changes in soil fertility status, other than Bray P, have oc-curred. These increased differences are attributed not only to decreasing check yield, but also increased fertilized yields. **Figure 5** demonstrates the increase in response and yield at two C-W/S locations.

Increases of soil Bray P differences between P fertilized and non-fertilized treatments were determined. The 10-year review (2000 to 2011) identif ed an increase in Bray 1 P of 1.9 to 3.1 ppm per year in those treatments receiving P. In the NS treatments, Bray 1 P decreased by an average rate of 0.50 to 1.0 ppm per year.

Summary

The Old Crop Swift Current trial reveals that in the low rainfall environments of the southwestern Canadian prairies, fertilizer P may remain in a labile form in areas of positive P balance and that producers may be able to take advantage of the past fertilization in years of high P prices. The long-term plots in Oklahoma shed light on the volatility of yield potential and N demands of winter wheat grown in the US Central Great Plains. The On-Farm CREA trials within the Central Pampas of Argentina demonstrate that soil test N and P adequately identify areas in which responses to fertilizer can be expected, while soil test S is providing little estimation of yield response in wheat production. This brief glimpse into the data from these long-term studies carried out across North and South America highlights the importance of such studies to contributing to our understanding of strategies to improve soil fertility and nutrient management for wheat production worldwide.

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Nutrient Management for Wheat in a Variable Climate

By Rob Norton

Profitable use of N and P to meet crop requirements in a variable climate such as the grain belt of southeastern Australia means adopting strategies that minimize risk. Using yield potentials, N and P demands can be estimated, but research shows there is no particular penalty if N is provided as the yield develops during the season. As yet there are no strate-gies for in-crop P application although research is pointing the way.

Nineteenth century poet Dorothea Mackellar described Australia as a land "of drought and flooding rains" and this phrase still resonates today. The southeastern wheat belt of Australia has been through an extended drought from the late 1990's until the floods of 2010 and 2011. **Figure 1** shows the annual rainfall for Horsham in the Victorian grain belt, indicating the large annual variation in rainfall, driven by conditions in the Pacific, Southern, and Indian Oceans.

This rainfall variation is an important driver of yield variation, where soil water at sowing plus in-crop rainfall can account for 61% of yield variation (Hochman et al. 2009). **Figure 1** also gives the wheat yields from a farm in the Horsham district, showing how yields generally follow rainfall. Wheat yields reflect the large differences in rainfall and simple and more complex models based

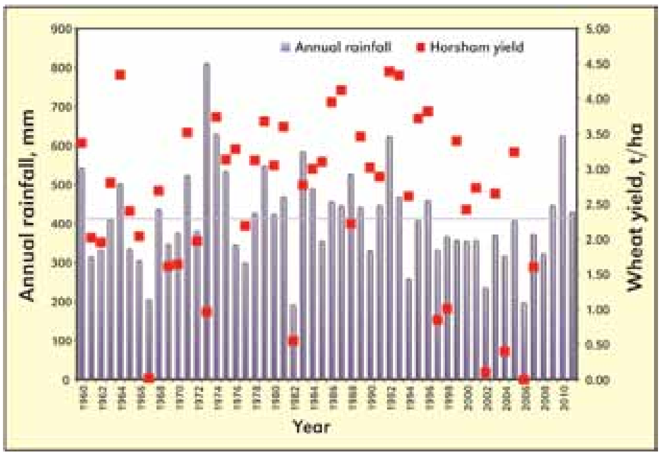

Figure 1. Annual rainfall and wheat grain yield from a farm near Horsham in the Victorian grain belt.

Table 1. Comparison of a range of various timings for N strategies on grain yield (t/ha) for eight site-years tested in the Victorian grain belt.

Post Sowing	2005 Sealake	2006 Hopetoun	2007 Walpeup	2005 Marnoo	2007 Kalkee	2005 Inverleigh	2006 Inverleigh	2007 Inverleigh
Urea deep banded	4.35	0.95	1.44	3.95	2.35	3.48	2.20	5.20
Urea deep banded + 50%@ Zadoks 31	4.11	0.98	1.40	3.98	2.83	3.40	2.54	5.69
Urea deep banded + 33%@ Zadoks 31 + 33% @ Zadoks 41	4.29	-	1.39	4.17	2.77	3.91	-	5.59
Urea topdressed @ Zadoks 31	4.44	0.93	1.61	4.27	2.72	3.43	2.25	5.24
LSD (p=0.05)	0.27	0.22	0.23	0.30	0.28	0.54	0.23	0.40

on rainfall allow growers to estimate yield potential at or near sowing, and therefore nutrient demand. Over application of N and P is a waste of money and resources, and too much N in particular in dry seasons can result in small grain size and a large price penalty. Under application means that yield potentials are not met.

Selecting the Right Rate for N and P

To estimate fertilizer rate, an achievable or target yield needs to be predicted. This water limited yield potential can be based on a water use efficiency of 20 kg/ha/mm of seasonal water supply (French and Schultz, 1983). The water supply includes measured or estimated plant available stored soil water plus an estimate of future rainfall. From this is it possible to then develop a nutrient budget based on the predicted yield of the crop (**Box 1**).

Based on the example in **Box 1**, it would be estimated that the crop would need 116 kg N/ha to achieve this target yield. There are several assumptions within this estimate including that the rooting depth of the crop is not restricted, the efficiency of soil and fertilizer N to grain N is 50%, and the mineralization rate of these soils will follow the model in **Box 2**. More significantly, it makes an assumption that there will be 250 mm of seasonal rainfall and the distribution of this rainfall is appropriate to achieve that yield.

A similar approach can be taken for P demand, using a water-limited yield potential and therefore an expected P removal. Typical grain P contents are around 3 kg/t of grain mean a target yield of 4.8 t/ha would need to be balanced with around 15 kg P/ha. This base rate would need to be adjusted for the P buffering capacity of the soil, any demands for P to raise soil P test, and account taken of any P lost through transport off the paddock. Because grain P can vary from 2.0 to 4.0 kg P/t (Jensen and Norton, 2012), growers may improve the precision of this budget by measuring actual grain P and derive actual removal.

Box 1: Yield Estimate
Available Soil Water – 100 mm
Expected seasonal water – 250 mm
Total Water Supply = 350 mm
Water Use Efficiency (WUE) – 20 kg/ha/mm
Non-Productive soil water – 110 mm
Yield Potential = WUE x (Available Water – Non-productive water)
= 20 x (350 – 110)
= 4,800 kg/ha (4.8 t/ha)

Box 2: Nitrogen Balance Estimate
Yield Potential = 4.8 t/ha
N demand = 45 kg N/t of grain = 216 kg N/ha
Mineral N at sowing = 50 kg N/ha (measured)
% Organic C (%OC) = 1.2%
In-crop mineralization estimate = %OC x (seasonal rainfall)/6
= 1.2 x (250)/6 = 50 kg N/ha
Soil N supply = N at sowing + Mineralization
= 50 kg N/ha + 50 kg N/ha = 100 kg N/ha
Fertilizer N to meet yield potential = (216 – 100) = 116 kg N/ha

Managing Risk Around the Right Rate for N

Given the uncertainty of future rainfall once the crop has been sown, applying the full dose of N at sowing is when least is known about the seasonal conditions. From fieldwork in the Victorian grain belt, Norton et al. (2009) compared timing strategies where N was deferred either in part or full to tillering or even later (**Table 1**). The delayed application of all N until tillering produced significantly higher yields at three sites and did not reduce yields at any site when compared to an atsowing application. Splitting 50:50 the applications did give benefits in three sites and no yield reduction at any site.

Based on these results, there would seem to be little yield penalty by delaying part or the entire N until later in the season, even on relatively high yielding sites. The caution here is that all those sites had at least 40 kg N at sowing in the profile, and this soil N supply was likely to be adequate to carry the crop through to tillering with little N stress.

If the season does not provide good rains in the late winter or spring, yield potentials can be adjusted down. Because part of the N has been withheld, there would be no penalty due to haying off, or a financial loss with low fertilizer efficiency. Growers now tend to apply maybe 20 to 30% of the N at sowing, and then apply added N (or not) as the seasonal conditions roll out.

Most wheat growers would now use some sort of tool to estimate yield potential and then match N supply to meet that potential. The rules of thumb used in the examples in **Box 1** and **Box 2** have been integrated with sophisticated crop simulation models and tools – such as Yield Prophet® (http://www.yieldprophet.com.au/yp/wfLogin.aspx), which enables an ongoing view of the yield and the potential response to N (Hunt et al. 2010).

Figure 2 shows part of a screenshot from the Yield

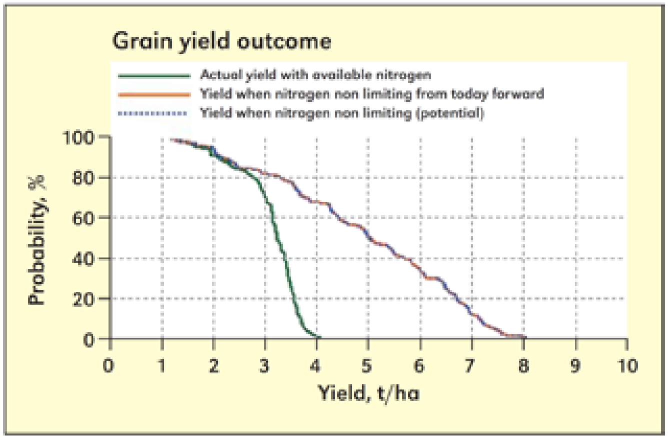

Figure 2. Probability of exceedance for a range of seasonal conditions using weather conditions to June 22, measured soil N and other agronomic inputs for a wheat paddock in the Wimmera region of Victoria.

Prophet® website showing the probability of exceedance of grain yield at a site in the Wimmera of Victoria. The outcome in the graph is based on yields from 100 years of rainfall records from the date of the report until crop maturity. This shows that if no added N is used, the median (50% probability) yield would be around 3.3 t/ha, while the conditions suggest yields would not exceed 4 t/ha. This outcome is based on the current N status of the paddock (101 kg N/ha).

The second line on the graph shows the yield in response to added N modeled over 100 years. This shows there is adequate water to take the median yield to 5 t/ha if N was not limiting, and the yield response ranges from 0 to 4 t/ha. This provides growers with the magnitude of the typical response, plus the range of responses likely given the variable climate.

Managing Risk Around the Right Rate for P

Phosphorus is usually applied at seeding in the drill row as this has long been seen as the most efficient delivery strategy. Rates are usually based on average removal, but this tends to over apply P in poor years and under apply it in better years. Topdressing of P in-crop does not supply the P near the roots because it is relatively immobile and will not leach into the root zone. Provided the important early crop demands are met with an at-sowing P source, and if products are developed that do not damage the crop canopy at appropriate use rates, P application could become tactical (Noack et al. 2010), similar to common N management strategies. Research into the right source, rate, time, and place for tactical P for wheat is currently under investigation (Noack et al. 2010).

Conclusion

In a variable climate, matching nutrient demand to supply relies on a good estimate of the yield potential. Nutrient budgets for N can be tailored around these variable yields to provide adequate N to prevent N stress early in the crop's life with little or no yield penalty. As the seasonal conditions unfold, additional N can be added (or not) to meet the rising (or falling) yield potential and nutrient demand. A similar approach to tactical application of P is an attractive option and current research is investigating appropriate products and their deployment to make this a viable strategy.

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Modern Corn Hybrids' Nutrient Uptake Patterns

By Ross R. Bender, Jason W. Haegele, Matias L. Ruffo, and Fred E. Below

Biotechnology, breeding, and agronomic advancements have propelled corn yields to new highs with little guidance as to how to fertilize these modern corn hybrids to achieve their maximum yield potential. Current fertilization practices, developed decades ago, may not match uptake capabilities of modern hybrids that contain transgenic insect protection now grown at population densities higher than ever before. A re-evaluation of nutrient uptake and partitioning can provide the foundation for fine-tuning our practices as we strive to achieve corn's maximum yield potential.

As summarized by Bruulsema et al. (2012), optimizing nutrient management includes using the right source at the right rate, right time, and right place—the 4R ap-proach. Research pertaining to primary macronutrient uptake, partitioning, and timing (Sayre, 1948; Hanway, 1962; Karlen et al., 1988), though fundamentally accurate for previous hybrids and management practices, may be unrepresentative of modern hybrids in higher yielding environments. The objective of this study was to determine how modern, transgenic insect-protected corn hybrids in high-yielding systems take up and utilize nutrients.