flax. Depending on the weed problem and herbicide used, control costs from $1.25 to $4.50 per acre (Nalewaja, personal communication). Unfortunately, many of the chemicals may cause some damage to flax (Table 6), and should not be used unless there is a weed problem.

Table 6. Effect of 0.75 pounds of Dalapon per acre on flax yields at Fargo, North Dakota in 1967.[1]

Treatment	Yield (bu/A)
Weed free	18.2
Weed free + Dalapon	17.7
Weedy + Dalapon	12.9
Weedy	9.0

[1]Unpublished data, J. D. Nalewaja

A combination of chemicals may be required for good weed control in flax (Table 7). Triallate gave 95 to 100 per cent control of wild oats. Addition of MCPA and dalapon gave nearly complete control of wild mustard and almost 85 per cent control of foxtail. The application of triallate + trifluralin + MCPA gave nearly complete control of the three weed species. Asulam 0.1 per cent gave good control of wild oats and wild mustard, and with the addition of MCPA about 80 per cent of the foxtail was controlled. All treatments gave a significant yield increase over the weedy control.

Table 7. Effect of combinations of pre- and postemergence chemicals of flaxseed yields at Fargo, North Dakota in 1972.[1]

Treatment[2]	Rate (oz/A)	Yield (lb/A)
Triallate + MCPA + Dalapon	16+4+12	1087
Triallate + Trifluralin	12+8+4	1045
Barban + MCPA + Dalapon	6+4+12	1040
Asulam + MCPA	16+4	1023
Asulam .1%S	12	1010
Control		656

[1]Unpublished data, J. D. Nalewaja

[2]Some of these chemicals are not cleared for use on flax. Data are shown only to indicate need for research in this area.

The above experiment was cited only as an example. Certainly, any of a number of experiments could be used to show yield increase as a result of chemical weed control. Bothun and Nalewaja (4) suggested "three approaches to improving weed control in flax could be (1) to develop varieties of flax resistant to MCPA and Dalapon to permit the use of higher rates for better weed control without flax injury, (2) to discover a more effective and safer time of application and to develop a better method of applying the present herbicides, and (3) to discover a herbicide which is more selective in flax." Perhaps determining rates, times and methods of applying combinations of preemergence and postemergence selective chemicals should be added.

Observations of commercial production and yield loss as a result of weeds experimentally indicate that greater emphasis should be placed on weed control. Surveys show a lower percentage of flax acres with application of selective herbicides than of small grains. Consequently, the average cost per acre for chemicals was about 20 cents less for flax than for wheat or barley. The cost of herbicides is very little in comparison to potential returns. Since flax is a poor competitor, the net return may be much greater for flax than for wheat or barley.

Seedbed Preparation

For best yields it is important to prepare a firm, moist seedbed. Flax is a relatively small seeded crop and consequently must be planted shallow but yet in enough moisture for fast germination. Diseases can readily attack flaxseeds and decrease stands.

Data are limited as to the best method of seedbed preparation or depth of planting. In general, seeds should not be planted deeper than one to 1½ inches. Bolley (5) stated: "A firm, compact soil underlying shallow planted seed always gives best results. Make the land so firm that the drill will press the seed down, evenly, only one inch under a moist dirt mulch."

The best method of preparing a firm seedbed depends somewhat on the previous crop. If a winter stubble cover is needed to control wind erosion, use a subsurface tiller to control weeds immediately after harvest. Where one to two inches of rainfall can be expected following small grain harvest, plow as soon as possible after the crop is removed. Break up large clods and firm the soil, leaving a smooth seedbed favorable for fall weed germination. Shallow spring tillage after the above fall operations provides an excellent flax seedbed. In central North Dakota, flax often is seeded on nonfallow with a plow-pony press drill combination to conserve all soil moisture possible and assure placement of seed in moist soil for quick germination.

Grassland or sod should be plowed not later than early August and worked much the same as small grain stubble to prepare a firm seedbed the following spring. Preparing a firm seedbed for flax after fallow can be obtained with little spring tillage.

Clean soybean stubble should be disked rather than plowed. Disking leaves a fairly firm seedbed, relatively clean, and reduces erosion problems. Clean corn cut for silage can be handled similar to soybean stubble. Corn for grain is less desirable, since it often must be plowed in the spring which does not provide a good seedbed for flax.

Seed Selection

Little difference exists in the several suggested varieties for commercial production. Certainly, a long season or late maturing variety is superior if planted early. If planting must be late, then an early maturing variety should be planted.

Independent of the variety grown, seed quality should be good. Handle home-grown seed carefully to minimize varietal mixtures. Flax seed should be

free of weeds, blight, broken or cracked seeds, and bits of straw and chaff which may carry diseases. Certified seed assures varietal purity, high seed quality and freedom from noxious weeds. Treat flax seed for protection against soil and seed borne diseases.

Planting Date

The advantage of seeding flax early has been known for many years. Nearly 60 years ago, Clark (8) stated, "Flax sown the latter part of April or the first week in May usually gives the best results." However, as evidenced by the greatest per-acre yield in the 1969 flax yield contest (12), under favorable conditions late seedings can result in good yields per acre. Certainly, many factors in addition to seeding date influence the final yield of flaxseed. In general, seeding a long-season variety early results in the best possible flaxseed yield.

Results have been reported from a number of experiments on date of seeding. Flor (9) reported results of six years of sowing the more popular varieties and experimentals at two-week intervals from late April to early June. Bothun (unpublished) continued the date of seeding study started by Flor. A within-year regression pooled over 10 years and a total of 42 dates of seeding indicate a 0.28 bushel per acre loss as a result of each day delay in seeding (Figure 3).

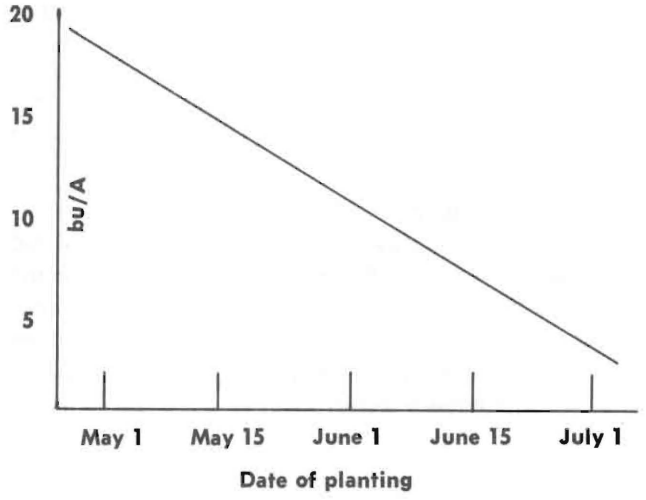

Figure 3. Effect of date of planting on flax yields at Fargo, North Dakota (from Flor (9) and Bothun, unpublished).

Seeding Rate

Experiments involving seeding rates of flax indicate little influence on yield with seeding rates from 10 to 60 pounds per acre (Figure 4). The flax plant apparently adjusts to an extremely wide range in seeding rate, primarily through basal branching. Certainly, with seed of low germination one needs to adjust the seeding rate. With reasonable germination (above 80 per cent) ½-bushel of seed per acre should respond as well as higher rates of seeding if weeds are controlled.

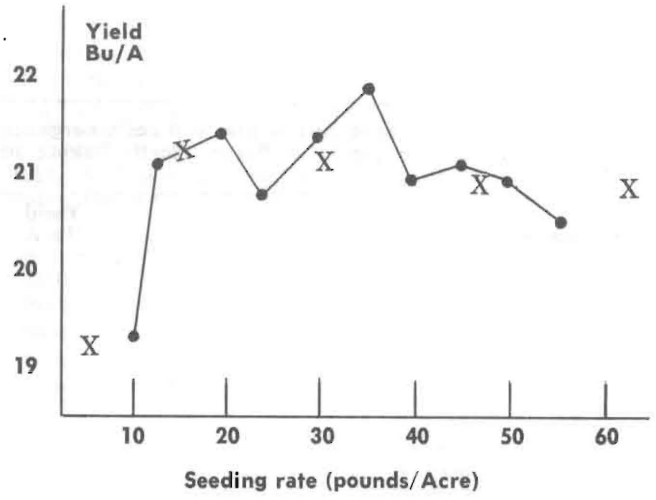

Figure 4. Effect of rate of seeding on flax yields (from Albrechtsen, (1) and Bothun, unpublished).

Row Spacing

As with rate of seeding, row spacing has little effect on flax seed yields. Alessi (2) indicated very little difference in yield with row spacings of 3, 6 and 12 inches (Figure 5). However, under weedy conditions a drastic reduction is evident with wider row spacing. Again, as with rate of seeding date,

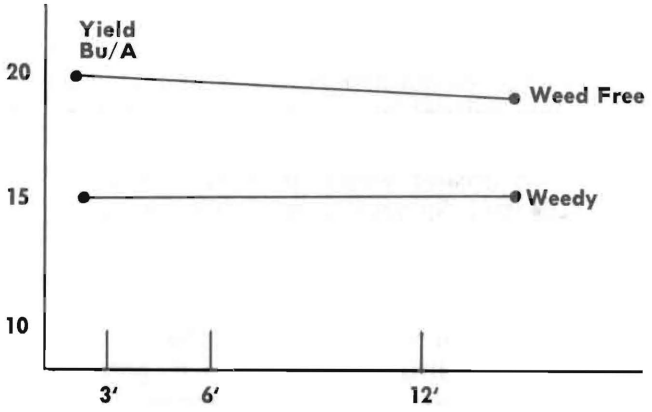

Figure 5. Effect of row spacing on flaxseed yield at Mandan, North Dakota (from Alessi, 2).

these data suggest that given the opportunity the flax plant will branch and produce good yields with relatively few plants per unit area.

Harvest Date

Once other practices have been followed to obtain good yields, it is important to harvest as much of the seed produced as possible. This requires timely harvest.

Ford (10) stated, "It is commonly believed that flax may be left standing for some days after it reaches maturity without loss of yield or quality of the seed." Data available on date of harvest suggests that harvest about one week before flax is generally considered ripe gives maximum yields (Table 8). Flax is considered ripe when 90 per cent of the bolls have turned brown. Ford's (10) work indicates that yields were maximum when moisture content of seed was between 10 and 20 per cent.

Table 8. Effect of moisture content at harvest on yield of flax.

Line 1		Line 2	
Moisture (%)	Yield (bu/A)	Moisture (%)	Yield (bu/A)
8.2	34.2	8.2	30.9
10.2	34.3	9.8	32.0
15.6	35.9	10.5	33.5
22.7	34.4	18.8	33.5
44.9	34.2	38.7	29.5

After Ford (10)

Of interest to seed growers was the decreased germination as harvest was delayed (Figure 6). With the exception of CI1664, grown in 1956 first harvest, a rapid decrease was noted in per cent germination with delayed harvest. Other seed characteristics apparently were not affected by date of harvest.

From the work with date of harvest one would conclude that harvest should be at least one week before 90 per cent of the bolls are brown. Certainly, delayed harvest would not be a good practice to produce seed flax for planting and likely would result in slightly lower yields.

Economical Analysis

Previously, we have discussed production practices that affect flaxseed yields. To make some inference as to what needs to be done, it becomes important to compare flax with other crops. Since North Dakota is primarily a state producing wheat and barley, let us compare these crops. In the years 1965-1969, the average gross return per acre in North Dakota was $37.53, $32.94 and $29.79 for

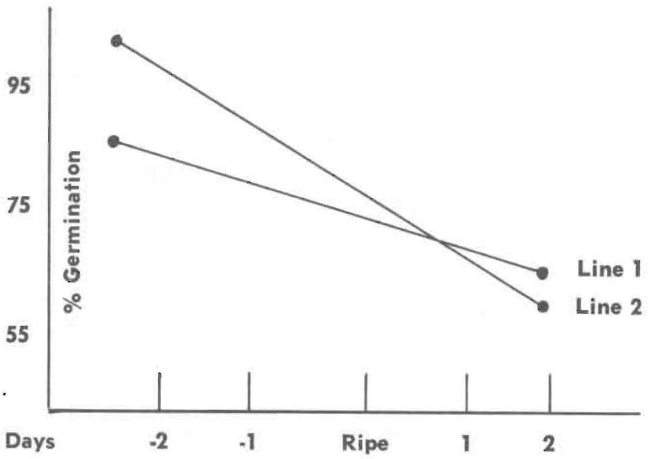

Figure 6. Effect of time of harvest on germination of harvested seed (from Ford (10)).

wheat, barley and flax, respectively (Table 9). However, production costs are not constant. An average crop of wheat removes approximately $8.45 of major nutrients, costs $2.50 for seed and $1.03 for herbicides. By making the same calculations for barley and flax, flax returns about $5.35 less than wheat and $1.26 less than barley. These data are not directly comparable to Taylor and Schaffner (15) in which flax was about $13 per acre lower than wheat and $3 lower than barley in net cash income assuming "better than average management". Primary differences exist in the assumed value of grain produced per acre and fertilizer costs. Whether the difference is $5 or $13 per acre, how can this be improved?

Table 9. Economical analysis of wheat, barley and flax as grown in North Dakota.

Crop	Value[1]	Fertilizer[2] Cost	Seed[1] Cost	Herbicide[3] Cost	Net
Wheat	$37.53	$8.45	$2.50	$1.03	$25.55
Barley	$32.94	$8.30	$2.10	$1.03	$21.51
Flax	$29.79	$4.90	$3.75	$ .84	$20.25

[1]After Taylor (12).
[2]Calculations based on Clagett et al (7).
[3]Weed survey of Extension Service, unpublished.

The most apparent way to improve flax yields in relation to other spring grains would be to plant earlier. Using the estimate of 0.28 bushel decrease per day delay in planting and the estimated per cent of flax planted in weekly intervals, one can calculate the expected yield to be 10.6 bushels per acre as compared to 10.7 actual yield (Table 10). If one were to plant at the same time as barley, then the estimated yield would be 14.9 bushels per acre. Planting at the same time as hard red spring, one

would expect 17.0 bushels per acre. Certainly, factors other than time of planting influence the resulting yield. Data from the recent flax yield contests (12) indicated date of planting appeared rather unimportant in predicting yield. In general, this group appeared to favor planting when soil moisture conditions and seedbed preparation were ideal. However, from experiments in North Dakota averaged over a number of years, it would appear that date of planting is the single most important factor in the low return per acre from flax.

Table 10. Economic effect of changing planting time of flax to planting time of barley and wheat.

Week Planted	Estimated[1] yield (bu/A)	Per cent of crop planted[2]		
		Flax	Barley	Wheat
April 9 - April 15	24.4		1.00	5.75
16 - 22	22.5		2.25	8.00
23 - 29	20.5	0.50	9.25	15.75
April 30 - May 6	18.5	2.00	14.25	16.75
May 7 - 13	16.6	9.25	18.25	17.75
14 - 20	14.6	6.00	9.75	9.00
21 - 27	12.7	18.75	24.25	16.25
May 28 - June 3	10.7	23.25	15.25	8.50
June 4 - 10	8.7	18.50	5.00	2.25
11 - 17	6.8	12.50	0.75	
18 - 24	4.8	6.25		
June 25 - July 1	2.9	3.00		
Effect of changing seeding date				
Expected flax yield (bu/A)		10.6	14.9	17.0
Increased return ($/A)			$11.95	$17.80

[1]Calculated based on 0.28 yield loss per day after April 9 and average yield of 10.7 bu/A when planted June 1.
[2]From North Dakota Crop and Livestock Statistics 1965-1970.

Summary

To grow flax:

1. Select a fertile field relatively free of weeds.
2. Apply fertilizer with regard to soil test and cropping history. However, not more than 10 pounds of nitrogen should be placed in the row with the seed.
3. Weed control is essential. Cultural control practices should be supplemented with recommended chemicals as needed.
4. Seedbed preparation should include weed control and shallow tillage to conserve moisture. Maintain a firm seedbed.
5. Select good quality, weed-free seed with high germination and treat with a fungicide before planting. If planting must be late, select an early maturing variety; however, late maturing varieties seeded early give best results.
6. Prepare to plant by late April or early May. Flax tolerates low temperatures except when seedlings are just emerging. Planting delayed after early May results in about ¼-bushel per acre per day loss in yield.
7. Plant shallow (one to 1½ inches) on a firm seedbed.
8. Seeding rate is not critical except for added weed control. Plant 30 to 60 pounds per acre.
9. Row spacing, as with seeding rate, is not critical except for added weed control. Seed flax with a press drill, leaving approximately six to seven-inch row spacing.
10. Harvest when 75 to 90 per cent of the bolls have turned brown for best yield and highest quality seeds.

References

1. Albrechtsen, R. S. 1965. *Influence of seeding rate on the components of seed yield in flax.* Proc. 35th Annual Flax Institute.
2. Alessi, J. 1970. *Influence of row spacing, irrigation, and weeds on dryland flax yield, quality and water use.* Agron. J. 62:635-637.
3. Anderson, W. B., and L. Reyes, Jr. 1967. *Zinc deficiencies in flax induced by phosphorus fertilization.* Proc. 37th Annual Flax Institute.
4. Bothun, R. E., and J. D. Nalewaja. 1964. *Cultural practices.* Proc. 34th Annual Flax Institute.
5. Bolley, H. L. 1930. *Flax facts.* Minnesota Extension Special Bulletin 128, North Dakota Extension Circular 90, Montana Extension Bulletin 107 and South Dakota Circular 293.
6. Chesnin, L. 1966. *Zinc in relation to flax production.* Proc. 36th Annual Flax Institute.
7. Clagett, C. O., T. E. Stoa, H. J. Klosterman, A. F. Kingsley and W. W. Sisler. 1952. *The soil depleting power of the flax crop compared with that of hard red spring wheat, oats and barley.* North Dakota Agricultural Experiment Station Bulletin 378.
8. Clark. C. H. 1917. *Seed flax production.* Farmers Bulletin 785. United States Department of Agriculture.
9. Flor, H. H. 1954. *Time of sowing and yield of flax varieties.* North Dakota Agricultural Experiment Station, Farm Research, 16:5.
10. Ford, J. H. 1958. *The effect of time of harvest on the yield and quality of flaxseed.* Proc. 28th Annual Flax Institute.
11. Gerrie, H., W. J. White and E. N. Larter. 1958. *Crop rotation studies with flax at Saskatoon, Saskatchewan.* Proc. 28th Annual Flax Institute.
12. Oelke, E. A. 1970. *Two year summary of production practices used by growers participating in the flax yield contest.* Proc. 40th Annual Flax Institute.
13. Sckerl, M. M. 1963. *Effects of selected rates and placement of certain fertilizers on some agronomic and chemical characters of Bolley flax.* M.S. Thesis, North Dakota State University.
14. Taylor, F. R. 1972. *Statistics of North Dakota Agriculture.* North Dakota Agricultural Experiment Station Bulletin 408, revised.
15. Taylor, F. R., and L. W. Schaffner. 1972. *Crop production cost and profit returns.* North Dakota Farm Research 29:3, 33-36.
16. Zubriski, J. C. 1962. *Progress report on flax fertility studies.* Proc. 32nd Annual Flax Institute.