Lower Leaf Scorch of Sugarbeets Resulting from Potassium Deficiency in the Red River Valley*

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The sugarbeet industry has existed in the Red River Valley for nearly 60 years. Phosphorus deficiency was the principal nutrient deficiency limiting production in the early years (8). With the changeover during the last decade from growing sugarbeets on fallow to non-fallow land, need for nitrogen fertilization of sugarbeets has developed (7). Research involving the requirement of other elements for sugar production is limited.

Sugarbeet production in this important dryland production region, partly as a result of large increases in acreage, has expanded to include coarser-textured soils. A leaf scorch affecting older leaves, apparently due to a non-pathological cause, and which affects fully developed plants growing on certain of these soils during late July and August, was brought to our attention by fieldmen. The most conspicuous field-observed feature of the disease, which is not caused by either nitrogen or phosphorus deficiencies, is the appearance of upright older leaves with varying degrees of brownish, dead leaf-blade tissue. The objective of this study was to determine the cause of the problem.

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Materials and Methods

Comparison of the observed syndrome with published descriptions and colored photographs of sugarbeet nutrient deficiencies, leaf analysis, soil analysis, and greenhouse and field experiments were all used to determine the cause of the lower leaf scorch. The investigations involved the occurrence of the abnormality at one site (Site 1) in Clay County, Minnesota during 1974 and two sites (Sites 2 and 3) in Norman County, Minnesota during 1976. Some selected characteristics of the soils at the three sites are given in Table 1.

Table 1. Some properties of plow layers of soils on which sugarbeets developed lower leaf scorch.

Site	Soil type	pH[a]	C Org.	C Inorg	N	CEC[a]	Exchangeable K	Exchangeable Na
			%	%	%	meq/100g	ppm	ppm
1	Glyndon	8.1	2.3	2.2	0.22	20.1	78	--
2	Glyndon	8.1	2.1	1.8	0.25	19.7	76	11
3	Hamar	7.8	2.3	0.2	0.21	16.8	40	6

[a] The pH was determined in suspensions with water: soil ratios of 2; the CEC was determined using sodium acetate (pH=8.2) as the index salt.

Disease Syndrome

Two other sugarbeet researchers, Dr. W. Bugbee and Mr. Ron Torkelson, as well as the authors compared abnormality symptoms on the plants with published descriptions (9, 10, 11) of known nutrient deficiencies.

Leaf Analysis

Samples of blades and petioles from recently mature leaves were taken from afflicted and non-afflicted plants at the three sites, dried, ground, and analyzed for Mg, Na, and K by atomic absorption spectrophotometry after digestion by a mixture of $HClO_4$ and HNO_3 acids.

Soil Analysis

Soil samples from the plow layer of areas at the three sites in which afflicted plants were present were taken, dried, and analyzed for exchangeable potassium using 1N ammonium acetate (pH=7) as an extractant.

Greenhouse Experiments

Soil samples from the plow layer around sugarbeet plants showing the abnormality syndrome at Sites 2 and 3 were taken, dried, and sieved through a plastic screen with 0.6-cm openings. Samples equivalent to 3,700 g of oven-dried soil were added to plastic pots and treated with the following treatments:

(a) Check
(b) 60 ppm KCl-K
(c) 60 ppm $MgCl_2$-Mg
(d) Complete mixture

All treatments, which were replicated three times, received a basal dressing of 40 ppm $Ca(H_2PO_4)_2$ - P and 50 ppm $(NH_4)_2SO_4$-N. The "complete" mixture in addition to P, N, Ca and S received 60 ppm Na(NaCl), 4 ppm Zn($ZnSO_4 \cdot 7H_2O$), 4 ppm Cu($CuSO_4 \cdot 5H_2O$), 10 ppm Mn($MnSO_4 \cdot H_2O$), 2 ppm FeEDDHA-Fe, 3.5 ppm B(H_3BO_3) and 1 ppm Mo($(NH_4)_6Mo_7O_{24} \cdot 4H_2O$). Additional N was added periodically as required. Four seeds of sugarbeets (cv. American 2 Hybrid B), subsequently thinned to two plants, were planted and harvested after 5 weeks. Sugarbeets were then replanted in the pots; these plants were harvested after 7 weeks. The soil was then removed from the pots and 60 ppm K and 60 ppm Mg were added to the relevant soil samples which had originally received these elements. In addition, 60 ppm Na were added to the soil samples which originally received the "complete" treatment. The soil samples were then returned to the pots. Sugarbeets were then planted and harvested after 8 weeks. All plant samples were oven dried, weighed, and analyzed for K, Na, Mg, and Ca.

Field Experiment

The abnormality syndrome was most uniformly displayed at Site 3. A field experiment was established at this site in 1977 to determine if potassium fertilizer would eliminate the lower leaf scorch. Three rates of potassium fertilizer, 0, 50 and 200 pounds K/acre, were applied in a randomized block design with six replicates. The potassium together with a basal dressing of nitrogen and phosphorus fertilizers were broadcast and incorporated prior to planting sugarbeets (cv. American 2 Hybrid B).

Results and Discussion

Disease Syndrome

The abnormality in growth was first noticed after the development of a complete leaf canopy in the commercial fields. Younger leaves of large well-developed plants were little affected by the abnormality. Since older blades were much more severely affected than older petioles the most striking feature of the disease was an aerial display of older blades with large areas of brown to dark brown dead tissue. Some younger leaves at this stage displayed a marginal chlorosis similar to that illustrated for potassium deficiency (9, p. 443, plate 2). The chlorosis was succeeded by a marginal leaf necrosis and development of necrotic spots in the leaf interveinal tissue. These spots subsequently coalesced.

A perusal of the color atlas of deficiency symptoms of Ulrich and Hills (10) leads to the conclusion that the problem was due to either magnesium or potassium deficiency. Because of (a) lack of lesions on older petioles, (b) the presence of necrotic areas gradually expanding to include most of the interveinal tissue, (c) the general appearance of older leaf blades, and (d) the illustrations for potassium (p. 19) and magnesium (p. 21) deficiencies in reference (10) it was concluded that the problem was due to magnesium deficiency. However, the field abnormality resembled very closely that for potassium-deficient mangold plants illustrated by Wallace (11, plate 142).

At each of the sites the leaf scorch was observed during a prolonged rainless period. Soil moisture contents of the plow layer in all three cases were at or near the permanent wilting point. However, at Sites 1 and 2, because of adequate subsoil moisture, no wilting of leaves was observed. Moderate wilting had occurred at Site 3.

Leaf Analysis

Data related to composition of recently mature leaves from healthy and diseased plants for potassium, magnesium and sodium are given in Table 2.

The magnesium data, based on published plant analysis data (10), would appear to indicate that this element was not responsible for the abnormal growth at any of the sites. There was no consistent difference between magnesium concentrations of healthy and diseased organs.

Interpretation of potassium data of recently mature leaves requires reportedly a knowledge of petiole sodium concentrations. According to Ulrich and Hills (10) blades must be used when petioles contain less than 1.5% Na; either blades or petioles, however, can be used if sodium concentration is greater than 1.5%. Critical values for petioles and blades were in both cases given as 1% K, while deficiency symptoms were considered to be expressed at lower values. Brown et al. (2) confirmed in a greenhouse experiment that petioles of potassium-deficient sugarbeet petioles contained less than 1% K. Ulrich and Hills (10) cautioned that leaf material for

Table 2. Concentrations of potassium, sodium and magnesium in recently mature sugarbeet leaves from commercial field in which plants were afflicted with lower leaf scorch.

	K, %[a]		Na, %[a]		Mg, %[a]	
Location	H	D	H	D	H	D
			Blades			
Site 1	1.84	1.37	3.02	1.20	1.69	1.30
Site 2	2.09	1.74	4.42	1.14	1.51	0.90
Site 3	1.50	1.37	1.03	0.45	1.05	1.11
			Petioles			
Site 1	3.90	3.33	4.07	1.81	1.54	0.79
Site 2	3.21	3.72	4.21	1.12	0.49	0.65
Site 3	2.78	3.64	1.02	0.45	0.64	0.54

[a] "H" and "D" indicate that the blades and petioles were taken from healthy and diseased plants respectively. Recently mature leaves, unlike older leaves of diseased plants, were not showing leaf scorch.

analysis should be collected as soon as symptoms appear. The length of time between the appearance of the symptoms and their recognition by fieldmen was not known. None of the analyzed, recently mature leaves from the diseased plants in the current study showed deficiency symptoms.

Blades from healthy plants contained more potassium than those from diseased plants. At Sites 2 and 3, where petioles from diseased plants contained less than 1.5% Na, the reverse was true for petiole potassium concentration. At Site 1 petioles from both diseased and healthy plants contained greater than 1.5% Na and both blade and petiole potassium concentrations were greater than the reported critical value of 1% (10).

Since petioles from diseased plants at Sites 2 and 3 contained less than 1.5% Na, comparison of blade potassium values was appropriate. In both cases blades of diseased plants contained greater than 1% K. Of some interest was the finding that leaves from diseased plants in all cases contained appreciably lower sodium concentrations.

In conclusion, it would appear that the plant analysis data eliminated magnesium deficiency as a causal factor of the lower leaf scorch. However, the published California data (10) did not support the alternative hypothesis that potassium deficiency was responsible. However, as previously indicated the leaves which were analyzed showed no chlorotic or necrotic symptoms.

Soil Analysis

Exchangeable potassium and sodium values are given in Table 1. The leaf scorch syndrome was most severe at Site 3 and the soil at that location contained the lowest amount, 40 ppm, of exchangeable potassium. Few data concerning critical values for exchangeable soil potassium are available in the Red River Valley. In several trials in which soils contained 85 to 100 ppm exchangeable K no response to potassium fertilizer by sugarbeets was obtained (J. T. Moraghan, unpublished data). According to Doll and Lucas (3) most field crops do not respond to potassium fertilizer when the exchangeable potassium is greater than 85 ppm for sands and loam sands and 100 ppm for sandy loams and loams. James (6) in Washington State reported significant responses to potassium fertilizer by irrigated sugarbeets at two sites where the surface soils contained 70 and 117 ppm exchangeable K. The corresponding exchangeable sodium values were 106 and 439 respectively.

Greenhouse Experiments

The influences of fertilizer under greenhouse conditions on growth of young sugarbeet plants on soil from Sites 2 and 3 are shown in Tables 3 and 4 respectively. The data show:

(a) That magnesium was not limiting growth in the two soils.

(b) That potassium deficiency was limiting growth of sugarbeets on both soils, but especially on the soil from Site 3.

(c) With continuous cropping uptake of both potassium and sodium decreased. However, the uptake of sodium proportionately dropped more than potassium.

(d) There was no significant difference at the end of the first harvest between the yields of dry matter with the "complete" and "potassium" treatments applied to the soil from Site 2. However, there was a tendency for higher yields to result from the application of the "complete" treatment to soil from Site 3. It is known that sodium can partially replace potassium in the nutrition of sugarbeets (4); added sodium in the complete treatment may have been the cause of the observed difference.

Severity of potassium deficiency symptoms increased with cropping. The potassium-deficient greenhouse plants resembled in appearance those shown by Ulrich and Hills (10) except that longitudinal lesions were largely absent from petioles of older leaves. The characteristic field symptom of upright older leaves with large parts of the blade brown to dark brown in color was not observed. Lack of expression of this symptom may have been associated with plant age. The plants developing this symptom in the field were older, much larger plants. Also, it has been reported that bright sunlight intensifies brown scorch of sugarbeets deficient in potassium (10).

Table 3. Influence of essential elements, including K and Mg, on dry matter production and nutrient uptake by sugarbeet tops grown in the greenhouse on a soil from Site 2.

Fertilizer		Yield	K	Na	Mg	Ca
		g	%			
Harvest 1						
0		1.9	3.16	0.35	2.77	2.37
Mg		2.1	3.15	0.41	3.14	2.38
K		3.7	5.25	0.39	2.70	1.96
Complete		3.7	4.29	3.44	1.70	1.13
	LSD(P=0.05)	0.6	0.14	0.03	0.26	0.17
Harvest 2						
0		3.4	1.71	0.12	2.83	2.79
Mg		3.5	1.89	0.11	3.44	3.07
K		7.7	2.58	0.06	2.47	2.59
Complete		9.0	2.51	0.99	2.34	2.13
	LSD(P=0.05)	1.1	0.19	0.12	0.37	0.21
Harvest 3						
0		4.2	1.00	0.08	2.61	2.95
Mg		4.4	1.26	0.08	2.82	3.53
K		9.8	2.15	0.06	1.88	2.36
Complete		9.8	2.62	1.59	1.50	1.88
	LSD(P=0.05)	1.7	0.06	0.07	0.05	0.54

Field Experiment

Application of either 50 or 200 pounds K/acre completely eliminated lower leaf scorch during August in the field experiment conducted in 1977 at Site 3. Plots not treated with potassium developed extensive brown scorching of older leaves during August. Appearance of

Table 4. Influence of essential elements, including K and Mg, on dry matter production and nutrient uptake by sugarbeet tops grown in the greenhouse on a soil from Site 3.

Fertilizer		Yield	K	Na	Mg	Ca
		g	%			
Harvest 1						
0		0.8	1.58	0.77	2.74	4.37
Mg		0.7	1.58	0.92	2.81	4.53
K		2.4	4.50	0.52	2.25	3.43
Complete		3.2	2.61	3.56	1.52	2.06
	LSD(P=0.05)	0.6	0.07	0.38	0.42	0.58
Harvest 2						
0		1.7	1.13	0.26	2.74	4.38
Mg		1.6	1.35	0.29	2.77	4.34
K		6.5	2.75	0.09	2.24	3.67
Complete		7.4	2.37	1.40	1.82	2.92
	LSD(P=0.05)	1.3	0.26	0.04	0.43	0.36
Harvest 3						
0		3.0	0.87	0.13	2.05	4.71
Mg		1.5	0.97	0.19	2.06	4.88
K		8.6	2.12	0.05	1.46	2.75
Complete		9.1	2.51	1.85	1.19	2.42
	LSD(P=0.05)	1.4	0.06	0.10	0.35	0.28

the potassium-deficient plants resembled those observed in afflicted plants in the same field in 1976, but the syndrome was not as severe. Over 10 inches of precipitation fell during the first 4 months of the 1977 growing season as against less than 3 inches during the corresponding period of 1976.

Lack of potassium affected growth of sugarbeet leaves within 10 days of emergence under greenhouse conditions. Differences in growth and appearance of leaves under field conditions in 1977 were not noticed until a nearly complete leaf canopy cover was obtained approximately 9 weeks after planting. Marginal leaf chlorosis followed by general scorching then developed on plants growing on plots without added potassium. The leaf scorch syndrome affected relatively large plants under field conditions.

General Discussion

From a study involving observation of visual symptoms, leaf analysis, soil analysis, and greenhouse and field experimentation the cause of a lower leaf scorch affecting sugarbeets in the Red River Valley was found to be due to potassium deficiency. The most efficacious of the diagnostic aids were greenhouse and field investigations. Although use of the field experimentation technique provided the cause of the problem, this approach resulted in a delay of a year before correct diagnosis was possible.

Leaf analysis using published critical levels (10) for potassium was unsatisfactory for diagnosing the problem. The fact that leaf material was not removed as soon as symptoms appeared may have affected the efficacy of this diagnostic technique. Alternatively, critical-level data appropriate for the Red River Valley may differ from those recommended for California. James (6) studied the response of irrigated sugarbeets to potassium fertilizer in Washington State and found that petiole-potassium values in the potassium-fertilizer responsive zone contained 1.56 to 2.42% K even though petioles contained 3.08 and 4.05% Na. He concluded that in the absence of additional data soil testing would be a better guide than leaf analysis for predictive purposes. The influence of sodium on translocation of potassium out of vascular tissue (5) undoubtedly complicates use of leaf analysis for predicting potassium deficiency.

Since many soils in the Red River Valley test very high in available potassium, potassium deficiency has not been considered a limiting factor for sugarbeet production. However, Rost and co-workers (8) nearly 30 years ago found that use of potassium fertilizer alone gave substantial increases in sugar in six experiments and concluded that ". . . the time is at hand when potash must be included in the fertilizer mixture for the growing of sugarbeets in the Red River Valley." Work relating soil-test values, including data for both available soil potassium and sodium, to the likelihood of responses to potassium fertilizer, and additional data concerning critical leaf potassium contents are needed.

Severity of the lower leaf scorch seemed to be more pronounced when surface soils became dry after a prolonged rainless period. Many researchers have reported that potassium deficiency was more severe during dry periods. Black (1) has discussed and reviewed literature concerning the following concepts which have been advanced to explain this finding:

(a) The role of water on movement of soil potassium to roots;

(b) The influence of soil water content on the K: Ca + Mg ratios of soil solutions;

(c) The higher concentrations of available potassium levels in top soils.

Summary

A lower leaf scorch was observed on sugarbeet plants in commercial fields in the Red River Valley. A

combination of greenhouse and field experiments established the causal factor as a deficiency of potassium. Soil analysis but not leaf analysis also supported this conclusion. Sampling of leaves sometime after the appearance of the disease symptoms may have affected the efficacy of leaf analysis as a diagnostic tool. Additional work concerning critical levels of available soil potassium, the influence of available soil sodium on potassium fertilizer response curves, and critical plant potassium levels is needed.

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