ZINC DEFICIENCY OF FLAX IN NORTH DAKOTA

J. T. MORAGHAN

"Chlorotic dieback" of flax (*Linum usitatissium* L.) was a commonly observed disease of flax in the Red River Valley over 40 years ago (1). The cause was not known at that time, but cold soil temperatures and the presence of lime accentuated the incidence of the disease. Severe "chlorotic dieback" was observed during May and June of 1982 in limited areas of flax growing on a Fargo clay soil at the Main Experiment Station (Figure 1).

Figure 1

Moraghan is professor, Department of Soil Science

"Chlorotic dieback" of flax is now known to be primarily due to zinc deficiency (4). The study of the problem in the field is often difficult because of the erratic and scattered nature of its occurrence within fields. Flax is one of the crops most susceptible to zinc deficiency, and the deficiency can develop in portions of fields in which growth of more resistant crops such as wheat, barley and oats would be normal. The cause of "chlorotic dieback" and the influences of zinc, phosphorus and iron fertilizers, levels of soil-extractable zinc and soil temperature on this disease were recently studied (4, 5, 6, 7).

Zinc Deficiency Symptoms

Severe zinc deficiency in flax can be easily recognized. Although the symptoms are distinctive they can vary markedly depending upon the severity and the stage of growth. Severe zinc deficiency is most likely to show up within two to four weeks of emergence; some recovery is often noted later in the season. Various stages of zinc deficiency are illustrated in Figure 2. The progression of the deficiency symptoms is:

Figure 2

(1) Growth slows down around the growing point of the main stem. The young leaves near the apex become stunted and develop a lighter color (Figure 2b). The older leaves on the main stem appear normal.

Figure 2b

(2) The basal portion of the young leaves near the apex then develop lighter areas which turn necrotic. The terminal meristem of the main stem dies when the deficiency is severe (Figure 2c). The leaves around the terminus of the main stem develop a rosette-like appearance due to the lack of stem elongation. The older leaves sometimes, but not always, develop an occasional bronze spot at this stage and may drop prematurely.

Figure 2c

(3) The death or severe retardation in the activity of the terminal meristem prematurely breaks apical dominance, as a result of which branches arise from one or both lateral meristems located at the cotyledonary node. The terminal meristems of the branches may grow normally (Figure 2d). This is frequently observed under field conditions and appears to be associated with warmer soil temperatures and greater root activity. However, with very severe zinc deficiency these branches may become affected similarly to the main stem (Figure 2e), and additional lateral branches may arise. In extreme cases of deficiency the plant may die. Lateral branches, such as those observed in Figure 2d, may develop normal panicles and yield excellent seed. The only apparent sign of zinc deficiency at flowering may be the extremely stunted main stem which is dwarfed by the large branches.

(4) If the terminal meristem on the main stem is not killed it may resume growth and produce normal leaves,

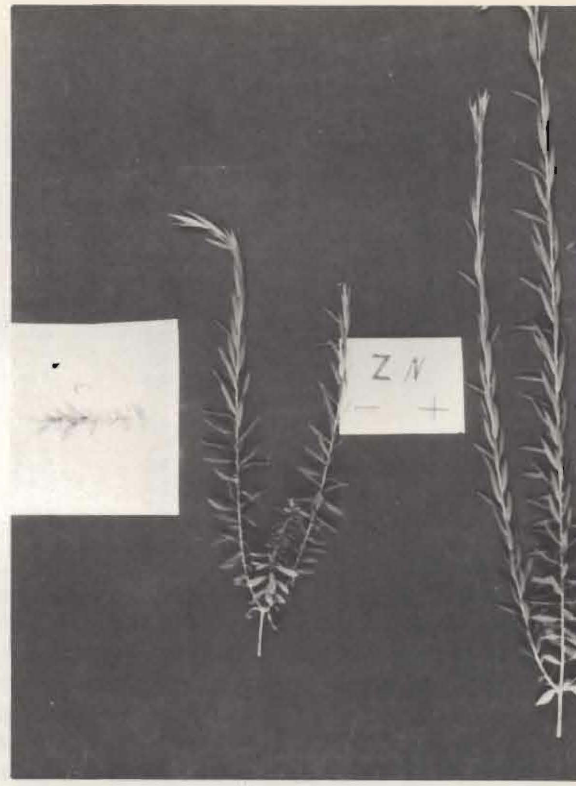

Figure 2d

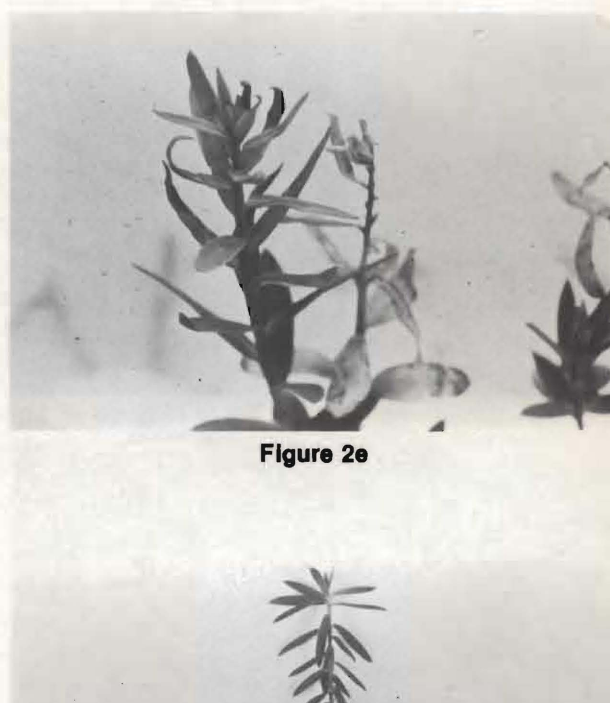

Figure 2e

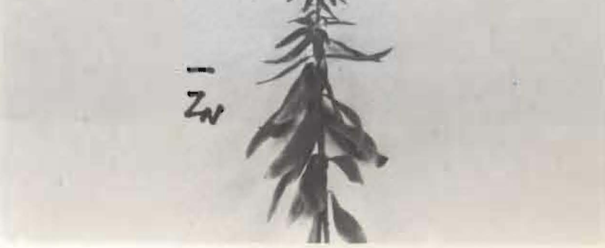

Figure 2f

especially with the advent of warm weather. Nevertheless, the leaves around the meristem, when the deficiency was evident, do not reach normal size and are subsequently bunched in an intermediate zone on the stem (Figure 2f).

Iron deficiency is another abnormality which affects flax in North Dakota. The problem is normally most severe when flax is grown on calcareous soils and the soils are excessively wet. Afflicted plants exhibit an intense chlorosis and portions of fields may appear white or yellow. Iron deficiency in flax, unlike zinc deficiency, does not produce the dieback-rosette syndrome.

Soil Temperature and Zinc Deficiency

The severity of zinc deficiency under field conditions generally decreases during June and early July. Although variations in photo-period or light intensity may contribute to recovery, the seasonal increase in soil temperature accompanying the recovery is probably a dominant causal factor. A greenhouse study at Fargo clearly showed the importance of soil temperature as a factor contributing to zinc deficiency in flax (4). Responses to zinc fertilizer and the incidence of dieback of main stems were greater at low soil temperatures (Table 1).

Table 1. Influence of soil temperature on incidence of main stem dieback in flax and response to zinc fertilizer.

Soil temp.	Applied Zn	Main stem dieback	Relative response to zinc[1]
°C (°F)	ppm		
7 (45)	0	Very severe	2.5
	4	Absent	
16 (60)	0	Severe	1.1
	4	Absent	
24 (75)	0	Absent	0.4
	4	Absent	

[1]Relative response = $\frac{\text{Yield (4 ppm Zn)-Yield (0 ppm Zn)}}{\text{Yield (0 ppm Zn)}}$

Phosphorus Level and Zinc Deficiency

High levels of soil or fertilizer phosphorus increase the chances that flax will respond to zinc fertilizer, if the soils are marginal in available zinc. Zubriski (9) concluded from field experiments that added zinc may be necessary for maximum yields of flax on some soils in North Dakota. At one site 20 pounds P_2O_5/acre in the row decreased yields but the detrimental effect was overcome by application of zinc fertilizer.

The influence of phosphorus and zinc fertilizers on zinc deficiency in flax grown at a soil temperature of 7°C (45°F) under greenhouse conditions was recently studied (7). The contents of "available" phosphorus P (8) and "available" zinc (2) in the soil were considered "low" and "marginal," respectively. The data are given in Table 2. Phosphorus deficiency was dominant and no dieback was observed in the absence of added phosphorus, due to poor growth and a resultant low requirement for zinc. The severity of zinc deficiency, as indicated by the incidence of dieback, increased greatly as the rate of phosphorus fertilizer was increased. Intermediate rates of zinc fertilizer were less effective as the phosphorus rate was increased. In this experiment, added phosphorus did not cause a decrease in dry matter production. This is, however, not always the case as indicated by the effect of phosphorus fertilizer observed in Figure 3. Phosphorus-zinc interactions are complex and reportedly may involve phosphorus toxicity and other effects (3).

Table 2. Influence of phosphorus and zinc fertilizers on incidence of main stem dieback in flax grown at a soil temperature of 7°C (45°F).

Zn, ppm	P, ppm			
	0	40	80	120
	Dieback, number of plants/pot[1]			
0	0	15	20	18
2	0	2	14	20
4	0	0	1	9
8	0	0	0	0

[1]Each pot contained 20 plants.

Figure 3

Zinc Deficiency and Iron Nutrition

The iron chelate, FeEDDHA, sometimes improves the growth of flax. A greenhouse study, however, showed that under some conditions FeEDDHA decreased growth and increased the incidence of main stem dieback (4). The detrimental effect of 2 ppm FeEDDHA-Fe on flax growth in the absence of added zinc is clearly shown in Figure 4. Application of zinc fertilizer overcame the problem.

Zinc Deficiency and Soil Zinc

The Fargo clay soil on which flax developed chlorotic dieback in the field in 1982 (see Figure 1) contained 0.6 ppm DTPA-extractable zinc in affected areas. When flax was grown under greenhouse conditions on seven soils maintained at a soil temperature of 15.6 (60°F) main stem dieback was associated with only three soils containing, respectively, 0.6, 0.8 and 0.9 ppm DTPA-extractable zinc (6). No main stem dieback occurred

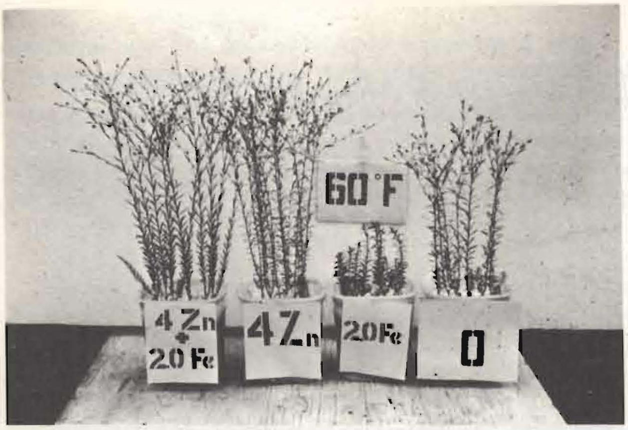

Figure 4

when flax was grown on the other soils containing 1, 1.5, 1.6 and 3.0 ppm DTPA-extractable Zn, respectively.

Zinc Fertilization of Flax

Farmers growing flax should inspect fields early in the growing season and look for main stem dieback. As mentioned earlier, the incidence of zinc deficiency is likely to be erratic. Affected areas can be sprayed with zinc sulfate or ammonium zinc sulfate solutions at the rate (in 10 gallons) of 0.2 to 0.4 pounds zinc per acre.

Sprays often adhere poorly to flax leaves and addition of a surfactant may improve results. A spray application of zinc, partly because of coverage problems when the leaf canopy is not well developed, is generally not as satisfactory as a soil applciation. However, spraying may be useful as an early growing season emergency measure.

Composite samples of soil obtained from entire fields will provide average values for DTPA-extractable zinc. If appreciable heterogeneity exists, the soil test may not predict the occurrence of limited areas of zinc deficiency. If a soil test indicates a field has less than 0.6 ppm DTPA-extractable Zn, an application of 10 pounds zinc per acre, as zinc sulfate, is recommended. The zinc should be broadcast and incorporated, preferably by a plow-down method. If only shallow incorporation is possible, application of zinc chelates will generally be superior to zinc sulfate. With zinc chelates the soil-applied rate can be reduced to 3 pounds zinc per acre. Zinc chelates may also be superior to zinc sulfate if a banded application method is used.

Summary

Flax is the most susceptible to zinc deficiency of the major crops grown in North Dakota. Zinc deficiency, once described as "chlorotic dieback," usually does not affect entire fields, but rather is present within relatively small irregularly shaped areas. Zinc deficiency is accentuated by low soil temperatures and is usually most obvious in fields in the early part of the growing season, especially if temperatures are below average. High levels of available phosphorus increase the likelihood of zinc deficiency in flax growing on soils marginal in available zinc. Application of phosphate fertilizers over a period of years will result in the availability of phosphorus to plants being increased. The incidence of zinc deficiency in fields which are marginal in available zinc is likely to increase with continued phosphorus fertilization. Application of the iron chelate, FeEDDHA, also increases the occurrence of zinc deficiency. The DTPA-extractable zinc level is, with certain qualifications, a useful guide for predicting the need for zinc fertilizer.

LITERATURE CITED

1. Flor, H. H. 1943. **Chlorotic dieback of flax grown on calcareous soils.** J. Am. Soc. Agron. 35:259-270.
2. Lindsay, W. L. and W. A. Norvell. 1978. **Development of a DTPA soil test for zinc, iron, manganese, and copper.** Soil Sci. Soc. Am. J. 42:421-428.
3. Loneragan, J. F., T. S. Grove, A. D. Robson, and K. Snowball. 1979. **Phosphorus toxicity as a factor in zinc-phosphorus interactions in plants.** Soil Sci. Soc. Am. J. 43:966-972.
4. Moraghan, J. T. 1978. **Chlorotic dieback in flax.** Agron. J. 70: 501-505.
5. Moraghan, J. T. 1978. **Chlorotic dieback and other nutritional problems affecting flax growth.** p. 27-29. In Proc. 47th Annual Flax Institute of the United States.
6. Moraghan, J. T. 1980. **Growth of flax and wheat in relationship to DTPA-extractable zinc.** p. 14-20. In Proc. 48th Annual Flax Institute of the United States.
7. Moraghan, J. T. 1980. **Effect of soil temperature on response of flax to phosphorus and zinc fertilizers.** Soil Sci. 129:290-296.
8. Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean. 1954. **Estimation of available phosphorus in soils by extraction with sodium bicarbonate.** USDA Circ. 939.
9. Zubriski, J. C. 1964. **The effects of fertilizers on flax.** H-15-8 Annual Report for 1963, Dept. of Soils, NDSU, p. 10-32.

LIST OF TABLES

LIST OF FIGURES