

**Increasing crop-uptake of fertiliser by improving soil pH/health
with prilled liming agents, prilled humate and VAM seed dressing.**

Project Consultant:
NRM Community Support Service – Shire of Kent, WA.



Cover Photo: Trial site looking north across plots on harvest day (30th November 2016).
Left-side is Mr Paul Leoni, NRM Community Support Officer for the Shire of Kent
and right-side is Mr John Jolly, Farmer Manager for landholder William Hurst.



Introduction:

Soil acidity is a major limitation to crop production throughout the inherently acidic soils of WA's central wheat-belt, and is consequently a high priority for research. While top soil (0-10 cm) acidity can be economically ameliorated by the surface application of lime products, this practice has been shown as a very slow and limited on reducing acidic sub-soil layers (10-30 cm). Sub-soil acidity (and aluminum in some profiles) limit plant nutrient uptake.

Cost effective methods and products need to be identified to rapidly neutralize sub-soil acidity. While there has been some interest in liquid lime products that can be banded at depth, major issues of concern that will limit its adoption include; cost (very expensive), the blocking up of tubes that deliver the product into the soil, and sources of clean water for its formulation on the farm. The recent release of prilled lime products that can be banded with the fertilizer has gained a lot of interest. These prilled lime products are believed to out-perform top-dressed lime and still be cheaper and more convenient than liquid lime products.

At the same time there has also been growing interest and on-farm experimentation with humate and fulvate products for improved yields through enhanced nutrient uptake. It is believed that these products enhance the effectiveness of liming agents.

This project compares limesand (top-dressed) with two alternative prilled lime agents, Calciprill and Magprill (banded with fertiliser) as a means of mitigating soil acidity and improving crop yields. Humates and vesicular arbuscular microbes (VAM), microbes known to enhance soil phosphorus uptake in low fertility soils, were also incorporated into each of the three liming treatments to evaluate the claim of enhanced yields and nutrient uptake.

Table 1. Description brief of each treatment.

Treatment Number	Description
1	Mace Wheat (MW) Only
2	MW + Granular Fertiliser (Ft)
3	MW + Ft + Lime Sand (LS)
4	MW + Ft + LS + Prilled Humate (Hu) + VAM
5	MW + Ft + Hu
6	MW + Ft + Hu + VAM
7	MW + Ft + Calciprill (Cp)
8	MW + Ft + Cp + Hu + VAM
9	MW + Ft + Magprill (Mp)
10	MW + Ft + Mg + Hu + VAM

Objectives:

The ten treatments evaluated (Table 1) were formulated in an attempt to achieve the following three objectives:

1. Reduction of soil acidity at depth (ie 10-30 cm) from banded prilled carbonate.
2. Increased crop uptake of fertilizer from banded lime treatments, especially prilled humate and VAM seed dressing.
3. Reduced sub-soil lime input costs by using prilled instead of liquid lime products.

The global hypothesis for this project was that highly soluble prilled carbonate products (CALCIPRILL & MAGPRILL), with or without prilled humate and a VAM microbe seed dressing, banded with fertilizer in the seed furrow, will raise sub-soil pH and enhance nutrient uptake and grain yield of crop more efficiently than standard soil pH management (e.g. top-dressed lime-sand).

Trial Location:

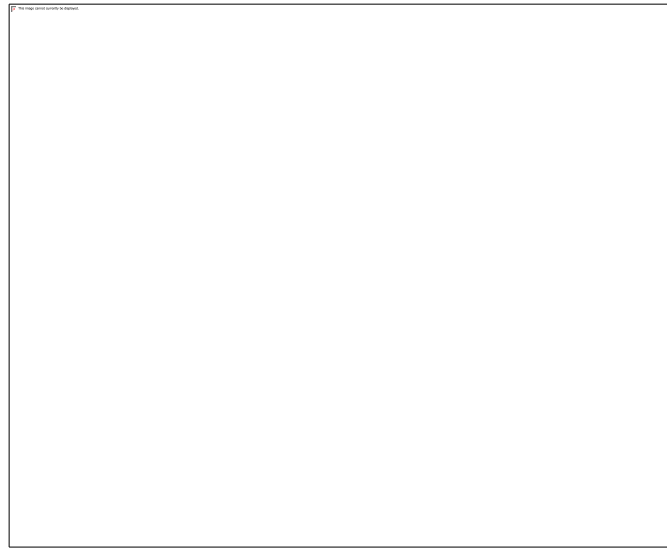
The project consisted of a single trial site at Mr William Hurst's property (Managed by Mr John Jolly) east of Titicup Road in the Shire of Kent, 27km (by road) east of Nyabing (Lat. 33.628083, Long. 118.358566).

Site Description:

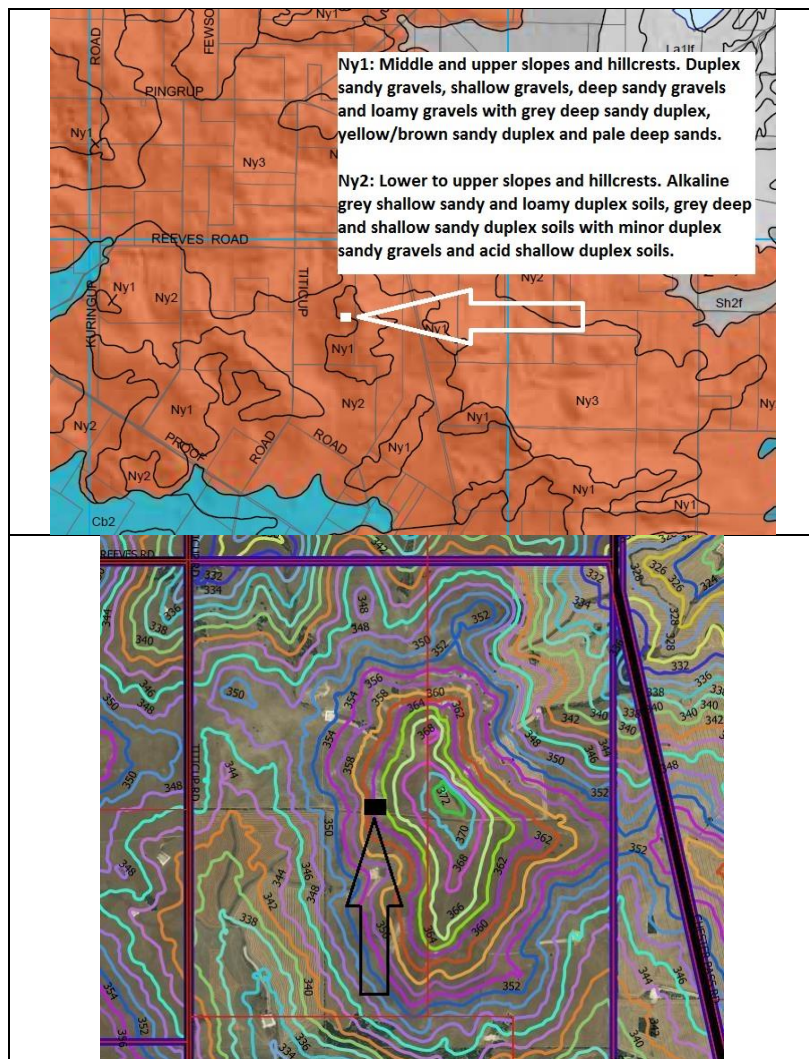
The trial site was a west facing sandy hillside (~2% gradient) with a soil profile of grey sand on yellow loamy sand, which sits over laterite cap-rock, where the depth to laterite ranged from >1m to 0.3m across the slope (photo below).



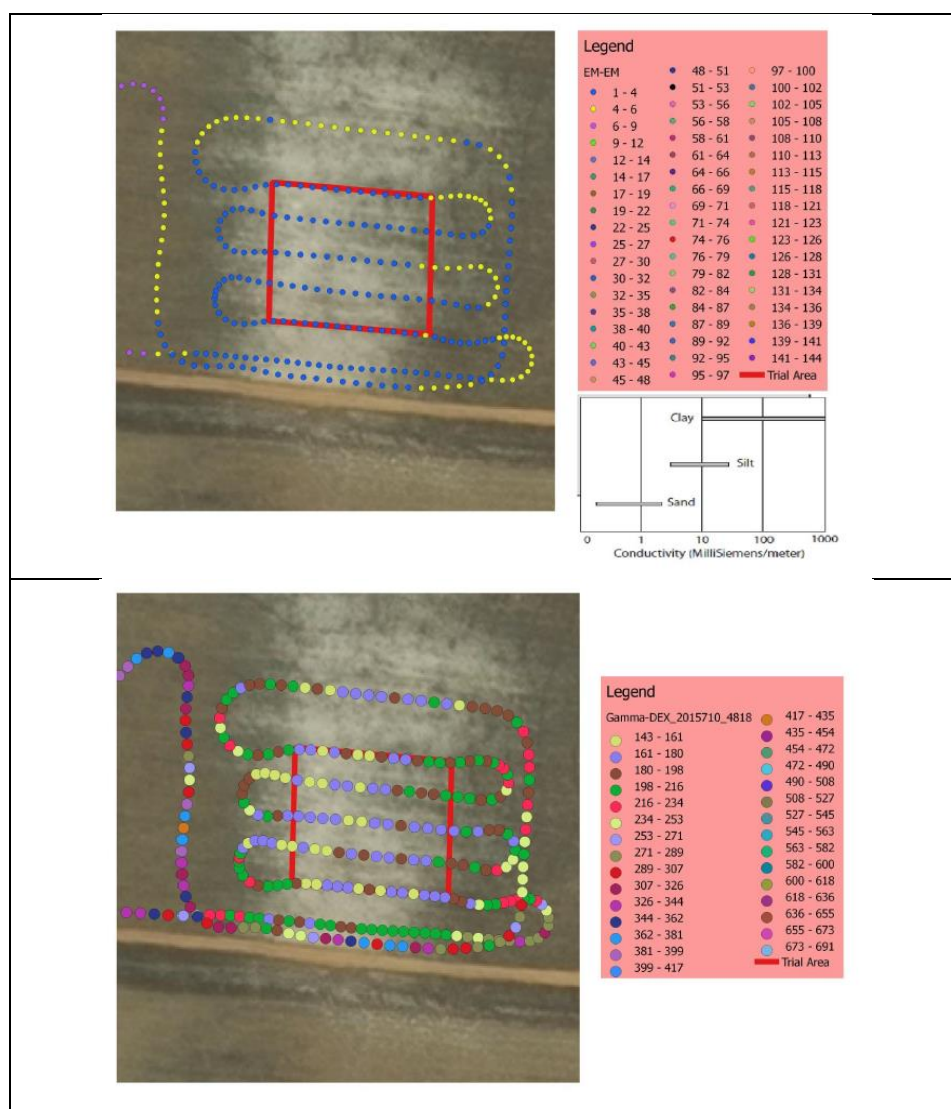
The image below shows the trial site in relation to paddock area.
(Lat. 33.628083, Long. 118.358566).



The images below shows the trial site located at soil type boundaries and near the top of the catchment, with 2m contour elevation lines marked on the map.



An EM38 and gamma survey suggested this site had very low electrical conductivity (ie salinity) and clay content (image below).



Methodology:

The experimental design consisted of ten treatments replicated within each of three blocks (Table 1). Treatments were laid out consecutively in the first block, and randomized within each of the remaining two blocks. The trial area was 40m long and 54m wide with the experimental plots aligned north to south along the contour of the slope. Each plot was 40m long and 1.54m wide with centers at 1.8m (ie 0.26m buffer between plots).

Prior to seeding baseline soil samples were collected from within each block at intervals of 10 cm to a depth of 40cm. On June 11th 2015 all treatments were implemented and the site sown to wheat (Mace). The entire site was top-dressed with urea (50 Kg/ha) on July 26th and foliar sprayed with copper and manganese on August 27th.

Treatment details are below.

	Seed & Fertiliser	Placement (& Date).	Rate / HA	Product Unit Cost	Product Cost / HA	Transport Cost / HA	Application Cost / HA	TOTAL Cost / HA	TREATMENTS									
CONTROL	Wheat (Mace AH/EPR).	Banded (11-June-2015).	70KG	\$300/T.	\$21.00	n/a	\$0.56	\$21.6	1	2	3	4	5	6	7	8	9	10
	Urea.	Top-Dressed (26-July-2015).	50KG	\$575/T.	\$28.75	\$1.60	\$0.40	\$30.8	1	2	3	4	5	6	7	8	9	10
	Liquid Mn/C/N.	Boomspray (27-August-2015).	700mL	-	-	-	-	-	1	2	3	4	5	6	7	8	9	10
VARIABLES	K-Till Extra.	Banded (11-June-2015).	95KG	\$765/T	\$72.67	\$3.04	\$0.76	\$76.5		2	3	4	5	6	7	8	9	10
	Nanarup Limesand.	Top-Dressed (11-June-2015).	1.5T	\$13.75/T.	\$20.62	\$27.00	\$12.00	\$59.6			3	4						
	Humate Prill (LawrieCo).	Banded (11-June-2015).	20KG	\$1,629/T.	\$32.58	\$0.64	\$0.16	\$33.4				4	5	6		8		10
	VAM (LawrieCo).	Seed Dressing (10-June-2015).	1.05L /70kg	\$8,052/KL	\$8.45	\$0.03	\$0.04	\$8.5				4		6		8		10
	Calciprill (Omya)	Banded (11-June-2015).	75KG	\$495 /T.	\$37.12	\$2.40	\$0.60	\$40.1							7	8		
	Magprill (Omya)	Banded (11-June-2015).	75KG	\$550 /T.	\$41.25	\$2.40	\$0.60	\$44.3									9	10

Treatment measurements included:

- Germination was assessed via plant counts on June 20th.
- Plant heights (cotyledons) recorded on July 12th.
- Plant samples were collected from all plots after stem elongation (1st open leaf, September 4th) and anthesis (whole shoots, October 7th) and analysed for nutrient status (CSBP Laboratory). Plant sampling at anthesis was also used to estimate crop biomass.
- The growing season rainfall was 155 mm and the plots were harvested on November 30th, the yields recorded and grain quality parameters of moisture (%), protein (%), hectoliter weight (Kg) and screenings (%) assessed by CBH (Nyabing and Pingrup).
- In March the following year each plot was soil sampled (0-10, 10-20 & 20-30cm) with sub-samples analysed for soil pH_{CaCl2}, lime requirement and soil nitrogen supply (potentially available ammonium N). Post-harvest assessment of soil quality sought to identify potential impacts of treatments on sub-soil condition regardless of the outcomes of the prior agronomic evaluation.

Statistical analyses were performed across the data where treatment means suggested there may be a positive responses. All statistical analyses were performed with Genstat 16th edition via a general Analysis of Variance routine with Fisher's unprotected least significant difference test across treatments.

Trial block layout/measurements and spray and rainfall inputs are below.

1.8m plot centres with plot width 1.54m gives 26cm buffer between plots (7 furrows/plot at 22cm spacing)

North

40m Long

	Replication ONE										Replication TWO										Replication THREE										
	Sequential										Randomised										Randomised										
	1	2	3	4	5	6	7	8	9	10	7	4	3	6	1	10	9	5	8	2	5	10	8	4	2	9	3	6	1	7	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Pre Treatment Soil Sampling	X													X															X		
Site EM38 & Gamma Survey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plant Counts	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plant Tissue Sampling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plant Tissue Sampling & Biomass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DAFWA Harvest Yield	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CBH Quality	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Post Harvest Soil Sampling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Paddock Spray Inputs			
2015-02-15	Weed spray		
	Water	50	L/ha
	Roundup CT 450	1	L/ha
	2,4-D Estericide 800	0.4	mL/ha
	Garlon 600-som vol	0.15	mL/ha
	Wetter 1000	0.25	%
2015-05-10	Weed spray		
	Water	50	L/ha
	Roundup CT 450	0.7	L/ha
	Hammer	15	mL/ha
	Wetter 1000	0.25	%
2015-05-19	Weed & Insecticide spray		
	Water	50	L/ha
	Roundup UltraMax	1.5	L/ha
	Sakura 850WG	118	g/ha
	Logran-b-power	30	g/ha
	Diuron 900WG	0.4	kg/ha
	Alpha Duo	0.1	L/ha
	Chlorpyrifos 500EC	0.15	L/ha
	LI 700	0.3	%
2015-08-20	Weed Spray		
	Water	50	L/ha
	Tigrex	0.5	L/ha
	Logran 750WG	15	g/ha
	Wetter 1000	0.2	%
2015-08-27	Fertiliser & Fungicide Spray		
	Water	75	L/ha
	Tilt 250EC	0.4	mL/ha
	Copper	0.4	mL/ha
	MCN-TRAX	0.7	mL/ha
	Wetter 1000	0.2	%
2015-09-04	Fungicide Spray		
	Water	75	L/ha
	Diemthoate	0.3	mL/ha
	Alpha Forte	0.05	mL/ha

Plot Location Rainfall Inputs		
Date	Rain	
(2015)	(mm)	
18-May	16	
22-May	1.5	
11-Jun	-	Seeding Date
19-Jun	29	
21-Jun	7	
22-Jun	3	
21-Jul	10.5	
23-Jul	4	
26-Jul	3	
1-Aug	17	
21-Aug	10	
23-Aug	2	
1-Sep	6	
4-Sep	-	First Tissue Sampling (young open leaves)
13-Sep	5	
14-Sep	2	
7-Oct	-	Final Tissue Sampling @ Anthesis (whole plant)
20-Oct	4	
26-Oct	3	
2-Nov	25	
15-Nov	6.5	
30-Nov	-	Harvest Date
	91.5	mm (from Seeding to 1st Tissue Sampling)
	98.5	mm (from Seeding to 2nd Tissue Sampling)
	137	mm (from Seeding to Harvest)
	154.5	mm (from 1-Jan to Harvest)

Results:

The entire site had a sandy infertile surface soil, not atypical of much of the region. Total exchangeable cations were ~ 0.8 meq/100g in the top-soil (0-30cm) and 1.3 meq/100g at depth (30-40cm), well below the minimum target for soil nutrient retention of 2.5 meq/100g. Key soil properties across the trial site, and down the soil profile, are summarised in Table 2.

Table 2. Key soil properties of the trial site prior to treatment establishment. Data are mean values across three replicate blocks for each of four soil layers.

Depth (cm)	OC (%)	TN (%)	Col-P mg/Kg	Col-K mg/Kg	S mg/Kg	EC dS/m	pH CaCl ₂	Al ¹ mg/Kg	CEC meq/100g
0-10	0.27	0.037	6.3	18	1.1	0.015	4.90	0.89	0.80
10-20	0.28	0.027	10.3	16	1.2	0.014	4.77	1.42	0.61
20-30	na	na	20.3	24	1.4	0.017	4.77	2.37	0.81
30-40	na	na	15.7	21	na	0.018	4.70	3.56	1.30

1 Plant available aluminium, CaCl₂ extractable.

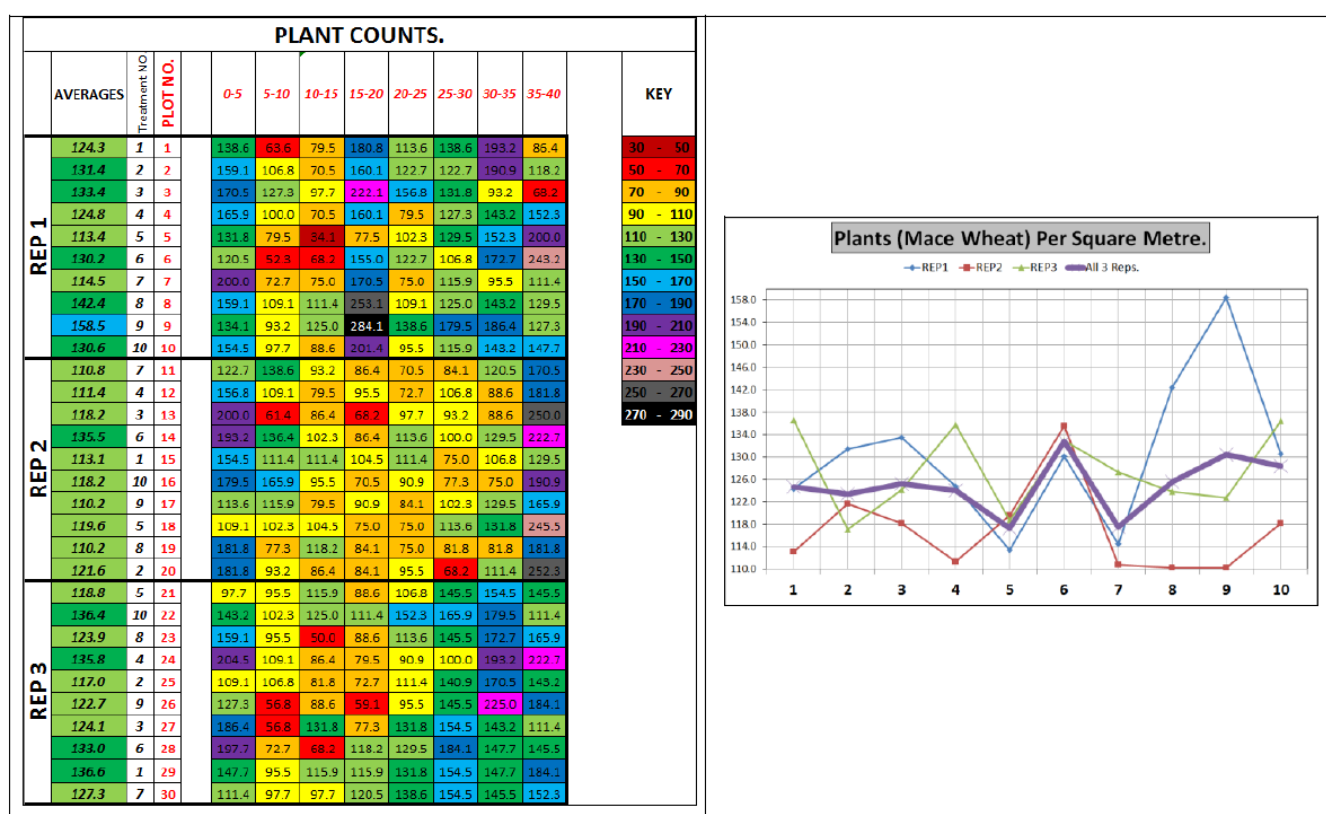
Of most significance was the acidic status of each soil layer (<5.0 pH_{CaCl₂}), and the high levels of plant available aluminum (Al) in the 30-40cm layer. Plant available Al in the sub-soil (20-40 cm) layer of block 1 was at toxic levels (> 3 mg/Kg), and was twice as high as that in block 2 and three times that of block 3, suggesting a very strong hostile sub-soil Al gradient down slope.

Germination plant counts (density) and cotyledon heights at five weeks provided estimates of early vigour. Mean values for these parameters across treatments ranged from 118 to 133 plants per square metre and 11.0 to 13.7 cm (Table 3). Note the graph on page 9 suggests VAM improves plant counts considerably.

Table 3. Agronomic properties evaluated across each treatment. Data are mean values of estimates across three replicate blocks. Properties with significant differences ($P<0.05$) between treatments have categories listed.

Treatment	Early Vigour		Anthesis	Harvest	Grain	Grain	Grain
	Density (m ²)	Height (cm)	DM (t/ha)	Yield (t/ha)	Protein (%)	HL (Kg)	Screenings (%)
1	125	12.6 ab	2.7	0.55	10.4 ab	76	14 a
2	123	11.4 a	3.2	0.68	10.4 ab	77	17 b
3	125	13.7 b	3.4	0.61	10.6 ab	77	17 ab
4	124	12.3 ab	2.7	0.49	10.6 ab	76	17 b
5	117	12.0 ab	2.1	0.42	10.4 ab	77	18 b
6	133	12.7 ab	3.2	0.64	10.8 ab	77	17 ab
7	118	12.6 ab	3.7	0.69	11.0 b	77	16 ab
8	126	11.0 a	2.6	0.52	10.3 a	77	17 ab
9	130	12.0 ab	3.5	0.64	10.6 ab	76	16 ab
10	128	12.0 ab	2.7	0.55	10.4 ab	76	17 b

A contour map and graph of plant counts is below.



Mean anthesis biomass (dry matter) estimates, crop yields and grain quality parameters for each treatment are also displayed in Table 3 (previous page). Grain yields were low and ranged from 0.42 to 0.69 t/ha. Significant differences between treatments across the agronomic properties were only found for cotyledon height, protein and screenings. In each case the differences gave only two categories.

Data on plant nutrient concentrations and mass uptake are outlined in Tables 4 & 5 on next page. For all treatments, shoot calcium and magnesium status was below optimal in both the September and October sampling, whilst potassium and sulphur were below optimal only in October. Aluminium concentrations were well above the critical limit in all treatments on both occasions, with individual plot analyses showing a distinct rising trend with distance down the slope.

Mass uptake of applied fertilizer nutrients at anthesis (Table 5) were analysed for statistically significant treatment differences. Of the eight applied nutrients only zinc uptake showed any significant treatment differences, with only two categories.

From both the agronomic and plant nutrient mass uptake data trends in plant responses to some treatments were observed. Notably, Calciprill alone (treatment 7) produced (at anthesis) the highest dry matter and mass uptake of Zn, Ca and Mg and (at harvest) the highest grain protein. Also, differences recorded between treatments 5 and 6 suggest that VAM alone (without prilled humates) could have produced higher crop performance.

Table 4. Concentration of applied fertilizer nutrients and aluminium in wheat shoots sampled in September and October.

Treatment	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	B (mg/ Kg)	Cu (mg/ Kg)	Fe (mg/ Kg)	Mn (mg/ Kg)	Zn (mg/ Kg)	Al (mg/ Kg)
Optimum Range	3.5 - 4.5	0.3 - 0.5	2.0 - 3.0	0.15 - 0.55	0.3 - 0.5	0.2 - 0.6	5.0 - 10	5 - 25	25 - 100	25 - 100	15 - 70	< 25
October												
1	1.2	0.15	0.8	0.08	0.13	0.13	4.3	5.3	62.5	72.5	14	54
2	1.3	0.18	0.8	0.10	0.14	0.12	4.2	6.0	54.7	70.3	14	67
3	1.3	0.20	0.9	0.10	0.14	0.13	4.4	5.0	53.2	65.7	15	59
4	1.4	0.18	1.1	0.10	0.12	0.12	3.7	5.5	50.1	59.6	13	52
5	1.3	0.18	0.9	0.10	0.16	0.14	4.5	6.4	52.3	71.6	15	64
6	1.3	0.20	0.9	0.11	0.15	0.14	4.5	5.6	55.1	77.6	17	63
7	1.2	0.19	0.9	0.10	0.14	0.13	4.3	5.9	52.9	78.9	18	60
8	1.4	0.18	0.9	0.10	0.15	0.13	4.7	5.5	52.7	73.9	16	59
9	1.2	0.17	1.0	0.10	0.12	0.12	4.4	6.4	52.1	71.6	13	60
10	1.2	0.20	0.9	0.10	0.12	0.12	4.7	5.4	50.2	67.7	17	60
	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	B (mg/ Kg)	Cu (mg/ Kg)	Fe (mg/ Kg)	Mn (mg/ Kg)	Zn (mg/ Kg)	Al (mg/ Kg)
September												
1	4.2	0.39	1.9	0.30	0.25	0.16	5.6	38	76.9	141.7	32	33
2	4.4	0.41	1.9	0.32	0.26	0.17	5.9	44	78.5	148.4	30	32
3	4.4	0.41	1.8	0.32	0.28	0.17	5.7	43	78.8	132.4	29	30
4	4.4	0.42	1.7	0.33	0.29	0.17	6.0	43	82.4	134.7	31	30
5	4.2	0.40	1.8	0.31	0.25	0.17	5.9	43	76.6	141.5	30	32
6	4.5	0.43	1.9	0.34	0.29	0.18	6.2	46	82.8	158.1	33	33
7	4.4	0.40	1.8	0.33	0.28	0.18	6.3	43	81.6	149.6	31	32
8	4.3	0.42	1.8	0.31	0.27	0.17	6.0	44	75.9	150.4	32	33
9	4.4	0.43	1.9	0.33	0.28	0.17	6.2	47	80.8	155.3	31	34
10	4.4	0.44	1.9	0.34	0.29	0.18	6.6	49	84.7	166.2	33	39

Table 5. Mass uptake of applied fertilizer nutrients at anthesis in each treatment. Data are mean values of estimates across three replicate blocks.

Treatment	N (Kg/ha)	P (Kg/ha)	K (Kg/ha)	S (Kg/ha)	Ca (Kg/ha)	Mg (Kg/ha)	Cu (g/ha)	Zn (g/ha)
1	32	4.1	22	2.2	3.7	3.5	15	38 ab
2	40	5.6	26	3.0	4.4	3.7	17	44 ab
3	43	6.7	32	3.3	4.3	4.3	16	48 ab
4	37	4.9	28	2.9	3.3	3.4	15	35 a
5	27	3.8	18	2.0	3.2	2.7	12	31 a
6	39	6.0	30	3.2	3.9	4.0	16	47 ab
7	43	6.4	31	3.5	5.7	4.7	21	60 b
8	36	4.7	23	2.5	4.0	3.2	13	40 ab
9	42	5.8	33	3.3	4.1	4.1	20	46 ab
10	33	5.3	25	2.6	3.3	3.3	15	46 ab

An inter-correlation of agronomic and plant nutrient status data from across the entire site showed some very significant relationships regardless of the treatments (Table 6 on next page). Amongst the agronomic properties, anthesis dry matter was highly correlated with yield, and both these parameters were negatively correlated with screenings. Of the numerous significant relationships observed between agronomic properties and plant nutrient status the most concerning was the very significant ($P < 0.001$) negative relationship between shoot aluminium concentrations (both samplings) and anthesis dry matter and grain yield.

Post-harvest assessment of soil quality parameters are outlined in Tables 7 & 8. There were no significant treatment effects on soil pH or soil N supply within each soil layer, regardless of samples collected on or off the furrow. Sub-soil pH was only measured on the furrow for the main lime treatments (2,3,7 & 9) and here there was a suggestion of elevated pH in the 10-20cm layer.

Nevertheless, treatment trends in soil parameters were observed, including: an increase in soil pH from both magprill alone (treatment 9) and top-dressed limesand (treatment 3); and an increase in soil N supply at 10-20cm in calciprill alone (treatment 7).

Estimates of lime requirement were very similar across treatments in each soil layer, suggesting that just over half a ton of pure lime mixed within the 0-30 cm layer is required to raise bulk soil pH by 1 unit. Soil N supply estimates were extremely low across all depths and treatments, ranging from 1.5 to 4.7 Kg/ha, and was indicative of the very low fertility of the site. Soil N supply was higher in soil on versus off the furrow, but only in the surface soil layer for the main lime treatments.

Table 6. Correlations of significance between the agronomic properties, and between the agronomic properties and crop nutrient concentrations measured (September and October) from all thirty plots. Nutrients are only presented where there was at least one significant correlation with an agronomic property. Pearson correlation coefficient critical values are; $R > 0.361$ ($P < 0.05$), $R > 0.463$ ($P < 0.01$) and $R > 0.57$ ($P < 0.001$).

						Anthesis	Early Vigour		
		Yield	Protein	HL	Screen	DM	Density	Height	Oct V Spt ¹
Yield		--	--	--	--	--	--	--	
Protein		--	--	--	--	--	--	--	
HL		--	--	--	--	--	--	--	
Screen		-0.74	--	--	--	--	--	--	
DM		0.97	--	--	-0.77	--	--	--	
Density		--	--	--	--	--	--	--	
Height		--	0.38	--	--	--	--	--	

Plant Nutrient Concentrations

N	Oct	-0.58	--	--	0.48	-0.58	--	-0.38	
	Spt	--	0.57	--	--	--	0.55	--	0.41
P	Oct	-0.50	--	--	0.59	-0.45	--	--	
	Spt	-0.54	--	--	0.63	-0.50	--	--	0.49
K	Oct	--	--	--	--	--	--	--	
	Spt	--	--	--	-0.43	--	--	--	-0.03
S	Oct	-0.41	--	--	0.41	--	--	--	
	Spt	--	0.38	--	--	--	--	--	0.48
Ca	Oct	--	--	--	--	--	--	--	
	Spt	0.60	--	--	--	0.59	--	--	-0.07
Mg	Oct	-0.59	--	--	0.49	-0.59	--	--	
	Spt	--	--	--	--	--	--	--	0.19
Cu	Oct	-0.56	--	--	0.42	-0.56	--	-0.38	
	Spt	--	--	--	--	--	--	-0.39	0.25
Zn	Oct	-0.44	--	--	0.39	-0.44	--	--	
	Spt	--	--	--	--	--	--	--	0.21
Al	Oct	-0.77	--	--	0.48	-0.74	--	--	
	Spt	-0.81	--	--	0.48	-0.75	--	-0.45	0.82

Table 7. Post-harvest assessment of soil pH and lime requirement. Soil pH data is segregated into samples collected off and on the furrow for the main lime treatments. Data are mean values of estimates across three replicate blocks, except for 20-30 cm data from block 1 only.

Treatment	Soil pH						Lime Requirement ¹ (t/ha)		
	Off 0-10 cm	On 0-10 cm	Off 10-20 cm	On 10-20 cm	Off 20-30 cm	On 20-30 cm	0-10 cm	10-20 cm	20-30 cm
2	5.35 +0.05	5.40	5.12 +0.06	5.18	4.91 -0.16	4.75	0.23	0.22	0.14
3	5.59 +0.42	6.01	5.15 +0.08	5.23	5.07 -0.08	4.99	0.23	0.22	0.15
7	5.57 -0.13	5.44	5.09 +0.01	5.08	4.99 -0.13	4.86	0.24	0.22	0.14
9	5.19 +0.33	5.54	5.03 +0.13	5.16	4.99 +0.05	5.04	0.22	0.22	0.14

¹Laboratory estimate of the mass of pure lime (t/ha) required to raise soil pH by 1 unit for a 0.1 m deep layer with 1g/cc density. This is not a standard test, and is indicative only.

Table 8. Post-harvest assessment of soil total carbon (TC), total nitrogen (TN) and soil nitrogen supply. Data are segregated into samples collected off and on the furrow for the main lime treatments. Data are mean values of estimates across three replicate blocks, except for 20-30 cm data from block 1 only.

Treatment	TC ¹ (%)	TN ¹ (%)	Soil Nitrogen Supply (Kg N / Ha)					
			Off 0-10 cm	On 0-10 cm	Off 10-20 cm	On 10-20 cm	Off 20-30 cm	On 20-30 cm
2			2.7 +1.6	4.3	1.9 -0.1	1.8	1.6 +0.5	2.1
3			3.0 +1.7	4.7	1.7 0	1.7	1.7 -0.1	1.6
7			2.4 +1.3	3.7	1.5 +1.2	2.7	1.6 +0.3	1.9
9			2.2 +1.0	3.2	2.7 -0.3	2.4	1.6 +0.1	1.7

1 analysis pending

Discussion of Results:

No significant treatment effects were observed for either the agronomic, nutrient uptake, or post-harvest soil quality parameters assessed in this study. However beneficial trends were recorded (see below). The study was confounded by two very significant site factors that undoubtedly suppressed crop growth across all treatments; (1) a substantial below average growing season rainfall and (2) a strong gradient of hostile sub-soil acidity which resulted in very high plant aluminum uptake across all plots.

The single biggest association with crop productivity across all plots was the negative response to plant aluminum concentrations in both the September and October sampling. This association was similar in strength to that of "distance up the slope", both explaining about 80% of the variation in crop productivity. Beneficial trends in plant responses were recorded, namely calciprill alone (treatment 7) produced (at anthesis) the highest dry matter and mass uptake of Zn, Ca and Mg and highest grain protein. Also, differences recorded between treatments 5 and 6 suggest that VAM alone (without prilled humates) could produce higher crop performance.

Post-harvest assessment of soil quality sought to identify potential impacts of treatments on sub-soil condition, but showed no significant elevation of sub-soil pH, even from samples collected on the furrow. However beneficial trends in soil parameters were observed, including: an increase in soil pH from both magprill alone (treatment 9) and top-dressed limesand (treatment 3); and an increase in soil nitrogen supply at 10-20cm in calciprill alone (treatment 7).

Due to the severity of sub-soil acidity across the central wheat-belt, future evaluations of prilled lime products will require applications at considerably higher rates. Laboratory analysis of the neutralizing value of the lime products rated the lime sand (Narnarup) at 64%, and both prilled products at 90%. As the prilled products are formulated from fine particles which readily disperse when wet there is no need to discount their neutralizing value for the slower activity of larger particles. Not so with the lime sand, which when discounted for particle size distribution gave effective neutralizing value of 38%. Consequently, the effective rate of lime application for the lime sand treatments (570 Kg/ha) were about eight times that of the prilled products (68 Kg/ha). Lime requirement estimates for the sub-soil at this site suggests that between 140 to 240 kg/ha of lime are required to lift the pH 1 unit in each 10 cm layer.

It is quite likely that any future trial will need to consider applying prilled products at a rate of at least 210 Kg/ha to be seen to significantly raise sub-soil pH by about 0.5 units over a 30 cm layer. While the strategic placement of prilled lime under the seed suggests that lower rates of a more expensive product can be used at greater effect, there is still a requirement that sufficient rates be used if sub-soil acidification is to be appreciably ameliorated for crop improvement.

The sever sub-soil acidity constraint and its strong gradient across the experimental plots of this trial highlights the need for comprehensive assessments of sub soil condition prior to the selection of future trial sites.

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Implications:

The trial was confounded by a severe shortage of plant available water (e.g. very low rainfall) and severe sub-soil acidity that resulted in toxic levels of plant aluminum concentrations that impacted negatively on crop productivity.

Recommendations:

The treatments (excluding prilled humate, which produced negative crop impacts) should be repeated (with VAM) at a site with more even sub-soil conditions. CALCIPRILL and VAM seed dressing showed particular potential for quality grain production and MAGPRILL showed particular potential as an effect agent for increasing soil pH.

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List of Appendices

1. **Experimental set-up/images.**
2. **Depth to Laterite Cap-Rock Transect.**
3. **Project extension activities.**

Appendix 1. Experimental set-up/images.



Baseline soil sampling, sowing June 11th.



Sowing June 11th.



Anthesis plant sampling, October 7th.



Harvest, November 30th.

Appendix 2. Depth to Laterite Cap-Rock Transect.

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			Depth (cm) to laterite cap-rock.					Distance (m)	
			0m	10m	20m	30m	40m		
			51		>100		70	0	
								1.8	
			16		14		40	3.6	
								5.4	
			24		12		>100	7.2	
								9	
			29		35		63	10.8	
								12.6	
			35		50		73	14.4	
								16.2	
			33		50		87	18	
								19.8	
			41		58		79	21.6	
								23.4	
			104		69		60	25.2	
								27	
			74		72		63	28.8	
								30.6	
			63		62		74	32.4	
								34.2	
			83		88		85	36	
								37.8	
			78		83		82	39.6	
								41.4	
			74		64		82	43.2	
								45	
			67		70		84	46.8	
								48.6	
			86		79		89	50.4	
								52.2	
			69		78		87	54	
								55.8	
			70		59		118	57.6	
								59.4	
			76		84		89	61.2	
					Test Pit			63	
			98		79		64	64.8	
								66.6	
			82		70		64	68.4	
								70.2	
			76		52		74	72	
								73.8	
			76		70		64	75.6	
								77.4	
			60		77		53	79.2	
								81	
			78		72		39	82.8	
								84.6	
			55		37		48	86.4	
								88.2	
			55		41		84	90	
								91.8	
			76		45		64	93.6	
								95.4	
			40		45		53	97.2	
								99	
			46		58		72	100.8	
								102.6	
			89		47		101	104.4	
								106.2	
			0m	10m	20m	30m	40m		
Rep.1	1	1							
	2	2							
	3	3							
	4	4							
	5	5							
	6	6							
	7	7							
	8	8							
	9	9							
	10	10							
Rep.2	7	11							
	4	12							
	3	13							
	6	14							
	1	15							
	10	16							
	9	17							
	5	18							
	8	19							
	2	20							
Rep.3	5	21							
	10	22							
	8	23							
	4	24							
	2	25							
	9	26							
	3	27							
	6	28							
	1	29							
	7	30							

Appendix 3. Project Extension Activities.

- **29th July 2016** – The Shire of Kent NRM Community Support Officer (Mr Paul Leoni) attended and presented at the GRDC RCN (Albany Port Zone) meeting in Frankland. Included in the presentation was a discussion of how the project came together, the project aims, design, a description of the site and some early observations of plant counts. Later in the meeting subsoil acidity management came up in the TOP-TEN list (@ 8%) for the Albany Port Zone, which reinforced the relevance of the project.

Top 10 Issues (Ranked %)	RCSN Meeting Actions on top 10 Issues	Top 10 Other High Ranking Issues **
Herbicide resistance & weed management (18%)	Existing national initiative on this area. However, potential for 1-3 year RCSN project activities to support this priority. RCSN booklet published - www.rcsn.net.au	Frost (20%)
Non wetting (16%)	Further development on potential 1-3 year RCSN project activities to support this priority.	Productivity (14%)
Snails and slugs (14%)	Further development on potential 1-3 year RCSN project activities to support this priority.	GM Technology (12%)
Sclerotinia (10%)	Combined with Canola yield limitation discussions at the closed RCSN meeting the next day.	High rainfall varieties (12%)
Rotations (9%)	No further project development at this stage but will remain on the RCSN priority list.	Grain marketing (10%)
N and P management (9%)	Further development on potential 1-3 year RCSN project activities to support this priority.	Stubble management (10%)
Soil acidity (8%)	Existing national initiative on this area.	Bio security (new pests and diseases) 10%
Canola yield limitations (8%)	Further development on potential 1-3 year RCSN project activities to support this priority.	Business management (HR, staffing etc) (7%)
Cereal disease (8%)	No further project development at this stage but will remain on the RCSN priority list.	Sodic soils (4%)
Water logging (1%)	No further project development at this stage but will remain on the RCSN priority list.	Long range forecasting-climate (3%)

- **4th August 2016** – DAFWA's Soil Constraints West 'Soil Acidity Tour 2015' started off at the trial site at Titicup Road, where the NRM Officer Paul Leoni presented to the group on the trial site, showcased the prilled lime products and talk about the importance of developing research in sub-soil acidity management. Chris Gazey (DAFWA) demonstrated a cut-away cross section of a furrow on one of the treatment plots and used a spray on indicator dye to show pH change in the cross section where lime treatments were highlighted by a colour change.



★★Recent NRM/Landcare Activities★★

'Soil-Constraints' Tour (4th & 5th August).

*Did you see a convoy of white Prado's passing through Nyabing on 4th August! DAFWA recently ran a tour incorporating field walks and soil pit discussions at trial sites that focus on soil acidity, soil compaction and subsoil constraints, including a visit to two lime-pit sources on the South Coast. **The tour included:***



Site 1: Titicup Road, Shire of Kent.

Trial, researching prilled lime (Calciprill & Magprill) & prilled humate (with VAM microbes/P), pre-mixed with granular fertiliser and banded at seeding, as an alternative to top-dressing lime-sand for mitigating acid soils/fertilisers.



Site 2: Kwobrup Road South, Shire of Kent.

Trial, researching liquid lime (Calsap & Calbud), pre-mixed with liquid fertiliser and banded at seeding, as an alternative to top-dressing lime-sand for mitigating acid soils/fertilisers.



Site 3: Nardlah Road, Shire of Broomehill-Tambellup.

Trial, researching sub-soil cultivation, focusing on reducing non-wetting soils and improving subsoils via deep ripping, using a special ripper with a winged tail on rear of the tyne, which allows non-wettable surface soil to drop into rip-lines.



Site 4: Homestead Road, Shire of Albany.

WALCO's Mt Many Peaks lime quarry. This is a clayey type of lime with a neutralising value between 70% to 90% and at around \$25/ton. Due to the clay content the site is closed during the winter rain season when product is wet.



Site 5: Ocean Beach Road, Shire of Denmark.

Shire of Denmark's Wilsons Inlet lime quarry. This is crushed limestone with a neutralising value between 85% to 95% and at around \$25/ton. Almost half the annual quota is sold locally, the remaining tonnage can go to other Shire areas.



Site 6: North Kendenup, Shire of Plantagenet.

Trial (by 'Stirlings-To-Coast' grower group), researching difference types of lime for acid soil mitigation, using standard practise of top-dressing.



Site 7: Shire of Kojonup.

Trial, researching difference types of soil cultivation vs soil wetters for mitigation of hydro-phobic surface soils and incorporation of top-dressed lime. The one-way plough seems to be reducing non-wetting more effectively than the mouldboard. Band wetter (with seed furrow) also is performing better than surface applied wetter.

- **19th August 2016** - The Nyabing Farm Improvement Group held their winter agronomy day on 19th August 2015. The day started with an in-house update on agronomy, followed by a tour of difference trial sites across the Nyabing area (especially canola crops, see photo below). This included a visit to the GRDC trial site adjacent at Titicup Rd and Paul Leoni (NRM Officer) gave a presentation to the group, explaining the trial design and products. There were about 20 local farmers present at the site for this presentation.