Marginal Copper Soil Test Range – Does It Exist?

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INTRODUCTION

Soil testing for micronutrients in western Canada was accelerated in the early nineties as awareness of the benefit of application of these nutrients, especially copper (Cu) in certain parts of the prairies increased. Copper attracted most of the interest, since approximately three million acres in Alberta (Penney et al. 1988) and one million acres in Saskatchewan (Kruger et al. 1985) have been identified as potentially deficient in copper. Copper deficiencies have also been established on organic (peat) soils in Alberta (Hartman 1992), Saskatchewan (Karamanos et al. 1985a; 1991) and Manitoba (Loewen-Rudgers et al. 1983).

Karamanos et al. (1986) developed a critical level of 0.4 ppm for spring wheat and 0.35 ppm for canola grown in northern prairie soils. Alberta Agriculture, Food and Rural Development in a recent publication (1999) also used 0.4 ppm as a critical level for copper deficiency without any specific reference to plant species. Karamanos et al. (1985b) proposed marginal range of 0.4-0.8 and 0.4-0.6 ppm for Gray and Brown soils, respectively. Alberta Agriculture Food and Rural Development (1999) have proposed a marginal range of 0.4 to 0.6 ppm and characterized the range of 0.6-1.0 ppm as "deficient in some instances".

"Marginal" is not a well-defined term in soil testing. As a matter of fact rarely can it be found in major textbooks. "Marginal" in the Oxford dictionary is defined, among other definitions, as "of or at the edge; not central; close to limit". In that sense, in soil testing it probably represents a soil test category that contains soil test values close to a limit, presumably of either deficiency and/or sufficiency. There are no specific scientific criteria to define marginal range and, in any event, the basis of categorizing soil tests into classes is indeed subjective and arbitrary (Duhnke and Olson 1990). Further, soil tests can only be used to determine the probability that a response will occur (Fitts 1955; Fitts and Nelson 1956). Hence, the fundamental separation of soil test levels to those at which crop responses are likely to occur from those that crop responses are unlikely to occur (Cate and Nelson 1965) recognizes the fact that a soil test can neither predict yield nor the absolute amount of a response (Dahnke and Olson 1990).

The objective of this study was to identify the frequency of "agronomic" as well as "economic" response of crops to Cu fertilization on "marginal" soils as defined above and contrast it to the same on "deficient" soils. "Agronomic" response was defined as that when a response was statistically significant at least at $P<0.05$, whereas, "economic" response when Cu application yielded at least a $2 return on $1 cost of fertilizer.

MATERIALS AND METHODS

We compiled a large number of spring wheat experiments conducted in western Canada by a number of researchers on soils with “deficient” and “marginal” Cu levels (Table 1). Copper deficient soils were defined as those containing less than 0.4 ppm of DTPA-extractable Cu. The definition of “marginal” is not as clear and varies with various laboratories, but it is normally extended between 0.4 and 1.2 ppm of DTPA-extractable Cu.

Table 1. List of experiments utilized in assessing responses on marginal soils.

Year	Number of deficient sites	Number of Marginal sites	Source
1982	1	6	Kruger et al. 1984
1983	5	Nil	Kruger et al. 1984 Karamanos et al. 1985
1984	6	Nil	Karamanos et al. 1985
1985	25	Nil	Karamanos et al.1985; Kruger et al. 1984
1987	9	Nil	Mahli et al. 187
1991	Nil	1	Westco
1993	Nil	5	Westco
1994	Nil	2	Westco
1995	2	Nil	Westco
1996	1	4	Agrium, Westco
1997	3	4	Agrium, Westco
1998	4	3	Agrium, Westco
1999	2	1	Agrium, Westco
2000	5	29	Agrium, University of Manitoba, University of Saskatchewan, Westco
Total	63	55	

When a number of Cu treatments were involved in an experiment, only the one providing both statistically significant and maximum yields was selected for inclusion into the database. When no significant responses were obtained, the treatment providing the highest yield, other than the control, was selected. The methods and products of Cu application are presented in Table 2.

The population of the 118 experiments was divided into the following categories:

1. Two categories based on DTPA-extractable Cu levels as per Table 1:
    a. Deficient soils: with levels of <0.4 mg/kg (ppm).
    b. Marginal soils: with levels >0.4 mg/kg (ppm) up to a maximum of 1.2 mg/kg (ppm).
2. Each of the above categories into textural classes as follows:
    a. Deficient soils: fine sandy loam, sandy loam, loamy sand, and loam.
    b. Marginal soils: sandy loam, loam, and clay loam.

3. Each of the categories under 1 above into soil test level sub-classes based on DTPA-extractable Cu as follows:
    a. Deficient soils: <0.2, 0.21-0.3, and 0.31-0.4.
    b. Marginal soils: 0.41-0.6, 0.61-0.8, and 0.81-1.2.

Table 2. Products, method of their placement, and rate of their application that resulted maximum yield in the experiments.

	$CuSO_4$ broadcast & incorporated					Cu-chelate soil		Cu-chelate foliar	
Calibration	1.8-2	2.7-3	3.6	4	5	0.5	1	0.2-0.24	Total
Deficient	7	1	14	9	3	3	2	3	63
Marginal	1	7	Nil	19	5	Nil	Nil	5	55

The statistical average, standard deviation, median, mode, minimum and maximum for each segment of the population were determined. Mode could not always be obtained. Return on cost of fertilizer was calculated based on $4.50 per bushel of wheat, $4.72 per lb of Cu in the form of $CuSO_4$, $34.34 per lb of Cu as Cu-chelate for soils application and $48.36 per lb of Cu-chelate for foliar application. These prices are manufacturer recommended retail prices.

RESULTS AND DISCUSSION

The results of the separation of the population of 188 experiments in the two broad categories of those experiments carried out on deficient and those on marginal soil DTPA-extractable Cu levels are given in Table 3. Average response in marginal soils was only 1.2 bu wheat/acre. Although maximum yield responses of up to 7.9 bu/acre were obtained on marginal Cu soils, the return to the fertilizer cost was never greater than $1.2 for every $1 of Cu fertilizer and the chance of obtaining a return of less than $1 was greater than ninety percent (Figure 1). Analysis of the population of the experiments under deficient and marginal soil Cu levels, respectively, based on textural classes and sub-classes of soil test levels was as follows:

Deficient Soils

Agronomic response (significant yield increase) on deficient soils was received in seventy-one percent of the cases. The response was economic (i.e., 2:1 return on fertilizer cost) only in forty percent of the cases. Break-even (i.e., 1:1 return on fertilizer cost) was obtained in sixty percent of the cases.

Table 3. Statistical characteristics of the population of the experiments when divided into those carried out on deficient (<0.4 mg Cu/kg soil) and on marginal (0.4 – 1.2 mg Cu/kg soil) soils.

	Marginal soils			Deficient soils		
	DTPA-Cu mg/kg	Δyield bu/acre	$Return/ $1 Cost	DTPA-Cu mg/kg	Δyield bu/acre	$Return/ $1 Cost
Average	0.64	1.2	0.2	0.25	11.08	1.92
Standard deviation	0.15	2.5	0.4	0.09	9.41	1.80
Median	0.61	0.8	0.1	0.20	10.56	1.40
Mode	0.61	4.5	0.7	0.20	13.10	0.08
Maximum	1.20	7.9	1.2	0.40	30.34	6.90
Minimum	0.41	-4.6	-0.7	0.04	-1.6	-0.27

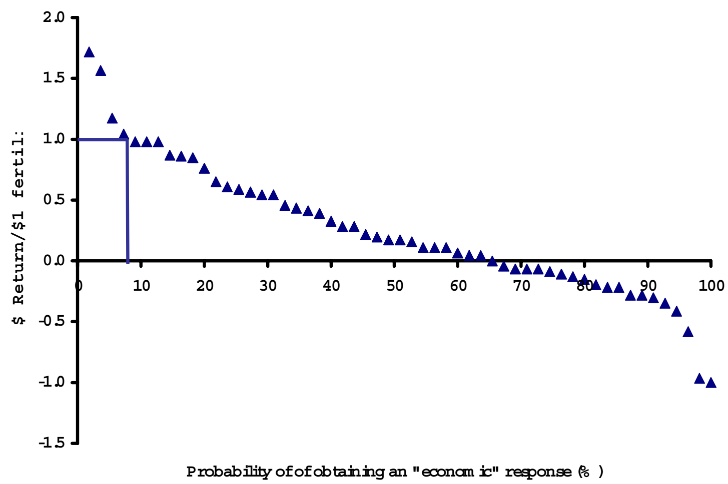

Figure 1. Probability of obtaining an “economic” response of wheat to Cu fertilization on soils containing “marginal” Cu levels.

When the population of the experiments was divided based on the DTPA-Cu levels into three categories, it became apparent that on average only soils that contained DTPA-Cu levels of less than 0.3 mg/kg could sustain economic yield increases due to Cu application (Figure 2). Economic yield responses on soils containing between 0.3 and 0.4 mg DTPA-Cu/kg soil were received in 33 percent of the times with breaking even fifty-eight percent of the times (data not shown).

Separation of the population based on soil texture (Figure 3) suggested that economic responses on average could only be sustained on sandy loams, loamy sands and possibly fine sandy loams.

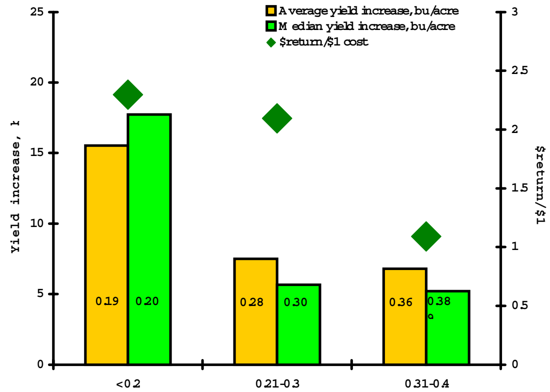

Figure 2. Statistical and economic characteristics of the population of deficient Cu soils based on DTPA-Cu soil test levels.

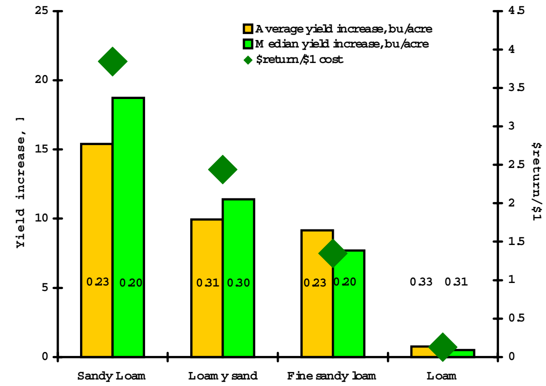

Figure 3. Statistical and economic characteristics of the population of deficient Cu soils based on soil texture.

Marginal Soils

Agronomic response (significant yield increase) on marginal soils was received in eighteen percent of the cases. The criterion for economic response (i.e., 2:1 return on fertilizer cost) was never met, unless a $6.00 per bushel price of wheat was used at which case only one experiment returned $2 for every $1 of fertilizer Cu cost. Break-even (i.e., 1:1 return on fertilizer cost) was obtained in less than ten percent of the cases (Figure 1). Separation of the population based either on DTPA-Cu soil test levels or texture did not result in improvement of economic returns of marginal soils (Figures 4 and 5).

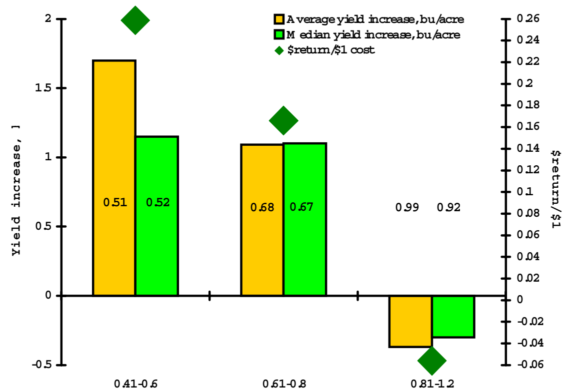

Figure 4. Statistical and economic characteristics of the population of marginal Cu soils based on DTPA-Cu soil test levels.

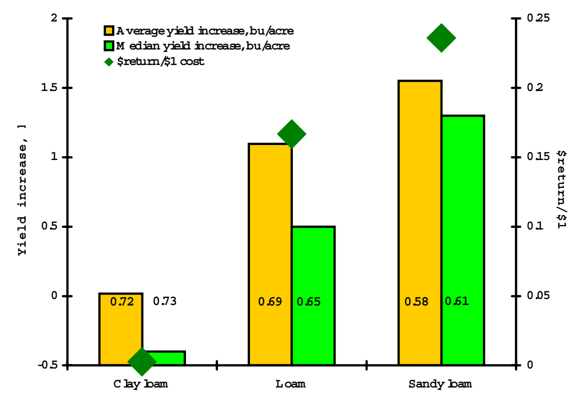

Figure 5. Statistical and economic characteristics of the population of marginal Cu soils based on soil texture.

CONCLUSION

The results of this study suggest that although agronomic responses may be obtained primarily on sandy soils that contain DTPA-Cu levels in the range of 0.4 to 0.6 mg Cu/kg, economic benefits from an agronomically effective application are not realized based on current wheat prices. An application is considered as agronomically effective when at least 3.5 lb Cu as CuSO4, or 0.5 lb Cu as Cu-chelate are broadcast and incorporated per acre in the soil, or when 0.2 lb Cu as Cu-chelate are applied as foliar application per acre.

The marginal range of >0.4 mg DTPA-extractable Cu/ kg of soil (ppm) currently utilized by a variety of soil testing laboratories operating in western Canada is virtually non-existent. Further, the results of this study suggest that the current critical level of 0.4 mg DTPA-Cu/kg soil can indeed be considered as a satisfactory "critical level" for assessing Cu deficiency of wheat grown either on sandy loams or loamy sands. A "marginal" range probably exists between 0.3 and 0.4 mg DTPA-extractable Cu/kg soil as both yield responses and economic returns in that range are neither consistent nor always economically sustainable.

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