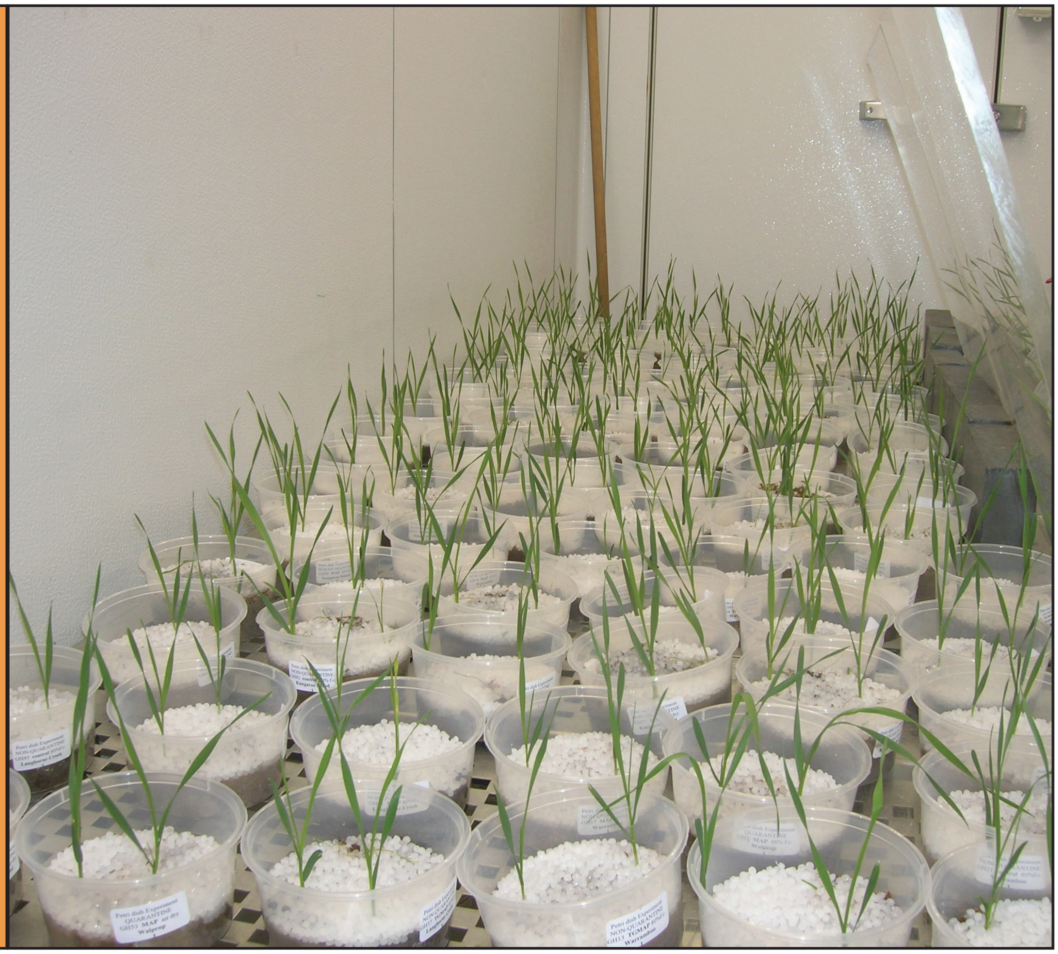
Fluid JOURNAL
Official Journal of the Fluid Fertilizer Foundation
Spring 2010
Vol. 18 No. 3, Issue #69

Dr. Therese McBeath, Prof. Mike McLaughlin, Dr. Jason Kirby, Prof. David Chittleborough, and Dr. Roger Armstrong

Diffusion of Fluid and Granular Phosphorus and Zinc Inhibited in Dry Soil

Studies conducted in six soils from the cereal growing regions of Southern Australia and Kansas.

Summary: *Fluid and granular fertilizers containing zinc (Zn) and phosphorus (P) were incubated for four weeks air dry and at optimal moisture in six soils from the cereal-growing regions of Southern Australia and Kansas. Following incubation, measurements were made of fertilizer diffusion, soluble nutrient concentration and labile nutrient concentration. The results demonstrated that a dry incubation inhibits the diffusion of P and Zn fertilizer and needs to be considered when dry sowing fertilizer and seed simultaneously. The dry incubation also decreased the lability of Zn at the point of fertilizer application, indicating that despite the presence of high concentrations of Zn, this Zn had already reacted with the dry soil and the amount of potential available Zn had been reduced.*



Laboratory experiments have indicated that fixation reactions of P slow down in dry soil, and the residual effectiveness of superphosphate decreased as soil water content increased. However, these experiments added P to the soil as liquids or powders and uniformly mixed the fertilizer with the soil. Indeed, much of the early glasshouse work on interactions between soil moisture and nutrient availability has used soils with fertilizer P and micronutrients uniformly mixed throughout the plant growth medium rather than banded as fluid or granular fertilizer, which is the normal method of field application. As a result of these laboratory studies, the common perception is that dry soil means that fertilizers do not react with the soil, and residual fertilizer efficiency in the year following drought is high.

Our recent research has shown that movement of soil water in and around granules can have a marked influence on chemical reactions that control fertilizer effectiveness. When a fertilizer granule is placed in moist soil, it draws soil water towards it and also draws solutes in the soil water into the granule. In a calcareous soil this enhances precipitation of calcium phosphate compounds in and around the granule, which reduces granular fertilizer effectiveness markedly. We have discovered this is one of the reasons delivery (into soil) of exactly the same fertilizer formulation in fluid form can enhance fertilizer efficiency markedly compared to granular products, especially in calcareous soil. It is therefore evident that changes in soil water status could markedly affect the reactions occurring in and around fertilizer granules in the soil, a phenomenon not well reproduced in most laboratory experiments when nutrients are uniformly mixed throughout the soil. The aims of this experiment

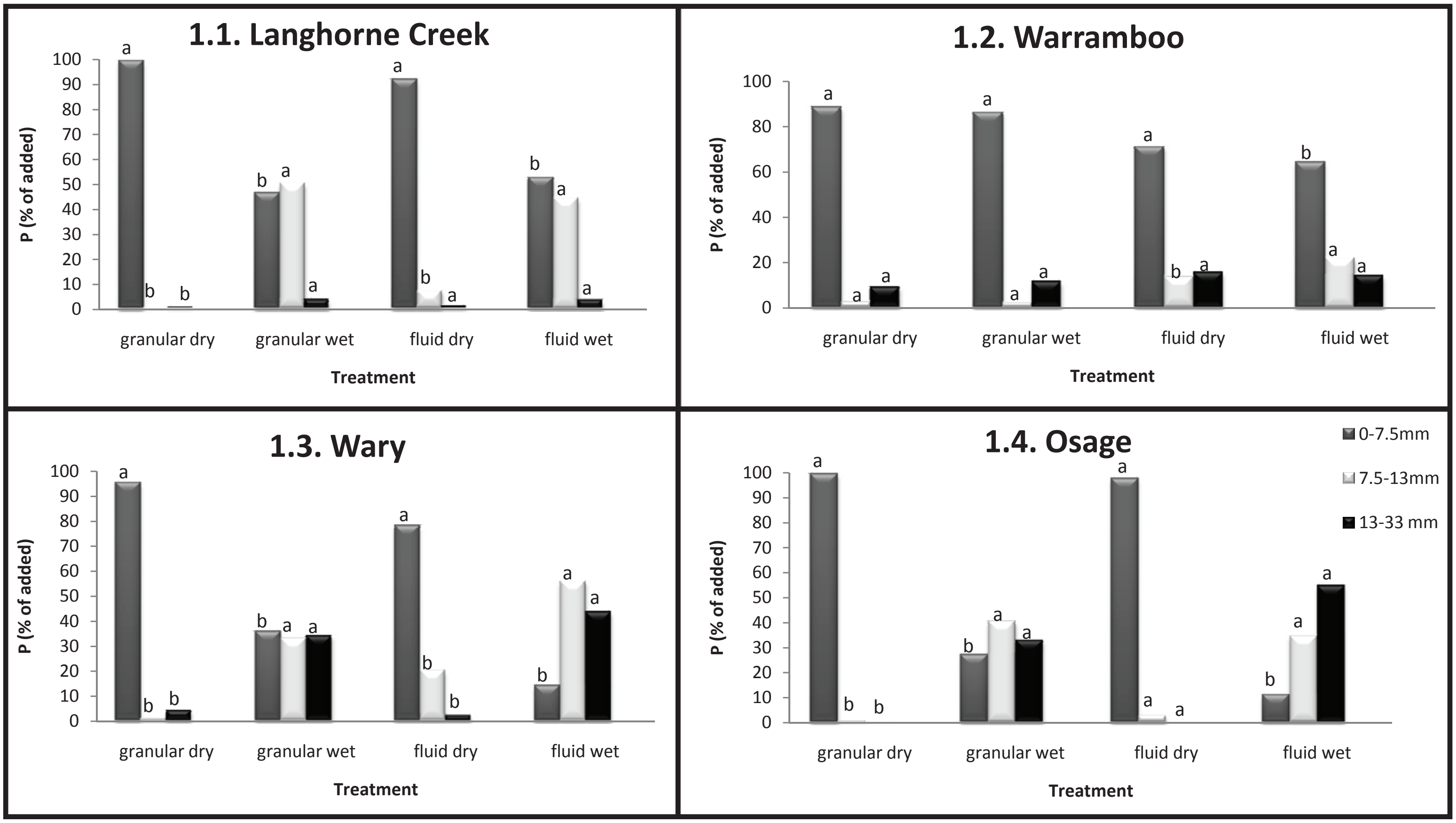


Figure 1.1 *Langhorne Creek, 1.2 Warramboo, 1.3 Wary and 1.4 Osage. Percentage of P derived from fertilizer in petri dish soil sections. Within a fertilizer and section, a column appended with a different letter represents a different P % of added (i.e. Fig 1.1. section 0-7.5mm dry is greater than wet and section 7.5-13 mm wet is greater than dry).*

were to investigate the effect of soil moisture and fertilizer form on the diffusion and lability of P and Zn in six different agricultural soils from Southern Australia and the U.S.

P diffusion/solubility

The most important effect of the treatment regime on P diffusion was the effect of incubation moisture on P diffusion. A dry incubation resulted in little or no diffusion of P (displayed as P% of added) away from the first section (0-7.5mm) of the petri dish where the fertilizer was added (Figure 1.1, 1.3. and 1.4). A moist incubation resulted in improved diffusion with the second petri dish section (7.5-13mm) having a greater amount of P than the first section for the non-calcareous soils (Langhorne Creek, Osage, and Wary). In contrast, there was not the same difference between incubation moistures for the calcareous Warramboo soil, suggesting that fertilizer diffusion is severely restricted even when this soil is incubated wet (Figure 1.2). There was a small diffusion advantage in the second section (7.5-13mm from application point) for the fluid P source when incubated wet in the Warramboo soil. We suspect that we have not observed the large differences between fluid and granular forms in the Warramboo soil because we used uncoated fertilizer in order to layer Zn on the fertilizer granule in the laboratory before adding it to the petri dish.

The issue with the restriction of diffusion is the increased probability of excessive P concentrations at the point of addition, which then participate in precipitation reaction reducing the lability of the fertilizer. This reduced diffusion effect, regardless of fertilizer form, needs to be considered when making decisions about dry sowing, especially in soils with high levels of calcium, iron, or aluminum.

The water soluble P data closely follow the diffusion data (Figure 2.1 to 2.4). The highest concentration of water soluble P is the first (0-7.5mm) section and diminishes away from the point of application. The wet incubation had the effect of increasing the amount of water soluble P in the second (7.4-13mm) section in all cases except for the calcareous Warramboo soil where there is no difference between treatments.
In this second section, the Langhorne Creek and Wary soil had more water soluble P for the fluid treatment than the granular, but the opposite was true for the Osage soil. The implications of the soluble P data will be better defined with the labile P data, which are currently being analyzed.

Zn diffusion/lability

When the Osage and Wary soil was incubated dry, there was virtually no diffusion of Zn away from the point of application. In comparison, there was some diffusion of Zn when incubated wet and therefore a greater percent of Zn added was located in the second (7.5-15mm) and third (13-33mm) sections (Figure 3.3-3.4). In contrast, in the highly calcareous Warramboo soil, the wet and dry incubated Zn fertilizer behaved in the same way with a small amount of Zn measured in the second and third sections in both cases (Figure 3.2). The Langhorne Creek data are difficult to interpret as the granular wet treatment data are not available (Figure 3.1).

The labile Zn in the first 0-7.5 mm petri dish section is presented in Figure 4 (the lability of Zn in the remaining sections is so low that it is not presented). The effect of the fertilizer was not significant. Therefore, data are compared on a wet incubation versus dry incubation basis.

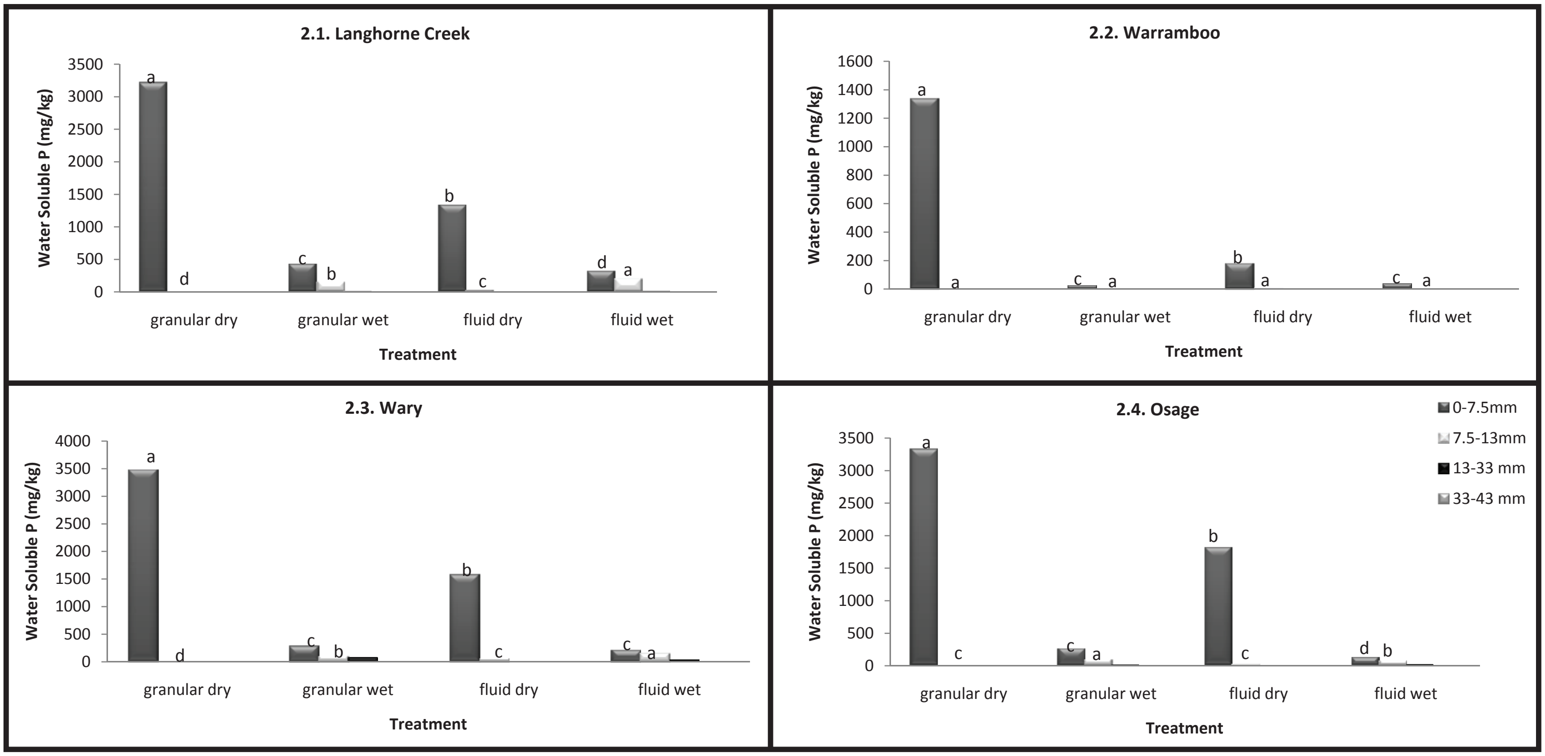


Figure 2.1 *Langhorne Creek, 2.2 Warramboo, 2.3 Wary and 2.4 Osage Water soluble P (mg/kg). Within a section, a column appended with a different letter represents a different Water soluble P. (i.e. Fig 2.1. section 0-7.5mm granular dry > fluid dry >granular wet> fluid wet). Water x fertilizer interaction P<0.001.*

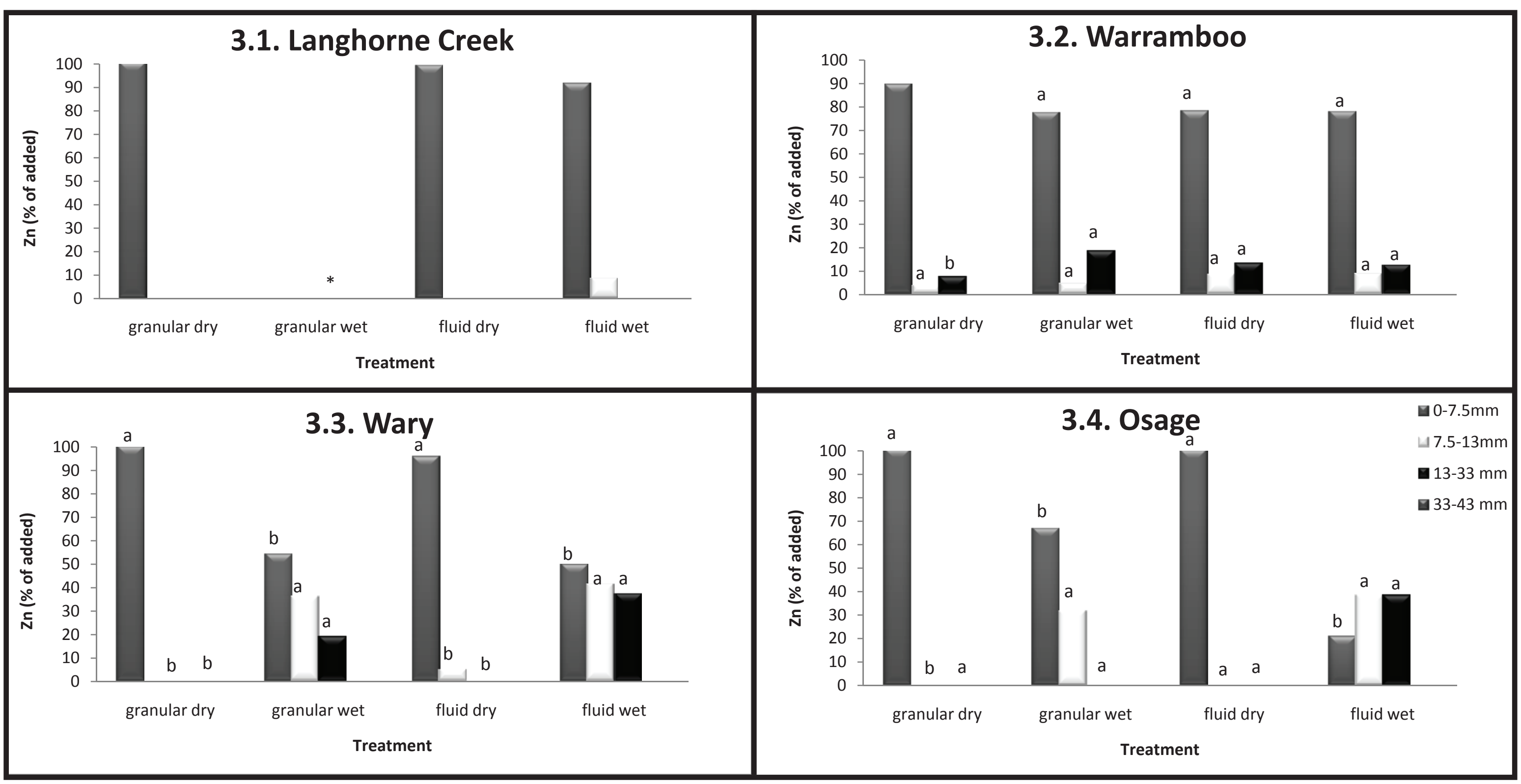


Figure 3.1 *Langhorne Creek, 3.2 Warramboo, 3.3 Wary and 3.4 Osage. Percentage of Zn derived from fertilizer in petri dish soil sections. Within a fertilizer and section, a column appended with a different letter represents a different % Zn added (i.e. Fig 3.3. section 0-7.5mm dry is greater wet and section 7.5-13 mm wet is greater than dry).*

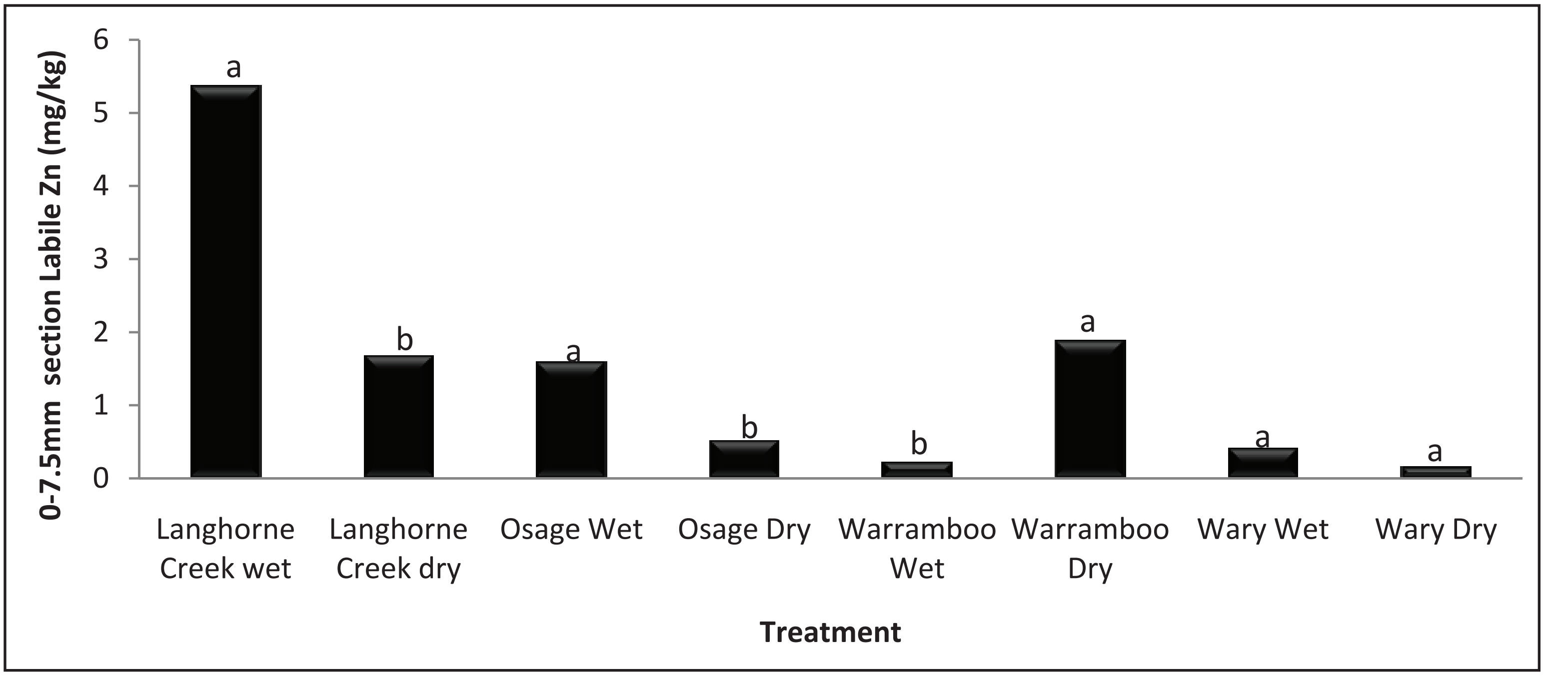


Figure 4. *Labile Zinc (mg/kg) in the first section (0-7.5mm from point of application) of the petri dish. Different letters indicate a significantly different labile Zn within a soil type.*

The data show that for two of the non-calcareous soils (Langhorne Creek and Osage) the amount of labile Zn at the point of fertilizer application is higher when fertilizer is incubated moist, while there was no effect of soil moisture in the Wary soil. In the calcareous Warramboo soil, the amount of labile Zn is higher when the soil was incubated dry, suggesting rapid fixation and or precipitation reactions in the presence of moisture. Detection of Zn is an issue, especially for the Warramboo, which has a very high fixation capacity for Zn. The higher level of labile Zn when wet suggests that while there may be high concentrations of Zn when incubated dry, the lability of this nutrient is diminished and must be assumed to be reacting with the soil.

Conclusions

The major finding of this study is that the diffusion of both fluid and granular forms of P and Zn are inhibited when incubated dry. In the highly calcareous soil, the diffusion of Zn and P was inhibited regardless of whether the soil was wet or dry. Labile Zn was found to be higher at the point of application when incubated wet, suggesting that while there may be high concentrations of Zn at the point of fertilizer application when incubated dry, the lability of this nutrient has been restricted.

The purpose of this experiment was to simulate the conditions of wet vs. dry sowing (where fertilizer is assumed to be provided at the time of sowing). Given the effect of soil moisture, filling in the continuum between wet and dry sowing with testing scenarios such as 'false starts' (where there is wet sowing followed by an abrupt dry spell and dry sowing but with optimum moisture conditions ensuing) will make a significant contribution to our ability to manage fertilizer additions for optimal availability.

This work suggests to us that there are three important areas requiring further clarification:

1. The effect of co-locating vs. physically separate application of Zn and P on fertilizer diffusion and lability
2. The effect of using uncoated vs. coated fertilizer granules on diffusion and solubility
3. The effect of wet-dry cycles on diffusion and solubility.

Dr. McBeath is a Senior Research Associate at University of Adelaide; Prof. McLaughlin is a Chief Research Scientist at University of Adelaide and CSIRO Land and Water; Dr. Kirby is an Environmental Inorganic Analyst, CSIRO Land and Water; Prof. Chittleborough is a Geochemical Pedologist, University of Adelaide; and Dr. Armstrong is a Senior Research Scientist, Department of Primary Industries.