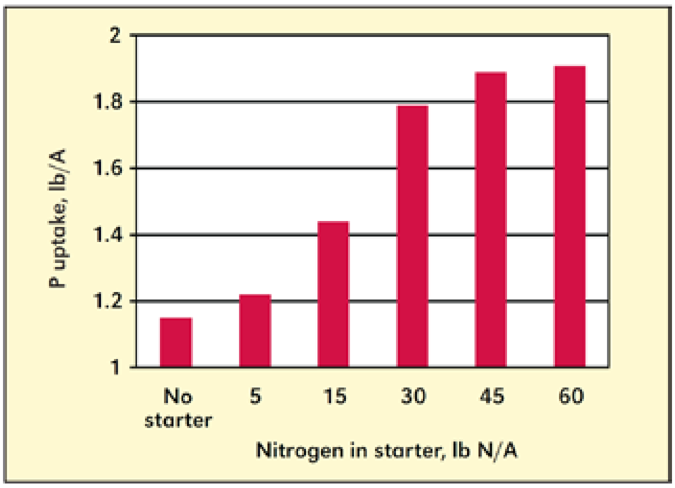

Figure 1. Average starter N-rate effects on 6-leaf stage whole plant P uptake (P and K rate constant at 15 lb P_2O_5 and 5 lb K_2O/A), 3-year average.

fertilizer was placed 2x2 or 2x0 , yields increased with increasing starter N rate up to the 30 lb N/A rate. Plant P content also increased with increasing N up to the 30 lb N/A rate (**Figure 1**).

The results of this research have shown that the addition of AVAIL® can improve P fertilizer performance. This work compared a no-starter check to fluid starter containing both N and P with and without AVAIL®. Use of starter increased corn grain yield by 19 bu/A over the no starter check (**Figure 2**). The addition of the polymer

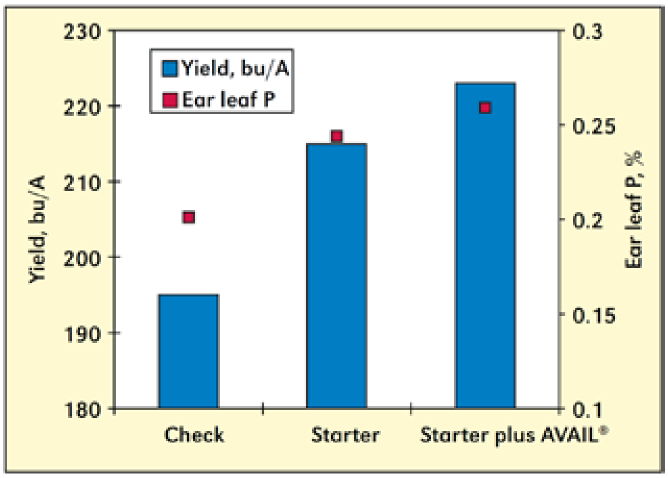

Figure 2. Starter and starter plus AVAIL® effects on corn grain yield and ear leaf P concentration, 3-year average.

AVAIL® to the starter fertil-izer further increased yield by an additional 9 bu/A. Corn ear leaf concentrations at silking were greater in plots receiving the starter plus polymer than in plots receiving no starter or starter alone. This indicates that the use of AVAIL® can result in an increase in P uptake by plants and ultimately in higher grain yield.

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Improving Soil Fertility and Wheat Crop Management Through the Long-term Study of Cereal Crop Rotations

By Brian Arnall and Fernando García

Long-term fertility trials are established and used across the globe. Unfortunately, for many reasons long-term trials are regularly discontinued. These trials are a wealth of data and information laden with golden nuggets of new and amaz-ing insight. In this article, such nuggets gleaned from long-term wheat trials in Canada, United States, and Argentina are presented.

Nothern Great Plains

The Swift Current "Old Crop" rotation is located in south-east Saskatchewan and was established in 1967. Swift Current is located in the driest portion of the Canadian Prairies and is known for its long-cold winters and short grow-ing seasons (Pelton et al. 1967). This report will focus on four of the original 12 treatments implemented in 1967: fallow-wheat-wheat with N and P fertilizer (FNP); fallow-wheat-wheat with P fertilizer only (FP); continuous wheat with N and P fertilizer (CNP), and continuous wheat with P fertilizer only (CP). On average, all cropped treatments designated to receive P received 9 to 10 kg P/ha/yr. The data, figures, and results are derived from Selles et al. (2011).

To evaluate trends over time, the data set was evaluated as three periods identified by water deficit estimations of 1967 to 1979; 1980 to 1993; and 1994 to 2005. The response in Olsen P (0 to 15 cm) soil test values were significantly affected by treatments among the three periods. During the first 12 years, there were no differences among the four treatments. During the second period; treatments began to separate, due to the higher frequency of cropping and therefore fertilization, and as a result the Olsen P of the CW rotations became significantly higher than the FWW. In the third period, FNP had significantly lower Olsen P than the other treatments. Phosphorus balance, calculated as fertilizer added – grain P removal, of the CW rota-tion was significantly higher than the FWW. During this time period, FWW received 43 kg P/ha less than the CW treatments. In the second period, P balance of the FWW was significantly lower than the first period and again significantly lower than the CW treatments. By the third period, the P balance of the FP and CNP was similar and the CP significantly higher than other treatments. The P balance of the FNP became negative; however, the Olsen P level was still significantly higher than at establishment.

The temporal trend in Olsen P levels was also assessed (**Figure 1**). All treatments showed linear positive trends that persisted for the first 20 years of the experiment. The P only treatments, CP and FP, maintained the increasing trend over the duration of 0.68 and 0.45 kg P/ha/yr, respectively. The rotations receiving both N and P created linear trends of 0.64 and 0.56 for CNP and FNP, respectively, for the first 20 years of the experiment then Olsen P stabilized for the remainder (**Figure 1**).

Many long-term trials have opportunity to incorporate split plots; the Old Crop rotation is one of those. In 1993, the researchers decided to split treatments receiving P fertilizer to provide an area in which P fertilization was discontinued. Withholding fertilizer P had no impact on grain yield in either treatment in the FWW rotation; however, 10% reduction in grain yield was observed in the CW systems (**Table 1**). Selles et al. (2011) noted that the yield reduction in CW was not consistent; however, for both CNP and CP there were 2 years in which yield reduction was more than 35%.

The results demonstrate that residual soil P accumulated during the previous 27 years (1967 to 1993) remained in forms readily available to the crop, confirming that in soils with high levels of residual P, crops rarely suffer production losses when fertilizer P is not supplied (Selles et al. 2011).

Central Great Plains

Oklahoma is home of several long-term winter wheat trials; including the Magruder Plots, the oldest continuous wheat plot west of the Mississippi River. These data are derived from a continuous winter wheat NPK study established in 1971 in northwestern Oklahoma. This report will focus on data from six treatments over a range of N rates from 0 to 112 kg/ha in 22.4 kg increments. Each treatment receives 20 kg P/ha and 56 kg K/ha annually.

For more than 30 years of production the N check plot recorded yields ranging from 0.75 to 2.84 t/ha, averaging 1.78 t/ha per year. The 112 kg N/ha plot (highest N rate) recorded a low of 1.42 t/ha and high of 5.94 t/ha with a 30-year average of 2.96 t/ha. The standard deviation of the grain yield from the two treatments was 0.55 and 1 t/ha, respectively. To aid in the review of these data, they were grouped into 5-year segments where general tends become visible. One is the increase in yield due to the addition of N fertilizer, calculated by subtract-ing the yield of the zero from the fertilized. With exception of the early 1980s, yield response has increased over time (**Figure 2**). It is evident the difference between good years and bad years, within each 5-year grouping, is also increasing in the fertilized plot. The last three periods: 1995 to 2000, 2001 to 2005, and 2006 to 2010, resulted in yield differences of 2.36, 3.20, and 3.83 t/ha, respectively (**Figure 3**). This trend identifies that the likelihood of either over or under fertilizing is also increasing as the variability in annual N removal increases. For each year, the economic optimum nitrogen rate (EONR) was calculated. When evaluated in 5-year groupings, EONR has been static at 112 kg N/ha since the early 1990s (**Figure 4**). However, within each 5-year grouping the range of EONR has been 90 kg N/ha or more since the

Table 1. Effect of withholding P on total wheat grain production during the period of 1994 to 2005.

Rotation	Grain Production, t/ha	
	P applied	**P withheld**
CNP	29.1	26.3*
CP	19.8	18.7*
FNP	21.3	21.0
FP	18.0	16.8
Nested LSD	1.8	

Significance between P applied and P withheld at p < 0.05.

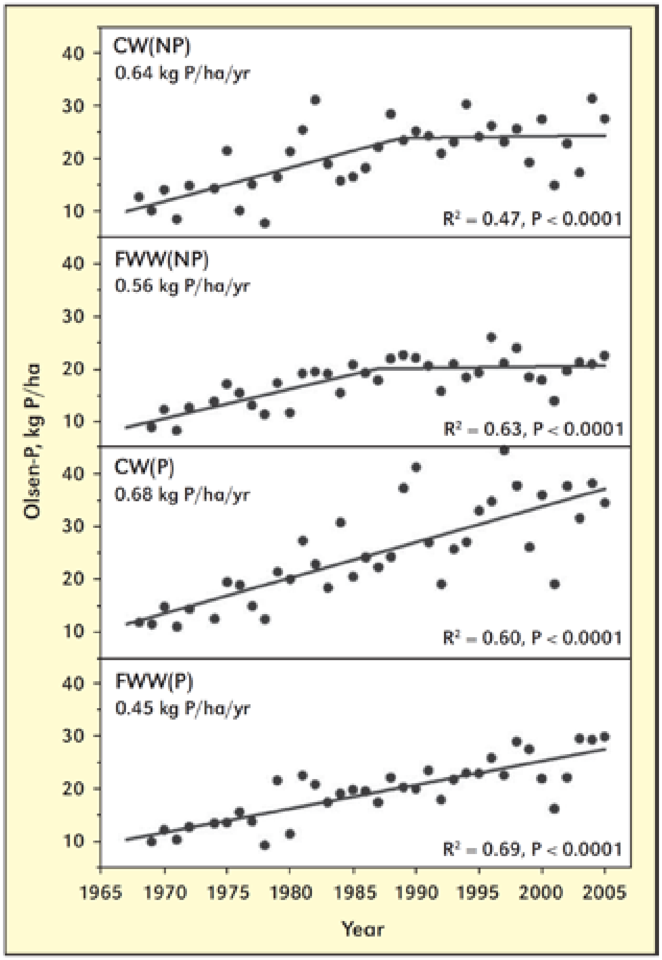

Figure 1. Trends in Olsen P for the original plots, 1967 to 2005. [Trend models given by following expressions: CW(NP) if time ≤22, $y = 9.9 + 0.64 \times time$, otherwise $y = 9.9 + 0.64 \times time - 0.61 \times (time - 22)$; FWW(NP) if time ≤20 $y = 8.9 + 0.56 \times time$, otherwise $y = 8.9 + 0.56 \times time - 0.59 \times (time - 20)$; CW(P) $y = 11.5 + 0.68 \times time$; FWW(P) $y = 10.4 + 0.45 \times time$]. From Selles et al. (2011).

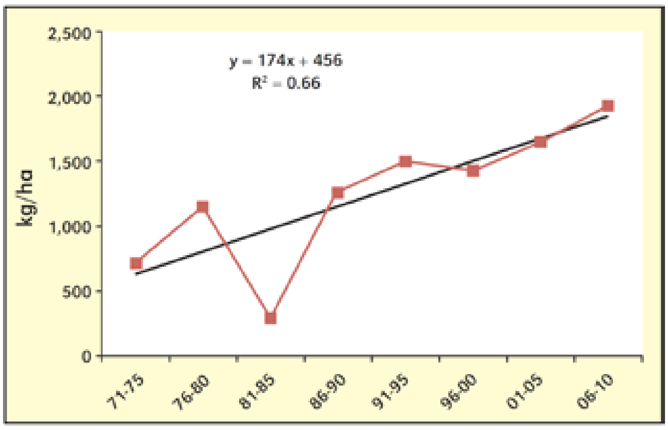

Figure 2. Yield increase due to N over time. Increase calculated as yield of the 112 kg N/ha treatment minus the yield of the 0 N treatment.

late 1990s (**Figure 4**).

Typical N management of the region consists of average yield goals calculated from the previous 5 years, plus 20%. This strategy would result in the over application of 1,672 kg N/ha over the period between 1976 and 2011. Use of 5-year EONR reduced over application to 1,187 kg N/ha, 30% less than the strategy based on yield goals plus 20%.

The data not only shows how the yield potential of winter wheat grown on the Great Plains has increased, but also how the response to added fertilizer N is also increasing with time. Much of this increase could be a consequence of improved varieties and better crop management strategies. More im-portantly, these data indicate the magnitude of the temporal variability in maximum yield and N requirements. This shows the need for in-season measurements that can adjust total N recommendation based upon environment and crop status.

Argentinean Pampas

The youngest of the three studies discussed is located in the Pampas Region of Argentina. Unlike the previous two experi-ments, this fertility study comprises 11 on-farm experimental locations. Sites belong to the Nutrition Network of CREA Southern Santa Fe, and reside in the three provinces of Santa Fe, Cordoba, and Buenos Aires. CREA (Regional Consortia for Agricultural Experimentation) are farm groups dedicated to develop and share knowledge and information on crop, soil, and farm management.

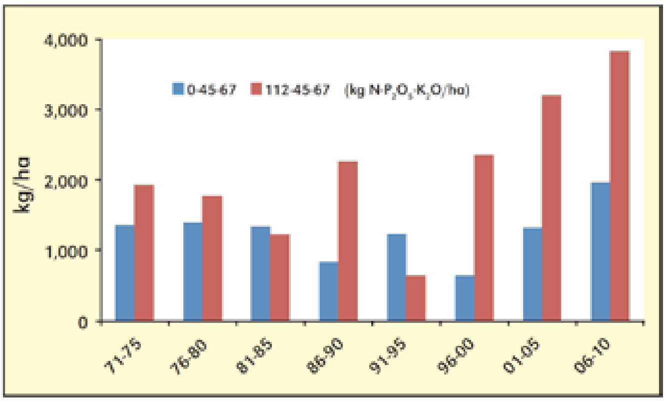

Figure 3. Yield difference between the highest and lowest yielding years within each 5-year grouping.

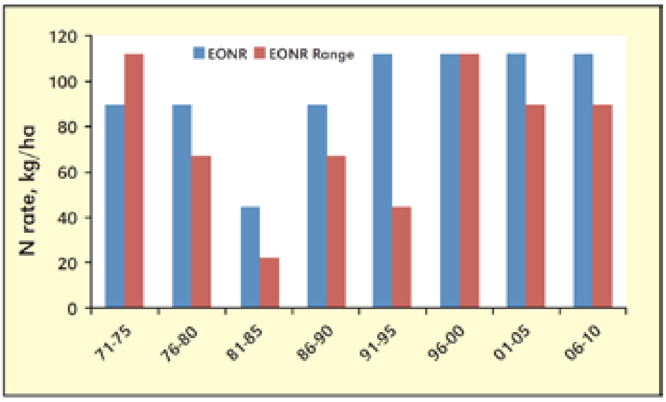

Figure 4. Economical optimum N rate (EONR) for 5-year groupings and the range in EONR value within each grouping.

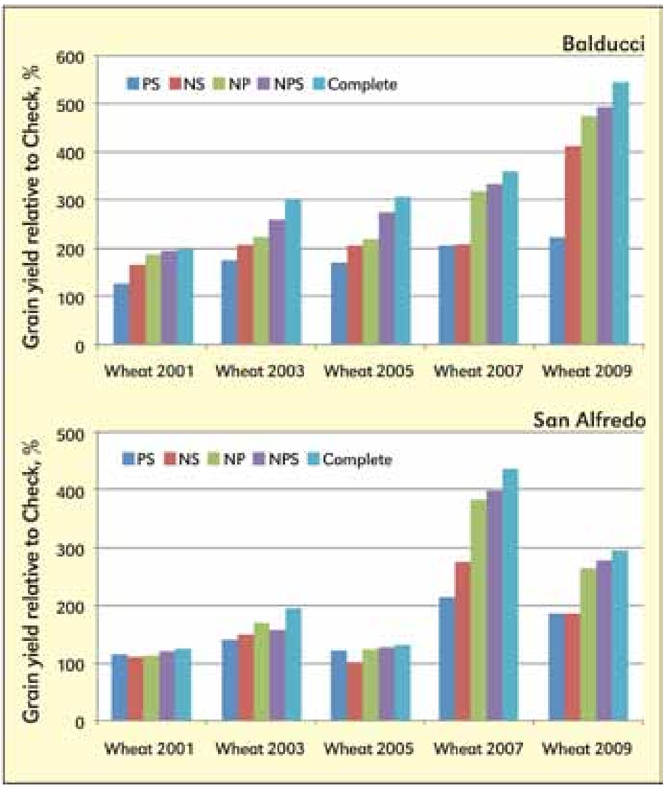

Figure 5. Relative wheat grain yields for different fertilization treatments in the sites of Balducci (C-W/S rotation) and San Alfredo (C-W/S rotation), considering the check yield as 100%.

The 11 locations are separated according to crop rotation into two categories: corn-wheat/soybean (C-W/S) and corn-soybean-wheat/soybean (C-S-W/S). Six treatments are applied at all locations: 1) Check, 2) PS, 3) NS, 4) NP, 5) NPS, and 6) Complete (NPS plus: K, Mg, B, Cu and Zn). Nutrient rates ap-plied to cereal crops were equivalent to grain nutrient removal + 10%, except for N for which rates were decided according to local calibrations of soil nitrate-N test at planting.

A summary of the first 6 years was presented in García et al. (2007), and since establishment in 2000; wheat has been included in 33 site/years: five cropping seasons from the C-W/S locations and three from the C-S-W/S sites. From these trials the correlation between crop response and soil test can be evaluated. Over the 33 site/years, there were significant grain yield increases at 16 site/years for N, 25 site/years for P, 6 site/years for S, 20 site/years for NPS, and 4 site/years for other nutrients (García et al., 2010).

Significant relationships were established between N response and soil nitrate-N availability at planting (0 to 60 cm), and sap nitrate concentration at tillering. Critical soil nitrate-N of 130 to 140 kg N/ha at planting (soil N + fertilizer N) have been established for wheat yields of 4 t/ha. Phosphorus responses were observed in 95% of the sites with soil Bray P levels lower than 15 mg/kg, as reported by Berardo (1994) and Zamuner et al. (2004) for the southern Pampas. A critical range of 15 to 20 mg Bray 1 P/kg has been defined. There was no relationship between S response and sulfate-S availability at planting, as it was observed for other wheat experiments in the Pampas (García, 2004). Conversely, corn yield responses to S were related with sulfate-S at planting (0 to 20 cm).

Yield differences among fertilized treatments and the check increased along years of evaluation, suggesting that 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) identified 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

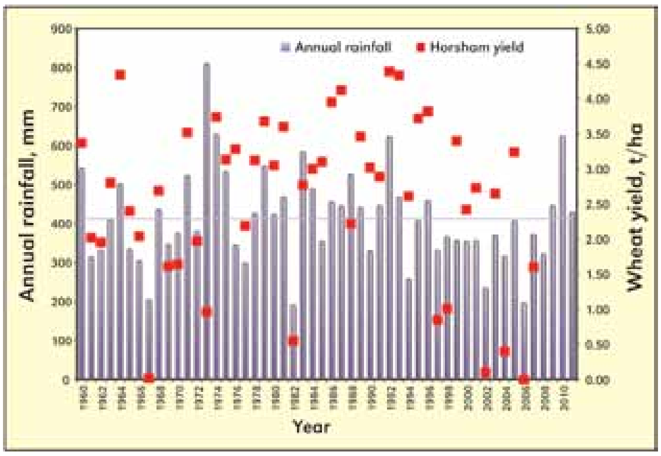

Figure 1. Annual rainfall and wheat grain yield from a farm near Horsham in the Victorian grain belt.