RESPONSES TO SULPHUR AND MICRONUTRIENT FERTILIZATION IN SASKATCHEWAN 1986-1988

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The prairie provinces have an estimated four million hectares of sulphur (S)-deficient soils (Bettany et al. 1983). The cultivated soils of Saskatchewan developed under a gradient of increasing effective precipitation from the Brown Chernozems in the south through the Dark Brown and Black Chernozems to the Dark Gray Chernozems and Gray Luvisols in the north. Reports of responses to S fertilization are common on Gray Luvisols but rare on Brown Chernozems. Janzen (1984) lists three factors which contribute to this tendency: 1) the potential for mineralization of S decreases from the Brown to the Gray soil zone because of widening C/S ratios and a declining proportion of ester-bonded sulfate in the organic matter, 2) higher crop S demands on soils in the more humid soil zones due to higher yields, greater frequency of stubble cropping, and more frequent cultivation of S-rich crops such as canola and alfalfa, and 3) greater leaching of gypsum ($CaSO_4$) with higher effective precipitation which positions deposits of gypsum at greater depth. Gypsum deposits are located at 40-60 cm in the rooting zone of the Brown soils and at 80-120 cm in the Dark Brown and Black soils. This factor may confound detection of S-responsive soils because the crop may initially show S deficiency symptoms but will recover once the roots contact the gypsum-rich layer.

The importance of S fertilization for alfalfa and rapeseed production on Gray Luvisols has been recognized for several decades. Rowles (1938) observed increases in forage and seed yield of alfalfa near Whitefox from the application of 26 kg S/ha in the forms of flowers of sulphur (elemental S), ammonium phosphate-sulphate (16-20-0-14) and ammonium sulphate (21-0-0-24). Alfalfa hay yields were increased an average of 60% with application of 22 kg S/ha in various forms to a Sylvania soil in the same area (Schalin 1947). Responses with rapeseed (canola) have been equally dramatic especially when high rates of nitrogen are applied in combination with S. Ukrainetz (1979) reported a yield response of 35-45% for mustard and rapeseed from the addition of 22 kg S/ha as gypsum to a soil near Loon River in northwestern Saskatchewan. Nuttall et al. (1987) observed significant canola yield responses to S fertilization in both northwest and northeast Saskatchewan; there was little benefit from boron (B) in these field trials.

Cereals require less S than forage legumes and canola but responses to S have also been observed with cereals. Beaton and Soper (1986) report work cited by Beaton et al. (1966) where wheat yield was increased 20% by application of 22 kg S/ha of elemental sulphur to a soil near Loon Lake. Nuttall (1979) reported an average residual S response of 6% with an application of 21 kg S/ha to oats. Barley grown over a three year period on Waitville loam yielded an average of 5% more with application of 22 kg S/ha.

The frequency of low soil test SO_4-S levels in samples submitted to the Saskatchewan Soil Testing Laboratory from the Brown and Dark Brown Soil Zones is considerable. For example, approximately 13% of those fields submitted in the fall of 1987 tested in the 0 to 28 lb/Ac SO_4-S (0-24") range, and 6% of the fields submitted in the fall of 1988 (extremely dry year). Present critical levels for recommending sulphur application in Saskatchewan are 28 kg SO_4-S (0-60 cm)for cereals, grasses, and potatoes and 44 kg SO_4-S for pulse crops, legumes, canola, mustard and flax(SSTL, 1988). Critical levels used in Alberta are considerably lower with sulphur fertilization recommended for extractable SO_4-S (0-60 cm) up to only 20 kg/ha for cereals and up to only 30 kg/ha for oilseeds, legumes, and irrigated crops. For coarse soils the critical level for S recommendations is 5 kg /ha lower than these values (Kryzanowski,1989). The lack of response to sulphur fertilization in the Brown and Dark Brown soil zones is attributed to several factors: 1) the presence of gypsum deposits within the rooting zone, 2) variability in available sulphur with topography and soil texture, and 3) greater sulphate mineralizing power of the organic matter.

MATERIALS AND METHODS:

Sites were selected in most cases based on results of analysis of field samples submitted from the field, or of samples taken for site screening purposes. Site selection was biased in favor of those sites testing relatively low in the nutrients being tested. In some cases the site established tested much higher in SO_4-S than did the samples representing the field as a whole. A relatively large number of sites in the Brown and Dark Brown Soil Zones were used for sulphur trials due to concern regarding the frequency of low S tests on soils of those zones and the lack of documented responses to S fertilization on them.

Soil chemical characteristics (Table 1) were determined using routine Saskatchewan Soil Testing Laboratory procedures as follows: pH and electrical conductivity determined in the 1:1 soil:water suspension, organic matter determined by a wet oxidation procedure, N and S present as 0.001M $CaCl_2$ extractable nitrate and sulphate were determined for the 0-24" depth soil, potassium and inorganic phosphate were determined in the 0.5M $NaHCO_3$ extract. Boron was determined in the N NH_4OAc extract (1:2 ratio), and copper, iron, zinc, and manganese in the D.T.P.A. extract (1:2), by I.C.P.-A.E.S. For each 15 cm thick layer of sampled soil, test levels were converted to kg/ha by multiplying ppm by 2.

All fertilizer treatments were spring broadcast, with no incorporation other than the pre-seeding tillage (if any) and seeding operation as carried out by the farmer cooperator. The plots were seeded, fertilized, and sprayed by the producer along with the rest of the field (except that no S or micronutrient containing fertilizers were applied to the plot areas). Blanket NPK treatments were also applied over each of the plot areas to meet or exceed requirements as indicated by current soil criteria for those nutrients.

The sulphur-treated plots discussed received 27 kg/ha of actual S as ammonium sulphate in 1986, 40 kg/ha in 1987, and 45 kg/ha in 1988. Treatments in 1986 and 1987 also included lower S rate treatments, but results from those rates are not presented. Total fertilizer N applications were balanced among treatments. Micronutrient treatments used were 9 or 10 kg/ha of actual copper or zinc applied as the sulphates, and 1.5 kg/ha of actual boron applied as a B fertilizer product (a sodium borate with 40% B_2O_3 equivalent). Each micronutrient was used as an experimental variable only at selected sites for which that corresponding soil micronutrient test level is given in Table 1.

Treatments were laid out in a R.C.B.D. design with six replicates. Individual treatments were approximately 4m x 12m in 1986 and 1987, and 4m x 5m in 1988. Single square-meter harvest yield samples were taken from each plot; samples from two square meters were taken from some of the low-yielding sites. Tissue samples were also taken at the heading stage for cereals and early flowering stage for canola. Samples of all above-ground material were analyzed for total contents of the nutrients under study at each site.

The mean yield values tabulated (Table 1) are those of the treatment receiving S fertilization but no micronutrients. This report discusses responses to the nutrients individually. Yield response to each micronutrient treatment was assessed by comparison (paired t-test) to the yield of the treatment receiving sulphur but no micronutrients. Yield responses to S fertilization was assessed by comparison to the check receiving no S or micronutrients.

This report is primarily on the effects of the treatments at each site on yield. Tissue nutrient levels are also presented and related to observed yield responses. Other aspects of the studies carried out under this project are not included in this report.

RESULTS AND DISCUSSION:

Sulphur (S)

The increases in yield due to S fertilization (i.e. mean yield of 40, 45, or 27 kg/ha S treatment minus yield of 0 S treatment) are graphed (Figure 1). Bars above and below the mean yield differences represent 90% confidence limits in this and all following figures. Letters below the graphed points indicate crop grown (C=canola, W=spring wheat, M=mustard, B=barley, F=flax, L=lentils, P=peas).

Table 1. Experimental site locations, soil characteristics and yield levels.

SOIL ZONE	TRIAL #	SOIL ASSOCIATION	LEGAL LOCATION	CROP	pH 0-6in	E.C. mS/CM 0-6in	O.M. % 0-6in	NO3-N 0-24in	P 0-6in	K 0-6in	SO4-S 0-24in	B 0-6in	CU 0-6in	ZN 0-6in	MEAN YIELD TRT. S+ KG/HA	COMMENTS
								Lbs/Ac								
1988 TRIALS																
BROWN	1	HAVERHILL	NW36-11-12-W3	DURUM	5.7	0.2	2.8	58	32	660	28		2.6		1366	DRY
BROWN	2	HAVERHILL	NW6-12-11-3	DURUM	7.3	0.5	1.9	50	26	440	24		3.0		2473	FAIR MOISTURE
BROWN	3	HAVERHILL	NW4-16-8-W3	MUSTARD	7.1	0.6	2.4	64	28	670	41	0.5			961	DRY
BROWN	4	HAVERHILL	NW34-15-8-W3	MUSTARD	6.1	0.3	2.5	81	20	570	33	0.3			866	DRY
BROWN	5	HAVERHILL	SW14-14-8-W3	WHEAT	6.7	0.3	2.0	60	28	660	20		2.4	1.8	1312	DRY
BROWN	6	HAVERHILL	SW14-14-8-W3	WHEAT	7.4	0.5	1.3	20	14	360	20		4.6		2033	DRY
BROWN	7	HAVERHILL	SW18-8-12-W2	WHEAT	6.6	0.3	1.5	60	25	530	25		2.0		1223	DRY, WEEDY
BROWN	8	HAVERHILL	NE16-9-14-W3	WHEAT	6.8	0.5	1.9	65	24	480					709	DRY, VERY WEEDY
DARK BROWN	9	REGINA	SW7-18-23-W2	BARLEY	7.8	0.8	1.7	83	22	420					1380	DRY
DARK BROWN	10	ELSTOW	NE30-28-7-W3	CANOLA	7.7	0.3	1.7	50	11	210		0.7	1.0	0.4	2122	IRRIGATED, THIN CROP
DARK BROWN	11	ELSTOW	SW2-41-28-W3	CANOLA	5.8	0.2	2.8	21	24	280	19	0.2	1.8		1023	DRY, WEEDY
DARK BROWN	12	ASQUITH	SW6-41-27-W3	DURUM	5.5	0.1	2.5	28	18	450	19		2.0		738	DRY, VERY WEEDY
DARK BROWN	13	REGINA	NE6-15-25-W2	WHEAT	7.6	0.6	1.7	52	19	480	42		3.4		601	VERY DRY, WEEDY
DARK BROWN	14	ELSTOW	NE31-34-13-W3	WHEAT	7.3	0.3	1.9	55	18	400	19	0.5			1726	DRY
DARK BROWN	15	ASQUITH	NE31-40-27-W3	WHEAT	5.8	0.1	1.9	18	15	240	21		1.2		1127	DRY , WEEDY
DARK BROWN	16	ELSTOW	NW35-34-20-W3	WHEAT	6.9	0.5	1.2	26	21	320	20		1.6		828	DRY, EXCESSIVELY WEEDY
DARK BROWN	17	ASQUITH	SW1-41-28-W3	WHEAT	6.0	0.2	1.4	17	23	190	18		1.0		1023	DRY, WEEDY
GRAY BLACK	18	GLENBUSH	NE26-51-16-W3	CANOLA	5.9	0.2	2.1	86	27	290	16	0.1			1247	FAIR MOISTURE
GRAY BLACK	20	WAITVILLE	NW7-53-7-W3	CANOLA	6.3	0.2	1.7	18	19	180	26	0.2			2077	GOOD MOISTURE
GRAY BLACK	21	WEIRDALE	NW14-51-17-W3	CANOLA	6.9	0.4	4.4	80	20	260	56	0.9			2272	GOOD MOISTURE
GRAY BLACK	22	NIPAWIN	NW21-50-13-W2	FLAX	6.3	0.2	2.2	27	18	170	12	0.2	1.2		740	DRY, VERY WEEDY
GRAY BLACK	23	TISDALE	SW32-43-15-W2	FLAX	6.1	0.2	2.0	18	36	220	17	0.2			277	VERY WEEDY
GRAY BLACK	24	WAITVILLE	NE10-50-12-W3	WHEAT	6.7	0.2	1.7	17	12	250	24	0.2			2265	GOOD MOISTURE
GRAY BLACK	25	GLENBUSH	NW13-51-13-W3	WHEAT	5.7	0.1	2.7	28	47	220	19	0.1			938	DRY, POOR GERMINATION
GRAY BLACK	26	WHITEWOOD	NW19-51-16-W3	WHEAT	6.4	0.1	1.7	15	20	190	20	0.2			2170	FAIR MOISTURE
GRAY	27	LACORNE	NW24-51-18-W2	CANOLA	5.7	0.1	1.1	72	29	230	14	0.3	1.4		1179	FAIR MOISTURE, WEEDY
TRIALS 1987																
BROWN	28	HAVERHILL	NE 18-7-28	WHEAT	6.9	0.4	1.6	27			22				4418	GOOD MOISTURE
BROWN	29	SCEPTRE	NE 12-8-28	WHEAT	4.5	0.5	3.3	114			48				3935	GOOD MOISTURE
BROWN	30	HAVERHILL	NE 22-12-28	WHEAT	7.9	0.5	2.6	34			85				1955	DRY AT SEEDING
BROWN	31	HAVERHILL	SW 5-5-27	WHEAT	7.1	0.3	2.0	47			42				2620	GOOD MOISTURE
DARK BROWN	32	REGINA	SE 5-16-21	LENTILS	7.6	0.5	3.5	44	30	680	60				2183	PATCHY GERMINATION
DARK BROWN	33	ELSTOW	NW 22-30-31	LENTILS	7.5	0.4	3.4	73	26	740	29				2553	GOOD MOISTURE
DARK BROWN	34	REGINA	SW 22-15-22	PEAS	7.8	0.6	2.8	39	19	580	3390				1950	FAIR MOISTURE
DARK BROWN	35	ELSTOW	SE 10-33-11	WHEAT	7.6	0.3	3.1	54	16	720	26				3878	GOOD MOISTURE
DARK BROWN	36	REGINA	NE 7-19-25	WHEAT	8.1	0.6	3.3	18	28	580	49				2915	GOOD MOISTURE
THIN BLACK	37	BLAINE LAKE	SE 14-42-17	CANOLA	7.0	0.3	3.8	13	13	110	47				1827	DRY CONDITIONS
THIN BLACK	38	OXBOW	NW 28-45-24	WHEAT	7.8	0.3	4.7	17	15	170	50				3230	GOOD MOISTURE

Table 1 con't ...

Table 1 continued

SOIL ZONE	TRIAL #	SOIL ASSOCIATION	LEGAL LOCATION	CROP	pH 0-6in	E.C. mS/CM 0-6in	O.M. % 0-6in	NO3-N 0-24in	P 0-6in	K 0-6in	SO4-S 0-24in	B 0-6in	CU 0-6in	0-(	YIELD T. S+ G/HA	COMMENTS
								-----------------	-----------------	----	-Lbs/Ac-	-----------------	-----------------	----		
CONTINUE TRIALS 1987																
THICK BLACK	39	YORKTON	SW 32-21-32	CANOLA	8.0	0.4	3.6	81	23	190	111				1025	WEEDY
THICK BLACK	40	WHITEWOOD	SW 22-24-1	CANOLA	8.1	0.4	3.1	65	13	210	163				2190	FAIR MOISTURE
THICK BLACK	41	YORKTON	NW 13-20-32	DURUM	7.4	0.4	4.3	31	11	170	524				3255	GOODGROWTH
GRAY BLACK	42	WEIRDALE	SE 18-49-12	BARLEY	7.9	0.4	2.6	120	17	140	11				3855	GOOD MOISTURE
GRAY BLACK	43	CARROT RIVER	NE 10-49-12	CANOLA	8.1	0.4	4.9	63	22	100	126				1198	WEEDY, SEEDS SHATTERING
GRAY BLACK	44	WAITVILLE	SW 16-43-18	CANOLA	6.9	0.3	4.1	53	45	280	23				1692	DRY, WEEDY
GRAY BLACK	45	WHITEFOX	SE 11-51-12	CANOLA	7.5	0.2	1.8	43	1.6	80	24				1050	WEEDY
GRAY BLACK	46	TISDALE	SW 16-43-15	CANOLA	6.9	0.5		176			34				1352	PATCHY GERMINATION
GRAY BLACK	47	WAITVILLE	SW 16-43-18	CANOLA	6.9	0.3	4.1	53	45	280		0.64	0.4	'	1373	DRY, WEEDY
GRAY BLACK	48	WHITEFOX	SE 11-51-12	CANOLA	7.5	0.2	1.8	43	16	80		0.96	0.2	(	1278	WEEDY
GRAY BLACK	49	WEIRDALE	SW 18-49-12	PEAS	8.1	0.2	2.4	24	40	140	33				1827	WEEDY
GRAY	50	KELSEY	SW 29-51-19	CANOLA	8.2	0.3	4.5	14	27	140		1.56	0.7	'	935	VERY WEEDY
GRAY	51	SMEATON-COMP	SE 2-53-19	CANOLA	7.1	0.2	1.2	31	38	150		0.48	0.5	(	474	PATCHY GERMINATION
GRAY	52	PINESAND	SW 14-52-18	WHEAT	7.9	0.2	1.8	24	25	80		0.72	0.6	(	1419	WEEDY
TRIALS 1986																
BROWN	53	SCEPTRE		WHEAT							94+		3.2		3358	GOOD MOISTURE
BROWN	54	HAVERHILL		WHEAT							51+		3.2		1455	DRY, THIN CROP
DARK BROWN	55	ASQUITH		CANOLA							27		1.1		2558	GOOD MOISTURE
DARK BROWN	56	ASQUITH		WHEAT							19		1.1		1520	WEEDY, HERBICIDE DAMAGE

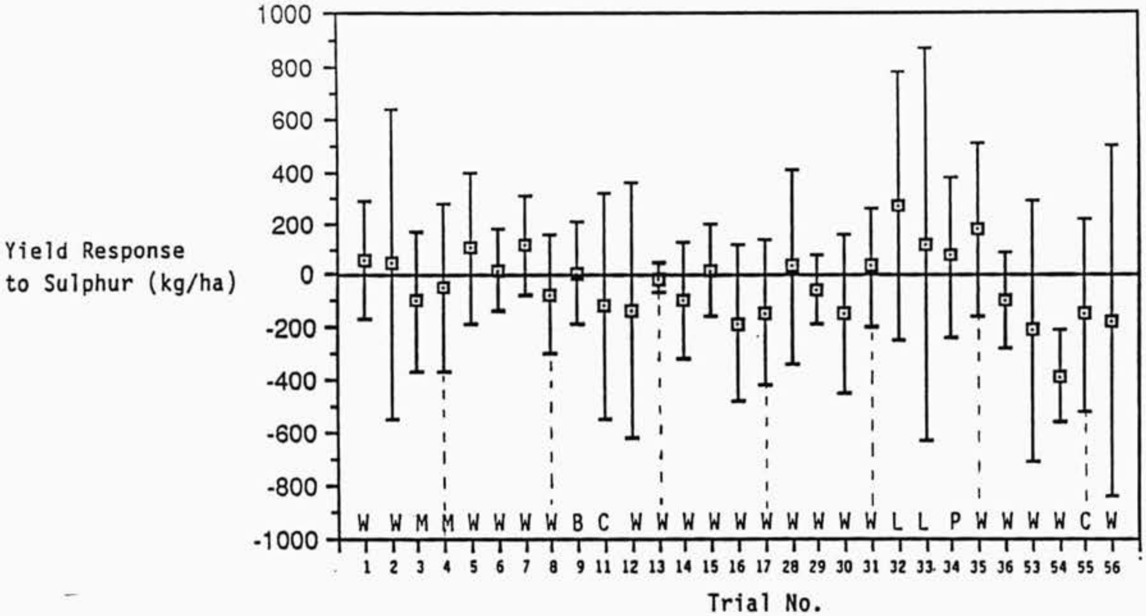

Figure 1: Effect of sulphur fertilization on yield in the Brown and Dark Brown Soil Zones.

Thirty of the trials (#1-17 in 1988, 28-36 in 1987, and 53-56 in 1986) were located in the Brown and Dark Brown Soil Zones. None of the positive responses on those sites were significant, nor do the results suggest any trends towards positive responses for years, crops, low soil test levels, etc. within that group. Approximately half of those sites were on soils testing 18-28 kg/ha in soil test SO_4-S, which is within a range where S fertilization is currently recommended for all crops. Canola was grown at four of the sites, and peas or lentils at three. Yields at many of the sites were low, particularly in 1988. However, these results, combined with the lack of evidence of S responses on these soils in earlier work, suggest a need to reconsider S fertilization criteria for the Brown and Dark Brown Soil Zones, at least where SO_4-S test levels exceed 20 kg/ha (0-24").

For sites in the Black and Gray Soil Zones, yield responses to S have been plotted against soil SO_4-S test levels, for canola and cereals separately. None of the individual responses with canola were significant (Figure 2). However, for the seven sites with S test levels below 35 kg/ha, S fertilization had a considerable (though not quite significant) positive effect on yield at the three highest yielding sites.

Responses by cereals to S at the six sites used tended to be positive, though none were significant (Figure 3). The largest yield difference was with barley at a site testing only 11 kg/ha in soil SO_4-S and producing almost 4 t/ha of barley.

Response of flax to S fertilization was determined in two trials (#22 and 23) on Gray-Black soils in 1987. A significant positive response was recorded where the soil S-test level was only 12 kg/ha. Response at the other was significantly negative, though yields were less than 300 kg/ha at that site.

Results with S fertilization on the Black and Gray Soils are inconclusive, with some tendency towards positive effects of S where low soil test levels and high yields occurred.

Sulphur tissue test levels were generally not suggestive of S deficiency (Figures 4 and 5). Current tissue test criteria suggest that tissue total S levels for canola (flowering) above 0.25%, and for flax (flowering) or cereals (prior to filling) above 0.15%, are sufficient. The minimum site tissue S content for 0 S treatment was almost 0.4% for the canola trials, and 0.17% for the cereal and flax trials. The cereal and flax trials with the lowest tissue S levels in the checks did not correspond with those having the greatest positive (though non-significant) yield response to S fertilizer. Tissue test results do not suggest that S deficiency was present at any of the sites.

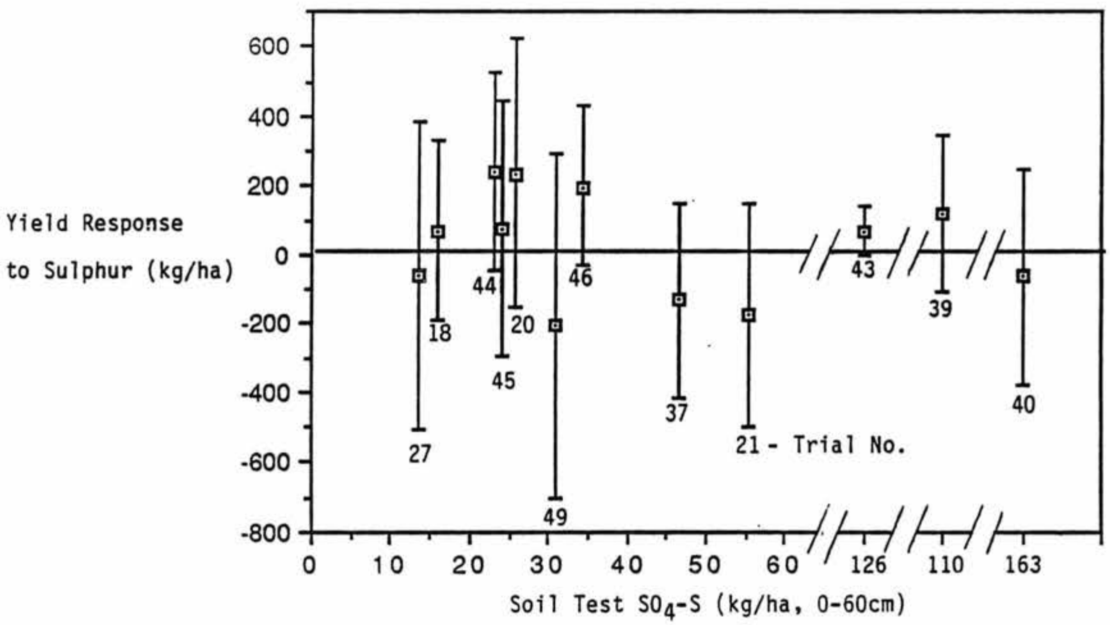

Figure 2: Effect of soil test S level on yield response to S fertilization of canola in the Black and Gray Soil Zones.

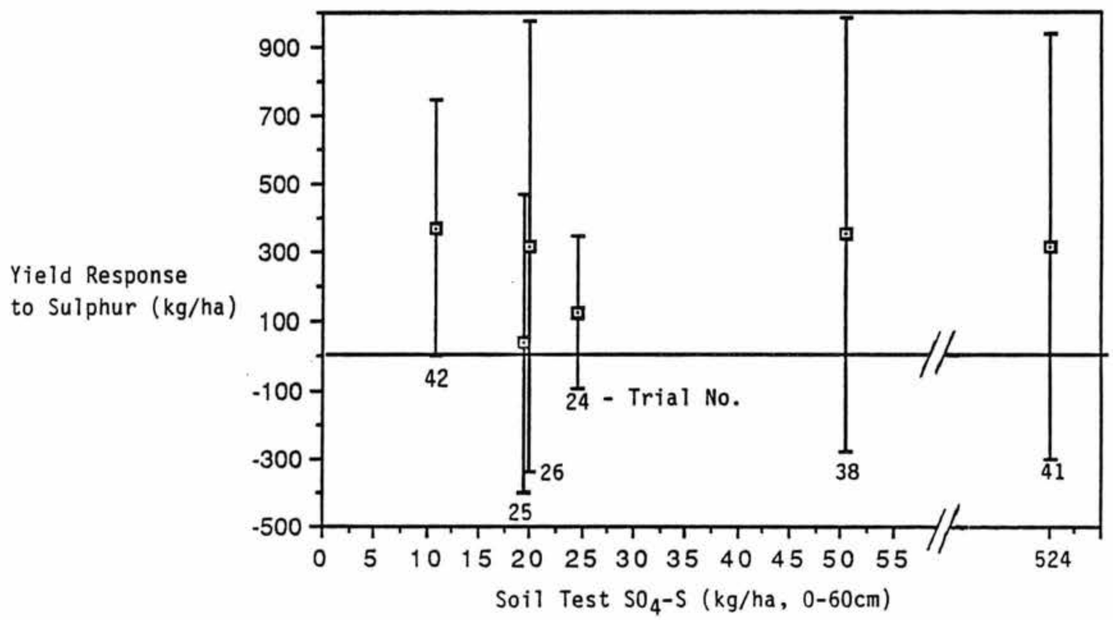

Figure 3: Effect of soil test S level on yield response to fertilization of cereals in the Black and Grey Soil Zones.

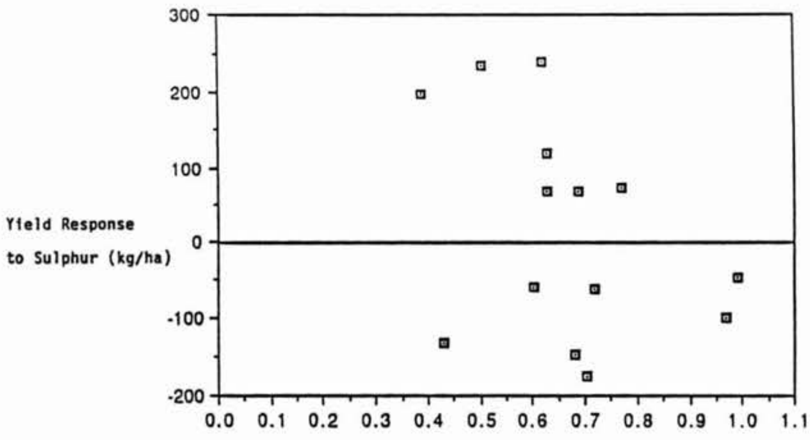

Figure 4: Yield response of canola and mustard to S fertilization as related to tissue total S levels of treatment not receiving S fertilizer.

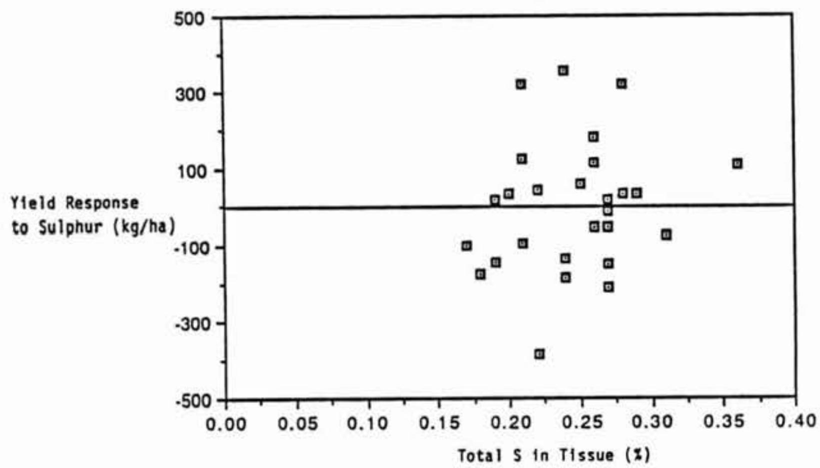

Figure 5: Yield response of cereals to S fertilization as related to tissue total S levels of treatment not receiving S fertilizer

Boron (B)

Most of the sites where B was an experimental variable had soil B test levels below the critical level as defined by current criteria (0.7 kg/ha). Response to B at two of the sites was significant (comparing the treatment receiving B to that not receiving B, with S applied to both, Figure 6). Both sites had relatively low test levels of B, and were in the Gray or Gray-Black Zones. However, the mean yield of the +S treatment (to which the yields with B are being compared) at each site was less than that of the -S treatment. This suggests that the response to B may be exaggerated by the method of comparison used for these two sites, since a negative response to the S is unlikely. Site #27 also had a similar apparent response to Cu fertilization, which tends to support that explanation; only four replicates at that site were harvestable. Site #23 produced less than 400 kg/ha of flax in all treatments.

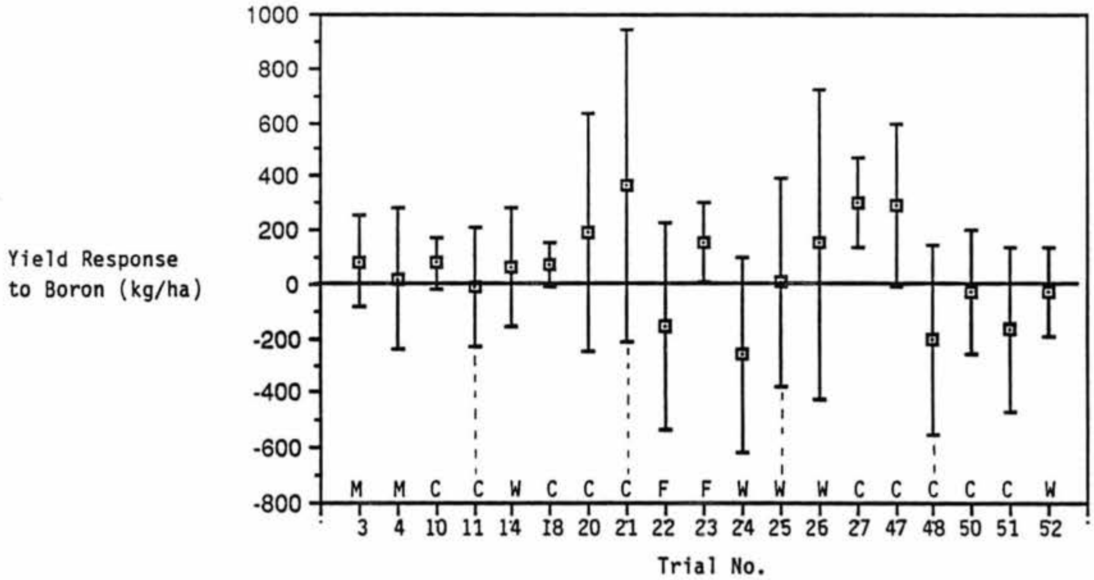

Figure 6: Effect of boron fertilization on yield.

There was a trend toward positive response to B for the sites in canola and mustard, but not for the sites in wheat or flax.

Copper (Cu)

Response to Cu was determined at 23 sites (wheat - 14, canola - 8, flax - 1)(Figure 7). An apparent slight yield reduction due to Cu occurred at site #53, which produced a high yield of wheat on a soil already high in soil test Cu, as well as at site #48, which produced approximately 1300 kg/ha of canola on a soil testing low in Cu.

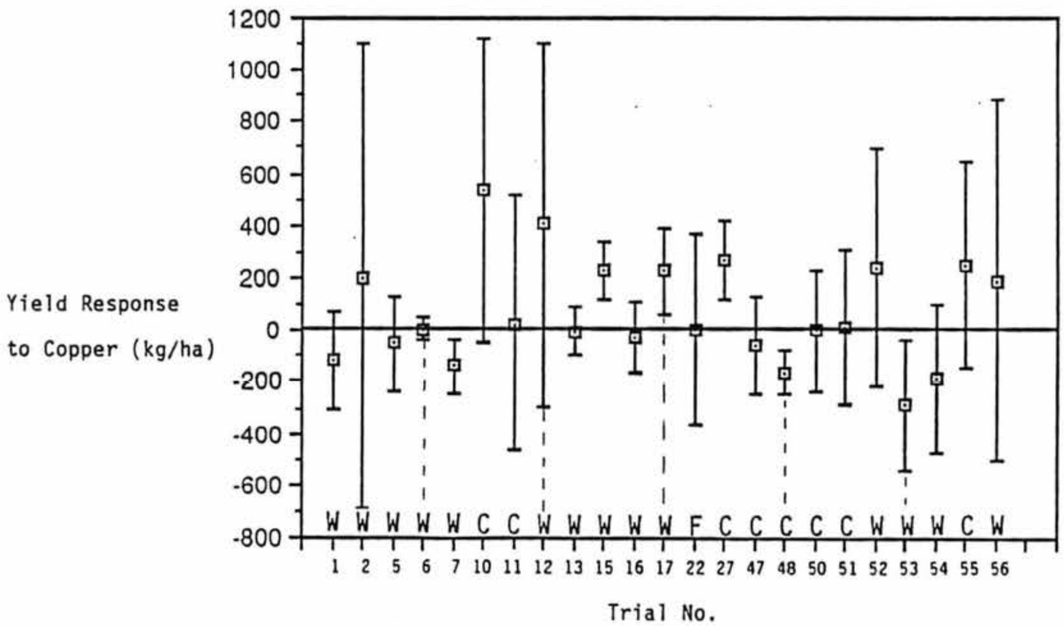

Figure 7: Effect of copper fertilization on yield.

A significant yield increase from Cu fertilization occurred at site #27, though this result is questionable (see discussion of this site under "boron"). Results from site #10 (irrigated canola) should also be interpreted cautiously. Positive (though not quite significant) responses to each of Cu, B, and Zn at that site, where patchy germination was a problem (which may limit the ability of square-meter harvest samples to provide an accurate measure of yield).

Four of the 1988 Cu sites were on Asquith soils west of Senlac. There was no response to Cu at the site in canola (#11). However, the copper treatments at all three of the other sites (#12, 15, and 17) produced considerably higher yields than those without Cu. The largest increase was on a very low-yielding, highly variable site (#12). However, significant positive responses to Cu of about 230 kg/ha of wheat occurred at sites #15 and 17; yields with Cu were approximately 1300 kg/ha. The mean tissue Cu levels in the 0 Cu treatments at all three of these sites, as well as at site #52 (where the Cu treatments produced about 240 kg/ha more than the checks, which was not statistically significant), ranged from 1.6 to 2.9 ppm (Figure 8). Current criteria in use at the Saskatchewan Soil Testing Laboratory classifies wheat tissue Cu levels below 3.0 ppm as "low", and 3.0 to 4.5 ppm as "marginal". These results would confirm the "low" range criteria in use. No other wheat site had tissue Cu levels below 4.0 ppm, nor indicated yield response to Cu. At all the sites where Cu was applied to canola, the 0 Cu treatments produced tissue with more than 4.5 ppm Cu ("marginal" range criteria in use is 1.7 to 2.7 ppm), and no convincing yield responses were obtained.

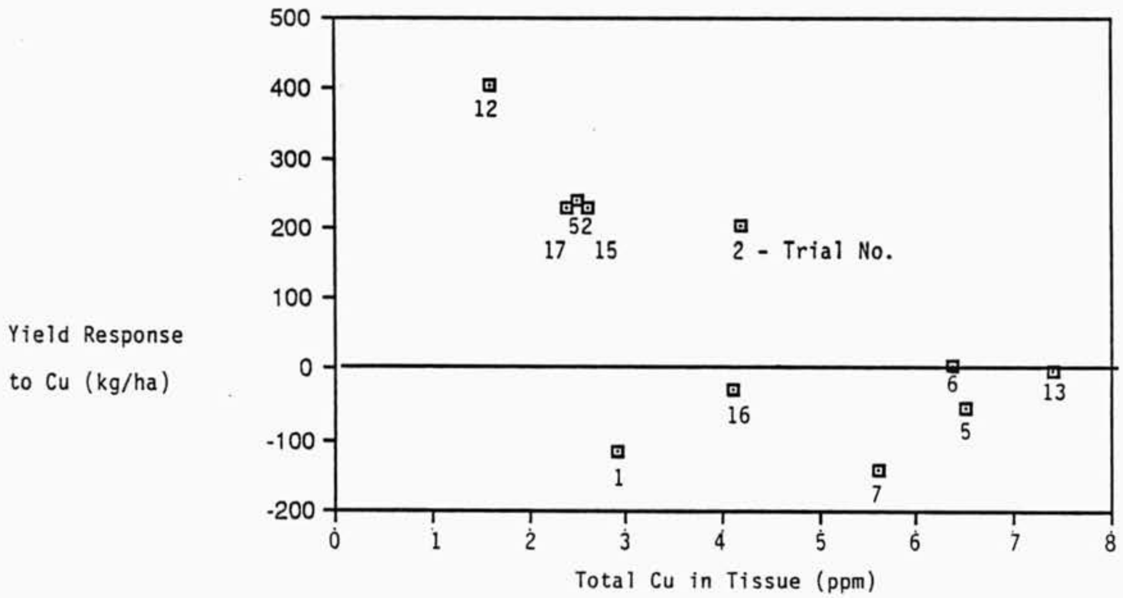

Figure 8: Yield response of cereals to Cu fertilization as related to tissue total Cu levels of the treatment not receiving Cu fertilizer.

Soil test levels of Cu at the sites where apparent responses of wheat to Cu were obtained were in the 0.6 to 2.0 kg/ha range. For the three sites on Asquith soils discussed, the Cu response occurred despite relatively low yields and Cu soil test levels(1.0 to 2.0 kg/ha) in a range currently regarded as sufficient. Also, this is not a soil type which was formerly considered very likely to be susceptible to Cu deficiency.

Zinc (Zn)

Zinc was a fertilization variable at five sites where canola was grown and two sites where wheat was grown (Figure 9). No significant responses were obtained. See the discussion of site #10 under "Boron". There was no evidence of yield response at the other sites, and tissues from the 0 Zn treatments had Zn levels considered high by current criteria ("marginal" range is 12-15 ppm Zn). All the soil test Zn levels were < 1.8 lb/Ac at these sites. Neither wheat not canola are known to be particularly sensitive to Zn deficiency. Sufficiency of soil Zn levels for sensitive crops such as corn, flax or the beans, should not be inferred from these results.

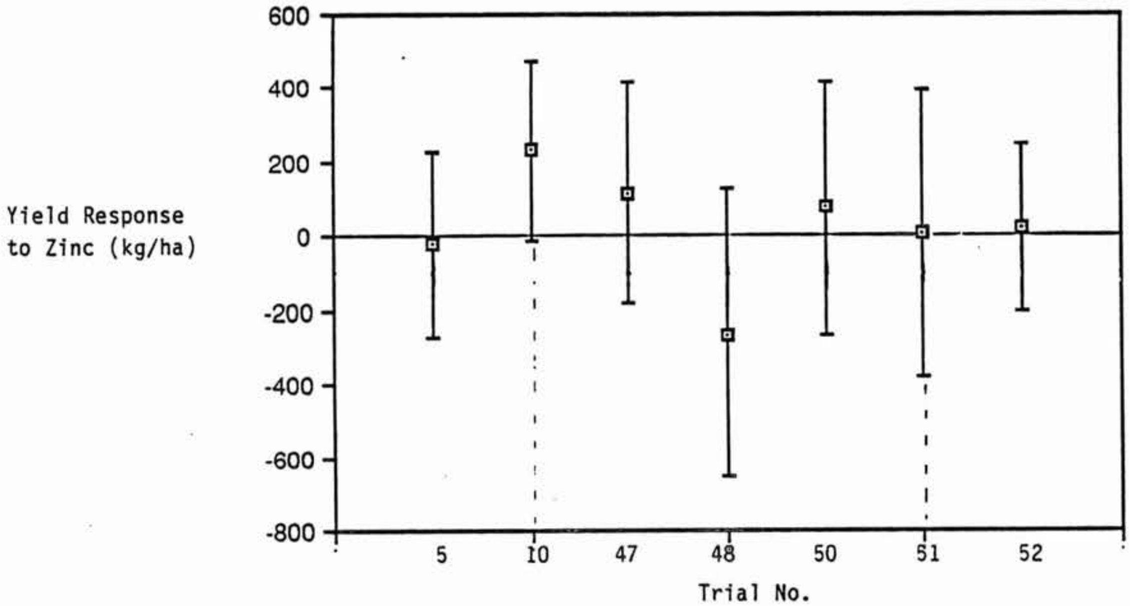

Figure 9: Effect of zinc fertilization on yield.

CONCLUSIONS:

There was no evidence of S response on 30 trials in the Brown and Dark Brown Soil Zones, for any soil S test level, crop, or yield level. Although yields on many of the sites were low, adjustment of current soil test deficiency criteria may be justifiable based in part on these results. Results from trials on Black and Gray soils were inconclusive.

Results from 19 trials with B fertilization showed a slight trend toward higher yields of canola, but not wheat, with B fertilization. Although specific conclusions cannot be arrived at from data presented, further work with B on canola would be warranted.

Responses of wheat to Cu fertilization were obtained on at least two sites near Senlac in 1988. Asquith soils were involved, yields were low, and soil test Cu levels were 1.0 to 2.0 kg/ha. Responses to Cu would not have been expected under these conditions. However, low tissue Cu levels support the finding. Karamonos et al. (1985) also reported responses to Cu on some sandy Chernozemic soils, though data was not presented. Further study of wheat response to Cu fertilization is warranted. In the current work, tissue Cu levels were an effective indicator of likely Cu deficiency for wheat, but evidence of response was obtained on soils testing relatively high in Cu by current criteria.

Significant responses by wheat and canola to Zn fertilization at seven sites were not obtained in this study.

The accuracy with which yield responses to S and micronutrient fertilization were determined should be considered. Relatively small yield increases (50-200 kg/ha) can make some of the applications of these nutrients economically beneficial where responses occur, particularly considering that residual effects are common. However, the precision with which response was determined at many of the sites was not in that range. For nutrients such as these which are not expected to produce response at most sites used, it is more important to be able to conclude for specific sites whether or not a response was obtained. Factors contributing to imprecision of yield response determination include the small area of each treatment harvested (one square meter), poor germination at some sites, and weeds at several sites.

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