FINAL REPORT

UA00154

Phosphorus requirements to accompany high nitrogen fertiliser levels (2015.04.01J)

PROJECT DETAILS

PROJECT CODE:	UA00154
PROJECT TITLE:	PHOSPHORUS REQUIREMENTS TO ACCOMPANY HIGH NITROGEN FERTILISER LEVELS (2015.04.01J)
START DATE:	01.03.2015
END DATE:	31.12.2015
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Summary

Ninety wheat and two canola studies were identified that report on nitrogen (N) x phosphorus (P) interactions in field sites from across Australia. Most data came from unpublished literature. To obtain maximum yield gains with fertilisation, both N and P need to be at adequate levels. The impact of low N on responses to P application appears to be of more significance compared to P deficiency on response to N fertilisation. This is possibly due to the different mobility and location of N and P in the soil profile, and different N and P requirements during the crop growth cycle. There is a need for more studies that investigate N x P interactions using modern farming techniques, varieties and fertilisers.

Other products may perform as well or better than those specifically referred to. Check www.apvma.gov.au and select product registrations listed in PUBCRIS for current information relating to product registration.

Old or Archival Reports (Projects that concluded in 2007 or earlier)

The information contained in these older reports is now several years old, and may have been wholly or partially superseded or built upon in subsequent work funded by GRDC or others. Readers should be aware that more recent research may be more useful for their needs. Findings related to agricultural chemical use are also potentially out of date and are not to be taken as a recommendation for their use.

Conclusions

This project has outlined the importance of both N and P fertility, reiterating that if either is not optimal, it can reduce yield potential. From the available data, which at this stage is restricted to a relatively few sites on a limited select range of soil types, the effect of not optimising N or P on soil test correlations is small, providing neither N or P is very low. Further work is needed to address N x P interactions on soil types where it is difficult to optimise N or P (e.g. Calcarosols) in order to determine the subsequent effect on soil test interpretation. Much of the existing work was done many years ago and there is a need for work that uses current farming techniques (e.g. minimum tillage), fertiliser products and plant varieties.
In summary, the review of the unpublished literature found:
o 94 field trials assessing N x P interactions.
o 92 wheat and two canola.
o 22 field trials (21 wheat, 1 canola) were considered Level A quality.
o Significant gaps were outlined (see below).
o If either N or P is not optimised, this can have a significant effect on the response of the other in terms of reduced yield increases to applied fertiliser.
o If N is optimised and there is no response to applying further N, this extra N applied upfront has no effect on the P response to applied P.

Recommendations

Through this scoping study, a number of research gaps have been identified.
Based on the review of published literature, unpublished literature, and suggestions from agronomists contacted as part of this scoping study, two important areas for future work have been identified. These are presented as two separate options. The first recommends further field trials to fill in gaps in existing data, and the second focuses on testing a range of modern agronomic practices that might provide further gains in the efficient use of N and P in cropping systems. While not mutually exclusive, the two options could stand alone as separate projects.

Option 1:
From the scoping study, several gaps were identified in terms of defining N x P interactions in certain soil types and crops which allow the assessment of P requirements under high N fertiliser levels. These trial designs are relatively simple and work on increasing N and P fertiliser levels separately through the use of specific fertilisers that deliver N and P separately (see Option 2 for agronomic context). While existing data are valuable, it was also found that most of the studies were undertaken several decades ago, when farming practices (e.g. tillage versus minimum-till), plant genotypes, and fertiliser products and methods of application were different. As such, there is a need for a set of consistent field trials, using current day practices, to be run across the cropping regions of Australia. Trials need to be improved by targeting soil types that are prone to either N or P deficiency.

Option 2:

While additional field trials that are well designed and use a consistent range of measures of soil fertility and crop production would be beneficial (Option 1), it is important to recognise that growers are using a range of different management practices, many of which have not been tested in well designed scientifically valid trials. The emerging practices are thought to be where the future lies and can potentially represent game changes in efficiency and gains in profitability. It is, therefore, recommended that as well as additional field trials that fill gaps in existing data (Option 1), a second project be undertaken (Option 2) in which a range of management options are trialled on a small number of sites. Through interactions with growers, it is clear that they are trying different options for N and P management on their farms, for example, split application of N. With these agronomic practices being used, but also being largely untested in rigorous, scientifically designed trials, it is recommended that trials be undertaken (on a limited number of soil types) to test a range of emerging N and P management options.

Outcomes

Economic Outcomes:
As a scoping study, this project has provided a guide to potential future work in regards to more efficient use of N and P fertilisers. This will have clear economic benefits in terms of improved profitability by optimising the system for N and P at the lowest applicable rates of N and P.

Environmental Outcomes
As a scoping study, this project has provided a guide to potential future work in regards to more efficient use of N and P fertilisers. Reductions in the use of these fertilisers will avoid over application and associated environmental risks.

Social Outcomes:
As a scoping study, this project has provided stakeholders with a greater knowledge and confidence upon which to base their farm management decisions.

Achievements/Benefits

There is growing interest in the interaction between the key plant macronutrients, N and P. In particular, there is interest in the effect of soil P levels on optimum yield responses in wheat and canola to high rates of N. To maximise profits, it will be necessary to co-optimise N and P applications. This will require a clear understanding of the interactions between N and P in soils, and how the addition of one will impact upon requirements for the other. Some work has been done in this area, including field trials, some of which has been published in the peer reviewed scientific literature, but with the majority remaining unpublished. This information has not been compiled and synthesised in a way that allows for key knowledge gaps to be identified. Therefore, there is a need for a scoping study that:
1. Reviews available published literature on N x P interactions in cereal (wheat) and oilseed (canola) crops (predominantly in Australia), and to produce a literature review that provides an understanding of the importance and nature of N x P interactions in plants and soils.
2. Identifies and summarises relevant unpublished literature on N x P interactions in cereal (wheat) and oilseed (canola) crops in Australia.
3. Makes recommendations on methodologies and approaches for addressing knowledge gaps, and includes an indicative budget for undertaking these activities.

These activities were all completed and are presented in the scoping study.

The scoping study was guided by four over arching questions. These questions and their answers represent the main achievements of this study, and are summarised as follows:

1. N x P interactions - the basic concept (brief overview of literature review).

Many soils suffer from multiple nutrient deficiencies, with both N and P being deficient in many Australian soils. Liebig's law of the minimum states that crop yield is proportional to the supply of the most limiting nutrient. It therefore follows that if the most severe nutrient limitation is corrected through the addition of fertiliser (or crop rotation, e.g. with a legume for N deficiency), the second most limiting nutrient can then become the most limiting factor and so on. Thus, as one nutrient deficiency is corrected another may become apparent.
The addition of multiple nutrients to the soil can have a synergistic, rather than additive, effect on plant growth. In this scenario, supply of N and P to plants increases their growth, but the addition of both N and P together increases growth more

than predicted based on the sum of their individual effects on growth. These synergistic effects are suggestive of an interactive effect of multiple nutrient supply on plant growth.

Equally, a nutrient that was not previously limiting can become limiting if another major nutrient deficiency is corrected. For example, plants grown in soils that are P deficient and have only just sufficient amounts of zinc (Zn), can become Zn deficient when P is supplied to the soil (i.e. P induced Zn-deficiency) as P supply greatly increases plant growth such that Zn becomes deficient. Indeed there are many other such examples, including some involving N and P supply. If a soil is strongly N deficient and moderately P deficient, the addition of N to the soil will increase plant growth, but only up to the point where P supply is sufficient. This concept is of central importance to this scoping study. That is, in cropping systems where N supply is high, it is possible that further gains in production can be made through optimisation of soil P supply. The concept of optimising N in agricultural systems has become more important in recent times (approx. the past 20 years) with many fertiliser strategies employing larger N rates (greater than 100kg/ha), which for this study is defined as high. Defining P requirements under high N fertilisation is therefore of upmost importance. In the literature review component of this report, these concepts were explored in more detail, providing specific examples from the peer-reviewed scientific literature.

2. What data is there in the literature to support an understanding and recommendations about P requirements to accompany high N fertiliser levels?
Both the published literature and analysis of obtainable unpublished data indicate that to obtain maximum yield gains with fertilisation, both N and P need to be at adequate levels - this is not a new concept. The impact of low N on responses to P application appears to be of more significance compared to P deficiency on response to N fertilisation, possibly due to the different mobility of N and P in soil environments, location of N and P in the soil profile, and different N and P requirements during the crop growth cycle. In low N and P environments, significant variance of relative yield can occur if a low application of N has been implemented. Generally basal N rates of approx. 50kg/ha and greater cause minimal decrease in the relative yield of the P response as the localised presence of both N and P near the seed promotes localised root growth. If the system is optimised for N (high N levels), then P requirements are maximised and there is no further effect on P requirements by adding more N. At optimal N yield, responses to P are maximised and this should have no effect on critical soil P levels, assuming the soil P test calibration has used sites where N is not limited. The data-set compiled in this study is dominated by single season response trials where N and P were applied individually using single N and P sources. Often the P product used (single and triple superphosphate) is different to those most widely used currently by growers. Further, the data-set is dominated by trials that were performed more than five years ago and therefore using wheat varieties that are not typically grown in broadacre Australian agriculture in 2015.

3. What gaps are there, either in data supporting the understanding or in the geographic spread of the data?
From the scoping study, there are a few gaps that were identified in terms of defining N x P interactions in certain soil types and crops which allow the assessment of P requirements under high N fertiliser levels. These trial designs are relatively simple and work on increasing N and P fertiliser levels separately through the use of specific fertilisers that deliver N and P separately. Typically, application occurred at sowing, with a very limited number of trials actually incorporating treatments that include in-season application of N. In the trials that did incorporate in-season N application, the N rates were simply split, with half applied at sowing with the other half applied in-season, usually at mid-tillering. This differs from the current practices of most growers, who provide the P required by the crop upfront using high analysis fertilisers, usually di-ammonium phosphate (DAP) and monoammonium phosphate (MAP). This means that some of the crop N requirement is also met with the application of P. If it is deemed that more N is required upfront, growers will add additional N sources (e.g. urea) at sowing with the potential of applying additional N in-season. Many trials outlined in the scoping study were also single year trials and therefore common rotation effects were not able to be assessed.

4. What research work still needs to be done in each state or grains region and why?
More research is needed that specifically targets soil types that are prone to either N or P deficiency. There is also an opportunity that N x P trials could be set up in co-ordination with future GRDC projects, in particular, the nutrient response curve project. In terms of targeted crops, the GRDC requested that this project investigate N x P interactions only for wheat and canola. Potential new GRDC projects may be directed towards estimating N and P requirements for other crop types based on a gap analysis of trials that has already been performed. In order to best utilise available funding, the N x P interaction should be assessed at the same time for these crop types. For defining critical soil test levels (for P in particular) and N x P requirements, wheat should be grown at all sites and used as a baseline due to the large number of response trials that have grown wheat. The scoping study revealed that a significant number of sites were not responsive to either N or P suggesting that previous fertiliser addition has already provided sufficient N and P for the time being. These examples highlight the need to undertake adequate soil testing prior to site selection. It is therefore recommended that more effort be

directed to targeting sites using soil testing and description of soil characteristics in order to best utilise GRDC funds.

Future research should incorporate treatments that include varying MAP and DAP inputs upfront with varying in-season N strategies to better match current agronomic practices. These treatments should be centred on current practices, with variations involving lower and higher fertilisation rates to determine efficiencies of fertiliser application in terms of utilisation % by the plants. Potentially sites should be used for multiple years (ideally at least four years) to reflect common rotation strategies and their effects on N and P requirements. As an example, Incitec Pivot (IPL) has long term trials that assess N x P requirements of various crop types, yet there are no comparative current season trials. For example, it is recommended that replicated phase rotations are used which can be achieved by growing both canola and wheat at the same site in the same year with the rotation switched in the second and third years in order to directly compare N and P requirements of the two crops plus potentially others as outlined in recommended future work Option 1.

Other research that still needs to be performed includes the investigation of genotypic drivers of N and P use efficiency, the effect of stubble retention and the effect of various rainfall scenarios on N and P requirements. Ideally, this work would include current and emerging farming practices. Such potential work is detailed in recommended future work Option 2. Please see below and refer to full scoping detail for further details on both recommended future work options.

Where this work should be done?
The following recommended future work emphasises options that are of greatest practical benefit to stakeholders. The work should also be designed in a scientifically robust manner in order that it can be published so as to maximise benefits.
Proposed targeted soil types for both wheat and canola:
Western region: Western Australia (WA). Forest gravelly soils that are prone to P deficiency through relatively high fixation ability. Typical sandier soil types might be prone to N deficiency but are typically at optimal P due to previous adequate applications of fertiliser.
Southern region: South Australia (SA). Calcareous soils that are prone to P deficiency. Target two contrasting rainfall zones e.g. Upper Eyre Peninsula (UEP) and Lower Yorke Peninsula. Mid-North region on typical red-brown earths. Mallee region on lighter soil types where high N inputs are generally required.
Victorian (VIC) Northern Mallee where sandier soil types prevail, Grey Vertosols in the south west in addition to more acidic soil types in the higher rainfall region of the south west e.g. Hamilton. Trials should also target the central regions.
Northern Region: New South Wales (NW). IPL trials are established at Rand and Grenfell so sites reflecting these soil types should not be a target.
Queensland (QLD). Nutrient interactions on typical black Vertosols are currently being investigated.

Other research

There is an opportunity to co-ordinate N x P research with future GRDC projects, in particular, the nutrient response curve project (2016 investment plan). In terms of targeted crops, the GRDC requested this project investigates N x P interactions for just wheat and canola. Potential new GRDC projects will aim to look at N and P requirements for other crop types based on a gap analysis of trials that have already been performed. In order to most efficiently utilise funding, the N x P interaction should be assessed at the same time for these crop types. For defining critical soil test levels (for P in particular) and N by P requirements, wheat should be grown at all sites and used as a baseline due to the large number of response trials that have grown wheat.

Additional information

Attachment

Detailed report.