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The effects of copper and zinc on wheat on newly cleared land in the wheatbelt of Western Australia

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The EFFECTS of COPPER and ZINC on WHEAT on NEWLY CLEARED LAND in THE WHEATBELT of WESTERN AUSTRALIA

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OF WESTERN AUSTRALIA

INTRODUCTION

Following the publication of recommendations for copper, zinc and molybdenum fertilisers for new land in Western Australia (Gartrell and Glencross 1968), numerous requests were received for information on the background experimental work. This bulletin presents the experimental methods and results associated with recommendations for copper and zinc fertilisers for the wheatbelt zones shown on the map on page 5.

Copper research before 1965

Copper deficiency of cereals in W.A. was first recognised in 1939. Between 1939 and 1945, Teakle, Wild, Turton, Burvill and Thomas, and their co-workers, found the deficiency was widespread on all soils of the Gingin-Dandaragan "red gum" country, the high level sandy and gravelly soils of the main wheatbelt and Great Southern, and coastal soils high in lime. Their work showed that bluestone 5 to 10 lb per acre cured the deficiency but no benefit was obtained from additional copper in subsequent years. Oxidised copper ore gave results equal to and sometimes better than bluestone when both were applied to give the same amount of copper per acre (12½ lb oxidised copper ore assaying 10 per cent copper contains 1¼ lb bluestone - 25% Cu).

Dunne (1948) reviewed the earlier work and added that on a few sandy soils rates of bluestone higher than 5 lb per acre could be damaging. He considered initial applications of 5 lb per acre most satisfactory and there was no known need for additional copper where a total of 10 lb per acre bluestone had been applied.

Toms (1958) reviewed earlier work and presented additional information which generally confirmed the conclusions of previous workers. However, he recommended one bag (187 lb) per acre of the then commercial copper - superphosphate mixtures on new land to give 150 lb per acre super. This was the minimum rate of super considered desirable for the first crop on new land. Before 1958 the main copper-super mixtures contained the equivalent of 7.5 lb bluestone per bag. In 1958 this was increased to the equivalent of 9.4 lb per bag. Thus to get a reasonably adequate super application more copper had to be used than was desirable.

Like earlier workers, Toms concluded that where 5 lb per acre bluestone or more had been applied, further applications did not increase cereal yield except for small areas, at Bremer Bay, Dandaragan and Gingin and the deficient limestone soils at Dongara.

In 1965, on the advice of this Department, the fertiliser companies reduced the copper and zinc content of their standard mixtures. Advantages to farmers of these reductions were:-

- Adequate rates of super, copper and zinc could be applied to new land using standard copper-zinc-super mixtures with little fear of costly yield reductions due to excess copper and zinc.

o Because the new mixtures contained less copper and zinc, they were cheaper than the old ones.

⊕ There was more super in each bag than before (in each 187 lb bag of new Cu Zn super there was 170 lb super compared with 150 lb super in previous mixtures).

The 1965 - 67 experiments

Most copper and zinc experiments carried out with cereals before 1965 tested the effects of single rates of copper and zinc, alone or in combination - few tested combinations of several levels of copper and zinc. Such experiments showed where copper and zinc would increase cereal yield but then results could not be used to determine whether different combinations would have been better.

The series of experiments commenced in 1965 tested the effects of combinations of a range of copper and zinc rates.

METHODS

The 1965 experiments

(a) Two experiments (One in Zone 15 and one in Zone 16) of identical design:

Cu x Zn Treatments: A 2 x 4 x 2 factorial combination of the following:

Bluestone at nil or 5 lb/acre,
Zinc oxide at nil, ½, 1½, or 3 lb/acre,
Manganese sulphate at nil or 14 lb/acre.

Replications : 3

Plot size : 10.5 lk x 500 lk

All 16 treatments received 180 lb/acre superphosphate and 2 oz/acre roasted molybdenite drilled with seed.

The bluestone and zinc oxide were mixed with the molybdenum - superphosphate.

Two nil molybdenum treatments were added to gauge the Mo effect.

(b) Ten experiments (all other 1965 experiments) of identical design:

Cu x Zn Treatments : A 4 x 3 factorial combination of the following:

Bluestone at nil, 2½, 5 or 7½ lb/acre,
Zinc oxide at nil, 1½ or 3 lb/acre.

Replications : 3

Plot size : 10.5 lk x 500 lk

All 12 treatments received 180 lb/acre superphosphate and 2 oz/acre roasted molybdenite drilled with seed, thirty lb/acre urea was topdressed immdeiately before seeding.

The bluestone and the zinc oxide were applied mixed with the molybdenum - superphosphate.

Three nil molybdenum treatments were added to gauge the Mo effect and an aerophos treatment was added to gauge the effect of trace element impurities in super. One treatment with either a higher or lower super rate was added for comparison with the super 180 rate used in all other treatments.

The 1966 and 1967 experiments

(a) Twenty six experiments of identical design:

Cu x Zn Treatments : A 4 x 4 factorial combination of the following:
Bluestone at nil, 2½, 5 or 7½ lb/acre,
Zinc oxide at nil, 3/4, 1½ or 3 lb/acre.

Replications: 3 (Results obtained from 2 reps only in Zone 5 experiment 6).

Plot size: 10.5 lk x 500 lk except Zone 6(a) experiments which were 10.5 lk x 400 lk.

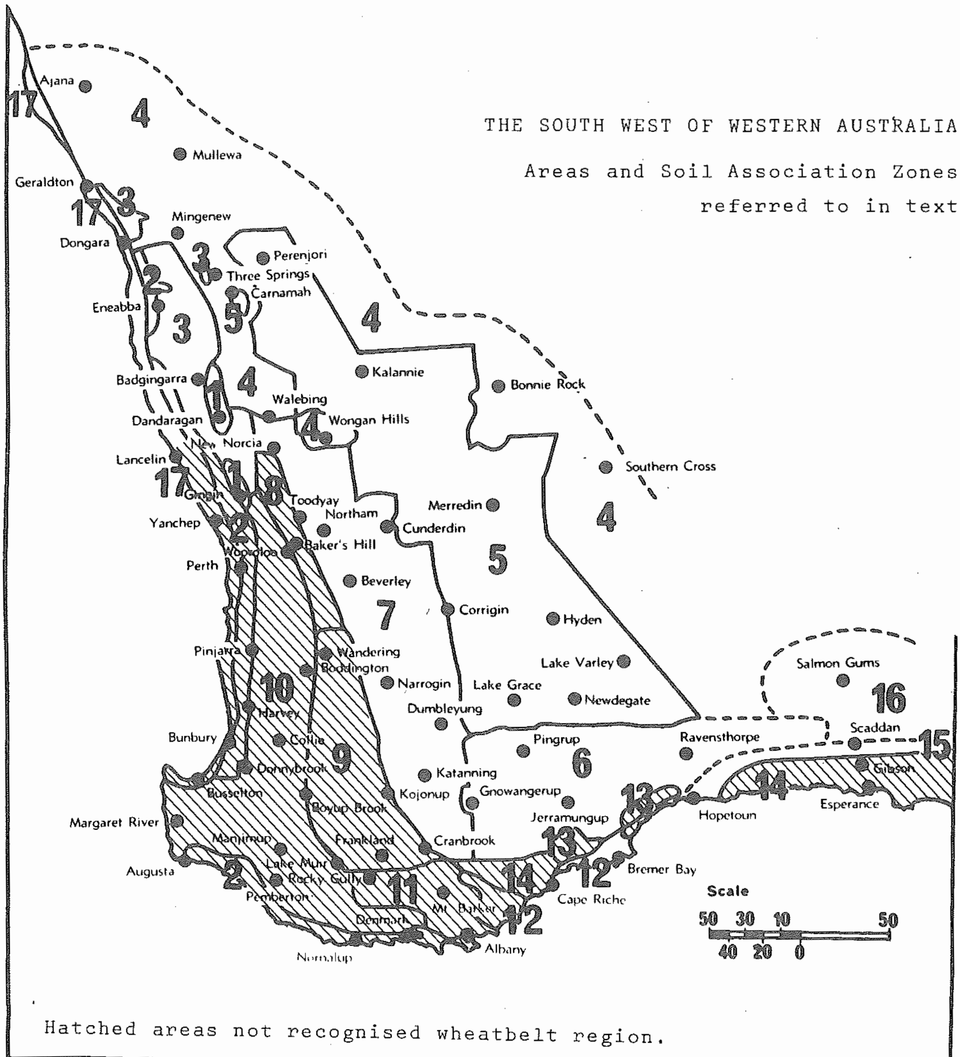
All 16 treatments received 180 lb/acre superphosphate and 2 oz/acre roasted molybdenite drilled with the seed. Urea at 50 lb/acre was broadcast immediately before seeding.

Bluestone and zinc oxide were mixed with the superphosphate.

Three nil molybdenum treatments were added to gauge the Mo effect. An aerophos and gypsum treatment was added to gauge the effect of trace element impurities in super. One treatment with either a higher or lower super rate was added for comparison with the super 180 rate used in all other treatments.

RESULTS AND DISCUSSION

Results of the 1965 - 67 experiments, together with previous experience, showed that the amounts of copper and zinc needed for best yields, were different in different parts of the wheatbelt. Major differences were associated with the soil association zones shown in the map. Trace element responses for each zone in the <u>wheat growing region</u> were determined as follows.



THE SOUTH WEST OF WESTERN AUSTRALIA

Areas and Soil Association Zones referred to in text

Hatched areas not recognised wheatbelt region.

ZONE 1: THE DANDARAGAN-GINGIN ZONE

Soils* in this zone are red earthy sands with yellow earthy sands on the ridges and leached grey sands in the centre of some valleys. Dark loamy soils occur on small chalk outcrops. Grey and brown diatomaceous earths are found in some valley floors. The soils are formed on Cretaceous sediments.

No trials were located in the zone between 1965 and 1967.

At least 7½ lb /acre bluestone is needed for the first application if wheat is grown and a further application of 5 lb/acre in a subsequent year has been claimed to be necessary. Zinc deficiency seems to occur more on the yellow and grey sands than on the other soil types in the area.

The application of ¾ lb to 1½ lb of zinc oxide per acre to all soils in the area would be a safe policy.

ZONE 2: THE NEAR-COASTAL DEEP LEACHED SANDS

The main soil is deep, grey, leached siliceous sand, apparently formed on weathered aeolianite.

The sands are generally unsuitable for broadscale farming because they are deficient in several plant nutrients and dry out very rapidly in rainless periods.

No experiments were conducted on the deep leached sands in 1965-67. Because of the low buffering capacity of these sands copper and zinc applications higher than 2½ bluestone and ¾lb per acre zinc oxide would probably have toxic affects on seedlings if drilled with a cereal crop.

ZONE 3: THE WEST MIDLAND GREY SILICEOUS SANDS

Dominant soils are grey, pale yellow and yellow sands, and gravelly sands overlying yellow mottled clayey sand. Lateritic sandy gravels and deep leached grey sands also occur. Soils of heavier texture occur on smaller areas where sandstones and shales are exposed.

The chief soils are derived from lateritic profiles developed mainly on Jurassic and Triassic sediments.

Experiments on grey sandy and gravelly surfaced soils

1. *Experiment 65GE11; G. Garratt, Allanooka; 8 - 20 in. grey sand over yellow gravelly sandy loam*

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* Descriptions of soils, and the soil association boundaries shown on the map, are based on the *Atlas of Australian Soils Sheet 5*, C.S.I.R.O. Division of Soils.

*

Mo (1)	SU(2) & A(3)	Zn (4)	Cu(5) 0	2½	5	7½	Zn Rates Means	LSD	Comparison (i)	(ii)	(iii)
+	SU	0	14.0	14.0	13.1	12.0	13.3	/0.05	2.31	1.21	1.05
+	SU	1½	13.7	17.1	18.5	17.2	16.6				
+	SU	3	12.9	16.1	17.3	17.3	15.9	/0.01	2.31	1.62	1.41
Cu Rates Means			13.5	15.3	16.3	15.5		/0.001	3.74	2.16	1.37
-	SU	0	15.1								
-	SU	1½			16.9						
-	SU	3				17.0					
-	A	0	1.9								
+	Su120	1½			15.2						

(a) Neither Cu nor Zn applied alone gave increased yield.
(b) Increased yields resulted where Cu and Zn were applied together. The best combination was Cu 2½ Zn 1½ or Cu 5 Zn 1½ depending on whether the difference between them was real.
(c) The extremely low soil zinc supply was shown by the very low yield and severe zinc deficiency symptoms on the aerophos treatments and demonstrates the nutrient value of the non calcium phosphate constituents of plain super.

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* Explanation of tables relating to all trials and showing relationship between wheat yields and rates of phosphate, copper, zinc, molybdenum applications.

(1) Mo : Presence (+) or absence (-) of 2 oz/acre roasted molybdenite (55% Mo) drilled mixed with superphosphate and any copper or zinc.
(2) SU : Superphosphate 180 lb/acre applied.
(3) A : Aerophos to give a phosphate application equal to 180 lb/acre super in 1965. In 1966 and 1967 gypsum was used with the aerophos so that both phosphate and sulphate were applied at rates equivalent to super 180 lb/acre.
(4) Zn : Zinc oxide applied in terms of lb/acre. Zinc oxide contained 75-78 per cent zinc.
(5) Cu : Bluestone applied in terms of lb/acre. Bluestone contained 25 per cent copper.

NOTE: Basal dressing to all plots in 1965 was urea 30 lb/acre; in 1966 -67 it was urea 50 lb/acre.

STATISTICAL COMPARISONS:

(i) LSDs for differences between any two treatments.
(ii) LSDs for differences between the mean of three treatments & the mean of any other three treatments.
(iii) LSDs for differences between the mean of four treatments and the mean of any other four treatments

2. *Experiment 66BA8; Research Station Badgingarra; 2 - 20 in. grey sand over yellow gravelly sand*

Mo (1)	SU (2) (3) A	Zn (4)	Cu (5) 0	2½	5	7½	Zn Rates Means	LSD	Comparison (i)	(ii)	(iii)
+	SU	0	8.3	8.8	8.9	9.6	8.9	/0.05	1.37	0.78	0.68
+	SU	¾	7.4	9.6	9.3	9.8	9.0	/0.01	1.84		0.92
+	SU	1½	6.9	9.4	10.2	10.3	9.2	/0.001	2.41		1.20
+	SU	3	6.6	9.5	10.0	9.8	9.0				
Cu Rates Means			7.3	9.3	9.6	9.9					
-	SU	0	7.2								
-	SU	¾		9.6							
-	SU	1½			10.7						
-	A	0	1.0								
+	Su120	¾			8.8						

(a) Zn reduced yield with Cu nil. Where Cu was added, Zn increased yield.
(b) Cu application gave a small increase with nil Zn. The increase to Cu was slightly greater in the presence of Zn.
(c) The best combination was Cu 5 Zn 1½.
(d) The large difference between plain super and aerophos + gypsum was probably due to the 400 to 500 ppm zinc in plain super.

Mean wheat yield (bu/ac) from the two experiments in Zone 3.

		Cu (Bluestone lb/ac) 0	2½	5	7½	$\bar{X}$
Zn	0	11.2	11.4	11.0	10.8	11.10
(Zinc oxide)	1½	10.3	13.3	14.4	13.8	12.95
(lb/ac)	3	9.8	12.8	13.7	13.6	12.8
	$\bar{X}$	10.43	12.50	13.03	12.73	12.18

In the two experiments, copper or zinc applied singly did not increase grain yield. Applied together, copper and zinc increased yield.

Where zinc oxide was applied, bluestone 5 lb/acre gave higher yields than bluestone 2½ lb/acre. Zinc oxide at 1½ lb/acre is needed for maximum pasture, oats and possibly wheat yields.

There is no evidence that applications additional to the original bluestone 5 lb/acre plus zinc oxide 1½ lb/acre are needed in subsequent years.

ZONE 4(a) THE WESTERN ZONE OF YELLOW SANDS

Chief soils are yellow earthy sands with patches of yellow gravelly soils. The smaller areas of grey siliceous sandy and gravelly soils may have the same properties as similar soils in zone 3, in which case they would require more copper and zinc than the yellow sands.

Parent material is probably a laterite profile developed on sedimentary rocks varying in age from Permian to Cretaceous.

Experiments on yellow sandy earth or earthy sand

1. *Experiment 65GE10; R. Stagg, Wongoondy-Bootenal; yellow earthy sand*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	LSD	Comparison (i)	(ii)	(iii)
+	SU	0	8.2	7.5	7.5	6.7	7.5	/0.05	2.99	1.73	1.49
+	SU	1½	4.3	8.5	7.3	7.1	6.8				
+	SU	3	5.4	6.4	7.0	7.5	6.0	/0.01	4.02	2.32	2.01
Cu Rates Means			5.9	7.5	7.3	7.2		/0.001	5.35	3.09	2.67
-	SU	0	9.1								
-	SU	1½			5.2						
-	SU	3				5.6					
-	A	0	4.4								
+	Su 120	1½									

(a) Nil Cu, nil Zn gave equal top yield.

(b) Zn added without Cu depressed yield.

(c) Cu 2½ increased yield where Zn had been added. The increase with Cu 2½ was the same size as the depression caused by Zn where no copper applied. Zn did not depress yield where Cu 2½ or more was used.

(d) The lower yield and zinc deficiency symptoms observed on the aerophos plots is indicative of a low soil zinc supply. For wheat the 4 to 500 ppm Zn in plain super appears to have met the requirements of the wheat in this instance but would probably not be enough for oats or clovers.

2. *Experiment 66GE6; A. McKay, Binnu; yellow earthy sand*

Mo	SU / A	Zn	Cu 0	2½	5	7½	Zn Rates Means	LSD	(i)	(ii)	(iii)
+	SU	0	21.1	22.0	22.5	20.6	21.7	/0.05	3.02	1.74	1.51
+	SU	¾	23.5	23.0	20.4	21.3	22.2				
+	SU	1½	22.0	23.3	20.2	22.2	22.1	/0.01	4.04	2.34	2.02
+	SU	3	22.5	21.9	20.2	20.0	21.3				
Cu Rates Means			22.5	22.7	21.0	21.2		/0.001	5.34	3.09	2.67
-	SU	0	21.8								
-	SU	¾		21.7							
-	SU	1½			21.5						
-	A	0	20.6								
+	Su 90	¾			19.4						

(a) Neither Cu nor Zn increased yield.

(b) Cu 5 & 7½ appeared to reduce yield slightly.

(c) The difference between plain super & aerophos + gypsum treatments was not significant. Thus there appeared to be no response to the trace element impurities present in plain super.

Mean wheat yield (bu/ac) from the two experiments in Zone 4 (a).

		Cu (Bluestone lb/ac)				
		0	2½	5	7½	$\bar{X}$
Zn (Zinc oxide) (lb/ac)	0	14.7	14.8	15.0	13.7	14.55
	1½	13.2	15.9	13.8	14.7	14.40
	3	14.0	14.2	13.6	13.8	13.90
	$\bar{X}$	13.97	14.97	14.13	14.07	14.28

Copper and zinc did not increase yield in the two recent experiments. Copper deficiency in wheat and barley, and zinc deficiency in oats have been recorded in trials and in farmers' crops on the yellow sands in this zone. A single application of bluestone 2½ lb/acre and zinc oxide ¾ lb/acre would normally be sufficient.

ZONE 4(b) THE NORTH-EAST AND EASTERN ZONE (PLUS WONGAN HILLS AND MILING AND CARNAMAH).

The chief sandplain soils are yellow earthy sands and gravelly sands, yellow sandy earths and gravelly earths. In the Miling-Carnamah section the chief soils are sandy neutral yellow mottled soils with some ironstone gravel.

The soils were probably formed from decomposing lateritic profiles which were developed on Archaean granite rocks.

Experiments on yellow sandy and gravelly surfaced sites

1. *Experiment 65M02; Shalz Bros., North East Kalannie; yellow earthy sand*

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	LSD	Comparison (i)	(ii)	(iii)
+	SU	0	11.3	12.5	12.7	11.4	12.0	/0.05	2.81	1.62	1.40
+	SU	1½	9.2	11.3	11.6	10.9	10.8				
+	SU	3	8.4	12.2	11.8	12.7	11.3	/0.01	3.78	2.18	1.89
	Cu Rates Means		9.6	12.0	12.0	11.7					
								/0.001	5.01	2.90	2.51
-	SU	0	8.2								
-	SU	1½			10.9						
-	SU	3				10.6					
-	A	0	7.0								
+	Su120	1½			10.2						

(a) Nil Cu, nil Zn gave near maximum yield.

(b) Even without Zn, Cu 2½ appeared to increase yield slightly but this difference was not statistically significant.

(c) Zn added without Cu depressed yield.

(d) Cu 2½ increased yield where Zn was added to an extent that Zn did not depress yield in the presence of Cu.

(e) The difference between plain super & aerophos was not statistically significant.

2. *Experiment 66GE7; J. Hunt, south east Perenjori; yellow earthy sand slightly gravelly in patches*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	LSD	Comparisons (i)	(ii)	(iii)
+	SU	0	19.8	20.1	18.4	18.8	19.3	/0.05	3.33	1.92	1.66
+	SU	3	22.8	19.3	19.8	19.0	20.2				
+	SU	1½	21.2	21.0	18.9	17.3	19.6	/0.01	4.46	2.58	2.23
+	SU	3	20.1	20.3	19.1	19.0	19.6				
	Cu Rates Means		21.0	20.2	19.1	18.5		/0.001	5.89	3.40	2.95
-	SU	0	20.3								
-	SU	¾		19.0							
-	SU	1½			16.0						
-	A	0	21.1								
+	Su 90	¾			12.1						

(a) Neither Cu nor Zn increased yield.

(b) Zn did not depress yield.

(c) Cu at 5 and 7½ depressed yield.

(d) There was no difference between the plain super & aerophos + gypsum treatments.

3. *Experiment 67MO7; M. Hudson, north east Kalannie; yellow brown sandy earth*

+	SU	0	10.8	11.0	10.8	9.5	10.5	/0.05	1.04	0.60	0.52
+	SU	¾	11.4	11.7	11.3	10.3	11.2				
+	SU	1½	10.7	12.1	10.0	9.4	10.6	/0.01	1.39		0.70
+	SU	3	8.5	10.0	9.1	8.2	9.0				
	Cu Rates Means		10.4	11.2	10.3	9.3		/0.001	1.84		0.92
-	SU	0	10.7								
-	SU	¾		10.5							
-	SU	1½			9.8						
-	A	0	9.2								
+	Su120	¾			7.8						

(a) Nil Cu, nil Zn gave near maximum yield.

(b) Overall, the best combination appears to have been Cu 2½, Zn ¾ but

this did not give statistically better results than the Cu nil, Zn nil treatment.

(c) Zn 3 depressed yield.

(d) Cu 7½ depressed yield; Cu 5 gave lower yields than Cu 2½.

(e) The difference between plain super and aerophos + gypsum would not be statistically significant.

4. Experiment 67M08; S. Bean, Marchagee; yellow brown earthy sand

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	LSD	Comparisons (i)	(ii)	(iii)
+	SU	0	21.5	20.2	21.2	20.8	20.9	/0.05	2.72	1.56	1.36
+	SU	¾	21.1	20.3	19.0	21.0	20.4				
+	SU	1½	20.3	21.1	19.9	20.6	20.5	/0.01	3.64		1.82
+	SU	3	19.5	19.2	20.6	19.6	19.7				
Cu Rates Means			20.6	20.2	20.2	20.5		/0.001			
-	SU	0	20.6								
-	SU	¾		19.6							
-	SU	1½			19.5						
-	A	0	19.8								
+	Su 120	¾			16.3						

(a) Cu Nil Zn nil gave top yield.

(b) Zn 3 appeared to reduce yield.

(c) The difference between plain super and aerophos + gypsum was not statistically significant.

5. Experiment 67GE7; J. Wright, Pindar; brown earthy gravel

+	SU	0	11.5	13.0	11.8	11.9	12.1	/0.05	1.46	0.84	0.73
+	SU	¾	12.6	12.8	12.5	11.5	12.4				
+	SU	1½	11.2	12.4	11.6	11.6	11.7	/0.01	1.96		
+	SU	3	12.8	12.4	11.0	11.0	11.8				
Cu Rates Means			12.0	12.7	11.7	11.5		/0.001			
-	SU	0	10.8								
-	SU	¾		12.0							
-	SU	1½			11.4						
-	A	0	8.3								
+	Su120	¾									

(a) Neither Cu nor Zn added to super affected yields significantly.

(b) Plain super gave a higher yield than aerophos + gypsum.

Mean wheat yield (bu/ac) from the experiments in Zone 4 (b)

		Cu (Bluestone lb/ac)				
		0	2½	5	7½	$\bar{x}$
Zn (Zinc oxide) (lb/ac)	0	16.2	16.1	15.6	15.3	15.80
	¾	17.0	16.0	15.7	15.5	16.05
	1½	15.9	16.7	15.1	14.7	15.60
	3	15.2	15.5	15.0	14.5	15.05
	$\bar{x}$	16.08	16.08	15.35	15.00	15.63

Wheat on the yellow sands of Zone 4(b) gives near maximum yields without added copper or zinc. Small yield increases with the lower copper and zinc rates have been recorded on these soils. A single application of bluestone 2½ lb/acre and zinc oxide ¾ lb/acre would be sufficient to prevent copper and zinc deficiencies in this zone.

ZONE 5: THE CENTRAL WHEATBELT

The main sandplain soils are yellow sandy and often gravelly earths, yellow earthy sands and ironstone gravels. On the western and southern fringes of the zone grey leached sands and gravelly sands are widespread. Areas of granitic tors and bosses and their associated gritty sands, appear to be less severely copper and zinc deficient than the laterite-derived sands.

The main yellow and grey sands and gravels are derived from decomposition of laterite profiles which were formed on Archaean granitic and (less frequently) basic dykes. The gritty almost gravel free sands which overly granitic rocks at shallow depth appear to be weathering products of the granitic rock.

Experiments on sandy and gravelly laterite derived soils

1. *Experiment 66LG3; R.F. Lloyd, Newdegate; brown earthy gravel*

Mo (1)	SU (2) A (3)	Zn (4)	Cu (5) 0	2½	5	7½	Zn Rates Means	LSD	Comparisons (i)	(ii)	(iii)
+	SU	0	7.9	11.4	13.4	13.3	11.5	/0.05	2.34	1.35	1.17
+	SU	¾	10.6	14.4	15.2	14.4	13.7				
+	SU	1½	9.8	12.8	15.0	14.6	13.1	/0.01	3.14	1.81	1.57
+	SU	3	6.9	12.9	14.3	15.1	12.3				
Cu Rates Means			8.8	12.9	14.5	14.3		/0.001	4.14	2.39	2.07
-	SU	0	8.7								
-	SU	¾		10.4							
-	SU	1½			9.6						
-	A	0	4.2								
+	Su278	¾			17.8						

(a) Cu increased yield with or without Zn.

(b) Zn appeared to increase yield particularly where Cu was applied.

(c) The best combination was Cu 5 Zn $\frac{3}{4}$.

(d) Aerophos + gypsum yielded less than the plain super.

2. *Experiment 66NA9; R. Mouritz, Hyden; brown gravelly earth*

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	LSD	(i)	(ii)	(iii)
+	SU	0	8.2	15.4	15.7	15.3	13.7	/0.05	2.42	1.15	0.93
+	SU	¾	5.1	13.4	15.7	13.0	11.8				
+	SU	1½	4.7	12.8	14.7	15.6	12.0	/0.01	3.24	1.87	1.62
+	SU	3	4.5	11.7	13.8	15.0	11.3				
Cu Rates Means			5.6	13.3	15.0	14.7		/0.001	4.28	2.47	2.14
-	SU	0	7.4								
-	SU	¾		12.7							
-	SU	1½			12.4						
-	A	0	7.2								
+	Su120	¾			13.1						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield when Cu rate was 5 or below. The higher the Zn the greater was the depression. At Cu 5, Zn did not depress yield.

(c) The best combination for wheat was Cu 5 Zn nil or Cu 2½ Zn nil. Cu 5 Zn ¾ gave the same yield as Cu 5 Zn nil. Cu 5 Zn nil was not statistically better than Cu 2½ Zn nil.

(d) Plain super & aerophos + gypsum yielded the same.

3. *Experiment 66MO16; R. Coupar, Wubin, brown gravelly earth*

+	SU	0	9.8	14.8	14.1	13.1	13.0	/0.05	1.99	1.15	1.00
+	SU	¾	3.6	13.2	13.6	14.3	11.2				
+	SU	1½	3.5	13.2	13.7	13.5	11.0	/0.01	2.67	1.54	1.34
+	SU	3	2.8	12.7	12.5	13.1	10.3				
Cu Rates Means			4.9	13.5	13.5	13.5		/0.001	3.52	2.04	1.76
-	SU	0	9.2								
-	SU	¾		10.5							
-	SU	1½			10.5						
-	A	0	1.6								
+	Su120	¾			9.8						

(a) Cu increased yield with or without Zn.

(b) Zn markedly depressed yield with Cu nil. With Cu 2½ & Cu 5 the Zn depression was smaller, the effect being greater with the higher Zn rates.

(c) Best wheat yield was obtained with Cu 2½ Zn nil.

(d) Aerophos + gypsum was inferior to plain super which indicates that Zn would be needed for oats or clover here.

4. *Experiment 66NA10; Gerard, Hyden; yellow gravelly loam*

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	LSD	Comparison (i)	(ii)	(iii)
+	SU	0	12.3	12.8	13.0	10.9	12.3	/0.05	2.10	1.21	1.05
+	SU	¾	9.4	14.4	14.8	14.4	13.3				
+	SU	1½	9.0	14.6	13.8	14.8	13.1	/0.01	2.82	1.63	1.41
+	SU	3	5.3	15.4	13.9	14.3	12.2				
Cu Rates Means			9.0	14.3	13.9	13.6		/0.001	3.72	2.15	1.86
-	SU	0	11.8								
-	SU	¾		14.7							
-	SU	1½			14.8						
-	A	0	5.1								
+	Su120	¾			14.0						

(a) Cu increased yield where Zn also added. Without Zn the small increases with Cu 2½ & Cu 5 were not statistically significant.

(b) Zn depressed yield with no Cu but increased yield where Cu was added.

(c) Cu 2½ Zn ¾ gave equal to the best yield.

(d) The inferiority of aerophos + gypsum compared with plain super indicates a need for Zn by oats or clover ley.

5. *Experiment 67NA5; C. Burns, Hyden; yellow grey gravelly sand*

Mo	SU / A	Zn	Cu 0	2½	5	7½	Zn Rates Means	LSD	(i)	(ii)	(iii)
+	SU	0	17.3	21.0	19.8	20.8	19.7	/0.05	2.68		1.34
+	SU	¾	10.3	17.2	20.1	21.2	17.2				
+	SU	1½	9.1	16.8	18.6	19.3	16.0	/0.01	3.59		1.80
+	SU	3	6.9	14.7	17.4	18.6	14.4				
Cu Rates Means			10.9	17.4	19.0	20.0		/0.001	4.71		2.36
-	SU	0	14.8								
-	SU	¾		16.2							
-	SU	1½			15.9						
-	A	0	16.0								
+	Su120	¾			16.1						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yields. With Cu nil & Cu¾ , all Zn rates appeared to depress yields. With Cu 5 & Cu 7½ only Zn 1½ & Zn 3 depressed yield and the magnitude of the depression was less than where lower Cu rates were used.

(c) Cu 2½ Zn nil gave equal top yield. Even with Zn nil, Cu 5 appeared inferior to Cu 7½. This difference may not have been real.

6. Experiment 67NA4; R. Miller, Hyden; yellow, gravelly sand

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means		Comparison (i)	(ii)	(iii)
+	SU	0	2.3	13.4	14.8	13.4	11.0	/0.05	2.82		1.41
+	SU	¾	0.9	13.2	16.1	14.9	11.3				
+	SU	1½	0.9	7.9	12.4	15.3	9.1	/0.01	3.85		1.93
+	SU	3	0.6	6.2	10.0	12.8	7.4				
Cu Rates Means			1.2	10.2	13.3	14.1		/0.001	5.21		2.61
-	SU	0	2.3								
-	SU	¾		9.3							
-	SU	1½			9.8						
-	A	0	3.9								
+	Su120	¾			8.8						

(a) Cu increased wheat yield with or without Zn.

(b) All Zn rates depressed yield with Cu nil. With Cu 2½ & 5 only Zn 1½ & Zn 3 depressed yield. With Cu 7½, Zn & 1½, if anything, increased yield.

(c) The best combination was Cu 5 Zn ¾ .

7. Experiment 67ME2; D. Hughes, Gabbin; grey brown gravelly sandy loam

Mo	SU/A	Zn	Cu 0	2½	5	7½	Zn Rates Means		Comparison (i)	(ii)	(iii)
+	SU	0	3.8	9.8	9.8	8.2	7.9	/0.05	1.50		0.75
+	SU	¾	4.6	9.0	8.9	8.8	7.8				
+	SU	1½	4.3	8.9	7.0	8.4	7.2	/0.01	2.01		1.01
+	SU	3	4.2	6.8	7.4	7.2	6.4				
Cu Rates Means			4.2	8.6	8.3	8.2		/0.001	2.63		1.32
-	SU	0	3.1								
-	SU	¾		7.5							
-	SU	1½			7.5						
-	A	0	3.6								
+	Su120	¾			6.4						

(a) Cu increased yield with or without Zn.

(b) Overall Zn tended to depress yield and rather surprisingly the Cu nil combinations do not follow this trend.

(c) Equal top yield was given by Cu 2½ Zn nil.

8. *Experiment 67NO10; H.R. Reilly; Benjaberring; yellow brown gravelly sandy earth*

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	6.0	6.4	6.3	7.8	6.6	/0.05	2.28		1.14
+	SU	¾	7.2	6.8	8.3	9.1	7.9				
+	SU	1½	7.0	8.4	6.8	8.6	7.7	/0.01	3.05		1.53
+	SU	3	6.7	8.3	9.2	8.1	8.1				
	Cu Rates Means		6.7	7.5	7.7	8.4		/0.001			
-	SU	0	4.5								
-	SU	¾		6.1							
-	SU	1½			7.8						
-	A	0	4.7								
+	Su120	¾			7.4						

(a) The yield pattern here is similar to that found in expt No. 12, 67ME3. Like 67ME3 and unlike most experiments which show a Cu response, there appears to be a trend towards slightly higher yield with increasing Cu and Zn rates.

(b) Zn¾ appears to have supplied enough zinc for maximum yields.

(c) Because of the variable results it is not possible to come to a logical conclusion about the best Cu rate.

(d) Plain super yielded the same as aerophos + gypsum which is surprising as a difference in favour of plain super would be expected where Zn increases yield when added to super, or super and Cu, as appeared to be the case here.

9. *Experiment 66MO15; H. McCashney, Kirwan; yellow sandy earth with some gravelly patches*

Mo	SU / A	Zn	Cu 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	9.5	16.0	15.1	13.9	13.6	/0.05	3.67	2.12	1.83
+	SU	¾	4.6	15.8	15.8	15.9	13.0				
+	SU	1½	3.5	16.0	14.4	15.2	12.3	/0.01	4.92	2.84	2.46
+	SU	3	3.4	14.4	16.2	14.5	12.1				
	Cu Rates Means		5.2	15.5	15.3	14.9		/0.001	6.49	3.75	3.24
-	SU	0	8.6								
-	SU	¾		16.2							
-	SU	1½			14.0						
-	A	0	3.9								
+	Su120	¾			12.8						

(a) Cu increased yield with or without Zn.

(b) Zn application cut yield when no Cu applied.

(c) Zn had no effect on yield where Cu 2½ or more was also added.

(d) Cu 2½ appeared to be sufficient for maximum yield regardless of the Zn rate. Best combination for wheat was Cu 2½ Zn nil.

(e) Difference between plain super and aerophos + gypsum treatment suggests zinc marginal for wheat and would be required for oats and clover.

10. *Experiment 67LG14; F. Thomson, South Lake Grace; orange brown sandy earth*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	7.0	14.3	15.4	14.8	12.9	/0.05	1.97	1.14	0.99
+	SU	¾	2.7	11.1	13.9	14.2	10.5				
+	SU	1½	2.3	8.3	12.3	14.7	9.4	/0.01	2.64		1.32
+	SU	3	2.7	9.0	11.3	12.6	8.9				
Cu Rates		Means	3.7	10.7	13.2	14.1		/0.001	3.49		1.75
-	SU	0	8.3								
-	SU	¾		11.0							
-	SU	1½			12.3						
-	A	0	0.9								
+	Su260	¾			Not sown						

(a) Cu increased yield with or without Zn.

(b) Zn application cut yield with Cu 0, 2½ or 5. With Cu 7½, Zn 3 appeared to depress yield. In no combination was it beneficial.

(c) With Zn nil or ¾ , Cu 5 appeared to be the Cu rate. With Zn 1½ & 3, Cu 7½ gave higher yields than Cu 5.

(d) For wheat the best application appeared to be Cu 5 Zn nil.

(e) Severe Zn deficiency symptoms were observed in wheat grown on aerophos + gypsum plots. This is reflected in the large differences between this treatment and the plain super. Zn ¾ would probably be needed for oats or clover here.

11. *Experiment 67ME1; D. Hughes, Gabbin; yellow earthy sand*

Mo	SU/A	Zn	Cu 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	5.3	9.6	8.9	10.3	8.5	/0.05	3.69	2.15	1.85
+	SU	¾	2.8	8.8	9.8	7.8	7.3				
+	SU	1½	4.4	10.6	11.8	8.6	8.9	/0.01	4.94		2.47
+	SU	3	6.2	9.2	9.1	7.8	8.1				
Cu Rates	Means		4.7	9.6	9.9	8.6		/0.001			3.24
-	SU	0	6.0								
-	SU	¾		8.2							
-	SU	1½			11.4						
-	A	0	5.7								
+	Su120	¾			7.9						

(a) Cu increased yield with or without Zn.

(b) The apparent differences between the different Zn combinations follow no logical or consistent pattern. It is therefore concluded that the apparent effects were not real and that Zn had no clear cut effect.

(c) Cu 2½ Zn nil appears to have given equal top yield.

(d) Plain super and aerophos + gypsum gave the same yield.

12. *Experiment 67ME3; J. Woodfield, Kununoppin; yellow earthy sand*

Mo(1)	SU(2) (3) A	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	9.6	10.7	10.5	10.4	10.3	/0.05	1.69	0.97	0.84
+	SU	¾	10.2	11.2	11.1	11.2	10.9				
+	SU	1½	11.9	11.6	11.0	12.0	11.6	/0.01	2.56		*1.28*
+	SU	3	9.6	11.3	12.5	11.7	11.3				
	Cu Rates	Means	10.3	11.2	11.3	11.3		/0.001			
-	SU	0	9.2								
-	SU	¾		10.9							
-	SU	1½			10.7						
-	A	0	9.5								
+	Su120	¾			9.6						

(a) Few experiments gave results like these in which there appeared to be a trend towards very slightly higher yield with increasing copper and zinc rates. The trend is most likely only a chance result.

(b) There appears to be a response to Cu 2½.

(c) Zn 1½ appeared to be the best Zn rate but is not consistent with the relatively high yield of the aerophos + gypsum treatments.

(d) Plain super and aerophos + gypsum gave the same yield.

13. *Experiment 67LG12; R. Crawford, Mt. Madden; yellow gritty sand overlying granite. (This soil type was included in this class because it may have been laterite derived).*

+	SU	0	14.5	14.5	14.0	14.7	14.4	/0.05	1.36	0.78	0.68
+	SU	¾	13.3	14.6	14.6	14.6	14.3				
+	SU	1½	13.4	13.3	14.7	14.0	13.9	/0.01	1.83		0.91
+	SU	3	12.5	14.8	14.9	14.8	14.3				
	Cu Rates	Means	13.4	14.3	14.6	14.5		/0.001	2.40		1.20
-	SU	0	14.4								
-	SU	¾			14.8						
-	SU	1½				15.2					
-	A	0	11.8								
+	Su250	¾				11.8					

(a) Cu did not increase yield without Zn.

(b) Zn depressed yield without Cu. Cu deficiency symptoms appeared in these cases.

(c) Where Zn was applied, Cu application restored yield to the Cu nil Zn nil level.

(d) The lower yield of the aerophos + gypsum treatment compared with the plain super yield suggests that the soil zinc supply would be too low for oats and clover here.

14. Experiment 66LG2; J. Carruthers, Lake Grace; grey sand/clay at 18 - 24 in.

Mo[1]	SU[2] A[3]	Zn[4] lb/ac	Cu[5] lb/ac 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	9.1	14.5	15.1	19.4	13.3	/0.05	2.34	1.35	1.17
+	SU	¾	4.2	16.9	19.0	16.5	14.2				
+	SU	1½	4.7	15.1	16.9	16.3	13.3	/0.01	3.13	1.81	1.57
+	SU	3	4.7	17.5	18.1	18.2	14.6				
Cu Rates Means			5.7	16.0	17.3	16.4		/0.001	4.13	2.39	2.07
-	SU	0	9.1								
-	SU	¾		17.4							
-	SU	1½			17.3						
-	A	0	4.6								
+	Su278	¾			21.7						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield with Cu nil but increased yield with all Cu rates.

(c) Best combination appeared to be Cu 5 Zn ¾.

(d) Plain super outyielded aerophos + gypsum as was expected from the severely zinc deficient wheat plants which grew on the aerophos + gypsum plots.

15. Experiment 67NO9; M. Quartermaine, Quairading; grey sand over gravel at more than 18 in.

+	SU	0	17.8	22.9	22.6	25.2	22.1	/0.05	6.57	3.79	3.29
+	SU	¾	15.3	21.6	24.9	22.8	21.2				
+	SU	1½	15.3	19.4	27.6	21.2	20.9	/0.01	8.80		4.40
+	SU	3	20.7	23.5	24.6	22.1	22.7				
Cu Rates Means			17.8	21.9	24.9	22.8		/0.001			
-	SU	0	18.1								
-	SU	¾		22.3							
-	SU	1½			26.0						
-	A	0	17.9								
+	Su120	¾			20.6						

(a) The yield pattern shows inconsistent and variable results. There appears to have been little overall effect of Zn and an increase to Cu up to the Cu 5 rate.

(b) Plain super and aerophos + gypsum yielded similarly.

16. Experiment 65MO3; R. Simpson, Kirwan; yellow gravelly sand

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	3.0	9.4	9.8	9.6	7.9	/0.05	1.43	0.82	0.71
+	SU	1½	2.8	8.0	9.2	10.1	7.6				
+	SU	3	1.9	8.4	8.2	10.1	7.1	/0.01	1.92	1.11	0.96
Cu Rates Means			2.6	8.6	9.1	9.9					
-	SU	0	5.1					/0.001	2.56	1.48	1.28
-	SU	1½			9.3						
-	SU	3				8.9					
-	A	0	2.1								
+	Su120	1½			8.1						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield at the lower Cu rates.

(c) For wheat, the best combination was either Cu 2½ Zn nil, or Cu 5 Zn nil.

(d) Where Zn was applied Cu 7½ was better than Cu 2½ and to a lesser degree Cu 5.

(e) Aerophos yielded less than plain super.

17. Experiment 65ME6; J. Rose, Noongar; grey and brown gravelly sand

+	SU	0	5.0	7.8	9.8	11.3	8.7	/0.05	1.94	1.12	0.97
+	SU	1½	4.6	7.9	8.9	9.6	7.8				
+	SU	3	4.9	7.1	9.6	9.2	7.9	/0.01	2.71	1.56	1.35
Cu Rates Means			4.8	7.6	9.5	10.1					
-	SU	0	5.0					/0.001	3.76	2.17	1.88
-	SU	1½			8.3						
-	SU	3				6.5					
-	A	0	3.6								
+	Su120	1½			8.1						

(a) Cu increased yield with or without Zn.

(b) Zn may have had a slight overall depressing effect.

(c) There was a trend toward higher yields with Cu 7½ compared with lower rates. At least Cu 5 was needed before near maximum yields were reached.

(d) The difference between plain super and aerophos was not statistically significant.

18. Experiment 65ME8; S.A. Fletcher, Belka; yellow gravelly earth

Mo[1]	SU[2] A[3]	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	9.1	13.7	12.9	13.5	12.3	/0.05	3.5	2.0	1.8
+	SU	1½	9.9	11.5	14.8	12.8	12.3				
+	SU	3	5.3	10.5	10.3	13.8	10.1	/0.01	4.8	2.8	2.4
Cu Rates Means			8.1	12.0	12.7	13.4					
-	SU	0	9.7					/0.001	6.4	3.7	3.2
-	SU	1½			14.1						
-	SU	3				11.2					
-	A	0	9.1								
+	Su120	1½			12.8						

(a) Cu increased yield with or without Zn.

(b) Zn 3 depressed yield with Cu 5 or less.

(c) Zn gave no consistent yield increase. Cu 5 Zn nil yielded the same as Cu 5 Zn1½.

(d) Cu 2½ Zn nil gave equal top wheat yield.

(e) The difference between plain super and aerophos yields was not statistically significant.

19. Experiment 65ME2; J. Rose, Noongar; yellow sandy earth

+	SU	0	10.3	12.5	11.7	13.6	12.0	/0.05	2.50	1.45	1.25
+	SU	1½	10.4	10.7	13.1	12.2	11.6				
+	SU	3	9.6	10.9	10.9	12.9	11.1	/0.01	3.37	1.95	1.69
Cu Rates Means			10.1	11.4	11.9	12.9					
-	SU	0	7.6					/0.001	4.49	2.59	2.23
-	SU	1½			13.3						
-	SU	3				10.9					
-	A	0	9.4								
+	Su120	1½			12.2						

(a) Cu increased yields in the absence and presence of Zn.

(b) Zn had no consistent effect on yield.

(c) There was a trend towards highest yield with Cu 7½.

(d) The difference between plain super and aerophos was not significant.

20. *Experiment 65ME7; S.A.J. Fletcher, Belka; yellow brown sandy gravelly earth*

Mo (1)	SU (2) (3) A	Zn (4)	Cu (5) 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	7.4	12.3	12.5	12.7	11.2	/0.05	3.53	2.06	1.79
+	SU	1½	5.6	10.5	12.1	12.5	10.2				
+	SU	3	7.3	10.0	12.1	12.6	10.5	/0.01	4.81	2.78	2.41
Cu Rates Means			6.3	10.9	12.2	12.6					
-	SU	0	5.2					/0.001	6.39	3.69	3.20
-	SU	1½			11.3						
-	SU	3				9.8					
-	A	0	4.9								
+	Su120	1½			11.2						

(a) Cu increased yield in the absence and presence of Zn.

(b) Zn appeared to depress yield at the lower Cu rates. Zn did not benefit wheat yield in any combination with Cu.

(c) There was a slight overall trend towards highest yields with Cu 7½ although the difference between Cu 7½ and Cu 2½ was not statistically significant. Cu 5 would be a safe compromise application for wheat.

(d) Plain super and aerophos gave the same result.

21. *Experiment 65MO4; R. Simpson, Kirwan; yellow earthy sand*

+	SU	0	4.0	11.7	11.3	9.6	9.2	/0.05	1.68	0.97	0.84
+	SU	1½	2.1	10.4	11.4	10.1	8.5				
+	SU	3	1.5	8.1	10.4	10.8	7.7	/0.01	2.27	1.31	1.14
Cu Rates Means			2.6	10.1	11.0	10.2					
-	SU	0	3.2					/0.001	3.02	1.74	1.51
-	SU	1½			12.1						
-	SU	3				10.1					
-	A	0	3.6								
+	Su120	1½			8.9						

(a) Cu increased yield in the absence and presence of Zn.

(b) Zn appeared to depress yield with Cu nil and Cu 2½. It did not depress yield with Cu 5.

(c) Cu 2½ Zn nil gave top yield.

(d) Plain super and aerophos gave the same result.

22. *Experiment 65NA9; N. Ballard, Harrismith; grey-brown sandy gravel*

Mo[1]	SU[2] A[3]	Zn[4]	0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	5.9	18.2	18.7	18.1	15.2	/0.05	1.57	2.11	2.81
+	SU	1½	3.0	17.6	19.8	20.5	15.2				
+	SU	3	3.2	17.6	19.8	20.4	15.3	/0.01	0.95	1.27	1.70
	Cu Rates Means		4.0	17.8	19.4	19.7					
-	SU	0	4.9					/0.001	0.71	0.96	1.27
-	SU	1½			19.5						
-	SU	3				19.6					
-	A	0	4.7								
+	Su120	1½			18.2						

(a) Cu increased yield with or without Zn.

(b) Zn appeared to depress yield slightly with Cu nil or Cu 2½ but increased yield with Cu 5 or Cu 7½.

(c) There was a trend, which was not statistically significant, towards higher yield with Cu 7½ compared with Cu 5 in the presence of Zn.

(d) Best combination was Cu 5 Zn 1½ or Cu 7½ Zn 1½.

(e) Plain super and aerophos yielded similarly.

Average response pattern for all sandplain sites in Zone 5

(a) Sandy and gravelly laterite derived soils in which zinc oxide ¾ lb/acre combinations were tested.
Experiments 1 to 15.

Mean wheat yields (bu/ac) from 15 experiments in Zone 5-(a)

		Cu (Bluestone lb/ac) 0	2½	5	7½	$\bar{x}$
Zn (Zinc oxide) (lb/ac)	0	9.2	13.8	13.9	13.6	12.63
	¾	7.0	13.4	14.8	14.2	12.35
	1½	6.9	12.4	14.0	14.1	11.85
	3	6.5	12.8	13.7	13.8	11.70
	$\bar{x}$	7.40	13.10	14.10	13.93	12.13

(b) Sandy and gravelly laterite derived soils in which zinc oxide lb/acre combinations were omitted.
Experiments 1 to 22.

Mean wheat yields (bu/ac) from 22 experiments in Zone 5-(b)

		Cu (Bluestone lb/ac)				
		0	2½	5	7½	$\bar{x}$
Zn (Zinc oxide) (lb/ac)	0	8.4	13.3	13.4	13.3	12.10
	1½	6.9	11.9	13.6	13.6	11.50
	3	6.0	11.9	13.0	13.5	11.10
	$\bar{x}$	7.10	12.37	13.33	13.47	11.53

The pattern of yield response to copper and zinc from the seven 1965 experiments in which Zn ¾ lb combinations were absent was similar to that of the fifteen 1966 and 1967 experiments which included the Zn ¾ combinations. Without zinc, Cu 2½ increased yield by 50 per cent compared with Cu nil and gave equal top yields for the Zn nil combinations.

Without copper, zinc oxide depressed yields at all rates of zinc oxide.

Cu 7½ Zn 3 gave the same yield as Cu 2½ Zn nil.
The best combination was Cu 5 Zn¾.

Relationship between response pattern and the presence or absence of ironstone gravel in the surface 6 in. of yellow to brown soils in Zone 5.

(c) Surface soil coloured yellow to brown with much ironstone gravel in the surface 6 in. and with Zn ¾ combinations included.

Experiments 13 to 20.

Mean wheat yields (bu/ac) from 8 experiments in Zone 5 - (c)

		Cu (Bluestone lb/ac)				
		0	2½	5	7½	$\bar{x}$
Zn (Zinc oxide) (lb/ac)	0	8.2	13.1	13.4	12.5	11.80
	¾	6.5	12.7	14.1	13.8	11.78
	1½	6.0	11.4	12.8	13.8	11.00
	3	4.7	11.1	12.3	13.0	10.28
	$\bar{x}$	6.35	12.08	13.15	13.28	11.22

(d) Surface soil coloured yellow to brown with little ironstone in surface 6 in. and with Zn ¾ combinations included.

Experiments 24 to 28.

Mean wheat yields (bu/ac) from 5 experiments in Zone 5-(d)

		Cu (Bluestone lb/ac				
		0	2½	5	7½	$\bar{x}$
Zn	0	9.0	13.0	12.8	12.8	11.90
(Zinc oxide)	¾	6.7	12.3	(13.0)	12.7	11.18
(lb/ac)	1½	7.1	12.0	12.6	12.9	11.15
	3	7.0	12.3	12.8	12.4	11.13
	$\bar{x}$	7.45	12.40	12.80	12.70	11.34

The comparison between (c) and (d) shows only small differences in response pattern. The gravelly sites appear only slightly more severely affected by copper deficiency than the sandy surfaced sites. With Cu nil, zinc depressed yields more on the gravels than on the sands. With Zn 1½ or 3, Cu 7½ appeared better than Cu 5 on the gravel sites whereas there was no clear difference on the sandy sites.

Zn¾ was no better than Zn nil in any Cu rate combination on the sandy sites. However because oats and clovers grown on these soils usually need additional zinc for best yields, Zn ¾ would be warranted if oats and clover were to be grown in subsequent years. If wheat alone was to be grown, Cu 2½ Zn nil would supply enough copper for maximum yields in the year of application but an additional copper application on the yellow sands might be needed in some places in a subsequent year.

One application of 5 lb/acre bluestone plus ¾ lb/acre zinc oxide is generally suitable for both sandy and gravelly surfaced yellow earths in Zone 5.

Response pattern on the grey surfaced sandy laterite derived soils in Zone 5.

(e) Surface soil coloured grey, gravel free in the surface 6 in. Zn ¾ combinations included.
Experiments 20 and 21 - see also experiment 22.

Mean wheat yield (bu/ac) from 2 experiments in Zone 5-(e).

		Cu (Bluestone lb/ac)				
		0	2½	5	7½	$\bar{x}$
Zn	0	14.1	18.7	18.9	19.8	17.88
(Zinc oxide)	¾	9.8	19.3	22.0	19.7	17.70
(lb/ac)	1½	10.0	17.3	22.3	18.8	17.10
	3	12.7	20.5	21.4	20.2	18.70
	$\bar{x}$	11.65	18.95	21.15	19.63	17.85

Compared with the yellow-brown sandy soils in Zone 5 - (d), wheat grown on grey sands has a similar copper requirement and a more definite zinc requirement.

Cu 5 Zn ¾ gave equal top wheat yields but Cu 5 Zn 1½ would probably be better where oats and clover are grown.

ZONE 6 (a) : THE GNOWANGERUP - WEST RIVER ZONE

The chief copper and zinc deficient soils are grey and brown sands with ironstone gravel in the profile which appear to have developed from lateritic profiles formed on Archaean granitic rocks. Other soils include extensive areas of almost gravel free sand over clay within 3 ft of the surface.

Experiments on brown gravelly sands

1. *Experiment 67KA2; W. Longmire, Badgebup; orange brown gravelly sandy loam.*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) lb/ac 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	1.7	9.5	9.5	9.0	7.4	/0.05	2.75	1.58	1.38
+	SU	¾	0.7	4.7	8.0	8.0	5.4				
+	SU	1½	1.1	3.1	6.6	7.9	4.7	/0.01	3.69		1.84
+	SU	3	0.2	5.2	4.9	5.8	4.0				
	Cu Rates	Means	0.9	5.6	7.3	7.7		/0.001	4.84		2.42
-	SU	0	1.2								
-	SU	¾		5.2							
-	SU	1½			7.1						
-	A	0	1.0								
+	Su120	¾			8.2						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield at all Zn rates and in all Cu combinations.

(c) Best combination for wheat was Cu 2½ Zn nil.

(d) There was no real difference between the extremely low yielding plain super and aerophos + gypsum plots.

The results from experiment 67KA2 were similar to those on the more severely copper deficient yellow-brown gravels in Zone 5.

Experiments on deep grey sand over gravel

1. *Experiment 67KA1; O. Bell, Jacup; grey sand over gravel at more than 18 in.*

+	SU	0	15.0	19.6	21.5	23.9	20.0	/0.05	3.58	2.07	1.79
+	SU	¾	13.5	24.2	26.0	*	21.2				
+	SU	1½	6.8	20.9	23.7	21.9	18.3	/0.01	4.80		2.40
+	SU	3	7.6	18.6	20.4	22.1	17.2				
	Cu Rates	Means	10.7	20.8	22.9	22.6		/0.001	6.34		3.17
-	SU	0	12.8								
-	SU	¾		24.1							
-	SU	1½			23.8			* Not sown			
-	A	0	11.9								
+	Su120	¾			*						

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield with Cu nil. Zn ¾ appeared to give best results with Cu 2½ and Cu 5. Unfortunately the Cu 7½ Zn ¾ treatment was not planted.

(c) Best combination was Cu 5 Zn ¾ .

(d) Plain super and aerophos + gypsum yielded similarly. In fact it is likely that the aerophos + gypsum treatment yielded less than the plain super treatment judging on the yield of the Cu and Zn nil + Mo yield and the response to Zn ¾ with Cu.

The results of experiment 67KA1 were also similar to those of experiments on equivalent soils in Zone 5.

Experiments on grey clay

1. *Experiment 66KA2; H. Mattner, Ongerup; Moort*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) lb/ac 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	16.5	16.8	18.6	18.3	17.6	/0.05	5.04	2.73	2.27
+	SU	¾	Not Sown	15.5	17.1	16.5	16.4	/0.01			
+	SU	1½	18.7	16.4	17.6	20.6	18.3				
+	SU	3	15.6	15.8	18.8	16.2	16.6	/0.001			
	Cu Rates	Means	17.0	16.1	18.0	17.9					
-	SU	0	16.7								
-	SU	¾		16.6							
-	SU	1½			18.1						
-	A	0	16.0								
+	Su120	¾			15.5						

(a) There was no consistent response to Cu or Zn.

(b) Plain super and aerophos + gypsum yielded similarly.

Results of the three experiments in Zone 6(a) indicate that an application of Cu 5 Zn ¾ would give the best results on yellow brown and grey sands associated with laterite. The grey clay (Moort) soils may not require copper or zinc. On the gravel free grey sands over clay at shallow depth Cu 2½ Zn ¾ appears to be sufficient.

ZONE 6 (b): THE ZONE EAST AND WEST OF LAKE MAGENTA.

The copper and zinc deficient soils in this zone are probably restricted to narrow ironstone ridges on which sandplain soils similar to those of zone 5 occur. The major sandy surfaced soils are grey or brown sands overlying a yellow mottled and often domed alkaline clay.

The lateritic soils were probably formed on Archaean granitic rocks. The sands which overlie domed clays were probably formed on Quaternary sediments.

Experiments on lateritic sands

1. *Experiment 67LG13; H. Van Nus, Mt. Madden; grey brown gravelly sand*

Mo[1]	SU[2] (3) A	Zn[4]	Cu[5] 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
+	SU	0	15.6	16.0	16.2	15.7	15.9	/0.05	1.15		0.57
+	SU	¾	16.8	17.9	18.0	17.3	17.5				
+	SU	1½	16.0	18.0	17.6	17.6	17.3	/0.01	1.54		0.77
+	SU	3	16.8	18.0	17.3	17.9	17.5				
	Cu Rates	Means	16.3	17.5	17.3	17.2		/0.001	2.02		1.01
-	SU	0	15.9								
-	SU	¾		18.0							
-	SU	1½			17.5						
-	A	0	11.6								
+	Su120	¾			18.6						

(a) There appears to have been a small response to Cu 2½ and Zn ¾ in this trial.

(b) The difference between plain super and aerophos + gypsum suggests Zn additions would give better oats and clover yields were they grown on this site.

The available evidence suggests that the laterite derived soils behave like similar soils in Zone 5 although the gravels south of Mt. Madden may need less copper and zinc. The sands which overlie domed clays probably supply sufficient copper and zinc for maximum crop and pasture production judging from the results obtained on identical soils in Zone 16.

ZONE 7: THE WEST WHEATBELT

The land surface in this zone is very dissected. Copper and zinc deficiencies occur on the residual lateritic mesas, buttes, ridges and spurs at high level and on some of the sandy and gravelly soils of the valley sides. These valley slope soils appear to have been derived from the weathering of the old lateritic profile.

Copper and zinc deficient soils in the Zone seem to have been derived from lateritic profiles which were developed on Archaean granitic rocks and in some places on basic rock intrusions. The heavier textured soils which are common and sometimes dominant in the area do not give rise to trace element deficiencies.

No experiments were carried out in Zone 7 in the 1965 - 67 series of experiments but experience indicates that the Zone's soils have copper and zinc requirements similar to equivalent soils in Zone 5.

ZONE 12: BREMER BAY ZONE

Chief soils have a grey sandy surface and overlie neutral and acidic yellow and brown mottled clays, some gravelly surfaced soils, some leached grey sands.

Parent material appears in most places to have been sediments of Tertiary age.

No experiments were conducted in this zone between 1965 and 1967.

It was found previously that sands with clay near the surface are severely copper deficient and require high rates of application for maximum yield. Bluestone 7½ lb/acre plus zinc oxide 2¼ lb/acre may be a suitable first application for these soils. A further application of bluestone 5 lb/acre and zinc oxide 1½ lb/acre may be beneficial.

ZONE 15: THE NORTHERN SECTION OF THE ESPERANCE PLAINS

Chief soils have a grey sandy surface over neutral, brown and red brown mottled and often domed clay frequently with ironstone gravel in the profile. Leached sands with and without ironstone gravel are common.

The soils of the area appear to be derived from old, often lateritic profiles developed on Tertiary sediments and Archaean granitic rocks.

Experiments on grey sand over brown and red brown mottled clay

1. *Experiment 65ES3; Rowan, Speddingup; 0 - 3 in. grey sand over red brown domed clay*

Mo[1]	SU[2] A[3]	Zn[4] lb/ac	Cu[5] 0	1	2	5	7	Zn Rates Means	Comparison (i)	(ii)	(iii)
		0	14.4			23.8			/0.05	2.3	
		½	11.1			24.0			/0.01		
		1½	10.0	20.6	22.6	23.2	23.0		/0.001		
		3	9.2			22.6					

(a) Cu increased yield with or without Zn.

(b) Zn depressed yield with Cu nil but had little effect where Cu was applied.

(c) Cu 2 gave equal top yield. Best combination would probably have been Cu 2 Zn nil but this was not one of the experimental treatments.

Results of experiment 65ES3 indicate that copper deficiency in Zone 15 is cured by the use of 2 lb bluestone per acre. Zinc deficiency also occurs in oats, linseed and clovers on similar soils in the area.

It appears that bluestone 2½ lb/acre zinc oxide ¾ lb/acre would satisfy deficiencies in Zone 15 but more information is needed.

ZONE 16: THE SALMON GUMS - SCADDEN ZONE

The chief sandy surfaced soils have a yellow and brown sandy surface and a sandy alkaline yellow mottled, sometimes domed, clay subsurface. Smaller pockets of leached sands also occur.

Parent material consists of either Quarternary sediments or Archaean granitic rock.

Experiments on sandy soils overlying grey or grey brown clay

1. *Experiment 65ES4; G. Rhind, Truslove; 4 - 6 in. grey sand over grey domed clay*

Mo(1)	SU(2) A(3)	Zn(4)	Cu(5) 0	2½	5	7½	Zn Rates Means	Comparison	(i)	(ii)	(iii)
								/0.05			
+	SU	0	17.9			18.1		/0.01			
+	SU	½	18.0			17.5		/0.001			
+	SU	1½	17.9	18.4	17.5	18.0	17.5				
+	SU	3	17.6			17.3					

(a) Neither Cu nor Zn increased yields at this site.

2. *Experiment 67ES3; J. Razyk, Scadden; 2 - 4 in. grey sand over grey brown sandy clay*

+	SU	0	17.3	19.7	17.1	18.4	17.1	/0.05	1.89		0.95
+	SU	¾	20.2	18.7	18.5	17.3	18.7				
+	SU	1½	17.8	19.7	19.0	18.2	18.7	/0.01			
+	SU	3	18.3	19.6	18.1	18.3	18.6				
Cu Rates Means			18.4	19.4	18.2	18.1		/0.001			
-	SU	0	18.7								
-	SU	¾		19.7							
-	SU	1½			17.5						
-	A	0	18.0								
+	Super	¾			18.2						

(a) Neither Cu nor Zn increased yield at this site.

(b) Plain super and aerophos + gypsum yielded similarly.

In 1968 Zn deficiency symptoms were observed in a number of wheat crops in Zone 16. Zinc supply appears marginal at least on some soils. Because of this farmers are advised to apply Cu 2½ Zn ¾ once although significant experimental responses to trace elements have not as yet been recorded.

ZONE 17: THE COASTAL ZONE

Chief soils are white to dark grey calcareous sands, siliceous sands with a bright yellow subsoil, some shallow grey brown sands with limestone, brown sands, yellow earthy sands and some leached grey sands.

Parent material is coastal aeolianite of recent geological age.

Although no experiments were conducted in the drier parts of Zone 17 between 1965 and 1967, wheat grown on the calcareous sands and yellow siliceous sands appears to require 10 lb/acre bluestone and 3 lb/acre zinc oxide if the copper and zinc are applied mixed with superphosphate. A further dressing of 5 lb/acre bluestone and 1½ lb/acre zinc oxide may be an advantage in subsequent years.

SEASONAL INFLUENCE ON RESPONSE PATTERN

Sufficient experiments were done each year on the yellow brown coloured gravelly and sandy earths in Zone 5 to permit a reasonably valid examination of the seasonal effect on the response pattern. The tables which follow indicate the distribution of experiments on the different soil types and the average wheat yields resulting from different copper and zinc combinations in each of the three years 1965, 1966 and 1967.

Distribution of experiments in Zone 5

Soil Type	Year 1965	1966	1967	Total
Yellow brown gravelly earth	3	4	4	11
Yellow brown earth	3	1	4	8
Total	6	5	8	19

Average wheat yields (bu/ac) from Zone 5 experiments on yellow brown earths and gravels

1965
Zone 5 experiments 16,17,18,19,20,21

		Cu (Bluestone lb/ac) 0	$2\frac{1}{2}$	5	$7\frac{1}{2}$	$\bar{x}$
Zn	0	6.5	11.2	11.7	11.7	10.28
(Zinc oxide)	$1\frac{1}{2}$	5.9	9.8	11.6	11.2	9.63
(lb/ac)	3	5.1	9.3	10.3	11.6	9.08
	$\bar{x}$	5.83	10.10	11.20	11.50	9.66

1966
Zone 5 experiments 1,2,3,4,9

Zn	0	9.5	14.1	14.3	13.1	12.75
(Zinc oxide)	$\frac{3}{4}$	6.7	14.2	15.0	14.4	12.58
(lb/ac)	$1\frac{1}{2}$	6.1	13.9	14.3	14.7	12.25
	3	4.6	13.4	14.1	14.4	11.63
	$\bar{x}$	6.73	13.90	14.43	14.15	12.30

1966
Zone 5 experiments 1,2,3,4,9

		Cu (Bluestone lb/ac)				
		0	$2\frac{1}{2}$	5	$7\frac{1}{2}$	$\bar{x}$
Zn (Zinc oxide) (lb/ac)	0	9.5	14.1	14.3	13.1	12.75
	$\frac{3}{4}$	6.7	14.2	15.0	14.4	12.58
	$1\frac{1}{2}$	6.1	13.9	14.3	14.7	12.25
	3	4.6	13.4	14.1	14.4	11.63
	$\bar{x}$	6.73	13.90	14.43	14.15	12.30

1967
Zone 5 experiments 5,6,7,8,10,11,12,13

Zn (Zinc oxide) (lb/ac)	0	8.2	12.5	12.4	12.6	11.43
	$\frac{3}{4}$	6.5	11.5	12.9	12.7	10.90
	$1\frac{1}{2}$	6.7	10.2	11.7	12.6	10.30
	3	6.2	10.0	11.5	11.8	9.88
	$\bar{x}$	6.90	11.05	12.13	12.43	10.63

Conclusions on seasonal influences:

(1) The response patterns for Cu and Zn were remarkably similar each year. The Cu 2½ rate was possibly better in 1966 than in 1965 or 1967. The best combination in 1966 and 1967 was Cu 5 Zn $\frac{3}{4}$ and the similarity between the 1967 and the 1965 results suggests that Cu 5 Zn $\frac{3}{4}$ would have been best in 1965 had this combination been included.

(2) The overall level of yields was higher in 1966 than in 1967 or 1965.

(3) Seasonal variation in copper requirement was not revealed in this set of results.

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