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Survey of the extent of copper deficiency of wheat on the Western Downs, Queensland

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Summary

Thirty-five sites from the major soils on which wheat is grown on the Western Downs, Queensland, were screened for Cu deficiency by applying two foliar sprays of 2% copper sulphate solution (0.5 kg ha^{-1} Cu) to strips within commercially planted wheat crops.

Copper deficiency was not widespread. Responses in grain yield were obtained at four sites (classed as deficient), and low concentrations of Cu in grain were recorded at an additional four sites (potentially deficient). Deficient soils occurred near quartz/sandstone rock outcrops, were grey to grey-brown clays of near neutral to alkaline pH, and had natural vegetation of brigalow and belah. Red-brown earths which carry belah or poplar-box in their natural state did not respond to applied Cu.

The Cu responsiveness of a soil was not correlated with its level of DTPA-extractable Cu, pH, level of bicarbonate-extractable P or DTPA-extractable Zn. However, grey or grey-brown clays on the Western Downs having DTPA-extractable Cu concentrations less than 0.4 ppm were generally deficient in Cu for wheat growing.

1. INTRODUCTION

Copper deficiency has occurred in livestock in an area bounded by Tara, Warwick and Texas in the Darling Downs and Western Downs regions of Queensland (Harvey 1952). Many graingrowers in this area believe that Cu deficiency is also reducing wheat yields. Previous observations (Whitehouse, personal communication 1977; Bourne, personal communication 1977; Frank, personal communication 1977) and research (Whitehouse and McClement 1969; Wall, Leslie, Glasby and Whitehouse 1972; Grundon and Best 1975; Grundon and Glasby 1976) showed that some soils in an area ranging from Wandoan to Goondiwindi (north-south) and from Chinchilla to Drillham (east-west) are deficient in Cu for wheat growth. However, the extent of the deficiency has not been documented. This survey aimed to examine the extent of Cu deficiency on the major soil types used to grow wheat on the Western Downs, Queensland, and to explore the possibility of using a soil test to identify Cu-deficient areas.

2. MATERIALS AND METHODS

Thirty-five sites were selected, 19 in 1977 and 16 in 1978, from the major soils on which wheat is grown in the shires of Taroom, Murilla, Tara, Wallumbilla and Waggamba. Each site was described in terms of topography, soil colour and texture (0 to 10 cm), and natural vegetation. Samples of topsoil (0 to 10 cm) were collected by taking 20 cores at random from each site. These samples were analysed for pH (1:5 soil:water), bicarbonate-extractable P (Colwell 1963) and DTPA-extractable Cu and Zn (Lindsay and Norvell 1978), to characterize the site and to discover if Cu deficiency is associated with soils of high 'available' P or Zn, nutrients which can depress uptake of Cu (Spencer 1966; Gilbey, Greathead and Gartrell 1970; Gartrell 1981).

On each site, a strip 30 m long (60 m in 1978) and 2 m wide of the commercial wheat crop was sprayed twice with a solution of 2% copper sulphate, the first spray being applied at about mid-tillering (Feekes stage 3) and the second at about early booting (Feekes stage 9.5 to 10). Each spray applied 0.5 kg ha^{-1} Cu. At grain maturity, 10 paired quadrats (20 in 1978) were taken from each site, each quadrat being a 1 m length of three rows. One quadrat of each pair was harvested from the treated strip and the other from immediately adjacent untreated crop where the plants were of about equal density. On each quadrat, measurements of number of heads, number of grains and grain weight were made. Grain Cu concentrations were determined on nitric/perchloric acid digests using inductively coupled plasma emission spectroscopy.

In 1977, post-planting rainfalls were light and grain yields were below district averages, while in 1978 there were frequent falls after planting and yields were high.

3. RESULTS AND DISCUSSION

The location, topography and natural vegetation of each site are given in Table 1, and characteristics of the surface soil are listed in Table 2. The following sites represent transects

Table 1. Location, topography and natural vegetation of each site

Site number	Year of trial	Location	Topography	Natural vegetation
1	1977	Wyaga	Flat; top of slope	Brigalow, belah
2	1977	Wyaga	Flat; top of slope	Belah, brigalow
3	1977	Wyaga	Slope; 2% near top of slope	Brigalow
4	1977	Wyaga	Slope; 2% near top of slope	Brigalow, belah
5	1977	Wyaga	Slope; 1½% near base of slope	Poplar box
6	1977	Wyaga	Slope; 1% near base of slope	Brigalow
7	1977	Wyaga	Flat; base of slope	Brigalow
8	1977	Tara	Flat; base of slope	Brigalow, belah
9	1977	Tara	Flat; base of slope	Brigalow
10	1977	Tara	Slope; 2% near top of slope	Brigalow
11	1977	Tara	Flat; base of slope	Poplar box
12	1977	Tara	Slope; 1% near base of slope	Brigalow
13	1977	Condamine	Flat; base of slope	Belah, wilga
14	1977	Condamine	Slope; 1% near top of slope	Poplar box
15	1977	Condamine	Flat; top of slope	Brigalow
16	1977	Wallumbilla	Flat; base of slope	Poplar box
17	1977	Wallumbilla	Flat; base of slope	Poplar box
18	1977	Wallumbilla	Slope; 1% near base of slope	Brigalow
19	1977	Wallumbilla	Flat; base of slope	Brigalow
20	1978	Wandoan	Slope; 2% near base of slope	Brigalow, belah
21	1978	Wandoan	Slope; 2% near base of slope	Brigalow, wilga
22	1978	Wandoan	Flat; top of slope	Brigalow, belah
23	1978	Wandoan	Flat; base of slope	Brigalow
24	1978	Wyaga	Slope; 2% near top of slope	Poplar box
25	1978	Wyaga	Slope; 2% near top of slope	Brigalow, wilga
26	1978	Wyaga	Flat; top of slope	Brigalow, belah
27	1978	Wyaga	Slope; 2% near top of slope	Brigalow
28	1978	Wyaga	Flat; base of slope	Brigalow
29	1978	Wyaga	Flat; base of slope	Brigalow
30	1978	Tara	Slope; 1% near top of slope	Brigalow
31	1978	Tara	Slope; 1% near top of slope	Brigalow
32	1978	Tara	Slope; 1% near base of slope	Brigalow
33	1978	Tara	Slope; 2% near base of slope	Poplar box
34	1978	Tara	Slope; 2% near base of slope	Poplar box
35	1978	Tara	Slope; 2% near top of slope	Brigalow

down slopes: 1 to 4, 6 to 7, 16 to 19, 20 to 22, 24 to 25, 26 to 29, 30 to 31 and 32 to 35. Most sites carried brigalow (*Acacia harpophylla*) or belah (*Casuarina cristata*) or both in their natural state. Soils were mostly grey to grey-brown clays characteristic of the brigalow soils of the Western Downs. Red-brown earth soils (belah/poplar box) were also included (Sites 5, 11, 14, 16, 17, 24, 33 and 34).

Table 2. Colour, texture and chemical analyses of surface soil (0 to 10 cm) from each site

Site number	Texture	Colour	pH	Bicarb-P (ppm)	DTPA-Cu (ppm)	DTPA-Zn (ppm)
1	Clay	Grey-brown	6.9	32	0.23	0.97
2	Clay	Grey-brown	6.8	34	0.23	1.60
3	Clay	Grey-brown	7.2	43	0.34	0.51
4	Clay	Grey-brown	7.1	33	0.35	0.67
5	Loam	Red-brown	7.0	14	0.37	0.60
6	Clay	Brown	6.9	20	0.23	0.36
7	Clay	Grey	7.3	29	0.71	0.43
8	Clay-loam	Grey-brown	7.3	14	0.57	0.25
9	Clay	Grey	7.7	26	0.68	0.27
10	Clay	Grey	7.2	9	0.59	0.27
11	Loam	Red-brown	7.0	9	0.55	0.30
12	Clay	Grey	7.1	16	0.57	0.23
13	Clay-loam	Red-brown	7.0	23	0.60	0.25
14	Loam	Red-brown	7.2	17	0.34	0.14
15	Clay	Grey	7.7	34	0.49	0.30
16	Sandy loam	Brown	6.7	35	0.20	0.71
17	Sandy loam	Brown	6.7	25	0.19	0.78
18	Clay	Grey	6.9	21	0.42	0.62
19	Clay-loam	Grey	6.8	19	0.51	0.79
20	Clay	Grey	7.6	12	0.33	0.71
21	Clay	Grey	7.8	15	0.46	1.16
22	Clay	Brown-grey	8.8	9	0.40	0.66
23	Clay	Grey	8.5	26	0.76	0.79
24	Sandy loam	Brown	7.5	23	0.56	1.38
25	Clay-loam	Brown	7.6	32	0.98	1.46
26	Clay	Grey	7.2	25	0.74	1.41
27	Clay	Grey	7.5	32	0.78	1.21
28	Clay	Grey	7.5	36	1.21	1.29
29	Clay	Grey	7.6	21	0.80	0.93
30	Clay	Grey-brown	7.3	19	0.68	0.66
31	Clay	Grey	7.1	13	0.88	0.63
32	Clay	Grey	6.8	15	0.94	0.66
33	Loam	Red-brown	6.2	12	0.40	0.35
34	Loam	Red-brown	5.7	18	1.82	0.43
35	Clay	Grey	6.4	10	0.39	0.46

Visual symptoms of Cu deficiency (Grundon 1979) were observed on Sites 1 and 2 by late stem elongation (Feeks stage 6), and untreated plants on these sites had almost died by the time treated plants had flowered (Feekes stage 10.5.1). Mild symptoms of Cu deficiency were observed on untreated plants on Sites 20 and 21 at the boot stage of growth (Feekes stage 10), but no further symptoms appeared as the crop matured. Untreated plants on all other sites appeared healthy and free of all nutrient deficiency symptoms.

Grain yields from the 29 sites which were harvested are shown in Table 3. Consistent improvements in yield parameters from applied Cu were obtained on Sites 1, 2, 20 and 21, the only sites where visual symptoms of Cu deficiency were observed during plant growth. On

Table 3. Grain yields and chemical analyses of grain from selected sites*

Site number	Treatment	Grain yield†			Grain Cu‡ (ppm)
		g per quadrat	mg per head	Number per head	
1	− Cu	0.0	0	0.0	0
	+ Cu	31.4*a*	542*a*	16.6*a*	1.7
2	− Cu	1.1	59	2.0	1.3
	+ Cu	36.2*a*	673*a*	20.4	1.3
3	− Cu	50.8	850	22.7	1.2
	+ Cu	60.3	822	22.2	2.3
4	− Cu	66.9	810	23.2	2.0
	+ Cu	79.0	858	25.7	2.1
5	− Cu	30.8	675	21.7	2.9
	+ Cu	28.4	704	21.9	3.8
6	− Cu	34.9	671	20.3	2.6
	+ Cu	33.8	602	18.2	3.1
7	− Cu	53.9	641	17.6	5.3
	+ Cu	49.6	648	17.5	4.7
8	− Cu	57.0	839	21.6	4.1
	+ Cu	48.7	821	20.5	4.5
9	− Cu	68.6	905	24.8	4.7
	+ Cu	61.8	794	22.2	5.0
10	− Cu	50.0	821	30.0	4.9
	+ Cu	51.3	872	31.1	5.6
11	− Cu	21.5	425	12.8	5.5
	+ Cu	23.1	461	14.4*a*	5.7
12	− Cu	77.6	574	20.5	4.2
	+ Cu	75.9	574	20.4	5.0
13	− Cu	32.0	690	21.2	4.8
	+ Cu	33.7	708	21.0	5.3
14	− Cu	35.1	648	19.6	4.3
	+ Cu	34.8	636	20.3	4.3
15	− Cu	72.9	714	24.3	5.0
	+ Cu	64.5	578	18.3	5.0
16	− Cu	74.9	695	21.3	3.5
	+ Cu	70.7	746	20.7	3.3
17	− Cu	38.4	642	18.1	3.3
	+ Cu	44.2	683	18.6	3.3
18	− Cu	41.4	731	22.5	4.6
	+ Cu	45.9	748	23.7	5.0
19	− Cu	44.1	722	21.7	4.7
	+ Cu	51.5	707	20.6	5.2
20	− Cu	91.9	1080	22.8	2.9
	+ Cu	105.2*a*	1221*a*	24.7	4.4
21	− Cu	56.8	682	15.2	2.0
	+ Cu	85.3*a*	930*a*	20.0*a*	3.5
22	− Cu	83.9	1466	31.7	3.8
	+ Cu	76.7	1373	30.0	4.8
24	− Cu	94.6	1222	32.2	2.5
	+ Cu	88.5	1089	30.4	5.6
25	− Cu	128.1	1373	36.9	4.8
	+ Cu	101.4	1170	32.4	6.1
26	− Cu	94.7	1128	31.0	1.7
	+ Cu	92.0	1028	30.6	3.1
32	− Cu	91.6	1009	31.6	3.7
	+ Cu	77.8	916	30.0	5.2

Site number	Treatment	Grain yield†			Grain Cu‡ (ppm)
		g per quadrat	mg per head	Number per head	
33	− Cu	72.4	1317	31.4	4.1
	+ Cu	68.1	1225	29.3	4.0
34	− Cu	46.7	1079	26.4	3.1
	+ Cu	47.1	1449	27.6	3.8
35	− Cu	99.9	1373	31.4	2.1
	+ Cu	96.1	1413	32.7	3.2

*Sites 23, 27, 28, 29, 30 and 31 were not harvested.
†Values are means of 10 quadrats (Sites 1 to 19) or 20 quadrats (Sites 20 to 35). A letter *a* after a '+ Cu' value indicates that the application of copper significantly improved yield ($P = 0.05$). A grain yield of 53.4 g per quadrat is equivalent to 1.0 t ha^{-1}.
‡Grain from quadrats of each treatment (plus Cu; minus Cu) bulked before analysis.

Site 11, Cu application significantly improved number of grains per head, but this result was not reflected in improved weight of grain on a per head or per quadrat basis.

On all Cu-responsive sites, the Cu concentration of grain from untreated plants was less than 3.0 ppm (Table 3). Grain from untreated plants on Sites 3, 4, 5, 6, 24, 26 and 35, however, also contained less than 3.0 ppm Cu. King and Alston (1975) proposed a critical value of 2.5 ppm Cu in wheat grain to delineate potentially Cu deficient wheat. On this basis, Sites 3, 4, 26 and 35 would also have been expected to respond to Cu applications.

From the data presented, we classed Sites 1, 2, 20 and 21 as 'deficient' in Cu and Sites 3, 4, 26 and 35 as 'potentially deficient'. The deficient soils were grey or grey-brown clays with a near neutral to alkaline pH (Table 2) and carried a natural vegetation of brigalow and belah (Table 1). All deficient sites occurred adjacent to rocky outcrops of quartz and sandstone where the natural vegetation was an association of silver- and narrow-leafed ironbark and wattle.

Whitehouse (1973b) suggested a tentative soil test value of 0.4 ppm DTPA-extractable Cu as a criterion for separating soils likely to respond to Cu. 'Available' Cu concentrations of the four deficient soils were respectively 0.23, 0.23, 0.33 and 0.46 ppm; those of the four 'potentially deficient' soils were 0.34, 0.35, 0.74 and 0.39 ppm. Five other sites (5, 6, 14, 16 and 17) had soils with less than 0.4 ppm but did not respond to Cu application. These soils were all brown or red-brown, and most were lighter in texture (sandy loam/loam). Although no sharply defined critical soil test value can be established from this work, the data suggest that in practice there is a substantial risk that grey-brown and grey clays in this region having DTPA-extractable Cu concentrations less than 0.4 ppm will be deficient in Cu for wheat growing.

There was no correlation between the responsiveness of a site to Cu fertilizer and the level of 'available' P or Zn. Strong, Best and Cooper (1980) showed that sites on the Western Downs with less than 15 ppm bicarbonate-extractable P have responded to dressings of phosphate, while Whitehouse (1973a) showed that responses to Zn fertilizers were most likely to occur on sites with a pH above 7.0 and less than 0.8 ppm DTPA-extractable Zn. On these criteria, the eight Cu deficient or potentially deficient sites had P levels ranging from deficient (sites 20, 21 and 35) to adequate but not high (sites 1, 2, 3, 4 and 26), and Zn levels ranging from deficient (sites 3 and 4) to adequate (sites 1, 2, 20, 21, 26 and 35) (Table 2). Similar ranges in 'available' P and Zn occurred in non-deficient soils. Although there is no evidence from this study that Cu deficiency is related to high natural levels of 'available' P or Zn, heavy or prolonged use of Zn or P fertilizers can induce Cu deficiency on sites low in 'available' Cu and P or Cu and Zn (Gilbey, Greathead and Gartrell 1970; Touchton, Johnson and Cunfer 1980). It is therefore recommended that the use of P and Zn fertilizers on such sites is carefully controlled.

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