

Grape and Wine
Research and
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Development of a sustainable soil management system with improved lime and immobile nutrient cycling capacity

FINAL REPORT to
GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Principal Investigator: **Mr John Whiting**

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Development of A Sustainable Soil Management System with Improved Lime and Immobile Nutrient Cycling Capacity

DAV 92/3

AGRICULTURE VICTORIA

Mr JR Whiting and Mr S McNab
Institute of Sustainable Irrigated Agriculture
Private Bag 1, TATURA VIC 3616

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GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

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SUMMARY

Soil acidity and low soil phosphorus concentrations are problems encountered in many vineyard areas. It is recognised that amelioration of the soil with lime and phosphorus fertilisers prior to commencing installing the vineyard is the preferred option for addressing the problem. However, some vineyards were established without complete preparation and as well in many vineyards there is a gradual increase in acidity and decline in soil phosphorus concentrations. Thus methods to improve soil conditions and maintain the sustainability of those conditions in established vineyards are required.

The aim of the current work was to evaluate some methods of soil management that have generally been tried alone and not as combinations of treatments. Thus surface application of lime and phosphorus, mulching with organic material and the addition of earthworms were tested in various combinations. The influence of the treatments on the movement of lime and phosphorus down the soil profile, the response of the vines in terms of nutrition and yield and earthworm populations were recorded. Trials were set out in two sites with different climates and soils.

Two years after the surface application of lime, soil pH changes were evident down to the 10 - 20cm zone. Phosphorus movement was only evident down to the 5 - 10cm zone. Mulching did not improve lime or phosphorus movement and there was a trend for the mulched treatments to provide more acidic conditions in the 5 - 10cm zone and deeper. The addition of earthworms also did not influence lime or phosphorus movement.

Mulching with straw produced some changes in vine nutrition with greater petiole nitrate, total nitrogen, calcium and potassium although these responses were not seen in all seasons and sites. The addition of lime and phosphorus improved the calcium and magnesium at one site and decreased manganese and nitrate at another site.

The vines at the lower rainfall trial site responded to the application of straw mulch with greater yields, due mainly to more bunches and heavier berries, but with delayed maturity. At the higher rainfall site there was no yield response to mulching, and at both sites there was no yield response to the addition of lime and phosphorus or earthworms.

The addition of lime and phosphorus at both sites enhanced worm populations whilst mulching only enhanced worm numbers at the lower rainfall site, by up to 5 fold over no mulching. The two sites had a different spectrum of worms, with *Aporrectodea caliginosa* being most common at both sites.

An additional experiment on the amount of organic matter produced *in situ* in a vineyard revealed that after one year an annual oat crop produced the most organic matter. Lower amounts were produced from a grass sward, canola and volunteer weeds. No significant yield differences were recorded between the treatments.

Overall, the work has clarified the effectiveness of various components of soil management systems. In lower rainfall areas, mulching with straw will provide some improved nutritional aspects, a large increase in earthworm populations and a significant yield increase. Aspects of grape and wine quality need further investigation. Maintenance of the straw mulch may be possible with annual cover corps in good seasons but if annual production is less than about 3t/ha DW extra straw may be needed. The influence of mulching and cover corps on frost control and pest and disease management need to be considered.

In a high rainfall area, the only response from straw mulch was on nutrient uptake, although the extra uptake of nitrate or potassium may not be seen as an advantage. Whilst initial mulching with straw will not result in any direct payback to cover the cost of applying it the low worm numbers under the vines was considered undesirable. Organic matter under the vine should be increased by slashing the mid row permanent sward material and spreading it along the vine line with custom designed machinery.

The addition of earthworms needs to be carefully considered. A species that will thrive at the site should be added as a species that does well elsewhere may not be suited. The species observed in the present work could not be classed as deep burrowing as far as grapevine root distribution goes. Further work is required on appropriate species and inoculation rates before adding earthworms could be recommended.

The application of lime and phosphorus to the surface clearly increased the populations of resident earthworms. This is presumed to relate to the lime component providing a more favourable soil pH. When lime is being added to vineyard soils, whilst it should be worked into the root zone, ie down to 30 - 40cm, there should also be some surface application to promote worm populations. Whilst deep ripping of phosphorus is common, in acid soils the vines may not respond if the roots are not able to grow down to and extract the phosphorus under the acidic soil conditions.

BACKGROUND AND INTRODUCTORY TECHNICAL INFORMATION TO PROJECT

Soil acidity is a widespread problem in Australia, resulting from long term leaching processes especially in high rainfall areas and in regions with porous soils. A high proportion of Australian vineyards are planted in naturally acidic soil (pH < 5.5 water) particularly the Adelaide Hills, Yarra, King, Hunter, Swan and Hastings Valleys. Acidic soil conditions reduce the availability of essential macro and micro nutrients to vines and increase the abundance of toxic elements such as aluminium and manganese.

Lime, which is used to correct soil acidity, is quite insoluble in water and requires contact with acidic soil for improved dissolution. Experiments with surface applications of lime have had little effect on soil pH in irrigated vineyards at three sites (S McNab, 1994). Previous experiments in acidic soils have also shown that surface applied lime has limited mobility in soil (Brown & Munsell 1939; Kotze and Deist 1975; Kotze and Joubert 1981; Selimi and Keatley 1970 and Woodhouse 1956). Some benefit can be derived from surface applied lime if calcium deficiency is the major influence on yield depression, however if yield depression results from raised toxic ion concentration then little benefit is observed beyond depth of incorporation (Farina and Cahannon, 1988).

The availability of phosphorus to vines is a major problem particularly in regions with acidic soil types. Recent collation of soil sample results from the AgPlus laboratory indicated that 88% of samples had marginal to deficient levels of phosphorus (J Whiting, unpublished data). The availability of phosphorus is reduced when soil pH falls below a value of about 5.5 (Sumner *et al* 1991) due to adsorption reactions. Phosphorus tends to penetrate soil very slowly if at all (Woodhouse 1956). Previous research on vines in soil with neutral pH has shown that phosphorus movement was limited to the top 0-15 cm 3 years after 1.0t/ha superphosphate application (Robinson and McCarthy, 1986). Phosphorus movement in acidic soils will be even less due to greater levels of phosphorus fixation occurring.

Earthworms and other soil macroflora can influence the distribution and availability of amendments and nutrients in soil. The concentration of plant nutrients in earthworm casts often exceeds that present in the total soil (Barley 1961). Earthworms have also been demonstrated to alter soil pH in one instance to neutrality irrespective of initial soil pH (Salisbury 1924) and by raising the pH of acid soil (Leger and Millette 1977). Earthworms and macroflora populations tend to decline when soil pH falls below 5.5 (in water). One possible technique for re-establishing earthworms, to be investigated in this project, is to surface apply lime and then apply an organic mulch to create more favourable conditions. The project will also evaluate an earthworm species which has been selected for tolerance to acidic conditions.

An understanding of the effects of earthworms and other soil macroflora on the mobility of lime and phosphorus is required to develop a sustainable soil management system for vineyards established in acidic soils. The soil management techniques proposed in these experiments will have other beneficial effects on soil structure, water utilisation and nutrient availability and will have an impact on the yield of existing and future vineyards.

The mulch treatments will give information that will aid in the development of techniques for establishing and maintaining soil macroflora populations in established vineyards and to determine yield effects for the mulch treatments alone.

OBJECTIVES OF PROJECT

The objectives of the proposed research are to develop management techniques that will assist in the development of a sustainable soil system. The individual objectives are:

1) To determine the effect of earthworms and other soil macroflora on lime and phosphorus movement in acidic soils in comparison with traditional soil management systems.

2) To determine the influence of organic mulches, herbicide strip and cover crop treatments on the establishment and maintenance of soil macroflora populations in acidic soil under vines.

3) To monitor vine performance under combinations of lime, phosphate, microflora and mulch treatments and to establish an improved optimal and sustainable soil management system under vines in acidic soil.

RESEARCH METHODOLOGY

Influence of mulch and earthworms on the incorporation of lime and phosphorus

Two trial sites were chosen with quite different soil types. One soil type was a yellow duplex soil classified by Northcote (1988) as Dy 3.41. This soil type is present in many "dryland" vineyard regions in Australia and is known for fairly permeable surface soils, low permeability of sub soil, acidic surface soil and low to very low fertility (mainly phosphorus and nitrogen). This trial site was located at Chateau Remy near Avoca, Victoria.

The second soil type chosen was a deep Krasnozem soil classified by Northcote *et al* (1975) as red rough-ped earths, Gn 4.11. This soil type is typical of the soils being used in some grape growing areas such as Drumborg and the King Valley and has characteristics such as well structured and friable, deep in high rainfall areas and naturally fertile. This trial site was at Hoddles Creek Vineyard in the Yarra Valley, Victoria.

Both soil types were tested for pH and phosphorus at several depths before treatments were applied. This was done to calculate the amount of lime and super phosphate needed to adjust pH and phosphorus concentrations up to acceptable levels.

At the Avoca site the vines used were 14 year old Cabernet Sauvignon planted with row spacing of 3.0m and vine spacing of 1.8m (5 vines per panel). The trellis system was a single bilateral cordon which was spur pruned and with no shoot positioning. The vines are not vigorous at this site. Vines are irrigated through a drip irrigation system.

At the Yarra Valley site the vines were 8 year old Pinot Noir planted with row spacing of 2.2 m and vine spacing of 1.5 m (4 vines per panel). The trellis system was a single wire bilateral cordon with spur pruning and vertical shoot positioning. The vines were relatively vigorous and on a steep slope. Drip irrigation is applied as necessary.

The treatments that were applied to each site were combinations of lime and superphosphate (LP), mulch (M) and added worms (W). In all, 8 treatments were applied as such:

1) lime and superphosphate
2) mulch
3) worms
4) lime and superphosphate and mulch
5) lime and superphosphate and worms
6) mulch and worms
7) mulch and worms and lime and superphosphate
8) control (no treatments)

Buffer panels were used between treatments.

The lime used was Kurdeez Agricultural Lime. The calculated rates needed to adjust the pH to 5.8 (CaCl) were made for a 1 m wide strip along the vine line and to a depth of 30 cm. At Avoca 1.0kg/m^2 (10t/ha) was applied in December 1992 and at the Yarra Valley site 2.0kg/m^2 (20 t/treated ha) was applied in January 1993.

The phosphorus concentration was adjusted to 20 μg/g (Olsen) with double superphosphate (18% phosphorus), again for 1m wide strip down to 30cm. This resulted in 70g/m^2 double superphosphate (695 kg/ha double superphosphate) at Avoca in December 1992 and 58g double superphosphate per m^2 (583 kg/ha double superphosphate) at Yarra Valley in January 1993.

Mulch was supplied as oaten straw at a rate of 2 bales per panel at each site. This equated to about 10t/ha straw at Avoca applied in December 1992 and about 20t/ha straw at Yarra Valley applied in January 1993.

Earthworms (*Aporrectodea trapezoides*) were collected from pasture sites and inoculated at 50 worms per panel. This equated to 18,000 worms/ha at Avoca and 38,000 worms/ha at Yarra Valley. Worms were added to the plots in June 1993. This species was chosen for its reputed ability to survive in acid soils and move lime to depth based on pasture studies.

At the trial sites, the movement of lime and superphosphate was monitored by measuring pH and phosphorus at various depths down the profile on an annual basis. Yields, fruit maturity and growth were also monitored apart from the Avoca site where the grapes were machine harvested by mistake in 1994. Leaf petioles were sampled to monitor vine nutrition concentrations. Three soil samples of 20cm x 20cm x 20cm each were taken in each plot in winter 1995 to assess earthworm populations.

The trial designs were based on randomised block design with nearest neighbour balance to allow for any changes along the vine row.

Results were analysed using Genstat.

Production of mulch with various crops

This part of the project was undertaken at the Victorian College of Agriculture and Horticulture, Dookie Campus, now part of Melbourne University. The trial was in a block of 14 year old Tarrango vines planted on a spacing of 3.3 m by 1.8 m. The soil is described as a red smooth-ped earth (Gn 3.12) which are very friable, deep, highly fertile in the natural state and free drainage (Northcote *et al* 1975).

In May 1993 six treatments were applied to both sides of a panel of vines. The treatments were:

1) Control (bare soil)

2) Annual crop oats - "Mortlock" @ 67kg/ha

3) Permanent sward - 48% Perennial Ryegrass ('Yatsyn':'Victoria'), 48% Annual Ryegrass ('Stampede'), 4% Balansa clover @ 42kg/ha.

4) Deep rooted crop - Canola "Barossa" @ 8.5 kg/ha

5) Straw mulch

6) Volunteer plants

During sowing, double superphosphate was added at a rate of 70 kg/ha.

Buffer panels and rows were used between treatments and the treatments replicated 5 times. Soil tests determined that phosphorus concentrations were low and rates of double superphosphate at 60g double superphosphate/m^2 (0.58t double superphosphate/ha) were added to a 1m wide strip under the vine.

The interrow crops were slashed twice during the season, green matter collected and weighed, sub samples taken to determine dry weight and the green matter placed below the vine along the vine row. Vine yields and fruit maturity was determined. This aspect of the trial work was curtailed after one season due to reductions in funding.

DETAILED RESULTS

Influence of earthworms and mulch on movement of superphosphate and lime in vineyard soils

Movement of phosphorus down the profile

The soil phosphorus concentrations down the profile before the treatments were applied are presented in Figure 1. Since there were no significant differences between treatments the mean of all plots is presented. Also the phosphorus data variance increased with increasing mean and a log transformation was used to stabilise the data. The phosphorus data at the Yarra Valley site revealed a number of very high values (up to 330μg/g) below 30cm. This indicated that phosphorus had been deep ripped in the block in the past. The quite low concentrations on the surface indicated no phosphorus had been spread over the surface. The deep ripped phosphorus does not interfere with the monitoring of surface applied phosphorus for our experiment. These high values (outliers) have been deleted from the data analysis so as not to confound the monitoring of phosphorus movement.

Both sites showed soil phosphorus concentrations in the deficient range and there was a steady decrease in concentration down the profile.

The phosphorus concentrations in the soil at both sites after one season (12 months) are presented in Figures 2 and 3 for the main plot effects. Significant interactions between the main treatments were rare and did not appear relevant.

At the Avoca site a significant increase in soil phosphorus was apparent down to the 20-30cm depth for the lime and phosphorus treatment although the values were still low and in the deficient range. Only the top 0-5cm had been brought up into an adequate range. Adding mulch significantly increased the phosphorus concentration down to the 5-10cm depth. Adding worms significantly decreased the phosphorus concentration in the 0-5cm depth.

At the Yarra Valley site adding lime and phosphorus significantly increased the soil phosphorus only at 30-40 cm and 40-50 cm depth. Also adding mulch significantly decreased soil phosphorus only at 40-50 cm depth. It is not clear how these results occurred but working with such low concentrations of phosphorus if some of the deep ripped phosphorus had been sampled it would have unduly influenced the results.

After two seasons a significant increase in phosphorus was evidenced down to the 5-10cm depth (Figures 4 and 5) at both sites from the surface applied lime and phosphorus. Again, some differences were noted at the greater depths at the Yarra Valley site probably due to the deep ripped superphosphate.

Interpretation of the interactions table reveals that combining mulch with lime and phosphorus or worms did not enhance the movement of phosphorus.

Lime movement

The initial soil pH levels down the soil profile (Figure 6) show moderately to highly acid soils. At Avoca pH was lowest at the 5-10 cm zone and then gradually increased with depth. However, at Yarra Valley pH steadily decreased with depth.

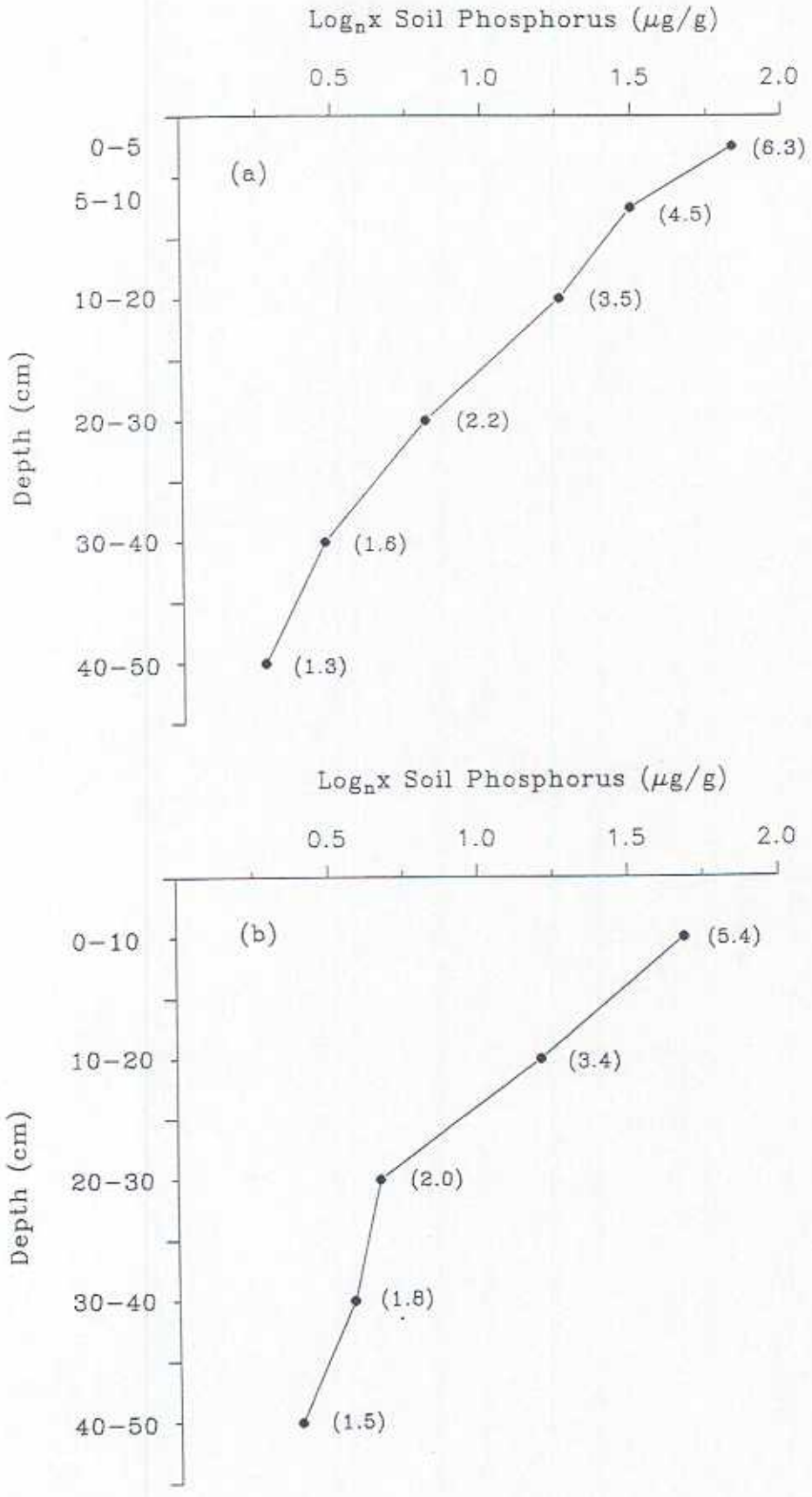


Figure 1. Soil Phosphorus concentration down the profile at Avoca (a) and the Yarra Valley (b) before treatments were applied. Mean of all plots. Values in brackets are retransformed means.

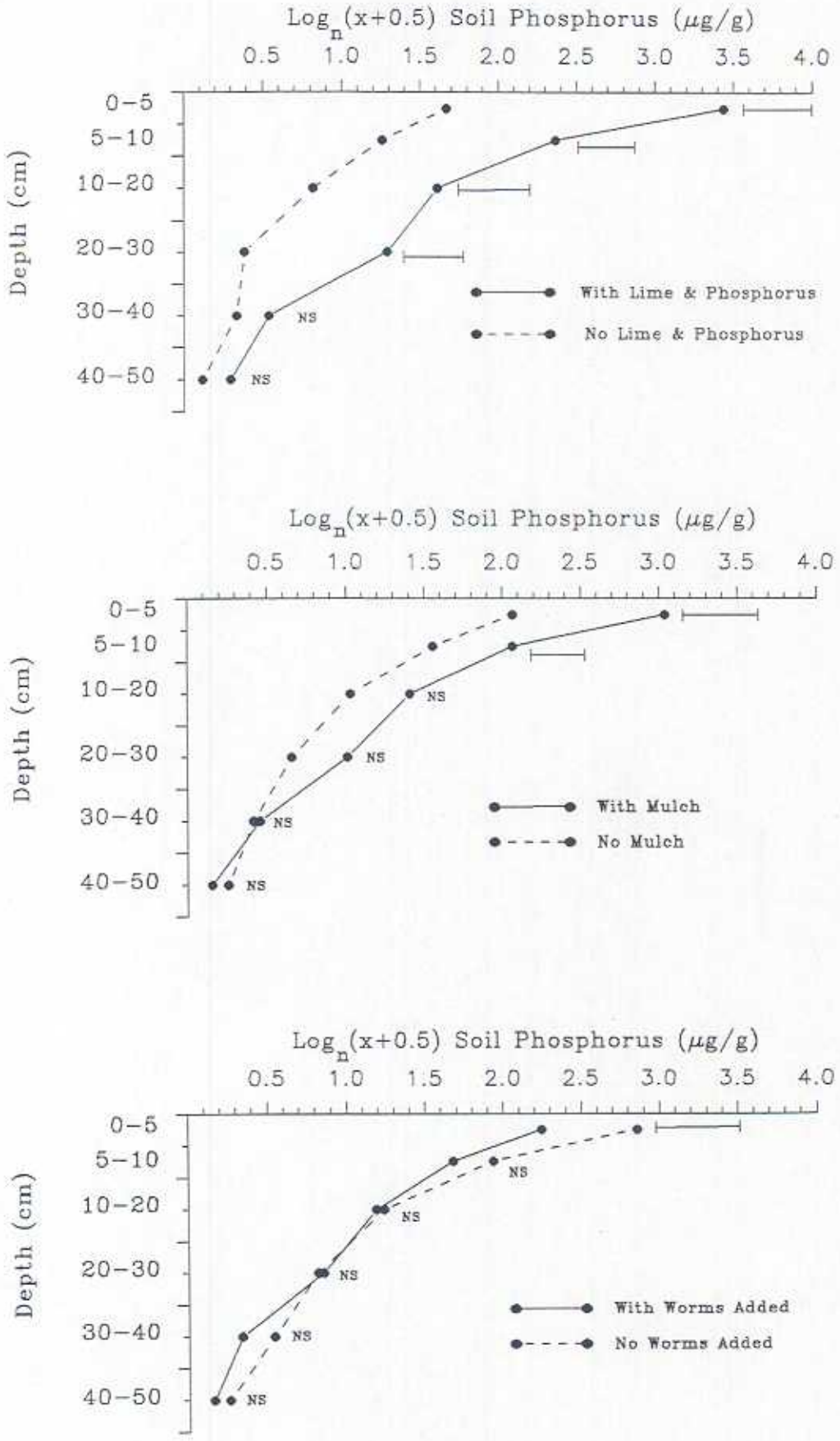


Figure 2. Soil Phosphorus concentrations down the profile for the main treatment effects at Avoca after one season. (⊢⊣ error bar with LSD of 5%, NS not significant).

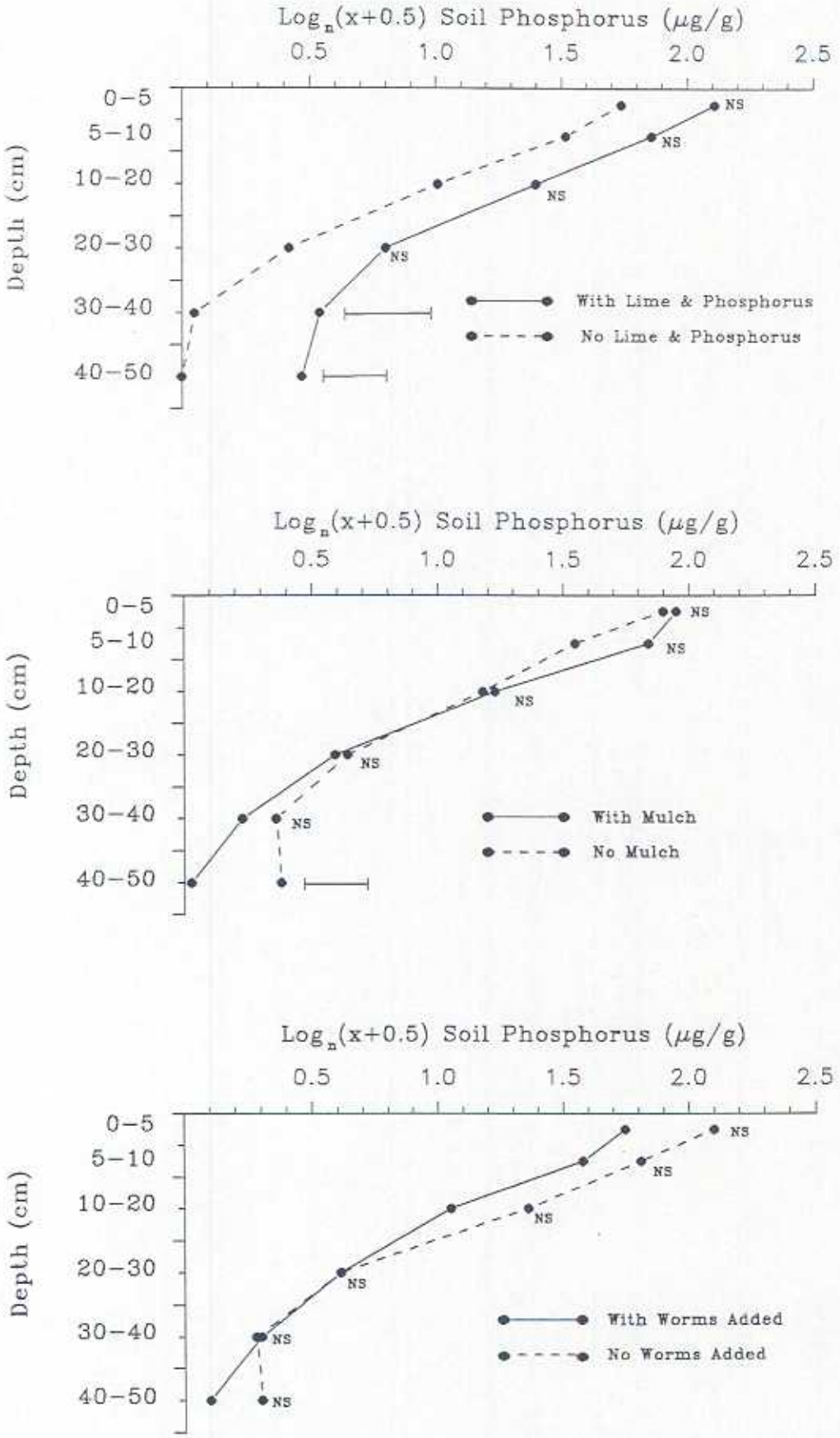


Figure 3. Soil phosphorus concentrations down the profile for the main treatment effects for the Yarra Valley after one season. (⊢⊣ error bar with LSD of 5%, NS not significant).

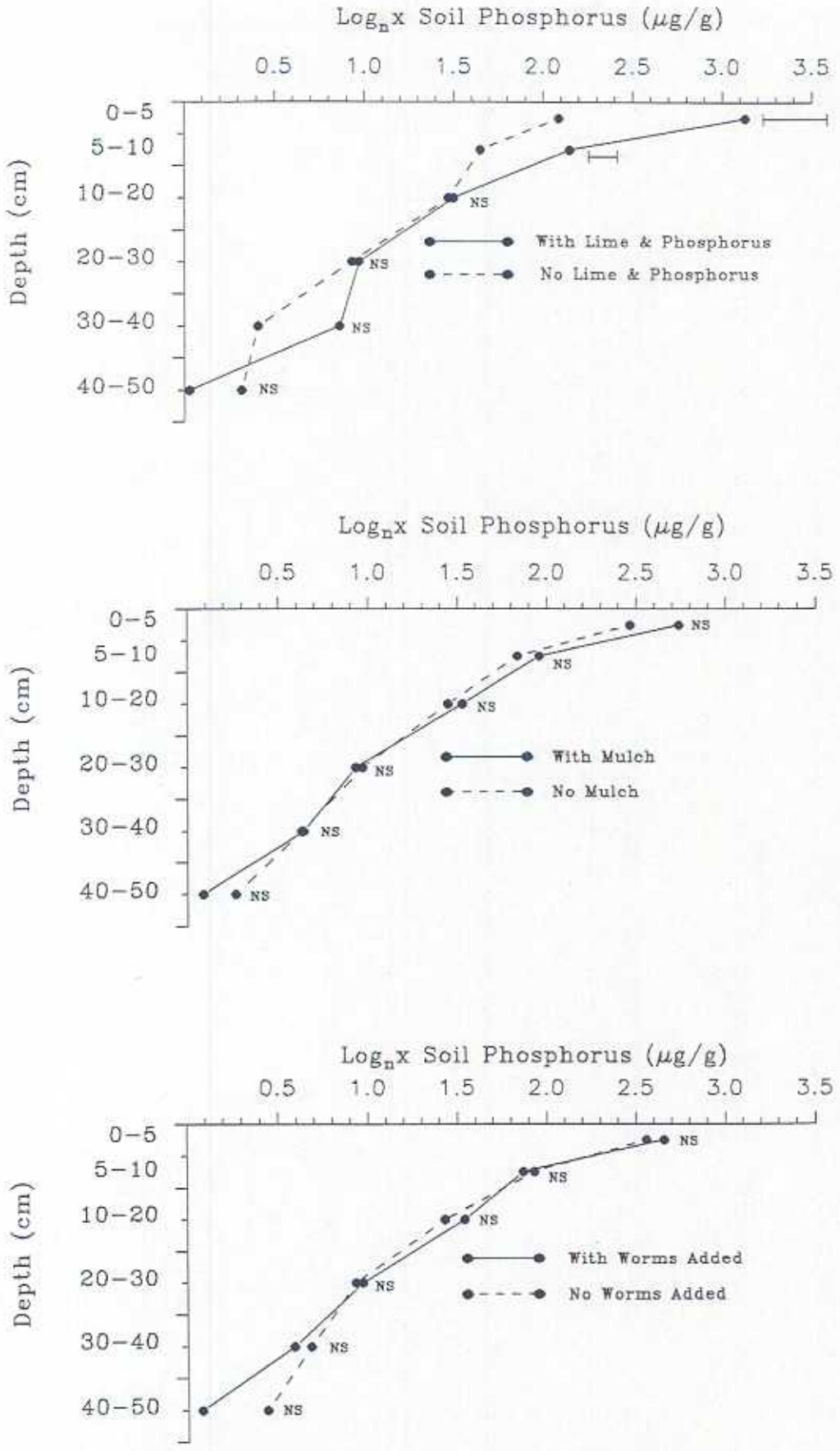


Figure 4. Soil phosphorus concentrations down the profile for the main treatment effects at Avoca after two seasons. (⊢⊣ error bar with LSD of 5%, NS not significant).

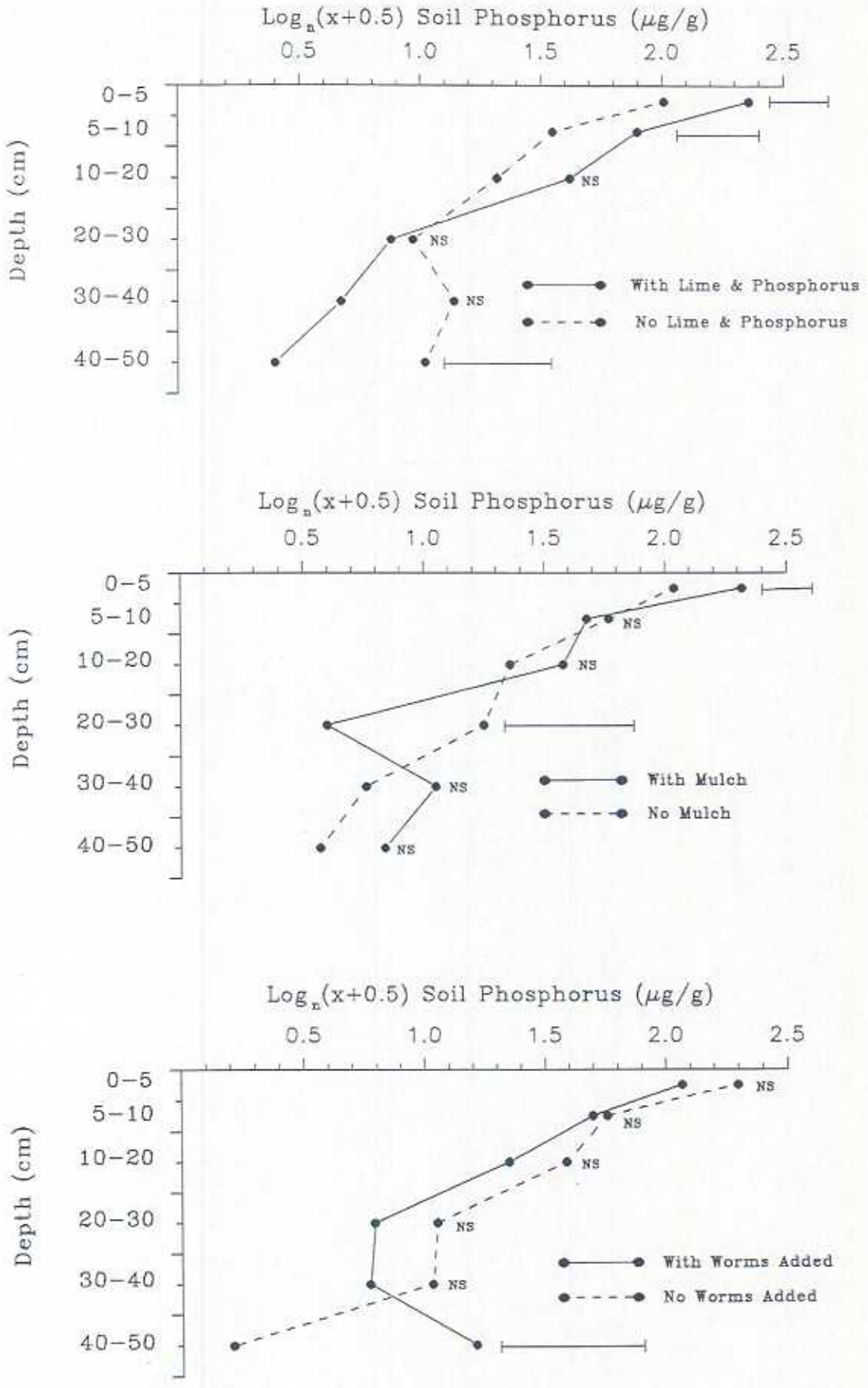


Figure 5. Soil phosphorus concentrations down the profile for the main treatment effects for the Yarra Valley after two seasons. (⊢⊣ error bar with LSD of 5%, NS not significant).

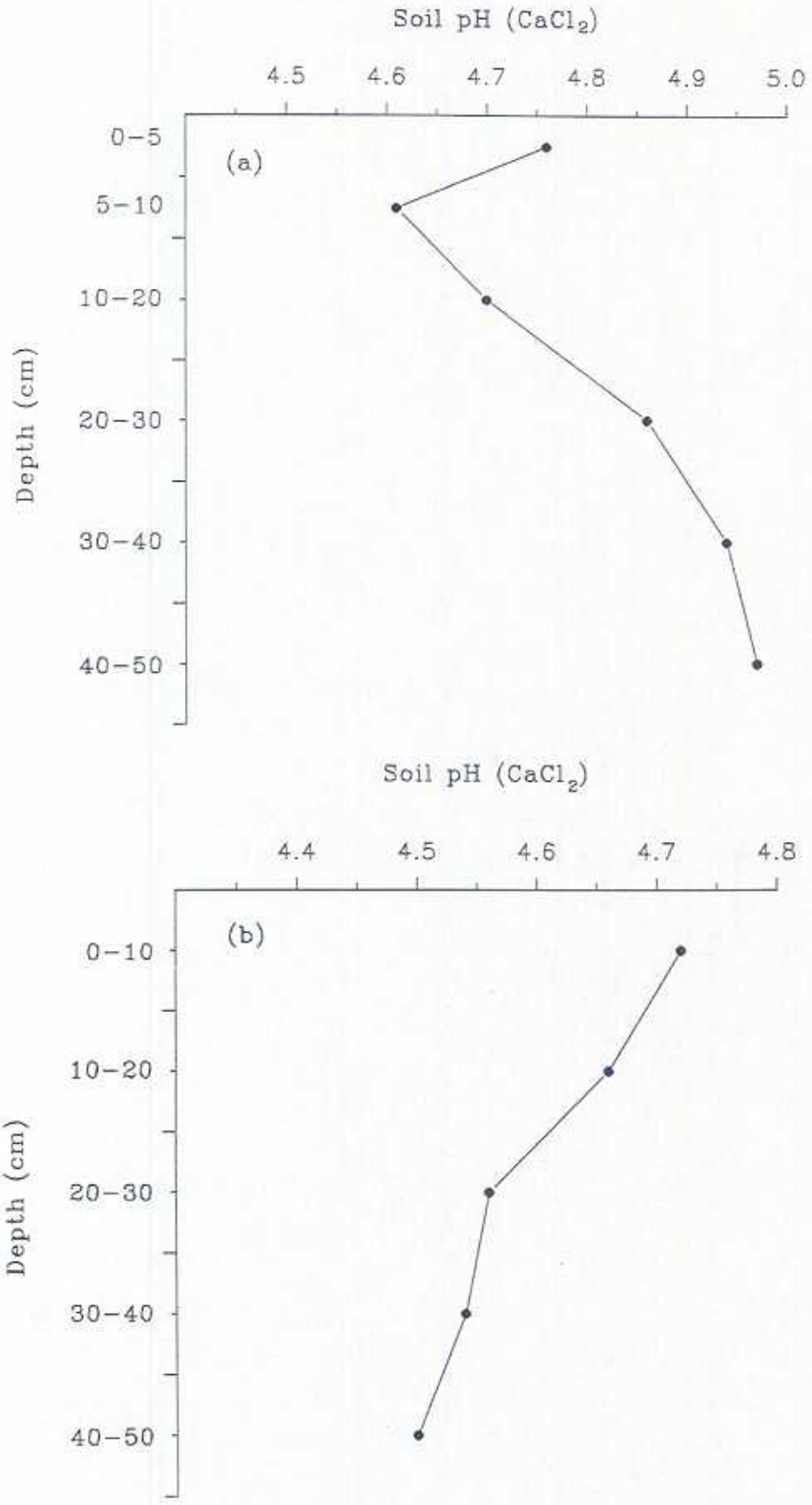


Figure 6. Soil pH down the soil profile at Avoca (a) and the Yarra Valley (b) before treatments were applied. Mean of all plots.

Twelve months after the application of lime there was an increase in pH under the lime treatment down to the 10-20 cm zone at both sites (Figures 7 and 8). Soil pH was brought back to an adequate level (ie > pH 5.3) down to the 5-10 cm depth. Mulching had no effect at Avoca but at the Yarra Valley the pH was reduced at the 10-20cm and 30-40cm depths. The addition of worms tended to lower the soil pH at both sites but the effect was only significant at the 5-10cm depth at the Avoca site.

After two seasons the addition of lime had maintained a significant effect down to the 10-20 cm depth at both sites (Figures 9 and 10). Again mulch tended to lower the soil pH but only significantly at the Avoca site at the 10-20 cm depth. The addition of worms had no significant effects at Avoca and only at 40-50 cm depth at the Yarra Valley.

Again, there were some interactions between the main treatments at some depths but there was no clear trend of one treatment enhancing or negating another.

Vine petiole nutrients

Petiole analysis results at flowering before the treatments were applied are presented in Table 1. No treatment differences were detected and the results are pooled over all plots.

TABLE 1: Vine petiole samples before treatments were applied at Avoca
[a]Based on Robinson, 1986 and Conradie, 1986

	AVOCA		YARRA VALLEY	
Nutrient (unit)	Mean of all plots	Interpretation[a]	Mean of all plots	Interpretation[a]
Sodium (%)	0.03	Normal	0.02	Normal
Potassium (%)	3.51	Adequate	1.52	Adequate
Calcium (%)	0.87	Marginal	1.28	Adequate
Magnesium (%)	0.52	Adequate	0.84	Adequate
Manganese (μg/g)	266	Adequate	132	Adequate
Total nitrogen (%)	0.97	Adequate	1.02	Adequate
Nitrate (μg/g)	22	Deficient	406	Marginal
Phosphorus (%)	0.15	Marginal	0.12	Deficient

Most nutrients were in the adequate range. At Avoca, calcium and nitrate were deficient and phosphorus marginal (but close to deficient). At the Yarra Valley nitrate was marginal and phosphorus deficient.

For comparing treatment effects after one and two years, the nitrate data required a log transformation. Only the significant results are reported here.

The lime and phosphorus treatment produced a significant increase in calcium and magnesium after 2 years at Avoca (Table 2) and a decrease in manganese and nitrate after one season at Yarra Valley.

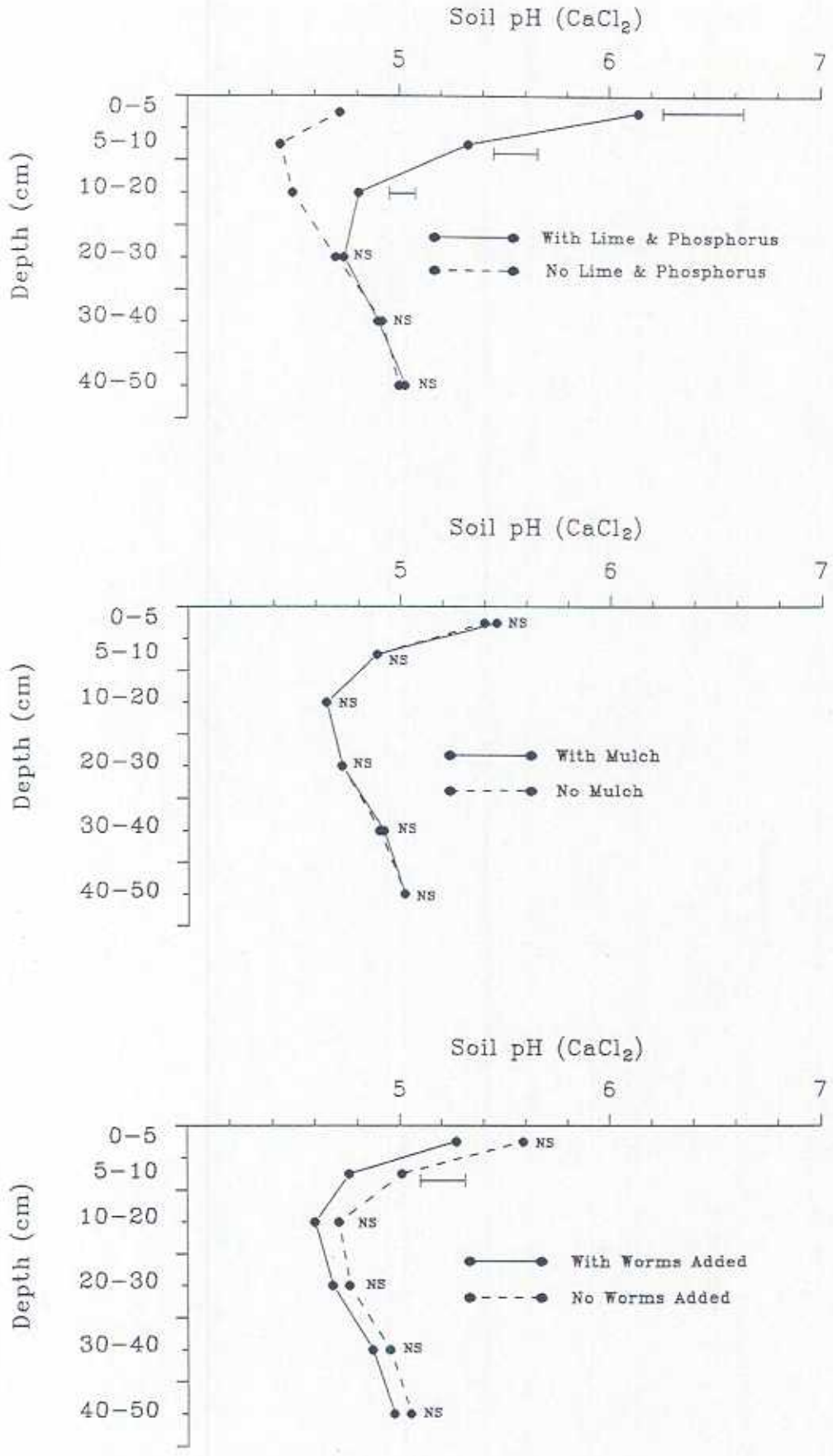


Figure 7. Soil pH down the profile for the main treatment effects at Avoca after one season. (⊢ error bar with LSD of 5%, NS not significant).

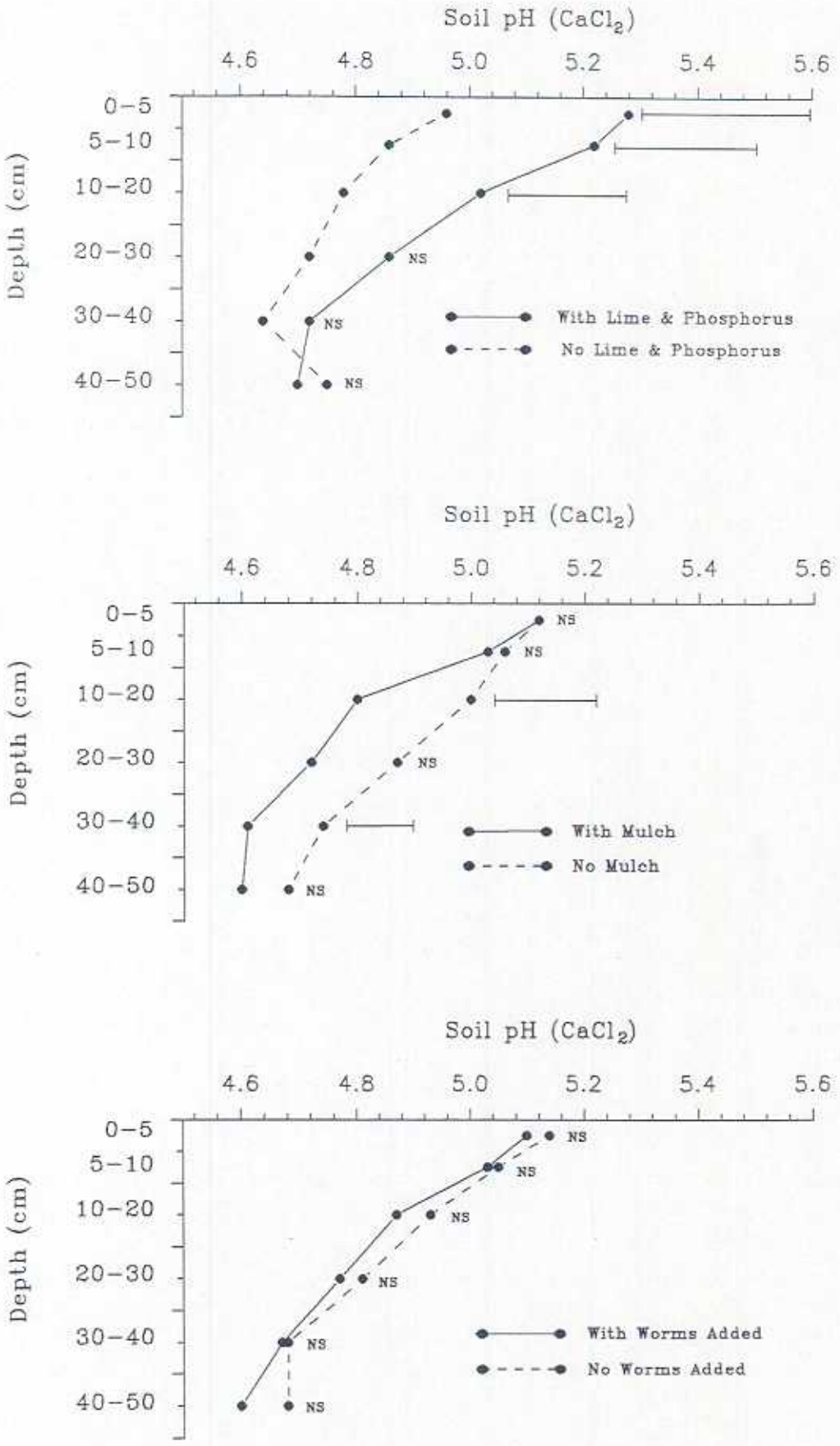


Figure 8. Soil pH down the profile for the main treatment effects for the Yarra Valley site after one season.
(⊢⊣ error bar with LSD of 5%, NS not significant)

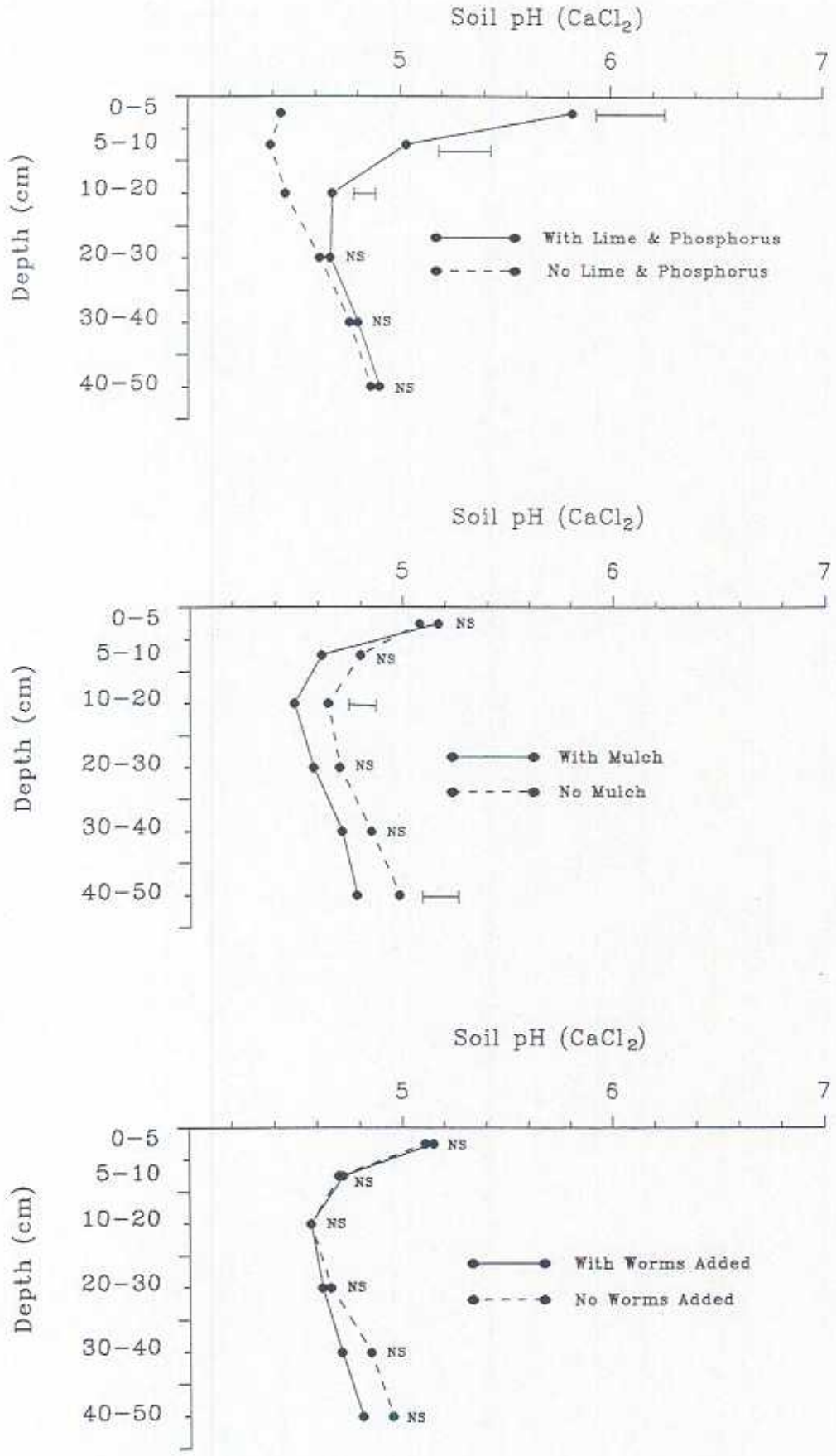


Figure 9. Soil pH down the profile for the main treatment effects at Avoca after two seasons. (⊢ error bar with LSD of 5%, NS not significant).

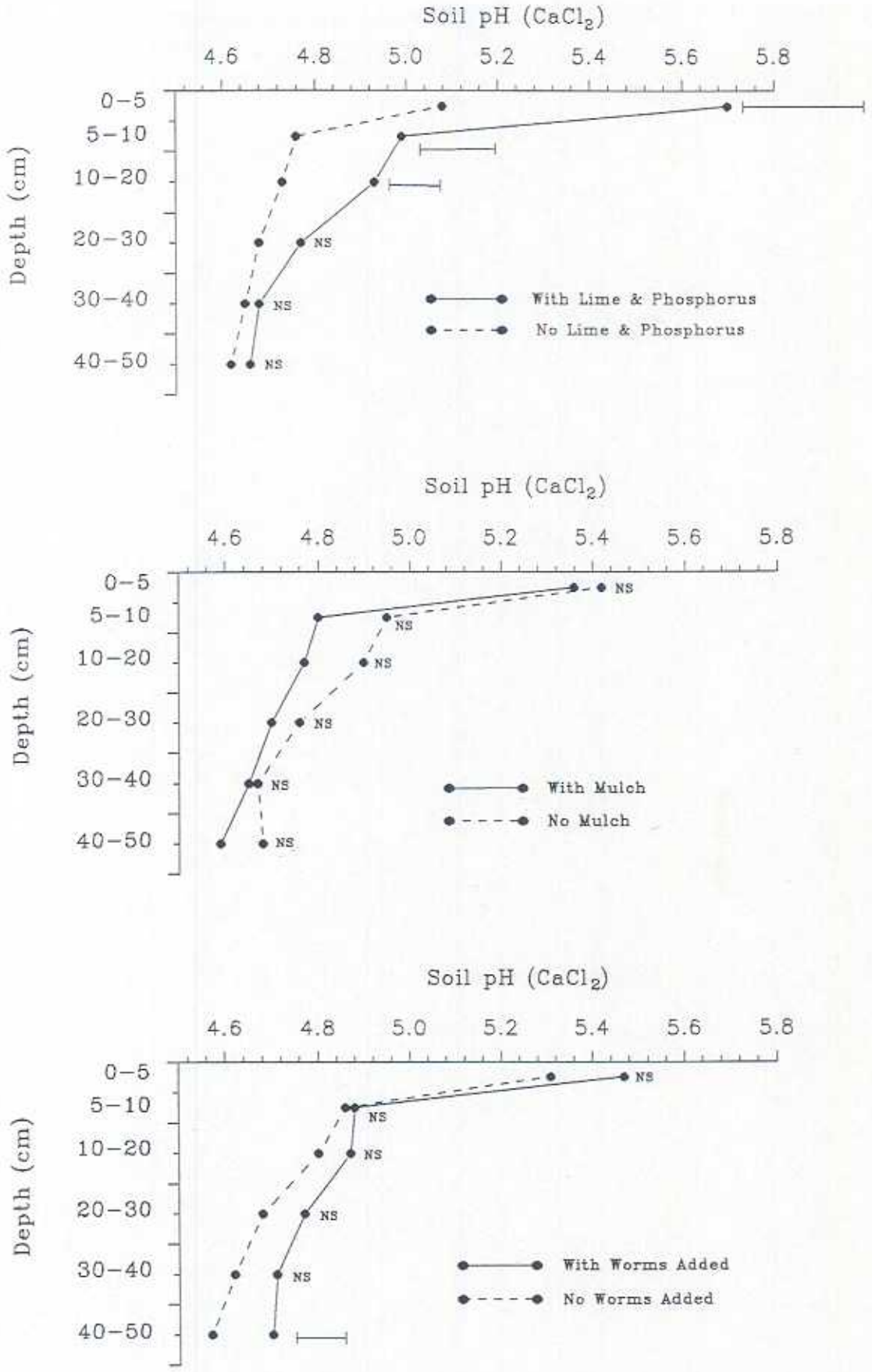


Figure 10. Soil pH down the profile for the main treatment effects for the Yarra Valley site after two seasons.
(⊢⊣ error bar with LSD of 5%, NS not significant).

TABLE 2: Vine petiole testing results where significant differences were obtained

		Treatment	Result		
			Treatment added	Treatment not added	LSD (P<0.05)
AVOCA	*After one season*				
	Nitrate (lnx) μg/g	Mulch	5.93	5.11	0.63
	After two seasons				
	Calcium %	L+P	0.98	0.86	0.07
	Magnesium %	L+P	0.58	0.51	0.05
	Potassium %	Mulch	3.73	4.02	0.27
	Total nitrogen %	Mulch	0.64	0.60	0.03
	Nitrate (lnx) μg/g	Mulch	6.79	6.10	0.14
YARRA VALLEY	*After one season*				
	Manganese μg/g	L+P	80.4	89.6	6.7
	Nitrate (lnx) μg/g	L+P	7.69	7.93	0.21
	Nitrate (lnx) μg/g	Mulch	7.97	7.65	0.21
	Potassium %	Mulch	2.72	2.38	0.17
	Calcium %	Mulch	1.42	1.36	0.06
	Total nitrogen %	Mulch	1.59	1.43	0.16
	After two seasons				
	Potassium %	Mulch	2.19	1.85	0.24
	Total nitrogen %	Mulch	1.11	1.03	0.07
	Nitrate (lnx) μg/g	Mulch	7.70	7.35	0.25

The mulching treatment produced most of the responses in both seasons. Nitrate was increased with mulch at both sites. Total nitrogen was increased by mulch at the Yarra Valley site in year one and at both sites in the second season. Mulching decreased the potassium at the Yarra Valley site in both seasons. Mulch also increased the calcium concentration in the Yarra Valley site after one season.

There were no significant interactions between treatments in either year at the Yarra Valley site. However, at Avoca in years one and two the combination of lime and phosphorus and worms did not produce the greatest petiole calcium value as expected. Also, after the second year at Avoca mulching combined with a no treatment of lime and phosphorus did not reduce sodium and potassium as expected.

Harvest and maturity data

At the Avoca site harvest data at the end of the first season, ie five months after the treatments were applied, showed no significant differences between any treatments and no significant interactions between treatments. For the 1995 harvest significant differences were detected with the mulching treatments. Adding mulch significantly increased yield, bunch number per vine, bunch weight and berry weight (Table 3). There was a significant decrease in soluble solids and no difference in berries per bunch or pruning weight.

TABLE 3 - Yields at Avoca - 1995

	With mulch	No mulch	LSD P<0.05
Yield (kg/vine)	2.73	1.87	0.30
Bunch number per vine	45.1	37.2	3.9
Bunch weight (g)	60.1	49.7	5.1
Berry weight (g)	0.87	0.77	0.03
Berries per bunch	69	65	NS
Soluble solids (°Brix)	26.7	27.1	0.3
Pruning weight (kg/vine)	0.6	0.5	NS

There were no significant main plot effects in the second and third harvests from the Yarra Valley. There was an occasional significant interaction but again, no clear reasons were evident. A summary of the Yarra Valley data is presented in Table 4.

TABLE 4: Yields at Yarra Valley - mean of all plots

	1993	1994	1995
Yield (kg/vine)	4.7	2.3	3.9
Bunch number per vine	45	39	30
Bunch weight (g)	105.3	60	129
Berry weight (g)	1.41	1.02	1.85
Berries per bunch	74.7	59.3	70.2
Soluble solids (°Brix)	21.9	20.1	19.0

Worm assessments

In Winter 1995 at the completion of the trial, each plot was sampled for earthworms. The numbers of eggs and number of juvenile, immature and adult stages of the various species were recorded.

The species of earthworms detected were *Aporrectodea trapezoides, Aporrectodea rosea, Aporrectodea caliginosa* and *Lumbricus rubellus* at both sites. *Allolobophora chlorotica* was also present at Avoca and *Octolasion cyaneum* was present at the Yarra Valley.

Some plots that had been inoculated with *Aporrectodea trapezoides* no longer had any present at the end of the experiment. Thus the worms had either migrated or been killed off by the conditions.

At Avoca the mean abundance of worms were *A. caliginosa* (34.9/m^2), *A. trapezoides* (15.8/m^2), *A. rosea* (11.8/m^2), *A. chlorotica* (10.6/m^2) and *L. rubellus* (1.6/m^2) averaged over all plots. In the Yarra Valley the numbers of worms averaged over the trial site was lower. *A. caliginosa* was most abundant at 24.0/m^2 followed by *L. rubellus* (17.9/m^2), *A. chlorotica* (3.0/m^2), *A. trapezoides* (1.6/m^2) and *O. cyaneum* (0.5/m^2).

It was also clear that the numbers for each species varied between the blocks laid out in the trial. At Avoca, *A. trapezoides*, *A. rosea*, *L. rubellus* and *A. chlorotica* preferred the lower end of the rows where the soil was slightly wetter and *A. caliginosa* preferred the upper end of the rows where the drainage was better and the soil contained some buckshot. At the Yarra Valley site all species preferred the upper end of the rows and very few worms (average 1.0/m^2) were present in the lower half of the experimental block.

At the Yarra Valley site, where a permanent grass sward was grown, the worm numbers were approximately 150-200/m^2 between the rows.

To analyse the influence of the soil treatments on worm numbers the numbers of each species were pooled, since some species were absent from many plots. Also a square root transformation was used on the data to reduce the variance which was much greater than the treatment means.

The addition of lime and phosphorus and mulch at the Avoca site significantly increased the total worm numbers. The retransformed means showed that lime and phosphorus increased the population by 2.5 fold and mulch increased the population by 5 fold. The treatment where worms were added showed no increase. The combination of lime and phosphorus with mulch produced the greatest population of worms (Figure 11).

At the Yarra Valley site only the lime and phosphorus treatment produced a significant increase in the worm population by a factor of 1.8 over no lime and phosphorus treatment. Mulch tended to decrease worm counts and the worms added treatment tended to increase the worm counts, neither significantly. The combination of lime and phosphorus and added worms gave the greatest population of worms (Figure 12).

FIGURE 11. WORM COUNTS AT AVOCA
LP=Lime&Phosphorus, M=Mulch, W=Worms

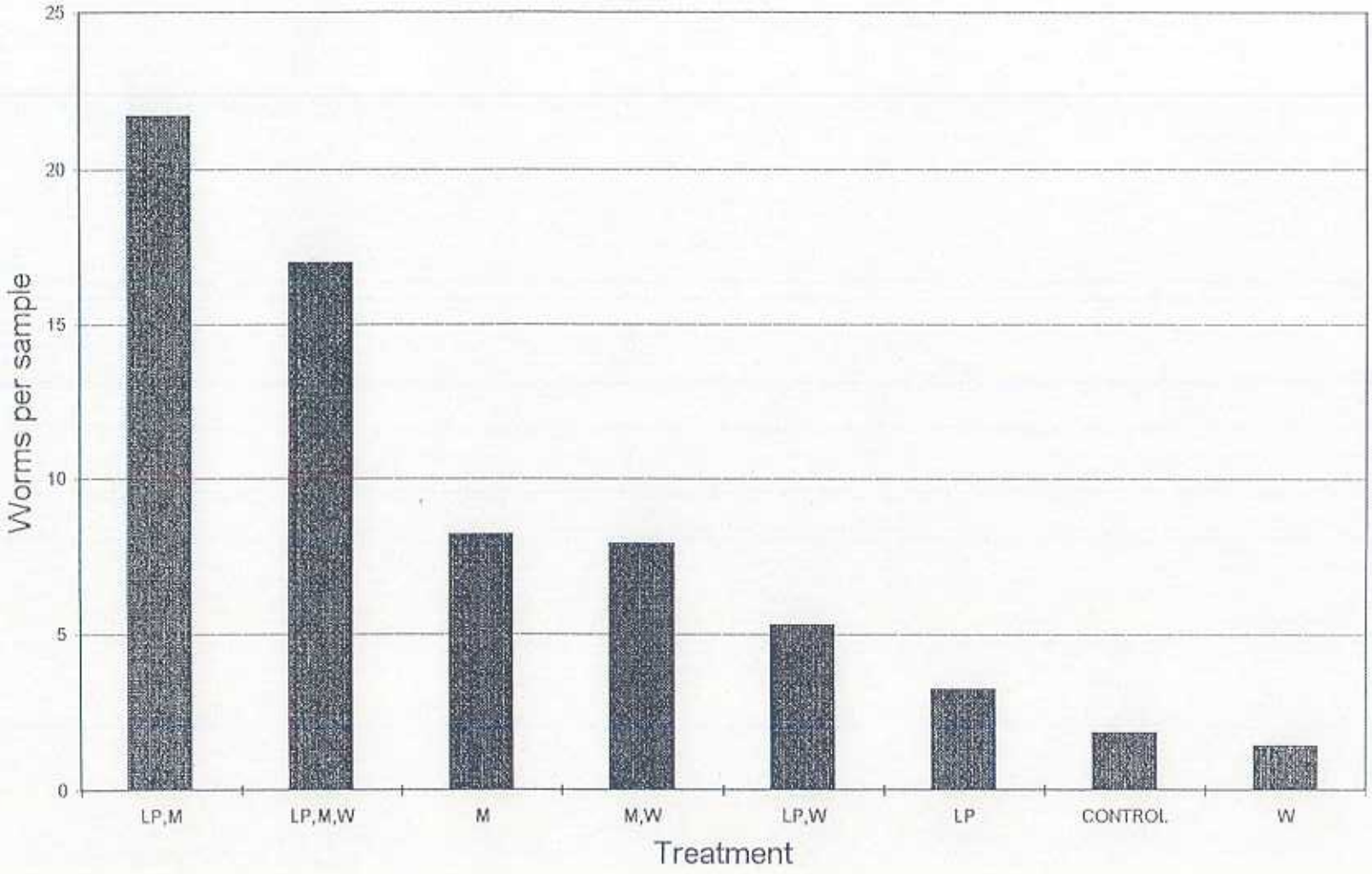
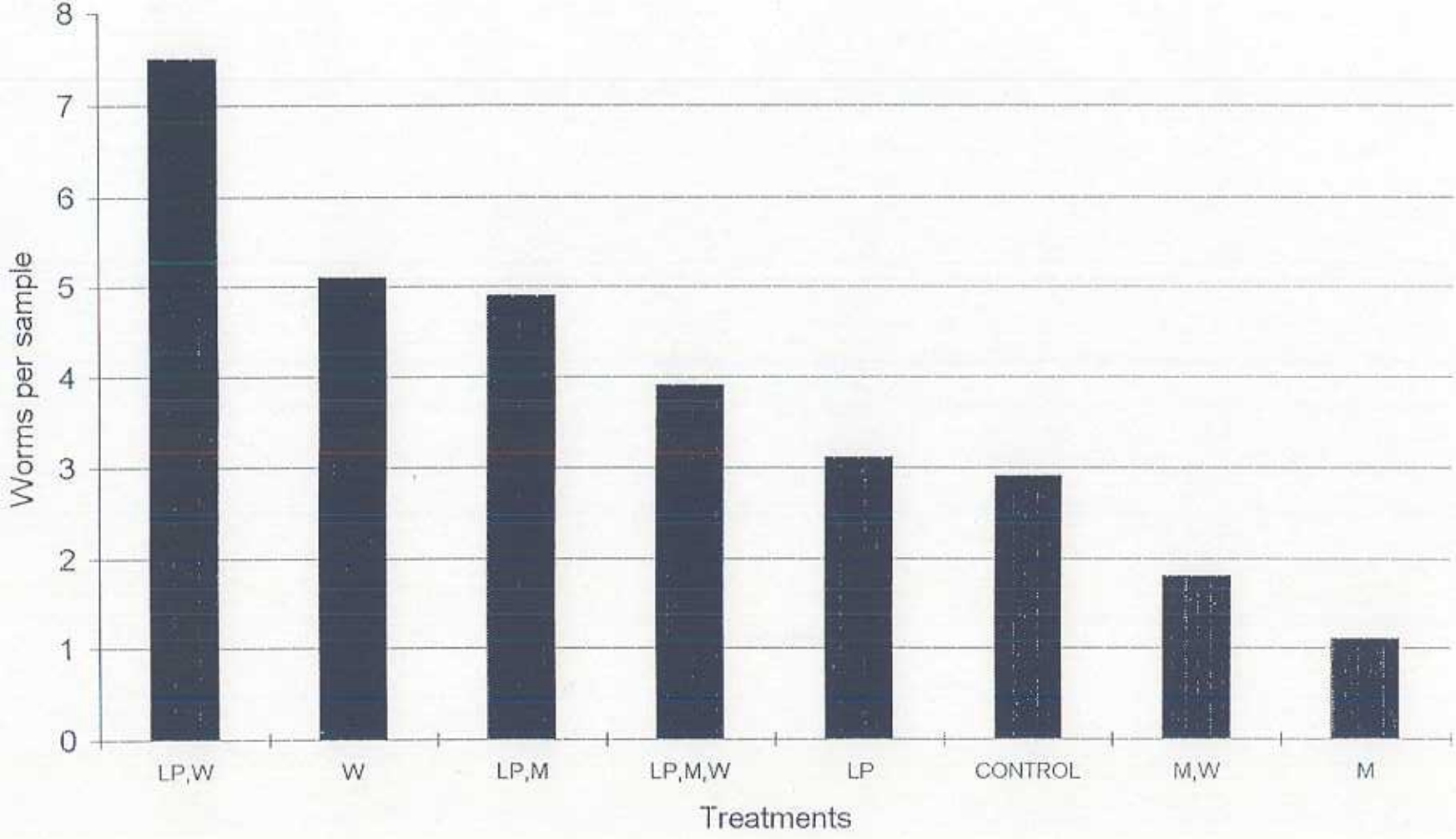


FIGURE 12. WORM COUNTS AT YARRA VALLEY
(see figure 11 for treatment code)



Dry matter production between vine rows

Dry matter from cover crops

The annual oat crop produced the greatest amount of dry matter (2.4t/ha DW) after one season. Production from the other systems was 1.7t/ha DW from grass sward, 0.9t/ha DW from Canola and 0.3t/ha DW from the volunteer plants. The straw mulch was applied at a rate of 11t/ha DW and the control treatments produced no organic matter.

Vine response

There were differences in yield but none were significant. The annual oat crop and the Canola treatment (which was planted undervine) gave the lowest yields. Bunch numbers per vine were quite even across the treatments. There were no significant differences in bunch weight, berry weight, berry number per bunch or sugar level.

DISCUSSION

The initial soil pH and phosphorus concentration were well below acceptable values for the two widely different soils studied. Many soil samples processed over a three year period by AgPlus had lower than desired phosphorus and pH values. About 75% of the samples were in the moderate to highly acid range and 88% of samples had phosphorus values in the marginal to deficient range (Whiting, unpublished). Thus, the problem of low phosphorus and pH is a widespread one.

Soil phosphorus values became lower with increasing depths in the soil at both sites. At the 40-50cm depth values were about ¼ of the upper surface values. Thus any deeper roots would not have much access to soil phosphorus. The sampling at the Yarra Valley site revealed that phosphorus had been deep ripped into the block in the past. This was not known at the time the trial site was chosen. The sampling has confirmed the presence of phosphorus below 30cm, but the detection was not even. Sinclair *et al* (1992) was unable to detect banded superphosphate in a vineyard in the MIA but the sampling conducted in our trial was able to detect deep ripped superphosphate. The average soil phosphorus results, with the high values included, showed phosphorus values up into the adequate range. No deep ripped phosphorus was detected at the Avoca site which matches the history of the block of vines provided to us.

There was a difference between the two sites for soil pH. In the Yarra Valley the soil pH continued to get lower with increasing depth but at Avoca after reaching a minimum pH at 5-10cm depth, soil pH increased (although still moderately acid) with increasing depth. This may relate to the origin of the soil and different amounts of rainfall at the two sites with the higher rainfall on the Yarra Valley producing more leaching and acidification.

The greatest treatment effect came from the lime and phosphorus additions to the surface. At both sites phosphorus moved down about 5-10cm and lime about 10-20cm. These depths of movement are similar to previous work, eg Robinson and McCarthy 1986 for phosphorus and McNab 1994 for lime.

It is clear that at the Yarra Valley site with the placement of superphosphate at depths of 30-50cm, the vines were not accessing the phosphorus because petiole levels were still low-deficient. Perhaps there is no feeder root growth at that depth and hence uptake is not occurring. Shallow placement of the phosphorus may be more desirable. Responses to phosphorus addition have been variable, eg Soderland *et al* (1988) reported no increase in petiole phosphorus after just over 2 years with superphosphate additions of up to 4.9t/ha.

The movement of lime and phosphorus did not influence yield or maturity. Some influence on petiole nutrients was observed but it is probable these responses were due to the lime component of the lime and phosphorus mix. There was no response in vine petiole phosphorus values even though the vine petioles were in the marginal-deficient range. Not all surface applied lime and phosphorus remained on the soil surface in the undervine band. Where mulch was not applied the lime and phosphorus appeared to remain in clumps with some apparently being washed off the undervine bank by rainfall. Under the mulch treatment lime and phosphorus remained evenly spread over the surface. Soderland *et al* (1988) reported no yield response to the addition of superphosphate at rates up to 4.9t/ha.

Neither mulching nor added worms enhanced the movement of surface applied lime or phosphorus. Also there were no clear and consistent interactions between the main treatments. The worm treatment may have had limited effects due to the very dry winter period in 1994. At both sites the worm species (*A. trapezoides*) added to the plots was not the dominant species, suggesting that its numbers dropped back

during the trial period. Although there was evidence of worm activity particularly under the mulch and also with non-mulched treatments it was perhaps not deep enough to ensure mixing of lime and phosphorus. Whilst numbers of worms were greatest under mulch at Avoca and lime and phosphorus treatments at both sites, they were mainly confined to the top 10-15cm of soil at both sites.

Although *A. Trapezoides* is described as a deep burrowing earthworm for pasture situations it is not deep enough for grapevine root systems. Another species of worm may have been more appropriate. So the main reasons for the lack of response to worms were the particularly dry winter of 1994 limiting activity and the relatively shallow burrowing habit of the worms.

There was a vine response to mulching at the Avoca site. This response was consistent with other work (Walpole *et al* 1993, Whiting and Orr 1994) and is related to moisture conservation in an area of limited rainfall. In the Yarra Valley where rainfall is high, mulch did not influence yield, although the status of some nutrients was changed. It is often noted that adding mulch depletes the nitrogen available to the vine but this was not seen in this trial nor earlier work (Whiting and Orr 1994, Sinclair *et al* 1994). Where normal amounts of nitrogen are applied to maintain healthy growth there appears to be no lack of nitrogen for the vine.

The mulch added in these and other experiments generally lasts about three years. This equates to a rate of loss or breakdown of about 3.5t/ha DW per year. None of the cover cropping treatments were able to replace this amount of organic matter in the one year the trial was conducted. The autumn break in that year was quite late (late May) and the plots made limited growth during the season. Also the grass sward was less than one year old and not a maximum production of dry material. Other work on cover cropping in the Grampians region has produced dry matter rates of between 4 and 6t/ha DM for oats and cereal rye respectively (Orr, pers comm). It would appear that in a good season or where irrigation can be used to start a cover crop early the amount of dry matter produced each year could be enough to maintain a straw mulch after an initial application of straw.

In a dry region the mulch improved the number of earthworms by 5 fold but tended to depress worm numbers in the higher rainfall sites, although not significantly. The latter result is unexpected because the organic matter was expected to encourage the build up of worms. It may be that mulch kept the soil too wet and discouraged the worms from breeding. The addition of lime and phosphorus encouraged the worm populations at both sites by between 1.8 and 2.5 fold. This is probably a response to the change in pH in the upper 10-20cm profile of the soil. Adding worms at a rate of 18,000/ha at Avoca did not increase the worm numbers but adding 38,000/ha tended to increase final worm numbers at the yarra Valley site. However, the species that was added, *A. trapezoides*, was only present in very low numbers at the Yarra Valley site. Whilst *A. caliginosa* was abundant at both sites, the numbers of other species depended on the site.

IMPLICATIONS AND RECOMMENDATIONS

The impact of the treatments evaluated in this work was not as great as anticipated. Seasonal conditions, the short term nature of the work and the shallow burrowing nature of the earthworms contributed. The value of organic mulch and lime and phosphorus in increasing worm numbers has been clearly demonstrated, but differences between sites noted. Thus we can now provide better guidelines for those wishing to increase worm populations. There is also a better understanding of the earthworm species present in vineyards, but more studies are needed to distinguish 'deep' burrowing worms.

The clear advantage of mulch in lower rainfall areas has been demonstrated again. At Avoca the extra yield in 1995, a very dry season, would have increased income by about $2,000/hectare. This, however, does not allow for any changes in wine style due to the larger berries and later maturity. This extra income would have easily covered the cost of adding the mulch, which is around $1,000/ha for materials that last 3 years.

There was no clear advantage in adding mulch to the vines in a high rainfall area. The generally lower worm counts in the Yarra Valley site was a surprise, but the number of years of bare undervine bank may have contributed. There were many more worms in the interrow grass sward. Thus in wetter sites lime and phosphorus were more important than adding straw mulch. There is little benefit from adding straw mulch in a high rainfall area and soil organic matter should be maintained by mowing the interrow grass sward and throwing the organic material under the vines.

The deep placement of phosphorus prior to our experiment at the Yarra Valley in an acid soil did not correct a low to deficient concentration of phosphorus in the vine petioles.

TECHNICAL SUMMARY

The project did not pursue any patents or result in anything that could be licensed.

The project has yielded information that will have impact on the way soil management is approached. Some of the major findings were:

- not all sites will provide a yield response to the addition of straw mulch
- straw mulch will not always increase earthworm populations
- vineyard sites can differ markedly in the numbers of worms and species present
- the addition of a certain species of earthworm to a vineyard site does not necessarily mean it will breed and build up in numbers
- weed free undervine areas do not support high numbers of worms
- growth from annual cover crops or grass swards may not always be enough to sustain the loss of straw mulch
- variance with soil phosphorus data was relatively high and required log transformation

REFERENCES

Barley KP (1961). The abundance of earthworms in agricultural soil and their possible significance in agriculture. Adv. Agron. 13:249-268

Brown BA and Munsell RI (1939). Soil acidity at various depths as influenced by the time since application, placement and amount of limestone. Soil Sci. Soc. Amer. Proc. 3:217-221

Conradie WJ (1986) Norms for leaf analysis of vines. Farming in South Africa, Viticulture and Oenology pamphlet E24 (South Africa Department of Agriculture and Water Supply) 2pp

Farina MPW and Channon P (1988). Acid-subsoil amelioration 1. A comparison of several mechanical procedures. Soil Sci. Soc. Am. J. 52:169-175

Kotze WAG and Deist J (1975). Amelioration of subsurface acidity by leaching of surface applied amendments. A laboratory study. Agrochemphysica 7:39-46

Kotze WAG and Joubert M (1981). Effect of liming on growth, yield and fruit quality of sample trees in a field trial. Agrochemphysica 13:31-35

Leger RG and Millette GJF (1977). Properties of four Quebec soils after incubation with five species of earthworms. Can. J. Soil Sci. 57:165-172

McNab S (1994) Lime and soil acidity in vineyards. Aust Grapegrower Winemaker 366a:91-92, 94

Northcote KH, Hubble GD, Isbell RF, Thompson CH and Bettenay E (1975). A description of Australian soils. CSIRO

Northcote KH (1988). Soils and Australian Viticulture. In: BG Coombe and PR Dry (Eds) Viticulture. Volume 1. Resources in Australia. Australian Industrial Publishers Adelaide, p61-90

Robinson JB and McCarthy MG (1986). Methods of application of superphosphate in vineyards. Aust Grapegrower and Winemaker 274:14- 15

Robinson JB (1986) Fruits, Vines and Nuts. In: Rueter DJ and Robinson JB Eds. Plant Analysis - An interpretation manual. Melbourne Victoria, Inkata Press p120-147

Salisbury EJ (1924). J. Linnean Soc. (Bot) London 46:415-426

Selemi A and Keatley JC (1970). Effect of soil management, pH and fertilisers on Packham's Triumph and Josephine pear. Aust. J. Exp. Agric. Anim. Husb. 10:218-223

Sinclair PJ, Blakeney AB, Battern GD and Osborne GJ (1994). Petiole nutrient concentrations under different soil management regimes and suggested new technology for tissue analysis. In" Nutrient and fertiliser management in perennial horticulture. Proceedings of a workshop 15-16 June 1994, pp26-32

Sinclair P, McLachlan G, Osborne G and Boys A (1992). Soil phosphorus distribution in vineyard soils. Aust Grapegrower Winemaker 340:98,99,101

Soderland R, Orr K, Toomey MJ and Harding E (1988). Responses of Chardonnay grapevines grown on phosphorus-deficient soils to additions of superphosphate. Aust Grapegrower Winemaker **292**:5-7

Sumner ME, Fey MV and Noble AD (1991). Nutrient status and toxicity problems in acidic soils. In 'Soil Acidity' Ed. B Urlich & M.E. Sumner. Springer Verlag, Berlin.

Walpole MD, Whiting JR and Code GR (1993). An evaluation of mulches as substitutes for herbicides during vineyard establishment. In: Eds CS Stockley, RS Johnstone, PA Leske and TH Lee. Proceedings of the Eighth Australian Wine Industry Technical Conference. Winetitles, Adelaide pp100-104

Whiting J and Orr K (1994). Evaluating the use of organic mulch in a vineyard. In Nutrient and fertiliser management in perennial horticulture. Proceedings of a workshop 15-16 June 1994, pp103-109

Woodhouse WW (1956). Effect of placement and rate of phosphate, potash and limestone on the growth of alfalfa and lespedeza. Soil Sci. Soc. Proc. 20:15-18