MICRONUTRIENT FERTILIZER PRACTICES IN SASKATCHEWAN

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1. INTRODUCTION

Micronutrients are essential elements required by plants in small quantities. The need for micronutrients has been studied and debated for many years. As crop production intensifies, the chances of experiencing micronutrient deficiencies in field crops increase.

Micronutrient Deficiency Symptoms--Micronutrients are involved in virtually every phase of plant growth and development. Visual symptoms of deficiency are often similar among various micronutrients. Hence, it is difficult to diagnose a specific deficiency without carrying out both soil and tissue analysis.

The visual symptoms of copper deficiency are related to the physiological effects of copper on plant growth. Copper deficient plants develop weak stems and appear to wilt slightly even under adequate moisture conditions. Filling of grain is curtailed in cereals and gives rise to rat-tailed ears. The most specific symptom, however, is the death of the tip of the youngest fully expanded leaf (Gartrell and Brennan, 1979).

Manganese deficiency symptoms also appear first in the youngest leaves. In monocots (e.g., cereals, and particularly oats), deficiency symptoms appear at the basal part of leaves as greenish grey spots and stripes. Oats are prone to deficiency at tillering and this disease is called "grey speck". The turgor of the affected plant is reduced and the upper part of the leaf breaks over near the middle. Manganese deficiency in dicots (e.g., field beans) is also characterized by small yellow spots on the leaves but differ from iron deficiency symptoms, where the whole young leaf becomes chlorotic.

Lack of zinc results in distinctive plant symptoms associated with a retarding of normal growth and lack of chlorophyll and often are expressed as chlorosis in the interveinal areas of the leaf.

Boron deficiency first appears as abnormal or retarded growth of the apical growing points. The youngest leaves are misshapen, wrinkled and are often thicker and of a darkish, blue-green color. Irregular chlorosis betweent the intercostal veins may occur. The leaves and stems become brittle, indicating a disturbance in transpiration. As the deficiency progresses, the terminal growing point dies and the whole plant is reduced and flower and fruit formation is restricted or inhibited.

The most important function of molybdenum in crop plants is associated with nitrogen metabolism. Molybdenum deficiency often induces interveinal chlorosis, and in some cases the chlorosis is more diffuse, resembling a nitrogen deficiency. Molybdenum deficiency frequently appears first in the middle and older leaves.

Removal of Micronutrients--Table 1.1 shows the approximate quantities of copper, iron, manganese and zinc contained in various common crops. In contrast to the value of one tonne of wheat straw in terms of the nitrogen contained in it (approximately $4.00), its value in terms of all four micronutrients in Table 1.1 is approximately $1.00 at current fertilizer prices. However, cost of replacement of micronutrients by fertilizer application can be as high as 100 X that of equivalent amounts of nitrogen.

Table 1.1. Copper, iron, manganese and zinc removed by common agricultural crops

Crop	Crop part	Copper Cu	Iron Fe	Manganese Mn	Zinc Zn
		$g.ha^{-1}$			
WHEAT	Seed	8	130	90	85
2700 $kg.ha^{-1}$	Straw	14	250	110	70
(40 bu/ac)	Total	22	380	240	180
BARLEY	Seed	20	200	50	120
3225 $kg.ha^{-1}$	Straw	12	100	90	50
(60 bu/ac)	Total	32	300	140	170
OATS	Seed	7	300	50	120
3050 $kg.ha^{-1}$	Straw	25	450	130	150
(80 bu/ac)	Total	32	750	180	270
CANOLA	Seed	10	190	70	100
1960 $kg.ha^{-1}$	Straw	7	140	75	35
(35 bu/ac)	Total	17	330	145	135

2. MICRONUTRIENT FERTILIZER PRACTICES IN SASKATCHEWAN

Recent studies on the available micronutrient status of Saskatchewan soils (Karamanos et al., 1983; 1984a,b; 1985; Kruger et al., 1984; 1985) have indicated that micronutrients can be a limiting factor in crop production in the Gray Soil Zone, and are especially probable in the Light Transition or Gray and Gray-Brownish Podzolic soils belonging to the Carrot River, Whitefox, Bodmin, La Corne, Pine, Smeaton, and Sylvania soil associations (Table 2.1). As is the case with macronutrients, the nature and magnitude of crop response to micronutrient fertilization depend on the availability of these nutrients in the soil and on the crop which is being fertilized.

Micronutrient Fertilization--Most Saskatchewan soils contain adequate levels of micronutrients (Kruger et al., 1984). Responses to copper fertilization have been obtained in Transition and Grey and Brownish-Grey Podzolic soils (Kruger et al., 1985) and some sandy

Chernozemic soils (Karamanos, unpublished data). Manganese deficiencies have been observed in cereals grown on organic soils (Karamanos et al., 1984b; 1985; Karamanos, unpublished data). Although zinc deficiencies have been claimed and reported especially on irrigated soils, no responses have been obtained to date on a large number of experiments carried out with cereals in several parts of the province. The only established response to zinc fertilization in Saskatchewan has been associated with high phosphorus applications (Singh, Karamanos and Stewart, unpublished data). However, zinc deficiencies may occur for corn, field beans, and flax on poorly drained soils. Boron deficiencies for alfalfa, and perhaps canola (although not documented in field studies) may be possible on sandy Grey Wooded soils. Generally, no iron or molybdenum deficiencies are known to occur on Saskatchewan agricultural soils.

Table 2.1 Soil associations with DTPA-extractable Cu levels in Class 2 (0.2-0.4 mg Cu kg^{-1})

Soil Association	Brief Description	Approximate Area Surveyed (ha)	Possible Maximum Area[1] (ha)
	Transition (Degraded Black and Wooded Calcareous) Soils		
Carrot River	Fine textured sandy loam soils developed on calcareous sandy alluvial deposits.	12,000	38,500
Whitefox	Degraded black sandy soils developed on alluvial deposits of the Saskatchewan and Torch Rivers.	500	21,500
	Gray and Brownish-Gray Podzolic Soils		
Bodmin	Gray podzolic coarse sandy and gravelly to gritty loams developed glacio-fluvial deposits.	5,000	187,000
La Corne	Brownish gray soils of fine to very fine sandy loam textures developed on sandy alluvial deposits.	1,500	20,000
Pine	Gray podzolic fine sands and loamy sandy on alluvial and aeolian deposits.	18,000	93,000
Smeaton	Brownish-gray soils of gritty loam to sandy loam textures developed on thin glacio-fluvial deposits overlying and sometimes mixed with heavy lake-modified boulder clay.	500	16,000
Sylvania	Gray podzolic fine textured sandy loam soils developed on sandy alluvial-lacustrine deposits.	2,000	31,000

[1] Derived from Saskatchewan soil Survey Report No. 13.

The response to micronutrients can be greatly modified by environmental conditions. Thus, cool and wet seasons tend to promote deficiencies. Normally, most early spring deficiency symptoms will disappear later on (July). Flooding or poor drainage may increase manganese availability to toxic levels.

Economic responses may not always be obtained. Annual variations in micronutrient responses can be expected. Some micronutrient fertilizers have a residual effect; that is, unused micronutrients remain in the surface horizon of the soil and may be utilized by subsequent crops. The residual values of some copper and zinc fertilizers have been assessed for one year only in some Saskatchewan soils (Tables 2.2 and 2.3).

Table 2.2. Residual DTPA-extractable copper in soil samples (0-15 cm) taken one year after application of copper fertilizer

Soil	Control (1984 levels) ($kg.ha^{-1}$)	Copper Treatments: Sulfate Rate[1] ($kg.ha^{-1}$)	Sulfate DTPA-Cu ($kg.ha^{-1}$)	Chelate Rate[1] ($kg.ha^{-1}$)	Chelate DTPA-Cu ($kg.ha^{-1}$)
Hatton fine sandy loam	0.38 (M)[2]	5	0.90 (A)	0.5	0.33 (D)
Asquith sandy loam	0.38 (M)	5	2.05 (A)	0.5	0.53 (M)
Sceptre heavy clay	4.50 (A)	5	4.92 (A)	0.5	4.51 (A)
Carrot River fine sandy loam	0.38 (M)	5	1.01 (A)	0.5	0.41 (M)
Carrot River fine sandy loam	0.40 (M)	5	1.64 (A)	0.5	0.56 (M)
Sylvania fine sandy loam	0.34 (D)	5	1.24 (A)	0.5	0.40 (M)
		10	0.86 (D)	1.0	0.38 (M)

[1] Fertilizer was applied in the spring of 1983 prior to seeding. Samples were taken in the spring of 1984.
[2] D = deficient; M = marginal; A = adequate.

Yield increases of up to 70% due to micronutrient fertilization have been obtained in some soils. However, yield increases of up to 20% may normally be expected on deficient soils. Some results from the 1983 and 1984 programs are given in Tables 2.4 and 2.5 for copper and manganese. No responses to zinc have been observed due to either annual or residual application of zinc fertilizers with the exception of soils with high phosphorus application (Fig. 2.1).

Planning a Micronturient Fertilizer Program--The extremely high cost of micronutrient fertilizers necessitates extreme care in identifying micronutrient deficiencies, selecting products and methods of application. Guidelines on micronutrient fertilization in Saskatchewan are now being developed as research on these nutrients expands in

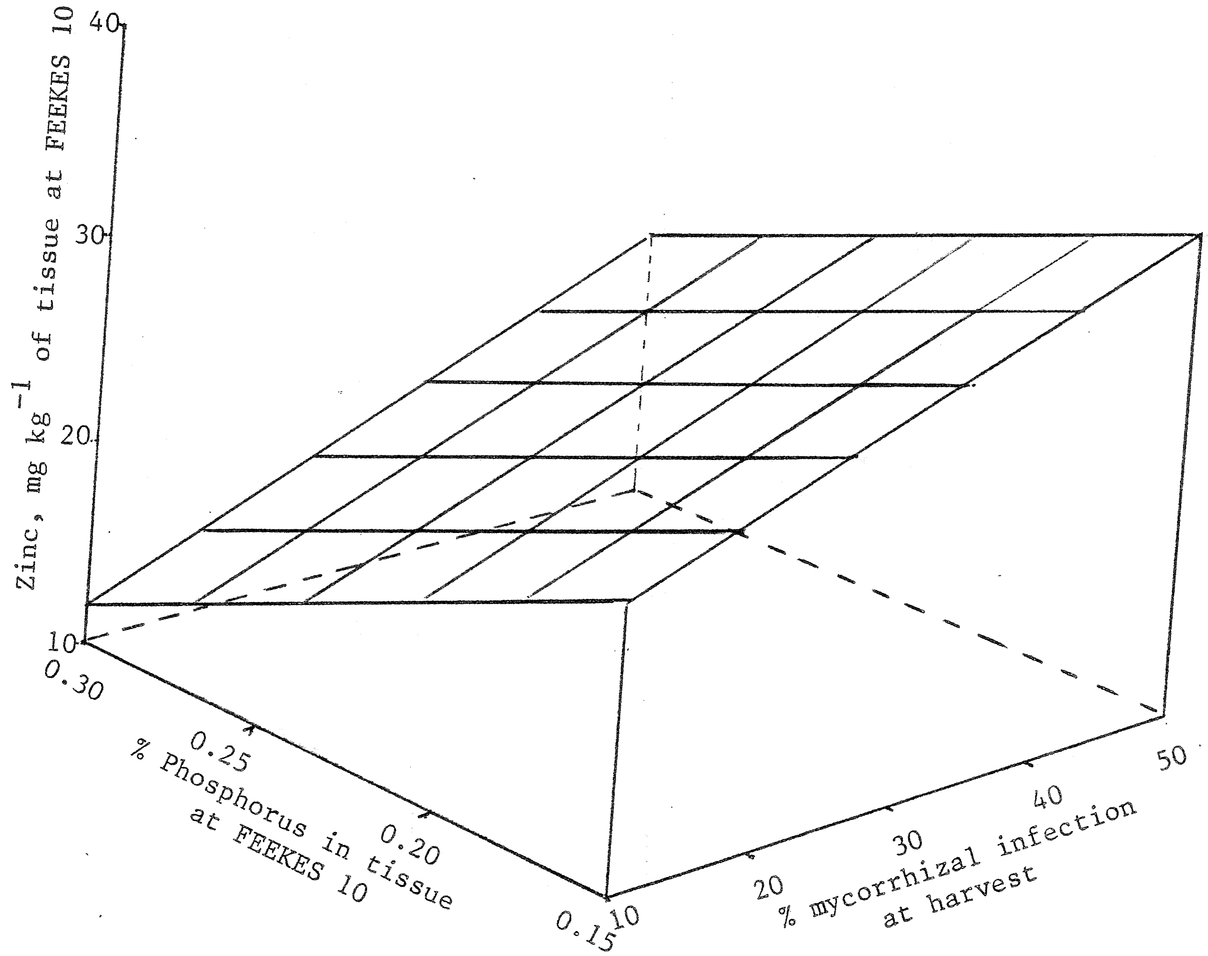

Fig. 2.1. Response of spring wheat to Zn fertilization on residual phosphorus plots at the University of Saskatchewan Kernen Farm. The response appears to be a result of interaction between Zn, P and mycorrhizae infestation of the roots of spring wheat (Singh, Karamanos and Stewart, unpublished data).

Table 2.2. Residual DTPA-extractable zinc in soil samples (0-15 cm) taken one year after application of zinc fertilizer

Soil	Control (1984 levels) ($kg.ha^{-1}$)	Zinc Treatments: Sulfate Rate[1] ($kg.ha^{-1}$)	Sulfate DTPA-Cu ($kg.ha^{-1}$)	Chelate Rate[1] ($kg.ha^{-1}$)	Chelate DTPA-Cu ($kg.ha^{-1}$)
Hatton fine sandy loam	1.10 (A)[2]	10	4.57 (A)	1	1.27 (A)
Asquith sandy loam	0.80 (A)	10	3.07 (A)	1	1.33 (A)
Sceptre heavy clay	1.20 (A)	10	1.60 (A)	1	1.30 (A)
Carrot River fine sandy loam	2.20 (A)	10	3.20 (A)	1	2.47 (A)

[1] Fertilizer was applied in the spring of 1983 prior to seeding. Samples were taken in the spring of 1984.
[2] A = adequate.

this province. The findings from this research are being communicated to the Saskatchewan Soil Testing Laboratory and adjustments to methodology and criteria used are being made as new information becomes available. Although the methodology followed by out-of-province Soil Testing Laboratories is normally correct, the interpretation of the results by these laboratories may not apply to Saskatchewan soils.

Soil Test Recommendations--Micronutrient soil testing techniques applicable to Saskatchewan conditions have been under review only in the last three years (1982-84).

The most up-to-date guidelines stemming from this research are as follows:

1. Sampling depth--The traditional method of soil sampling in Saskatchewan has been to obtain samples from 0-15, 15-30, and 30-60 cm depth. Although in some countries (e.g., Australia), a 0-25 cm sample is recommended, guidelines are being developed on the basis of the traditional soil sampling method. Thus, samples from the 0.15 cm depth are required for the diagnosis of deficiencies of most micronutrients that are relatively immobile in soil. A soil sampling depth of 60 cm may be required for boron, which can easily be leached in soil.

   No yield increase prediction is available, and neither is it possible for micronutrients, as application of small quantities of fertilizer are frequently adequate to produce a "maximum" response to the added nutrient.

Table 2.4 Yield increases due to annual and residual copper fertilization in 1983-84 experiments

Fertilizer Source of	Rate $kg.ha^{-1}$	1983 Crop	1983 Yield increase $kg.ha^{-1}$	1983 Yield increase %	1984 Crop	1984 Yield increase $kg.ha^{-1}$	1984 Yield increase %
			Sylvania fine sandy loam				
Sulfate	5	spring wheat	0	0	canola	425	50
		canola	0	0	spring wheat	426	20
	10	spring wheat	0	0	canola	610	72
		canola	184	10	spring wheat	515	24
Chelate	0.5	spring wheat	58	27	canola	0	0
		canola	184	10	spring wheat	0	0
	1.0	spring wheat	881	40	canola	65	19
		canola	428	23	spring wheat	0	0
			Bodmin sandy loam				
Sulfate	5	canola	180	20	n.d.	n.d.	n.d.
Chelate	1.0	canola	460	50	n.d.	n.d.	n.d.
			Carrot River fine sandy loam				
Sulfate	5	spring wheat	*	*	flax	713	66
Chelate	0.5	spring wheat	*	*	flax	0	0
			Hatton fine sandy loam				
Sulfate	5	spring wheat	**	**	spring wheat	880	59
Chelate	0.5	spring wheat	**	**	spring wheat	0	0
			Asquith sandy loam				
Sulfate	5	spring wheat	0	0	spring wheat	660	45
Chelate	0.5	spring wheat	0	0	spring wheat	345	24
			Sceptre heavy clay				
Sulfate	5	spring wheat	0	0	spring wheat	***	***
Chelate	0.5	spring wheat	0	0	spring wheat	***	***

n.d. = not determined
* damaged by midges
** plot lost due to farmer's early harvest
*** drought damage

Table 2.5 Yield increases due to manganese fertilization in organic soils

Fertilizer Source	Rate kg.ha^{-1}	Method of placement	Crop	Yield increase kg.hg^{-1}	%
		Meadow Lake			
Sulfate	10, 20 or 40	seed-placed	oats	1070	44
Chelate	3	foliar	oats	1115	46
		Carrot River			
Sulfate	10	seed-placed	barley	410	11
		broadcast	barley	350	10
	20	seed-placed	barley	1410	36
		broadcast	barley	0	0
	40	seed-placed	barley	1350	35
		broadcast	barley	650	17
	80	seed-placed	barley	295	8
		broadcast	barley	1235	33
		Carrot River			
Sulfate	5	seed-placed	barley	650	15
	10	seed-placed	barley	1000	23
	20	seed-placed	barley	0	0
	40	seed-placed	barley	0	0
		Carrot River			
Sulfate	5	seed-placed	barley	650	15
	10	seed-placed	barley	1000	23
	20	seed-placed	barley	0	0
	40	seed-placed	barley	0	0
		Carrot River			
Sulfate	3	foliar	alfalfa	603	14

2. Sampling time--levels of "available" micronutrients in the soil may change drastically with water content or soil temperature. Normally, little change has been observed in the chelated forms of micronutrients from year to year. Sampling for micronutrients can thus be combined with that for other soil fertility parameters.

3. Interpretation of soil testing values--The Saskatchewan Soil Testing Laboratory has been using interpretive criteria based mostly on published American work (Tomasiewicz and Stewart, 1982). Recent work in Saskatchewan suggests that a number of modifications be introduced (Table 2.6).

Table 2.6. Criteria used in interpretation of micronutrient soil tests in Saskatchewan Soil Testing Laboratory and proposed modifications or alternate methods

Element	Extraction method	Critical level[1] kg ha^{-1}	Modification	Alternate method
Copper	DTPA	0.4	marginal: Gray soils < 0.8-1.0[2] D. Brown < 0.6 Organic soils *3	--
Iron	DTPA	5-9 (marginal range)	--	--
Zinc	DTPA	1.0 1.0-2.0 (marginal for high phosphate levels and irrigation	Cereals < 0.5[4] Corn < 1.0 Alfalfa < 1.1 1.0-2.0 (marginal for high phosphate levels only)	--
Manganese	DTPA	2.0	-- organic soils *3	(a) oats: tissue FEEKES 6 < 16 $mg.kg^{-1}$ FEEKES 10 < 9 $mg.kg^{-1}$ (b) Bioassay with[5] <u>E. adhaerens</u>
Boron	NH_4OAc	0.7 (> 7.0 - toxic)	0-60 cm rather than 0-15 cm depth	--
Molybdenum	Anion exchange resin	0.10 (> 1.3 - toxic)	-- --	-- --

1 See Tomasiewicz and Stewart (1982).
2 Low limit for cereals; high for canola and alfalfa.
3 It has been shown that the Mn/Cu ratio is an important factor for the nutrition of cereals on organic soils (Karamanos et al., 1985). Thus, Mn deficiency occurs when Mn/Cu < 1 and Cu when Mn/Cu > 15.
4 This "critical" level may actually be much lower than 0.5 $kg.ha^{-1}$. No yield increases due to zinc fertilization were obtained on a soil containing 0.5 kg DTPA $Zn.ha^{-1}$.
5 Germida, Karamanos and Stewart, unpublished data.

3. GENERAL MICRONUTRIENT FERTILIZER RECOMMENDATIONS

Crop Fertilization--The micronutrient fertilizer requirements are normally uniform for all crops providing a deficiency has been identified.

Selection and Placement of Fertilizers--Selection of micronutrient fertilizers is governed by the same rules to those for macronutrient fertilizers. The cost of fertilizer, its effectiveness and its residual value must be taken into account. Chelates are normally effective in the first year of application, but have no residual value. Although the rate of application for chelates is 1/10 of that of sulfates, their cost could be as high as 3 X that of sulfates for the year of application, and as high as 30 X accounting for the residual value of the latter. Although oxides have the same residual value to that of sulfates, they are slightly more expensive, and further, appear ineffective for the year of application when applied in the spring (Table 3.1).

Table 3.1. Evaluation of copper products with spring wheat on a Carrot River fine sandy loam.

Product	Rate $kg.hg^{-1}$	Yield $kg.ha^{-1}$
Copper oxide (solid)	5	1432
Copper sulfate (solid)*1	5	2248
Copper sulfate (liquid)*2	5	2343
Copper sulfate (foliar)3	0.25	1028
Control	-	1078

Placement of Fertilizer Materials--The most effective placement of granular micronutrient fertilizers is broadcast and incorporation for copper and zinc or banding for copper and seed-placement for manganese. No recommendations can be offered for the rest of the micronutrients, since no responses to them have been obtained in this province.

Fertilizer Application Equipment--Granular fertilizers can be broadcasted, banded, or seed-placed in blend with macronutrients. If the copper source is blue-stone, copper sulfate blending is not possible and the best way of application is with an air-seeder in bands, or it could be broadcasted separately with a small spreader. Incorporation of the fertilizer is an essential operation in **all** cases. Dissolved blue-stone to be applied in liquid form can cause serious damage to sprayer nozzles and corrosion, and should be avoided. Chelates are always in liquid form and can be sprayed with normal spraying equipment. Although they can be mixed with herbicides, their application after emergence is generally ineffective.

Commercial Fertilizers--The most common micronutrient fertilizers in Saskatchewan are listed in Table 3.2. The advantages and disadvantages of these materials in terms of methods of application, and particularly cost, must be considered prior to purchase.

Table 3.2 Composition of micronutrient fertilizers available in Saskatchewan.

	Cu	Zn	Mn	S	Mg
Copper fertilizers					
Copper oxide	15%	-	-	-	5%
Copper sulfate	25%	-	-	13%	-
Copper chelate	0.22 $kg.L^{-1}$				
Zinc fertilizers					
Zinc sulfate.oxide	-	36%	-	9%	-
Zinc chelate	0.22 $kg.L^{-1}$				
Manganese fertilizers					
Manganese sulfate	-	-	28%	11%	-
Manganese chelate	0.22 $kg.L^{-1}$				

4. SPECIAL SOIL PROBLEMS

Peat Soils--Peat soils may be deficient in 3 micronutrient elements--manganese, copper and boron. Boron deficiencies in Saskatchewan organic soils have not been documented.

The availability of micronutrients in peat soils is highly dependent on environmental conditions, depth of the peaty phase, drainage and the "balance" of available micronutrients present. Karamanos et al. (1985) have shown that the ratio of DTPA-extractable Mn/Cu in organic soils is important for the proper nutrition of cereals. Examples of the adverse effect of copper or manganese fertilization on the growth of barley due to copper induced manganese deficiency or manganese induced copper deficiency are shown in Tables 4.1 and 4.2.

Eroded Knolls, Ridges and Slopes--Study of the spatial variability of copper, manganese, iron and zinc (Singh et al., 1985; Singh and Karamanos, unpublished data) have shown that the concentration of available micronutrients decreases on knolls and ridges and increases at depressions. The distribution of the four micronutrients suggests that removal of the A horizon will affect the levels of "available" zinc to a greater extent than the other three micronutrients, especially when associated with the presence of calcareous horizons.

Table 4.1. Effect of the interaction of manganese and copper on the yield ($kg.ha^{-1}$) of barley in an organic soil at Carrot River

Copper Rate	Manganese placement	Manganese Rate, $kg.ha^{-1}$ 0	10	20	40	80
0 $kg.ha^{-1}$	Seed-placed	3878	4289	5288	5230	4172
	Broadcast	3761	4113	3819	4407	4995
20 $kg.ha^{-1}$	Seed-placed	3643	4466	3819	4054	4113
	Broadcast	3820	3996	3995	3937	4290

Table 4.2. Effect of the interaction of manganese and copper on the yield of barley in an organic soil previously fertilized with 10 kg $Cu.ha^{-1}$

Treatment	Yield $kg.ha^{-1}$
Control	4348
5 kg $Mn.ha^{-1}$*	4995
10 kg $Mn.ha^{-1}$	5347
20 kg $Mn.ha^{-1}$	3291
40 kg $Mn.ha^{-1}$	4583

* Manganese treatments were seed-placed

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