1989

Soil acidity and eastern wheatbelt plant nutrition.

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SOIL ACIDITY

AND

EASTERN WHEATBELT PLANT NUTRITION

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CONTENTS:

SOIL ACIDITY

EASTERN WHEATBELT PLANT NUTRITION

1. The effects of soil acidity on subterranean clover growth in the cropping areas of Western Australia.

(W.M. Porter, J.S. Yeates, M.F. Clarke, G.K. Michels.)

Background

Large responses to lime in permanent sub. clover pastures have occurred on soils with pH ($CaCl_2$) values less than 4.2 in the high rainfall areas of Western Australia (Yeates et al., 1984; Yeates, unpublished). Glasshouse work (Yeates, unpublished) has shown these responses to be primarily due to effects of lime on Rhizobium nodulation, in agreement with results reported by Bromfield et al. (1983b), and Coventry et al. (1985). At soil pH ($CaCl_2$) values below 4.2 nodulation of sub. clover is greatly inhibited, and nitrogen fixation and growth reduced.

Soils on which pasture-crop rotation farming is practised and which have pH ($CaCl_2$) at or near 4.2, are common in parts of W.A. Wool producers have reported so-called 'pasture deterioration' from much of this area. Research on soil acidity problems and lime is specifically needed in these areas because of the particular nature of many of the soils involved (sandy surfaced duplex soils), the high probability of the induction of nutrient problems (particularly Mn deficiency in the cropping phase of the rotation) though the indiscriminate use of lime, and the relatively high cost of a lime ($20-40/ha per application).

The aims of the project are:

(i) To investigate the responsiveness to lime of subterranean clover based pastures on acid soil of the cropping areas of Western Australia.

(ii) To determine the reasons for responses to lime in the field, particularly the possible involvement of legume nodulation effects and the alleviation of soil/water repellence.

(iii) To develop practical identification and management strategies for acid soils problems.

Six field experiments in the medium rainfall cropping areas of south-west Western Australia form the core of the project. The experiments were established in 1987 (two sites sown to subterranean clover and one to cereal) or 1988 (three sites sown to clover). At each site a 1:1 cereal:pasture rotation has been maintained.

Positive effects of lime on pasture growth were measured in 1987 at one site (Kelly's 20% response -87N03) and in 1988 at three sites (Kilpatrick 10% 87AL35, Kelly 30% -87N03 and Reed 50% 88TS54). Lime increased nodulation in 1987 at both the sites which were in pasture that year (Kelly's 87N03 and Hewitt's 87N02).

Summary of Results

1988 Seed Yields

Only small effects of lime on seed production were seen in 1988. Even at Read's site (88TS54) where a 50% increase in clover dry matter production due to lime had been observed in 1988, there was only a 10 to 15% increase in seed in the high lime plots relative to the nil lime plots.

1989 Pasture Growth

Because of the high value of autumn/winter pasture to the farm economy, measurements of plant growth during that period were emphasised in this year's evaluation of the effect of lime on pasture. All six experiments were sampled soon after the break of the season. Sites which were to be cropped were sampled before the pasture was disturbed by seeding operations.

Increases in total pasture production ranged from nil (Kelly -87N03 and Hewitt -87N02) through 10 to 15% (Lesson -88N076 and Reed -88TS54) to 30% (Kilpatrick -87AL35). Molybdenum application had no observable effect at any of the sites, consistent with the conclusion that acidity-induced-molybdenum-deficiency is not a factor in the lime responses at these sites.

The response at Kilpatrick's (87AL35) may be due to an effect of lime on water repellence of the soil. The soil at the site was water repellent and bare patches in the pasture in unlimed plots were similar to patches caused by water repellence. A study of the effect of liming on the wetting and waterholding characteristics of the soil at this site will be commenced during the current funding period.

Lime in crop/pasture rotation on acid soils

Trial: 87AL35

Property: G. Kilpatrick, Woogenellup.

History: 1987: Lime applied, sown to barley.
1988: Clover regenerated. Lime increased October production by 10% (0.46 t/ha increase).
1989: Sown to oats (see P. Dolling's summary for results). Before being sown, pasture growth was measured.
Mar 22: Visual observations. Sparse stand (<500 clover plants/m^2), 2 to 3 trifoliate leaves most commonly, grazed, cotyledons yellowing.
May 17: Production measured. 8 quadrats (0.25 m^2) per plot. Samples from 2 quadrats in each +Mo plot were kept separate for determination of composition of sample.

Treatment		1988	March 22	May 17 Density ('000/m^2)			Dry matter (t/ha)			
Mo	Lime	Seed t/ha	cot'den Yellow rating	Clover	Grass	B'leaf	Clover	Grass	B'leaf	Total
-	0	0.63	7.0	-	-	-	-	-	-	-
	1.25	0.55	7.0	-	-	-	-	-	-	-
	2.50	0.57	7.5	-	-	-	-	-	-	-
	5.00	0.59	5.5	-	-	-	-	-	-	-
+	0	0.58	8.5	4.9	14.4	0.1	0.22	0.18	0.07	0.47(100)
	1.25	0.51	8.0	-	-	-	0.30	0.21	0.12	0.63(134)
	2.50	0.62	7.0	-	-	-	0.24	0.34	0.08	0.66(140)
	5.00	0.52	5.0	3.2	12.7	0.3	0.28	0.36	0.06	0.70(148)
Lime effect:		N.S.	-	-	-	-	-	-	-	$p<0.09$

Comments:

A large effect of lime was observed at the May sampling. There were many, large (20 to 50 cm across) bare areas covering 10 to 20% of the nil lime plots. Poor pasture growth covered a slightly larger area, with reasonable growth covering the rest of the nil lime plots. Molybdenum had not affected the pasture. The pasture in the 5 t lime/ha plots was uniformly a similar level of production to the 'good' patches in the nil lime plots.

The 50% lime response ($p<0.09$) measured from the pasture cuts was smaller than expected on the basis of these observations.

The cause of this lime response is not known. While most lime responses in pasture have been attributed to effects on nodulation of subclover, this may not be the case in this experiment. Soil acidity normally reduces nodulation most severely in a pasture regenerating the year immediately after a crop, when high pH microsites have been destroyed by cultivation. At this site, clover growth in 1988, the year after a 1987 crop of barley, was only increased to a small extent (10%) by lime. The large response observed in 1989 (50% plus), occurred after a year of pasture during which high pH microsites (particularly the top centimetre or two) had a chance to be re-established.

The soil at this site was water repellant at the beginning of 1989. The appearance of the pasture on the nil lime plots is consistent with it having been affected by water repellence. However, measurements of water repellence of soil samples from the trial revealed no effect of lime (ethanol drop test, W. Crabtree, D. Carter, pers. comm.).

Lime in crop/pasture rotations on acid soils

Trial: 87N02

Property: J. Hewitt, N. York.

History: 1987: Lime applied and Dalkeith sub. clover sown. No response.
1988: Wheat.
1989: Sub clover regenerated.
May 5: Lemat (100 ml/ha), Decis (200 ml/ha).
May 18: Set up inoculation trial.
June 13: Clover 5+ leaf, Grasses patchy.
June 27: Calibrated visual ratings of pasture production.
June 28: Pursuit (250 ml/ha).
July 4: Sampled inoculation trial.
Sept 15: Lemat (500 ml/ha).

Results:

Lime (t/ha)	1988 Seed (t/ha)	June 27, 1989 Density ('000/m^2)				Production (t/ha)			
		Clover	Grass	B'leaf	Total	Clover	Grass	B'leaf	Total
0	0.46	0.80	2.9	3.0	6.7	0.27	0.05	0.35	0.66
1.25	0.42	0.91	4.2	2.5	7.6	0.27	0.13	0.24	0.59
2.50	0.42	0.82	3.1	3.0	6.9	0.40	0.02	0.51	0.95
5.00	0.45	0.87	4.1	2.3	7.3	0.21	0.02	0.29	0.56
Lime effect:	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.09
lin	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
quad	N.S.	N.S.	N.S.	N.S.	N.S.	0.09	N.S.	N.S.	0.08

Inoculation experiment (with J. Howieson).

The interaction between lime and inoculation was studied in small (1 m x 1 m) subplots of the main plots. In two replicate blocks of the main experiment, 20 subplots were pegged out, 10 on a nil lime plot and 10 on a 2.5 t/ha plot. The 10 subplots represented 5 treatments (2 N sources, 2 inoculation rates, 1 control) replicated twice (one set on an area which had received 10 kg N/ha and the other no nitrogen in 1988. Seven weeks later, 50 plants were dug up from each control and inoculation plot and scored for nodulation. Each nodule was given a rating according to its size and position (see Table below) and the total score for each plant calculated:

Nodule scores given according to size and position.

Nodule Position	Nodule size Large	Medium	Small
Tap root: upper (2.5 cm)	25	15	5
Tap root: lower	10	6	2
Lateral upper inner	15	9	3
Others	5	3	1

Nodule scores:

Treatment	Lime (t/ha) 0	2.5	mean
Control	127 a	221 b	174
Low inoculum	178 ab	159 ab	168
High inoculum	230 b	171 ab	200
Mean	178	183	181

Lime effect and inoculum effect not significant ($p<0.4$). Interaction significant ($p<0.03$). Letters followed by the same letter are not different ($p<0.05$).

Nil lime and nil inoculum resulted in lower nodulation (127) than where either lime or inoculum were added (159-230).

Comments:

The site was grazed early when sheep broke through the fence. The winter production measured therefore is less than actual production.

The increase in clover growth ($p<0.09$) due to lime application was associated with an increase in nodulation where no extra inoculum was supplied ($p<0.05$). Unfortunately no measurements of plant growth were made on the inoculation experiment so it is not known whether inoculation and lime produced the same effect on clover growth as they did on nodulation (i.e. a negative interaction).

Lime in crop/pasture rotations on acid soils

Trial: 87N03.

Property: J. Kelly, Grass Valley.

History: 1987: Lime applied and Dalkeith sub. clover sown. Small response to lime.
1988: Wheat.
1989: Sub. clover regenerated.
May 5: Lemat (100 ml/ha), Decis (200 ml/ha).
May 18: Set up inoculation trial.
June 13: Clover 6-7 leaves, some very large (21 leaves). Silver grass 5-6 leaf, Capeweed large (15-30 cm across).
June 21: Calibrated visual ratings of pasture production.
Aug 8: Plate meter estimate of pasture production.
Sept 12-21: 80-100 sheep grazed fenced area(c. 2.5 ha). Had little impact.
Sept 13: Lemat (500 ml/ha), Gramoxone (500 ml/ha).
Sept 29: 'Large number' of red legged earth mites present.

Results: June 21 (Calibrated Visual Ratings, cores).

Treatment		Density ('000/m^2)			Dry matter (t/ha)			
Mo	Lime t/ha	Clover	B'leaf	Total	Clover	Grass	B'leaf	Total
0	0	0.98	0.16ab	1.15	0.59	0.49	0.19	1.27
	1.25	1.29	0.11ab	1.40	0.57	0.47	0.27	1.31
	2.50	0.46	0.19ab	0.64	0.40	0.13	0.60	1.12
	5.00	1.10	0.08a	1.18	0.40	0.28	0.39	1.07
+	0	1.22	0.29ab	2.19	0.48	0.27	0.83	1.58
	1.25	0.83	0.35b	1.18	0.34	0.20	1.39	1.94
	2.50	0.45	0.81c	1.35	0.11	0.22	0.81	1.13
	5.00	0.64	0.16ab	0.81	0.17	0.24	0.70	1.11
Lime effect		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Mo effect		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

LSD 0.05: Broadleaf density: 0.25 x $10^3/m^2$

August 8, 1989 (Plate meter)

Mo	P	Lime (t/ha) 0	1.25	2.50	5.0	Mean
0	9	1.51	1.48	1.42	1.41	1.46a
	60	1.72	1.76	1.73	1.62	1.71b
	mean	1.62	1.62	1.58	1.51	1.58
+	9	1.55	1.63	1.42	1.47	1.52ab
	60	1.64	1.64	1.80	1.42	1.62ab
	mean	1.59	1.64	1.61	1.44	1.57
mean	9	1.53	1.56	1.42	1.44	1.49
	60	1.68	1.70	1.76	1.52	1.67
	mean	1.60	1.63	1.60	1.48	1.58

Statistically significant effects:
Mo x P interaction: $p < 0.009$
(data followed by the same letter not different, $p < 0.05$)
(Lime, linear component: $p < 0.093$)
(P, main effect: $p < 0.084$)

Inoculation experiment (with J. Howieson)

The background to this experiment and methods used are the same as those described in the previous trial (87N02).

Nodule Scores

Treatment	Lime (t/ha) 0	2.5	mean
Control	147 ab	110 a	129 p
Low inoculum	150 ab	216 c	183 q
High inoculum	176 bc	117 ab	147 p
Mean	158	148	153

The effect of inoculum ($p < 0.011$) and the interaction between inoculum and lime ($p < 0.003$) were statistically significant.

Clover plants which had received a low level of inoculum (0.2 g peat inoculum/m^2) had higher nodule score than the control, however, plants which had been inoculated with a high inoculum level had the same nodule score as the control.

Comments

Early growth of the broadleaf component (mostly capeweed) of the pasture appeared to be improved by lime where molybdenum had been applied ($p<0.05$). However the production was less where no molybdenum had been applied. The reduction in growth at 5 t lime/ha was associated with symptoms thought to be due to manganese deficiency.

In winter (8/8/89), P application improved total production where no molybdenum had been applied, but not where molybdenum had been applied. This is consistent with a marginal Mo deficiency in which P increases the availability of soil Mo. In contradiction of this however, the lack of a response to Mo or lime leads to the conclusion that the pasture was not Mo deficient.

Similarly, the effects of lime and inoculation on nodulation are difficult to interpret. A reduction in nodulation due to a high rate of inoculum is unexpected.

Lime in crop/pasture rotations on acid soils

Trial: 88N076

Property: Ian Leeson, S. Goomalling.

History: 1988: Lime applied and sub. clover sown.
1989: Sown to wheat (see P. Dolling's summary for results).
Before cropping pasture growth was measured.
May 24: Calibrated visual ratings of pasture production.

Results:

Treatment			May 25, 1989 (+Mo plots)								
		1988	Density ('000/m^2)				Dry matter (t/ha)				*
P	Lime t/ha	Seed t/ha	Clover	B'leaf	Grass	Total	Clover	B'leaf	Grass	Total	Visual rating
9	0	0.82	2.61a	1.55	2.27	6.43	-	-	-		1.0
	1.25	0.87	3.81bc	1.99	3.72	9.52	-	-	-		3.0
	2.50	1.05	3.92c	2.00	2.08	8.01	-	-	-		3.5
	5.00	0.26	3.41abc	2.02	3.25	8.69	-	-	-		2.5
	mean	0.75	3.44	1.89	2.83	8.16	-	-	-		2.5
60	0	1.01	3.09ab	1.00	2.81	6.91	0.20	0.05	0.18	0.43	1.0
	1.25	0.49	2.68a	1.70	4.28	8.66	0.18	0.09	0.19	0.45	3.0
	2.50	0.64	3.81bc	1.15	3.33	8.29	0.24	0.05	0.19	0.48	3.2
	5.00	0.78	3.62bc	1.47	3.37	8.46	0.23	0.08	0.16	0.47	2.8
	mean	0.73	3.30	1.33	3.44	8.08	0.21	0.07	0.18	0.46	2.5
mean	0	0.91	2.85p	1.28	2.54	6.67	-	-	-		1.0
	1.25	0.68	3.25pq	1.84	4.00	9.09	-	-	-		3.0
	2.50	0.84	3.87r	1.58	2.70	8.15	-	-	-		3.4
	5.00	0.52	3.52qr	1.75	3.31	8.58	-	-	-		2.6
	mean	0.74	3.37	1.61	3.14	8.12	-	-	-		2.5
Lime p<		N.S.	0.011	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.001
P p<		N.S.	N.S.	0.09	N.S.	N.S.	-	-	-	-	-
PxLime p<		N.S.	0.044	N.S.	N.S.	N.S.	-	-	-	-	N.S.
Edf		1	18	18	18	18	6	6	6	6	18
EMS		0.03	0.30	0.32	4.44	5.14	0.0049	0.0004	0.0032	0.0022	0.75

* "Visual ratings": each block of four plots (e.g. Rep 1, 9 kg P/ha) was rated from 1 (worst) to 4 (best). Each rating (1,2,3,4) was used only once. Thus it is not appropriate to compare ratings between P rates.

Comments

The pasture on the nil lime plots was visually markedly poorer than on the limed plots (see 'visual rating' column). The density of clover plants was increased by liming by about 35%. In high P plots, a higher rate of lime was required to achieve a density increase than in low P plots.

Neither clover dry matter nor any other measure of pasture growth was affected by treatment.

Lime in crop/pasture rotation on acid soils

Trial: 88N077

Property: W. Jones, East Ejanding.

History: 1988: Lime applied and sub clover sown.
1989: Sown to wheat (see P. Dolling's summary for results).
Before cropping pasture growth was observed.
May 23: No visual response in clover growth. Plant densities ($\pm$SD) estimated from 12 cores (10 cm diam): Clover 3600 $\pm$ 1000/m^2; Broadleaf (mostly capeweed) 500 $\pm$ 350/m^2; Grasses: 1500 $\pm$ 1700/m^2; Total: 5700 $\pm$ 2300/m^2.

Lime in crop/pasture rotations on acid soils

Trial: 88TS54

Property: N. Reed, W. Three Springs.

History: 1988: Lime applied and sub. clover sown. Lime increased September dry matter by 65% (1.5 t/ha).
1989: Sown to wheat (see P. Dolling's summary for results. Before cropping pasture growth was measured.
June 1: Calibrated visual ratings of pasture production.

Lime (t/ha)	1988 Seed (t/ha) - Mo	+ Mo	Mean	1/6/89 Dry matter t/ha
0	0.81	1.23	0.95 (100)	0.78 (100)
1.25	1.18	1.09	1.06 (111)	0.85 (109)
2.50	1.20	0.85	1.00 (105)	0.88 (112)
5.00	1.38	0.96	1.34 (141)	0.91 (116)
Mean	1.15	1.03	1.09 (114)	0.86 (110)
Lime		N.S.		N.S.
Mo		N.S.		-
L x Mo		N.S.		-

Comments

The site is extremely variable. A seed yield increase of 40% and an early pasture production increase of 16% associated with liming were not statistically significant.

The interaction of lime and nitrogen in a lupin/wheat rotation.

Trial: 88ME102

Property: E. Abe, N. Corrigin.

Soil: Deep yellow earth, gradational increase in texture with depth.

History: 1987: Lupins with Super Cu Zn Mo.
1988: Lime applied, sown to wheat with rates of nitrogen.
1989: Apr early: Super (100 kg/ha) topdressed.
Apr 30: Danja (100 kg/ha) sown with drilled super (100 kg/ha).
May 1: Simazine (2 L/ha) incorporated with Phoenix harrows.
June 1: Brodal (125 ml/ha).
June 9: Sertin (500 ml/ha) and Fusilade (125 ml/ha).
July 6: No visual response.
Sept 13: No visual response.
Sept 26: Sampled 20 plants per plot, reps 1 and 2, just prior to flowering.

Results:

Lime (t/ha)	Dry matter 26/9/89 (g/plant)	Grain yield (t/ha)
0	16.5	1.80 (100%)
0.5	16.7	1.86 (103%)
1	16.9	1.77 (98%)
2	15.7	1.78 (99%)

It is unlikely that the lime effect is only due to random variation ($p < 0.06$).

The effect of lime in a lupin/cereal rotation

Trial: 88ME103

Property: E. Abe, Corrigin.

Soil: Deep yellow earth, gradational increase in texture with depth.

History: 1987: Lupins with Super Cu Zn Mo.
1988: Lime applied, sown to five wheat varieties.
1989: As for 88ME102 (Interaction of lime and nitrogen in a lupin/wheat rotation).

Results:

Lime (t/ha)	Dry matter 26/9/89 (g/plant)	Grain yield (t/ha)
0	11.4	1.80 (100%)
1	12.2	1.76 (98%)
2	10.1	1.76 (98%)
4	12.2	1.75 (97%)

No effect of lime on grain yield ($p<0.05$).

Effect of lime on wheat/lupin rotations on acid, eastern wheatbelt yellow sandplain soil.

Trial: 80M30.

Property: Merredin Research Station.

Soil: Norpa loamy sand (gradational yellow earth).

History:
1980: 5 Lime x 2 (Wheat/Clover) x 2 Molybdenum rates (0,+).
1981: Resown - same species, no Mo applied.
1982: Volunteer pasture.
1983: Wheat plots sown to wheat, clover to triticale; Mo was applied to those plots which had not received Mo in 1980.
1984: All plots sown to wheat. Yielded 1.6 t/ha, no lime response.
1985: Lupins, yielded 1.1 t/ha, small (6%) lime response.
1986: Wheat (200 kg Super/ha, 100 kg Agran/ha) yielded 1.3 t/ha (control). Lime increased grain yield by 20% at 4 t/ha.
1987: Wheat (150 kg Super/ha, 90 g Mo/ha and 73 kg Agran/ha) yielded 1.5 t/ha. No lime response.
1988: Gutha (50 kg/ha) with Agras #1 (150 kg/ha) yielded 1.1 t/ha (control). Lime gave linear response up to 35% at 4 t/ha.
1989: May 3: Simazine 2 L/ha.
May 4: Sown to Yorrel (120 kg/ha inoculated) with Super (100 kg/ha).
Jun 16: Brodal 150 ml/ha.
Sep 27: Sampled 30 plants/plot rep 1 only.
Nov 8: Harvested.

Results:

Lime (t/ha)	Dry matter 27/9/89 (g/plant)	Grain yield (t/ha)
0	5.4 (100%)	0.40 (100%)
0.5	5.5 (102%)	0.40 (100%)
1.0	5.7 (106%)	0.41 (102%)
2.0	5.6 (104%)	0.45 (112%)
4.0	6.9 (128%)	0.39 (98%)
mean	5.8 -	0.41 -
Significance:	N.S. (Lin: $p < 0.10$)	N.S. ($p < 0.90$)

The slight effect of lime in increasing lupin plant weight in September was not reflected in grain yield. It is possible that the high lime rates induced a manganese deficiency, restricting the lupins ability to respond to lime effects. No observations have been made to confirm this hypothesis. Split seed was observed at high lime rates in an adjacent experiment (80M31) in 1985.

Lime applications in a wheat/lupin rotation.

Trial: 80M31.

Property: Merredin Research Station.

Soil: Norpa loamy sand.

History: 1980: 5 lime rates applied to large plots (10 m x 60 m), sown to Nungarin. Drought.
1981: Resown to Nungarin. No lime response observed.
1982: Resown to Nungarin
1984: Wheat (Gutha 50 kg/ha, DAP 98 kg/ha yielded 1.8 t/ha (control). Lime increased yield by 10% ($p < 0.01$).
1985: Yandee lupins (220 kg Super/ha) yielded 0.76 t/ha (control). Lime reduced yield by 20-30% ($p < 0.05$).
1986: Wheat (200 kg Super/ha) yielded 1.5 t/ha (control). Lime increased yield by 10-20% ($p < 0.05$).
1987: Wheat (150 kg Super Mo/ha, 73 kg Agran/ha) yielded 1.2 t/ha (control). Lime increased yield by 12-17% (N.S.).
1988: Lupins (150 kg super/ha) yielded 1.1 t/ha. No lime effect.
1989: May 9: Roundup (1 L/ha).
May 20: Spear (40 kg/ha) sown with Agras (138 kg/ha drilled on even numbered subplots) or Agras + Mo (123 kg/ha) drilled on odd numbered subplots).
July 4: Brominil-M (1.4 L/ha).

Results:

Lime t/ha	Dry matter 27/9/89 (g/plant) -Mo	Dry matter 27/9/89 (g/plant) +Mo	Grain yield (t/ha) -Mo	Grain yield (t/ha) +Mo	mean (%)
0	2.3	2.2	1.06	0.97	1.01 (100)
0.5	2.6	2.3	1.36	1.22	1.29 (128)
1	2.9	2.2	1.28	1.23	1.26 (125)
2	2.2	3.0	1.51	1.43	1.47 (146)
4	3.0	2.6	1.83	1.73	1.78 (176)
Lime effect: p<	N.S.		0.001 (linear)		
LSD 0.05			0.25		
Mo effect p<	N.S.		0.001		
Lime x Mo:	N.S.		N.S.		

Comments:

The large effect of lime on wheat yield (75% increase) does not appear to be due to the alleviation of a molybdenum deficiency. The molybdenum treatment is confounded with rate of Agras. A slightly higher rate of Agras was applied in the nil molybdenum plots (138 kg/ha) compared to the plus molybdenum plots (123 kg/ha). Plots which received molybdenum yielded slightly less (7%) than plots which did not receive molybdenum. This effect did not vary with lime rate.

The effect of lime on regenerating clover

Trial: 88NA82.

Property: C. Walton, W. Yealering.

Soil: 25 cm sand/loamy-sand over sandy-gravel over loam.
pH Ca (0-10 cm) 5.1

History:
1986: Pasture very clover dominant.
1987: Crop sown with 90 kg/ha DAP appeared very N deficient (cereal variety trial).
1988: Rates of lime applied, cultivated and sown to sub. clover (not inoculated or lime pelleted).
1989: Apr 20: Topdressed 210 kg super/ha and 90 kg KCl/ha.
May 5: Cultivated.
May 29: Sown to Dalyup oats (60 kg/ha) with double super (70 kg/ha) and Agran (60 kg/ha).
Nov 29: Harvested.

Results

Grain Yield 1989 (t/ha)

Lime 1988 t/ha	KCl 1988 (kg/ha) 0	50	100	mean
0	2.64	2.62	2.76	2.68 (100%)
1	2.64	2.70	2.80	2.71 (101%)
2	2.53	2.69	2.57	2.60 (97%)
4	2.47	2.73	2.54	2.58 (96%)
mean	2.57 (100%)	2.69 (105%)	2.67 (104%)	2.64 -

Lime effect and K effect marginally significant ($p < 0.07$). Note, both treatments were applied prior to the previous clover pasture and K was re-applied as a basal application (90 kg KCl/ha) in 1989.

It is likely that the small positive effect of 1988 potassium treatments were due to their effect on increasing sub. clover growth in that year. The small negative effect of lime may either have operated by depressing the 1988 clover growth, and so residual N, or by directly reducing the growth of oats.

Demonstration of liming recommendations

Trial: 89ME62

Property: B. Butler, E. Bruce Rock.

Soil: Gravelly sandy loam, pH Ca (0-10 cm) 4.5

History: 1989: May 22: Topdressed lime.
May 25: Cultivated across plots with cone seeder to 6 cm. Sown to Gutha (50 kg/ha) with super Cu Zn Mo (250 kg/ha drilled), rates of nitrogen (topdressed).
May 26: Sprayseed (1.5 L/ha).
Jun 26: Brominil M (1 L/ha) and Hoegrass (1 L/ha).
Sep 13: No lime response visible.
Sep 26: Sampled 50 plants/plot, anthesis.

Results

Dry matter production (g/plant) 26/9/89.

Lime	Nitrogen (kg/ha)				
t/ha	0	10	30	90	mean
0	1.67	1.47	2.63	2.88	2.16 (100%)
1.25	1.54	1.66	2.51	4.04	2.44 (113%)
2.50	1.54	1.57	2.56	4.11	2.44 (113%)
5.00	1.79	1.87	1.98	4.70	2.59 (120%)
mean	1.64	1.64	2.42	3.93	2.41 -
	(100%)	(100%)	(146%)	(240%)	-

Grain Yield (t/ha)

Lime	Nitrogen (kg/ha)				
t/ha	0	10	30	90	mean
0	0.51	0.67	0.90	1.24	0.83 (100%)
1.25	0.53	0.68	0.82	1.23	0.82 (99%)
2.50	0.83	0.76	0.85	1.12	0.89 (107%)
5.00	0.58	0.76	0.86	1.26	0.86 (104%)
mean	0.61	0.72	0.86	1.21	0.85 -
	(100%)	(118%)	(141%)	(198%)	-

There was no effect of lime or interaction between N and lime either in plant dry weight at anthesis or in grain yield ($p < 0.4$). Nitrogen alone substantially increased plant weights and grain yield ($p < 0.001$).

Use of gypsum to ameliorate subsoil acidity

Background

Lime is of no short term (<20 years) value in alleviating subsoil acidity. Lime incorporated into the topsoil, even at high rates, 'leaches' into the subsoil only very slowly. Incorporating lime into the subsoil is not currently practiced, would be very expensive, and is not possible on many soils (e.g. steep slopes or shallow gravels).

In a number of studies overseas, gypsum has been found to reduce the severity of subsoil acidity. The mechanisms by which this occurs are not fully understood.

To study the effect, a joint research programme has been commenced with the University of Western Australia's soil chemistry group.

In 1989 a series of experiments were established on Norpa soils of the eastern wheatbelt. On some of these soils subsurface acidity has been shown to markedly reduce wheat yields.

Procedure

Four sites were chosen to represent a range of productivity (severity of subsoil acidity) and location (Table 1).

Three sources of gypsum were compared; two from lakeside deposits (Lake Wallambin, 117°40'E 31°00'S) and one by-product gypsum (CSBP phosphogypsum). The two lakeside gypsums were coarse (seed gypsum) and fine ('Kopi' or aeolian surface deposits).

Table 1. Location and productivity of experiment sites.

Experiment	Location	Lat. E Long. S (±5')	Productivity
89ME92	S. Burracoppin	118°45'E 31°40'S	V. poor
89ME93	N.W. Trayning	117°40'E 31°00'S	Good
89ME94	N.E. Bencubbin	118°05'E 30°40'S	V. poor
89MO50	E. Dalwallinu	116°45'E 30°15'S	V. poor

The fine (Kopi) gypsum was the main treatment used. Previous studies with gypsum on heavy soils have confirmed the fine (Kopi) gypsum dissolves and leaches more rapidly than coarse (seed) gypsum (M.R. Howell, pers. comm.).

In the low rainfall environment of the eastern wheatbelt it was thought that this high rate of dissolution would be desirable in ensuring rapid movement into the subsoil.

The fine gypsum was applied at rates of 0.33, 1, 3 and 9 t/ha. The coarse and phospho-gypsums were applied at 1, 3 and 9 t/ha.

Two rates of lime (2 and 4 t/ha) were also applied in all combinations with 3 rates of fine gypsum (0, 1 and 3 t/ha). The effect of lime was examined for two reasons. First, to examine whether lime may modify the effect of gypsum on subsoil acidity or *vice versa*. Second, because gypsum applied to the acid topsoil may increase the severity of topsoil acidity, lime was applied to neutralise the topsoil acidity and allow effects on subsoil acidity only to be studied.

A number of extra 'nil' plots were left to allow future treatments to be applied.

Results

Gypsum appeared to increase wheat growth in two of the experiments (Table 2, see Appendices for details). In those two experiments lime also increased wheat growth to about the same extent. Applying both lime and gypsum had no effect above that of either ameliorant alone, except in 89ME92 grain yield, where the increase achieved from applying gypsum only (c.25%) or lime only (c.5%) was exceeded by applying both (c.55% increase).

Table 2. Summary of results of effects of gypsum, lime or both on vegetative and grain yield at four sites. (No statistical analyses yet performed, G = Gypsum, L = Lime).

Expt	Vegetative Yield	Grain Yield
89ME92	G (3 or 9 t/ha): 30% increase L (2 or 4 t/ha): 30% increase G + L: 30% increase Negative interaction?	Control: 0.44 t/ha G: 25% increase L: 5% increase G + L: 55% increase Positive interaction?
89ME93	No effect of any treatment except coarse G: 30% increase. No effect	Control: 1.5 t/ha G: 5 to 10% increase L (4 t/ha): 5% increase G + L: 10% increase Little effect
89ME94	G: 25 to 35% increase L: 30% increase G + L: 35% increase Negative interaction?	Control: 0.41 t/ha G: 5% increase L: 20% increase G + L: 25% increase Lime effect only
89M050	G: 5% decrease L: 10% decrease G + L: No effect No effect	Control: 0.58 t/ha G: No effect L: 10% increase G + L: No effect. No effect

Future work

Studies will be conducted on:

- the movement of lime and gypsum through the soil profile.

- the effects of lime and gypsum on the aluminium chemistry of the soil profile.

- the mechanism by which gypsum and lime are increasing plant growth.

The alternate aim of the research is to evaluate gypsum as a practical method of managing subsoil acidity, both natural (in wodjil soils) and man-induced (as may be occuring in the high and medium rainfall areas).

Gypsum for amelioration of acid soils

Trial: 89ME92

Property: G. Beck, S. Burracoppin.

Soil: Norpa loamy sand.

1989 Details:
- May 9: Gypsum topdressed.
- May 25: Roundup (1 L/ha). Sown to wheat (50 kg Gutha/ha) drilled with Super Cu Zn Mo (250 kg/ha), topdressed with Agran (175 kg/ha) and KCl (50 kg/ha).
- July 6: 2 to 2.5 leaves. No observable response. Soil samples taken for moisture determination.
- Sep 27: Sampled 50 plants/plot.
- Nov 21: Harvested.

Results

Moisture content (%) 6/7/89

Treatment (t/ha) Gypsum	Lime	H_2O %
0	0	6.18
0	4	6.25
9	0	6.12

Treatment effect not significant ($p < 0.06$).

Vegetative yield (g/50 plants)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	50	-	-	-	-
Fine	-	59	55	70	65
Coarse	-	-	56	65	60
Phosphogypsum	-	-	47	71	67
Fine + 2 t Lime/ha	70	-	61	65	-
Fine + 4 t Lime/ha	66	-	63	67	-

Grain yield (t/ha)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	0.44	-	-	-	-
Fine	-	0.41	0.56	0.60	0.53
Coarse	-	-	0.53	0.54	0.57
Phosphogypsum	-	-	0.56	0.60	0.57
Fine + 2 t Lime/ha	0.49	-	0.54	0.68	-
Fine + 4 t Lime/ha	0.50	-	0.58	0.69	-

Gypsum for amelioration of acid soils

Trial: 89ME93

Property: R. McAndrew, N.W. Trayning.

Soil: Norpa loamy sand.

1989 Details:
May 12: Gypsum topdressed.
May 30: Roundup (1 L/ha). Sown to wheat (50 kg Gutha/ha) drilled with super Cu Zn Mo (250 kg/ha). Topdressed with Agran (175 kg/ha) and KCl (50 kg/ha).
July 5: 2½ leaves. No effect visible.
Sep 28: Sampled 20 plants/plot. Grain quarter full.
Nov 22: Harvested.

Vegetative yield (g/20 plants)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	59	-	-	-	-
Fine	-	60	61	68	49
Coarse	-	-	52	76	81
Phosphogypsum	-	-	66	54	51
Fine + 2 t Lime/ha	54	-	60	56	-
Fine + 4 t Lime/ha	53	-	62	58	-

Grain yield (t/ha)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	1.53	-	-	-	-
Fine	-	1.49	1.55	1.57	1.64
Coarse	-	-	1.53	1.71	1.69
Phosphogypsum	-	-	1.55	1.57	1.60
Fine + 2 t Lime/ha	1.55	-	1.64	1.61	-
Fine + 4 t Lime/ha	1.64	-	1.71	1.72	-

Gypsum for amelioration of acid soils

Trial: 89ME94

Property: A. Putts, Welbungin.

Soil: Norpa loamy sand.

1989 Details:
- May 10: Gypsum topdressed.
- May 30: Roundup (1 L/ha). Sown to wheat (50 kg Gutha/ha) drilled with super Cu Zn Mo (250 kg/ha). Topdressed with Agran (175 kg/ha) and KCl (50 kg/ha).
- July 5: 3½ to 4 leaves. No observable response. Soil samples taken for moisture determination.
- Sep 28: Sampled 50 plants/plot.
- Nov 16: Harvested.

Results

Moisture content 5/7/89

Treatment (t/ha) Gypsum	Lime	H_2O %
0	0	3.12
0	4	3.58
9	0	3.50

Treatment effect not significant ($p < 0.30$).

Vegetative yield (g/50 plants)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	59	-	-	-	-
Fine	-	69	70	76	73
Coarse	-	-	74	77	75
Phosphogypsum	-	-	66	78	80
Fine + 2 t Lime/ha	81	-	74	86	-
Fine + 4 t Lime/ha	74	-	84	80	-

Grain yield (t/ha)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	0.41	-	-	-	-
Fine	-	0.43	0.45	0.40	0.57
Coarse	-	-	0.45	0.46	0.38
Phosphogypsum	-	-	0.46	0.45	0.42
Fine + 2 t Lime/ha	0.50	-	0.47	0.50	-
Fine + 4 t Lime/ha	0.49	-	0.52	0.54	-

Gypsum for amelioration of acid soils

Trial: 89M050

Property: T. Pipe, E. Dalwallinu.

Soil: Norpa loamy sand.

1989 Details:
- May 11: Gypsum topdressed.
- May 17: Roundup 1 L/ha, Sprayseed 2 L/ha. Sown to wheat (50 kg/ha) drilled with super Cu Zn Mo (250 kg/ha). Topdressed with Urea (130 kg/ha) and KCl (51 kg/ha).
- Sep 28: Sampled 50 plants/plot.
- Nov 29: Harvested.

Vegetative yield (g/50 plants) 28/9/89

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	80	-	-	-	-
Fine	-	74	57	71	70
Coarse	-	-	68	73	79
Phosphogypsum	-	-	70	76	73
Fine + 2 t Lime/ha	70	-	79	73	-
Fine + 4 t Lime/ha	74	-	78	81	-

Grain yield (t/ha)

	t Gypsum/ha				
Treatment	0	0.33	1.00	3.00	9.00
Nil	0.58	-	-	-	-
Fine	-	0.70	0.66	0.56	0.59
Coarse	-	-	0.56	0.61	0.59
Phosphogypsum	-	-	0.58	0.62	0.55
Fine + 2 t Lime/ha	0.65	-	0.69	0.46	-
Fine + 4 t Lime/ha	0.63	-	0.59	0.68	-