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Fluid and Granular Fertilizers, Differences in Efficiency on Alkaline Soils

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Funds allocated by the Fluid Fertilizer Foundation were used in 2000 to conduct a series of experiments in controlled environment (growth chamber) conditions to test if the high efficiency of fluid fertilizers observed in the field on Eyre Peninsula (in South Australia) was mainly related to a placement effect and/or to a chemical effect. Experiments were also set up to measure the residual effects of fluid fertilizer compared to granular. Chemical analyses are currently in process. Our report this year is focussed on the determination of the relative importance of placement and chemical effects of fluid fertilizers in a range of soil types.

Soil types and characterisation:

Four different alkaline soil types were chosen. These soils were representative of three regions in southern Australia: Upper Eyre Peninsula (South Australia), the Wimmera (Victoria) and the Central Mallee (Victoria). These regions have a Mediterranean climate with mean annual rainfall ranging from 300 mm/year for Upper Eyre Peninsula to 500 mm/year for the Wimmera. Soils from Upper Eyre Peninsula were classified as Supravescent and Hypervescent Calcarosols (Isbell, 1996) and are colloquially named grey and red calcareous soils respectively in the present study. Soil from the Wimmera area was a cracking clay, classified as a Grey Vertosol (Isbell, 1996). Soil from the Central Mallee was a Sodosol. The soils were sampled to a depth of 10 cm and were air dried and sieved to < 2 mm before storing at room temperature prior to analysis.
A large range of chemical analyses were performed on these soils and the main results are summarised in Table 1.

Table 1: Typical soil properties of alkaline soils from southern Australia. Chemical characteristics reported are: organic carbon (Org. C), organic phosphorus (Org. P), Oxalate extractable aluminium and iron (Al and Fe-oxalate), total phosphorus in soil (Total P) calcium carbonate content ($CaCO_3$ %) and phosphorus buffer capacity (PBC).

	Upper Eyre Peninsula		Wimmera	Central Mallee
	Grey calcareous	Red calcareous	Cracking Clay	Sodosol
Org. C, %	1.2	0.7	1	0.7
Org. P, mg/kg	243	87	126	52
Al-oxalate, mg/kg	215	633	1374	492
Fe-oxalate, mg/kg	97	207	1185	351
Total P, mg/kg	761	98	293	137
$CaCO_3$ %	87	5.1	0.4	0.6
PBC	63	36	51	19

Plant experiment - Design:

A pot experiment was designed to assess the importance of P placement in the effectiveness of fluid fertilizers on alkaline soils. The four soil types previously described were used. Determination of the L value (amount of isotopically exchangeable P taken up by plants) was performed by labelling soil with carrier-free ^{32}P and then using plants to sample the specific activity of soil exchangeable P *i.e.* the ratio $^{32}P/^{31}P$. By applying the principle of isotopic dilution, it is possible to deduce the precise amount of exchangeable P taken up by the plants from the fertilizers added and/or from the soil. The bioavailability of P from fertilizers *i.e.* the real efficiency of a fertilizer, can thus be assessed.

In each pot, 250 g of soil was mixed with fertilizer and wetted with 10 ml of a nutrient solution free of Zn, N and P and incubated for one week. The fertilizers were all applied so that the final rates were equivalent to 60 kg P ha^{-1}, 60 kg N ha^{-1} and 12 kg Zn ha^{-1}. Six P-fertilizer treatments were applied with four replicates each. Three granular fertilizers, monoammonium phosphate (MAP) (N:P:K = 10:22:0), diammonium phosphate (DAP, 18:20:0), or triple super phosphate (TSP, 0:20:0), and three fluid fertilizers, ZAP (technical grade MAP (TGMAP) + ammonium nitrate + $ZnSO_4.7H_2O$), ammonium polyphosphate (APP, 16:23:0 w/v) or orthophosphoric acid (H_3PO_4)(26% P w/w), were added to the pots. Fluid fertilizers were dripped onto the soils with 20 ml of deionised water. Granular fertilizers were ground and mixed with the soil. Deionised water was then added in all treatments to bring the soils to 90% of their water holding capacity. Consequently, for each type of soil, the total volume of fluid added to all treatments was similar. Controls were grown in the same conditions but without P fertilizers, with 8-fold replication. After a week of incubation of the soil-fertilizer mixtures at 20°C all the treatments were sprayed with carrier-free ^{32}P with an activity of 3MBq/kg soil. Two germinated wheat seeds (cv. Frame) were then sown 10 mm below the soil surface and after 5 days, one seedling was removed, leaving a single plant in each pot. Plants were then grown for five weeks in a controlled environment growth chamber (15/20°C, 8h night/16h day) and watered every day to 90% of the water holding capacity with deionised water. Shoots were harvested and dried at 70°C before weighing.

Results:

Dry weights of shoots are shown in Figure 1 and indicate that, even in a pot experiment in which fertilizers were uniformly mixed with soils, the differences between the efficiency of fluid and granular fertilizers on the highly calcareous grey soil were significant. In the cracking clay, where fluid fertilizers have not previously been applied in the field in Australia, dry matter was also significantly greater with fluids, while in the red calcareous soil and the Sodosol, no significant changes were observed.

The differences in dry weight of shoots obtained in this pot experiment on grey highly calcareous soil confirm the reported high efficiency of fluid fertilizers in these soils compared to granular fertilizer. The data reported here indicates that in this soil and in the grey cracking clay, the efficiency of fluid fertilizer in the field is at least partly due to a chemical effect besides any putative placement effect. Conversely, in the case of the red calcareous soil, field data from 1998 and 1999 concluded that fluid fertilizers were more efficient than granular. However, no difference was measured in the present pot experiment.

Figure 1: Dry weights of shoots after 5 weeks of growth as a function of fertilizer applied. The two right - hand bars in each group represent the controls with 4 replicates each (CtA and CtB). The treatments were ZAP, Polyphosphate (Poly), Phosphoric Acid (Phos), DAP, MAP and TSP.

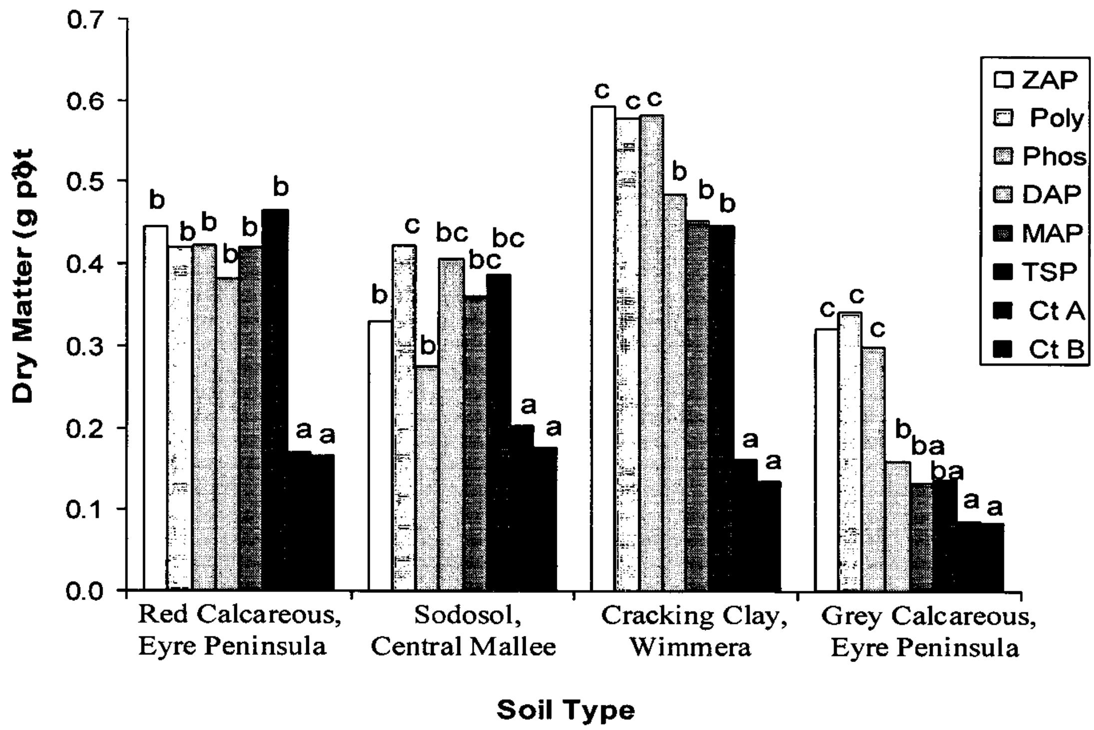
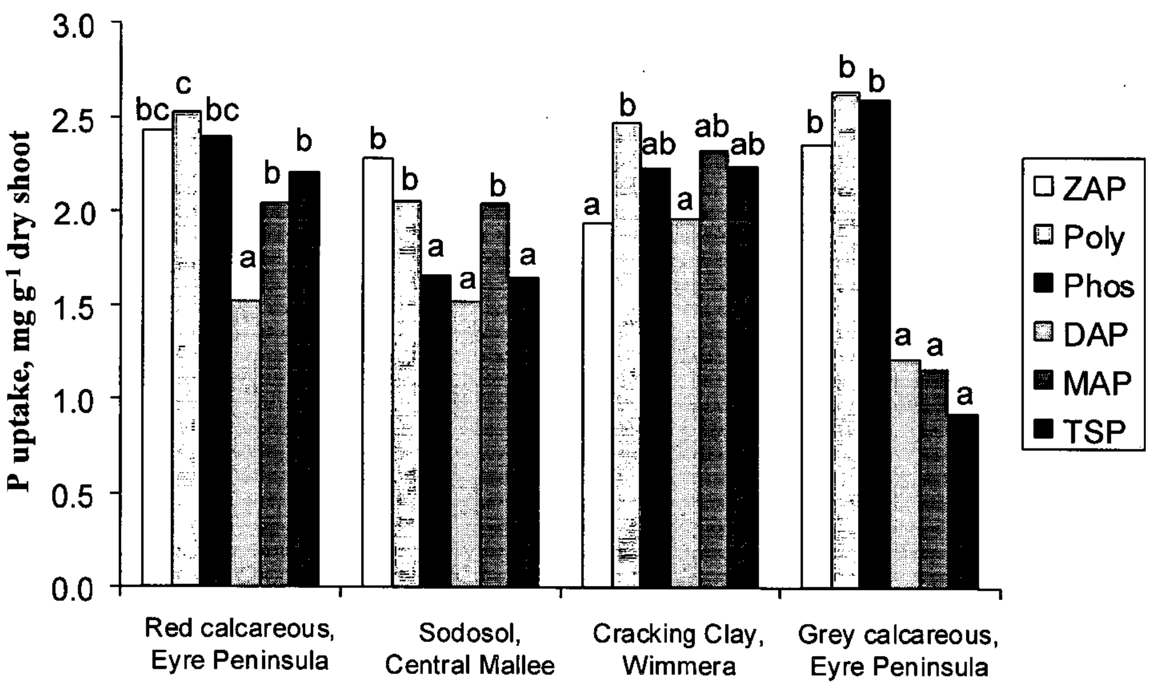
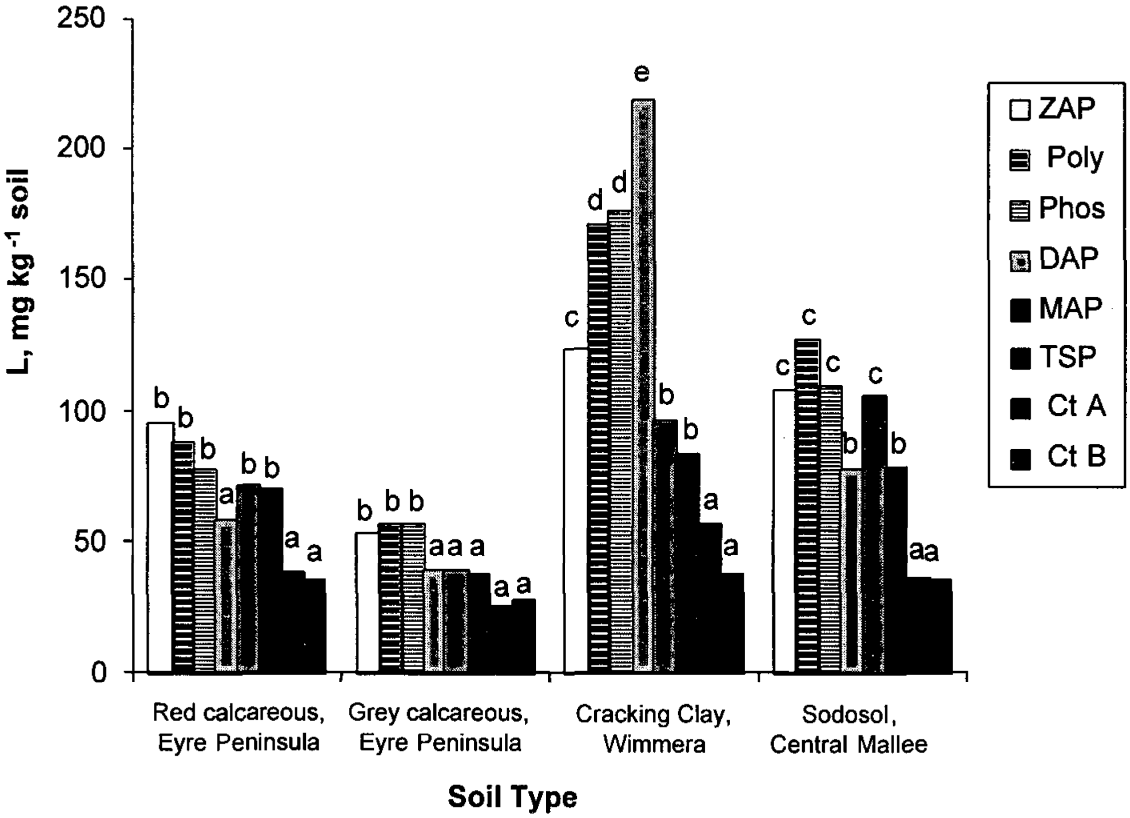


Figure 2: Differences in P concentrations (P concentraton in plants with fertilisers minus P concentration in control plants) of the plants after 5 weeks of growth in a controlled environment. Each treatment had four replicates.



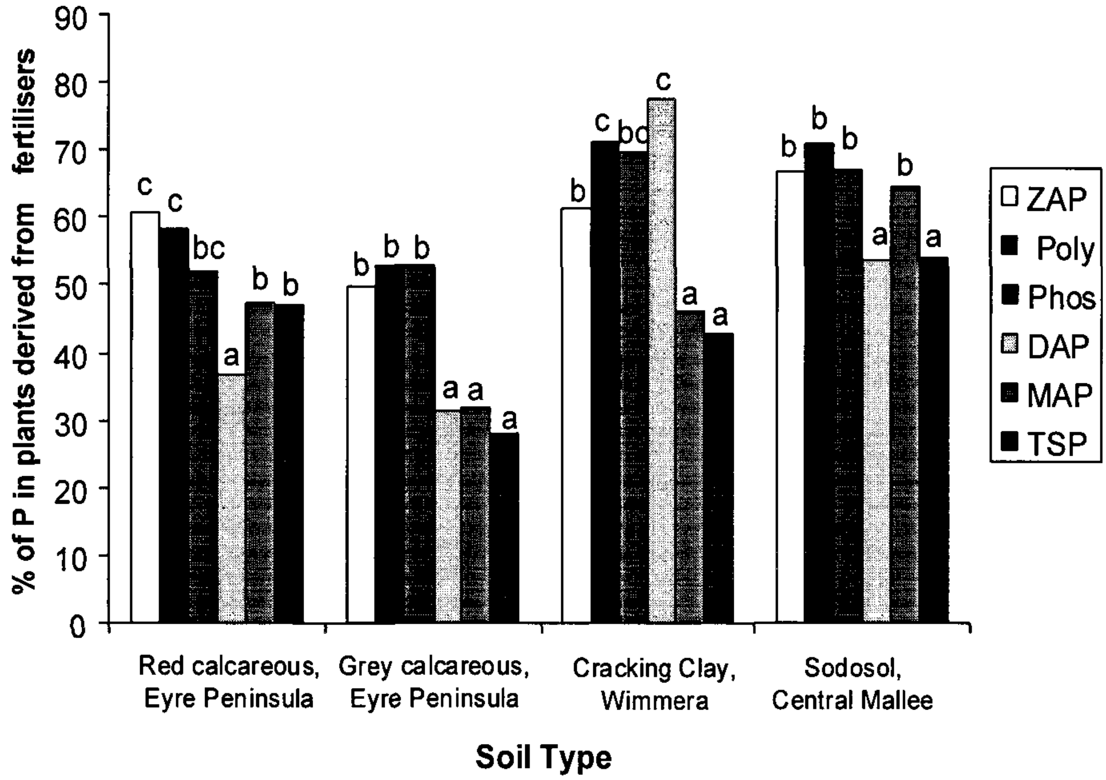
Uptake of P by plants from soils from Upper Eyre Peninsula and from the Wimmera area were greater with fluid APP than with other treatments. In the grey calcareous soil, all fluid treatments significantly increased both dry weight of shoots and P uptake by plants. In the Sodosol, the MAP treatment was equivalent to all fluid treatments.

Figure 3: Amount of isotopically exchangeable P taken up by plants (L) as a function of fertilizers applied.



The amount of isotopically exchangeable P taken up by plants varied greatly with soil type and with the form of fertilizers added. In the grey highly calcareous soil from Eyre Peninsula, it is noteworthy that the application of granular fertilizers MAP, TSP or DAP did not increase the amount of exchangeable P in the soil compared to the controls (Figure 3). It is apparent then that P from granular fertilizer added to these grey calcareous soils is rapidly immobilised and rendered unavailable to plants. This immobilisation process is likely to be due to precipitation of P as calcium phosphate compounds which immobilise P in a non-exchangeable form *i.e.* a non bioavailable form. Placed in the same extreme conditions *i.e.* in a soil containing 87% $CaCO_3$ (Table 1), fluid fertilizers increased by 42% the amount of P available in the soil compared to the granular applications. In the other types of soil, the effect of fluid fertilizer was less dramatic. However, in the case of the soil from the Wimmera, the increase in the amount of exchangeable P taken up by plants was greatest in the case of granular DAP, but isotopically exchangeable P uptake from applications of ZAP, APP and orthophosphoric acid were significantly higher than from MAP or TSP.

Figure 4: Proportion of P in plants derived from fertilizer and expressed as a % of total P in the shoot.



The amounts of P taken up by shoots from the fertilizer (not from the pool of P already present in the soil) are shown in Figure 4. It is noteworthy that fluid fertilizers always performed as well as or better than the granular fertilizers. The percent of P taken up by plants from the fertilizer applied is an exact indication of the real efficiency of the fertilizer. In the grey highly calcareous soil from Eyre Peninsula, plants took up 50% of their P from the fluid fertilizer and only 30% from the granular. In this case, we can conclude that the efficiency of fluid fertilizers was at least 20% better than the granular. In the red calcareous soil, even when fluid fertilizers did not increase shoot dry weight (Figure 1) or the exchangeable P (Figure 3), plants were able to take more P from APP or ZAP application (Figure 4). In the cracking clay, plants took up more P from fluid fertilizers except in the case of DAP. Finally, in the Sodosol no significant differences were observed between fluid and granular fertilizer.

Discussion and Conclusion:

We conclude from the data presented here that in the grey highly calcareous soil, the effect of fluid fertilizer was due in this instance to a chemical effect rather than a placement effect. Effectively, with this soil type in a pot experiment, fluid fertilizer doubled the production of dry matter and the P uptake by shoots. The increase in available P in the soil was about 40% compared to granular and plants were able to take up nearly double the amount of P from fluid fertilizer compared to granular. These results support the field data obtained by Holloway *et al.* (submitted for publication).

In the case of the red calcareous soil, field data indicated higher yields with fluid than with granular fertilizer while in the present experiment, no significant increase in dry matter or L value was measured. However, increases in P taken up by plants from ZAP and APP treatments were recorded (Figure 4) which strongly suggests that these two forms of fertilizer provided more available P than the others.

A possible explanation for the different results obtained between field and laboratory experiments on the red calcareous soil, is that in the pot experiment, soils were maintained at the same level of moisture, which was relative to the water holding capacity of each soil. However each soil has different water retention curves and the watering of the pots needed to be adjusted according to these curves. The interaction of soil moisture with fluid *vs* liquid fertilizer placement is one area that needs further work.

In the case of the cracking clay, fluid fertilizers increased the dry weight of shoots but not P uptake by plants. In this soil type, DAP appears to be the most efficient fertilizer followed by the fluid forms. However, field experiments will be necessary to allow unequivocal conclusions on the respective efficiencies of DAP and fluid fertilizer in cracking clay soils. In the case of the Sodosol, fluid fertilizers were not more efficient than granular.

The pH of phosphoric acid and APP solutions used in this experiment were 5.23 and 6.38 respectively. It is apparent that factors other than acidification of the soil solution and subsequent dissolution of Ca-P compounds are likely to be responsible for the increased efficiency of fluid fertilizers compared with granular in calcareous soils.