No-till Corn Responds to Fluid Fluid Starters

Response is significant in five of six experiments in Argentina.

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Summary: *There was significant response to starter fertilization in five of six experiments, as indicated by the contrast between the check and fertilized treatment. Fluid sources were not different to granular at the same rate and Phosphorus:Nitrogen (P:N) ratio. All evaluated grades were able to supply enough P or Sulfur (S) to achieve a reasonable replacement percentage (application vs. removal) but not for Potassium (K) in Mercedes, where the need for K in the starter is clearly demonstrated.*

Although the use of urea ammonium nitrate (UAN) and other N-S fluids has a wide and deep development in Argentina for many years, the availability of P sources, long awaited by fluid fertilizer users, may offer special and distinct challenges to all the value chain, from distributors to end users. Several local fertilizer firms are currently marketing P-based fluid fertilizers, either importing or manufacturing from imported phosphoric acid or solubilizing ammonium phosphates with sulfuric acid followed by neutralization.

The application of NP or NPS/NPKS fluids as a starter has to have distinctive advantages over the solid granular blends via a rapid adoption from farmers, as well as lack of major disadvantages. Among the main concerns of farmers using starters--solid or fluid--is the effect of placement on toxicity to seeds, which has to do with the urea N and ammonium N amounts and the proximity of the fertilizer to the line of seeds.

N and P are the same nutrients used in starters and considered the major contributors to grain yield, but also K and S are often included in starters, either solid or fluids. Since a corn crop yielding 10 Mg ha^{-1} would remove 38, 48, and 10 kg ha^{-1} of P, K, and S respectively, the challenge is to apply as much at sowing to cover replacement without waste and potential phytotoxicity.

Objective

The objective of this work is to find out the best NPKS grades and rates as a starter placed along the row of seeds at planting to maximize grain production in two regions of Argentina. We aim to get a simple blend proportion among common fluid sources that would be easily adopted by retailers and farmers.

Methodology

Site characterizations involved two field experiments that were carried out in the experimental stations of INTA Mercedes (Corrientes province, 29º11'S – 58º02' W) and in a farmer field near Pergamino (Buenos Aires province, 33º56'S – 60º33' W), during three consecutive seasons (2011-12, 2012-13, and 2013-14).

Soils. The soil of the experiment at Pergamino is loamy clay, slightly acid Typic Argiudoll, with medium organic content, very well supplied with exchangeable K and cations, representative of Pampean soils used for grain crop production. On the other hand, the soil of the experimental site at Mercedes is a sandy loam Aquic Argiudoll, equally endowed with organic matter but much lower in available K. A composite soil sample was collected at both sites at planting to characterize the initial fertility of the site of the experiment, which is shown in Table 1 along with other agronomic characteristics of the crops for every season.

Treatments. The experiment was a factorial of two rates and two grades of fluid fertilizer mixes plus a single rate of granular fertilizer blend and a check with N only (Tables 2 and 3). In Pergamino (Table 2), the fluid blend was an NPS one, made by mixing ammonium polyphosphate (APP, 11-37-0, sp. gravity 1.42 kg dm-3), urea ammonium nitrate (UAN,32-0-0, sp. gravity 1.32 kg dm-3) and ammonium thiosulphate (ATS) 26-0-0-12S, sp. gravity 1.32 kg dm-3) with a 1:1 and 2:1 N:P ratio. The granular blend used Single super-phosphate (0-20-0-125) and diammonium phosphate (18-46-0) to prepare a grade close to supply the same quantity and ratio of nutrients of the first fluid treatment. The experiment included a check without any fertilizer other than N, totaling seven treatments

Plots. All plots received enough N as UAN between V6 and V8 stages to standardize all treatments in 160 kg ha-1 and thus compensating the N supplied at sowing by the different treatments. Conversely, the check treatment received

Table 1. Soil fertility and agronomic characteristics of the experimental site-year at each location.

Location	Texture	pH	OM	P-Bray 1	$S-SO_4$	K	Mg	Sown	Hybrid
	top soil		$g\ kg^{-1}$	$mg\ kg^{-1}$		$cmolc\ kg^{-1}$			
Pergamino									
2011-12	Loamy clay	5.7	37.5	14.6	7.8	1.25	1.44	Nov-15	NK 900
2012-13		5.5	35.3	44.7	17.5	1.29	2.00	Dec-13	Arvales 2310 MG
2013-14		5.5	20.0	3.8	6.0	0.94	1.82	Oct-24	DK 192
Mercedes									
2011-12	Sandy loam	5.8	24.2	10.0	8.0	0.12	1.98	Dec-22	DK 390 HX RR
2012-13		5.5	17.8	10.7	4.9	0.14	1.20	Aug-30	M510 HX RR2
2013-14		5.5	22.0	5.2	5.1	0.13	1.23	Sep-20	DK 190

part of the total N at sowing to compensate what other treatment supplied to crop with N.

Table 2. Nutrient combination in the experiment of Pergamino site, Buenos Aires province.

	Starter		Nutrients w/starter			Urea			Ratios	
Treatments	**Ratio**	**Rate**	**N**	P_2O_5	**S**	**Sowing**	**V-6**	**N Total**	P_2O_5:N	**S:N**
	TSA:APP	$kg\ ha^{-1}$								
Check	-	0	-	-	-	36	312	160		
Granular A	-	65	3	18	6	33	309	160	0.8	0.3
Fluid 1	1:1	120	22	22	7	-	300	160	1.0	0.3
Fluid 2	1:1	180	33	33	11	-	275	160	1.0	0.3
Granular B	-	75	7	26	4	21	307	160	1.3	0.2
Fluid 1	1:2	120	19	29	5	-	307	160	1.5	0.3
Fluid 2	1:2	180	29	44	7	-	286	160	1.5	0.3

Blends. The site in Mercedes had the same treatment arrangement except that the blends included K, that is, the fluid was an NPKS (Table 3). The fluids were made by mixing different properties of ammonium polyphosphate (APP), UAN and potassium thiosulphate (0-0-25-17 S, sp gravity 1.45 kg dm-3). The granular blend used single superphosphate (0-20—0-12 S), urea (46-0-0), and potassium chloride (0-0-60) to prepare the grades shown in Table 3. The N supply was constant at the 120 kg N ha-1 rate, lower than in Pergamino due to the reduced yield potential of this environment.

Design. The experimental design was a randomized block one, with four replications. The plots of each replication were 4 rows (2.8 m) and 20 m in length

Fertilization. Fertilizer was applied in Pergamino with field machinery using 0.7 spaced row planters equipped with a fluid fertilizer applicator. Fertilizer application rates were regulated by an electric pump and a calibrated nozzle to deliver the differential rates to a manifold and tubes for each row, so that each row received a uniform flow. The treatments in Mercedes were applied by hand at sowing, delivering the designed rates of each product in a furrow aside of the row of seeds opened with a hoe right after sowing.

Crop management

After emerging, plant population was estimated by counting plants in 1 m segments at stages between V-3 and V-6. The methodology of estimation varied among the year and location.

Grain yield at physiological maturity was measured by collecting and counting ears at the center of a plot. A sample of the threshed grain was collected to evaluate 1,000 grain weight and thus estimate the number of grain per ears, as affected by the various fertilizer treatments.

Ears were threshed with a stationary machine and grain was weighed and moisture measured. Grain yield was expressed at Mg ha^{-1} (t ha^{-1}) at commercial moisture (13.5%). Grain yields were analyzed statistically by using the general lineal models of the SAS package to evaluate the treatment and other effects. Comparisons of treatment means were performed using a protected LSD test.

Results

Weather. The weather scenario of each experiment was characterized by recording daily precipitation, solar radiation, and temperatures at each site. The most striking differences among environments, year, and locations resulted in a large variation of weather scenarios. Not only were there differences among years but also between locations; furthermore, the planting date in Mercedes differed by 112 days from one year to another (Table 1). Figure 1 shows the accumulated annual rainfall within each location, compared with the long-term (LT) record for each site. Precipitations during the first (2011-2012) and the second year (2012–2013) of the experiments were below and above normal respectively at each site, while in the third year (2013-2014) the crops thrived in a short water supply but then later normalized and exceeded historical precipitations.

Plant stand. Despite concerns about potential phytotoxicity of starter fertilizers affecting plant stand, during none of the

Table 3. Nutrient and fertilizers applied with each product rate and blend combination for Exp. St. INTA Mercedes, Corrientes province.

Treatments	Starter		Nutrients w/starter				Urea			Ratios	
	Ratio	**Rate**	**N**	P_2O_5	K_2O	**S**	**Sowing**	**at V-6**	**N Total**	P_2O_5:N	K_2O:N
		$Kg.\ Ha^{-1}$									
Check	-	0	-	-	-	-	43	218	120	-	-
Granular A	-	100	2	18	12	8	43	215	120	0.9	0.6
Fluid 1	1:1:1	150	21	18	12	8	0	215	120	0.9	0.6
Fluid 2	1:1:1	250	35	31	21	14	29	184	120	0.9	0.6
Granular B	-	110	7	29	10	7	0	217	120	1.4	0.5
Fluid 1	1:2:1	150	20	28	9	6	0	217	120	1.4	0.5
Fluid 2	1:2:1	250	34	46	16	11	0	188	120	1.4	0.5

six trials was there any deleterious effect observed causing stand reduction or decreased plant population (Table 4).

Yield. The different fertilizer treatments affected corn yields, responding significantly to base fertilization in five of six sites, as indicated by the contrast between the control and the other treatments (Table 4). Figure 2 shows the grain yield for each year and the sites, and Table 4 depicts the significance of the main effects evaluated in the experiments.

Table 5 summarizes the statistical analysis by site-year where the significant effects appear only at the site of Mercedes during the first year. In general, other differences between the control and the fertilized plots appear to be small and of little consistence. Even the effect of rates is not homogeneous across the P and N ratio. The accompanying picture demonstrates the lack of differences between granular and fluid sources at the same, or close to, nutrient rate.

Although strongly influenced by the magnitude of the check yield that received no nutrients other than N, there were linear responses to P, K, and S in the experiments. Figures 3 and 4 show the relationship between relative yields and amounts of applied nutrients over base fertilization, regardless of source or P_2O_5:N ratio in Pergamino and Mercedes, respectively.

In high P fertility soils, as in Pergamino, the responses to P are rather low, regardless of the rate of applied P, fertilizer source, or P_2O_5:N ratio. The levels of available P (Bray) were close to sufficiency, indicating "well supplied" in the sites chosen for the first and second season (15 and 45 mg kg^{-1} or ppm) but insufficient in the third season (3.8 mg kg^{-1} or ppm). At this site we observed a larger

Table 4. Plant population in counts at V-3 to V-6 in each year-location experiment.

	Mercedes			Pergamino		
Treatment	**2011-12**	**2012-13**	**2013-14**	**2011-12**	**2012-13**	**2013-14**
	pl m-2					
Check	6,9	3,8	4,5	6,1	5,6	6,2
Granular A	5,8	4,2	4,3	6,7	6,1	6,3
Fluid 1	5,8	3,4	4,7	6,4	5,6	6,0
Fluid 2	6,0	5,2	4,9	6,8	6,8	5,9
Granular B	6,0	4,4	5,0	6,4	6,0	6,4
Fluid 1	6,0	4,8	4,5	6,4	6,3	6,2
Fluid 2	6,5	4,4	4,9	7,0	6,0	6,1

Table 5. Summary of statistical analysis of the experiments.

	Mercedes			Pergamino		
	2011-12	**2012-13**	**2013-14**	**2011-12**	**2012-13**	**2013-14**
	Pr > F					
Treated vs. Control	<.0001 **	<.0001**	<.0001**	0.076#	0.46 ns	0.012*
Granular vs. Fluid	0.0004 **	0.33 ns	0.33 ns	0.72 ns	0.85 ns	0.67 ns
Fertilizer Rate	<.0001 **	0.47 ns	0.003 ns	0.47 ns	0.42 ns	0.75 ns
N:P ratio	<.0001 **	0.38 ns	0.45 ns	0.52 ns	0.91 ns	0.82 ns
Rate* N:P ratio	0.88 ns	0.15 ns	0.35 ns	0.96 ns	0.73 ns	0.53 ns
LSD 5%	643	597	875	471	2263	1180
CV %	6.7	6.9	8.8	3.5	18.6	11.9

response as the site was consecutively cropped; in the first season we got only 0.1% of more yield per kg of applied P, but in the second season this number grew to 0.3% and in the third season to 0.6% (Figure 3, left).

The same is observed on the response to S (Figure 3, right), as indicated by the gain in yield per unit of S. The increase was also growing as the site was consecutively cropped in spite of differences in S-SO_4 content in the soil.

The relationship with sulfur is not as good as with phosphorus or potassium, but equally reveals that more than anything else final yields are in close association with the amount of nutrients applied.

On the other hand, a low fertility environment, as in the Mercedes site, the response to P was much larger than in Pergamino for either season, likely due to the lower soil P content (about 10 mg kg^{-1} or ppm). Each kg of additional P_2O_5 applied in Mercedes represents about 0.9% of yield increase in all three seasons. Similarly, the responses to K are clearly linear in the three years, with an average of 2.4 % of yield increase per each kg of K_2O applied in the starter as a result of a K level in soil being below the sufficiency point.

Soil fertility. A very important concern regarding sustainability of agronomic practices everywhere is the maintenance of soil fertility, along with positive economic results--particularly in Argentina, where most of the P is applied at sowing. The regular common practice is to apply amounts that usually are not sufficient to cover the removal of nutrients with harvest. Therefore, it is of strategic importance that starter concentrations of P,

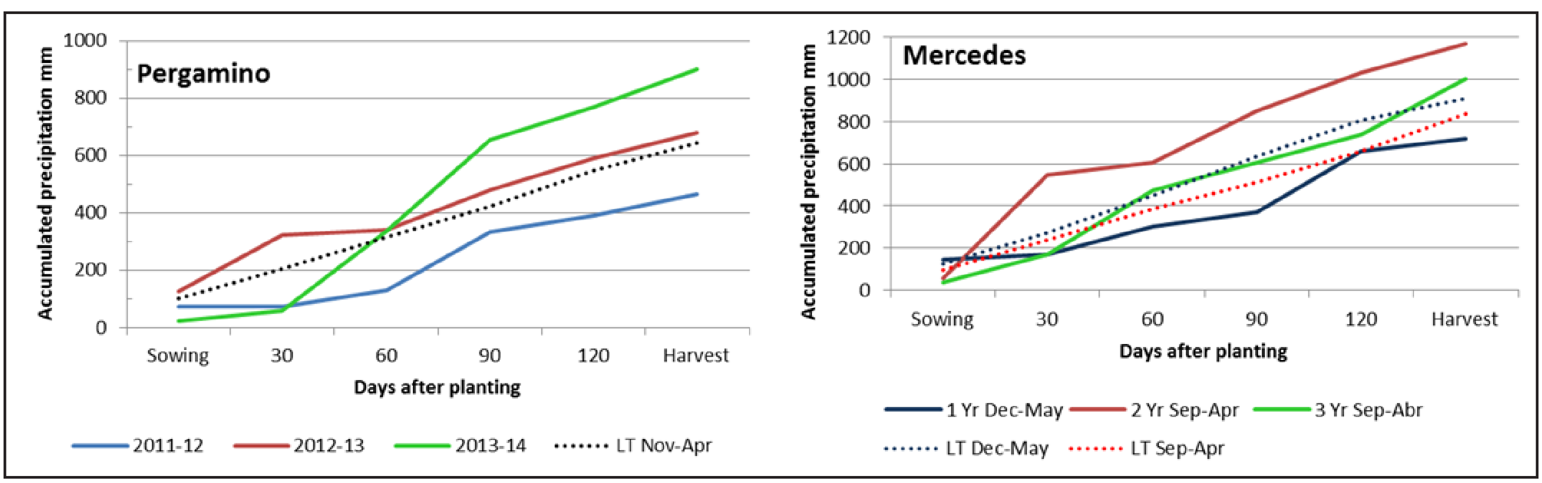

Figure 1. *Accumulated rainfall during the growth cycle of corn at each location and year and historic long term record of the same period in each location. Reference of the monthly periods for comparison is shown in the LT legend.*

S, and K supply as close as possible rates compatible with removal quantities, while keeping the costs at reasonable levels with expected profitability.

Nutrients. Tables 6 and 7 show the average nutrient removal in each site, assuming the concentrations in grain indicated by Heckman et al. (2003) and the actual yields of the experiments, averaging the three seasons in each location. At Pergamino, only higher rates showed positive balances for P, as indicated by applied/removal rates over 100%, while in Mercedes only lower rates had negative balances for this nutrient. This site received noticeably lower rates than required in potassium and would indicate the need to modify the ratios to supply something less in P and higher in the K starter. However, given the small differences between treatments, relative yields (less than 10%), the cost of the nutrients, and the proximity to a positive balance would indicate the most convenient grade and rate to recommend and use for corn production.

Summing up

There was a significant response to starter fertilization in five of six experiments as indicated by the contrast between the check and the fertilized treatment.

Fluid sources were not different from granular at the same rate and P:N ratio

The P:N ratio 1:1 performed better than 1:1.5 only in the Mercedes site, indicating the need of less N compared to P. In the Pergamino site the treatment effect was reverse, since the 1:1.5 ratio was better than 1:1, thus showing more N need than P, regardless of the rate.

Only in one trial in Mercedes was the

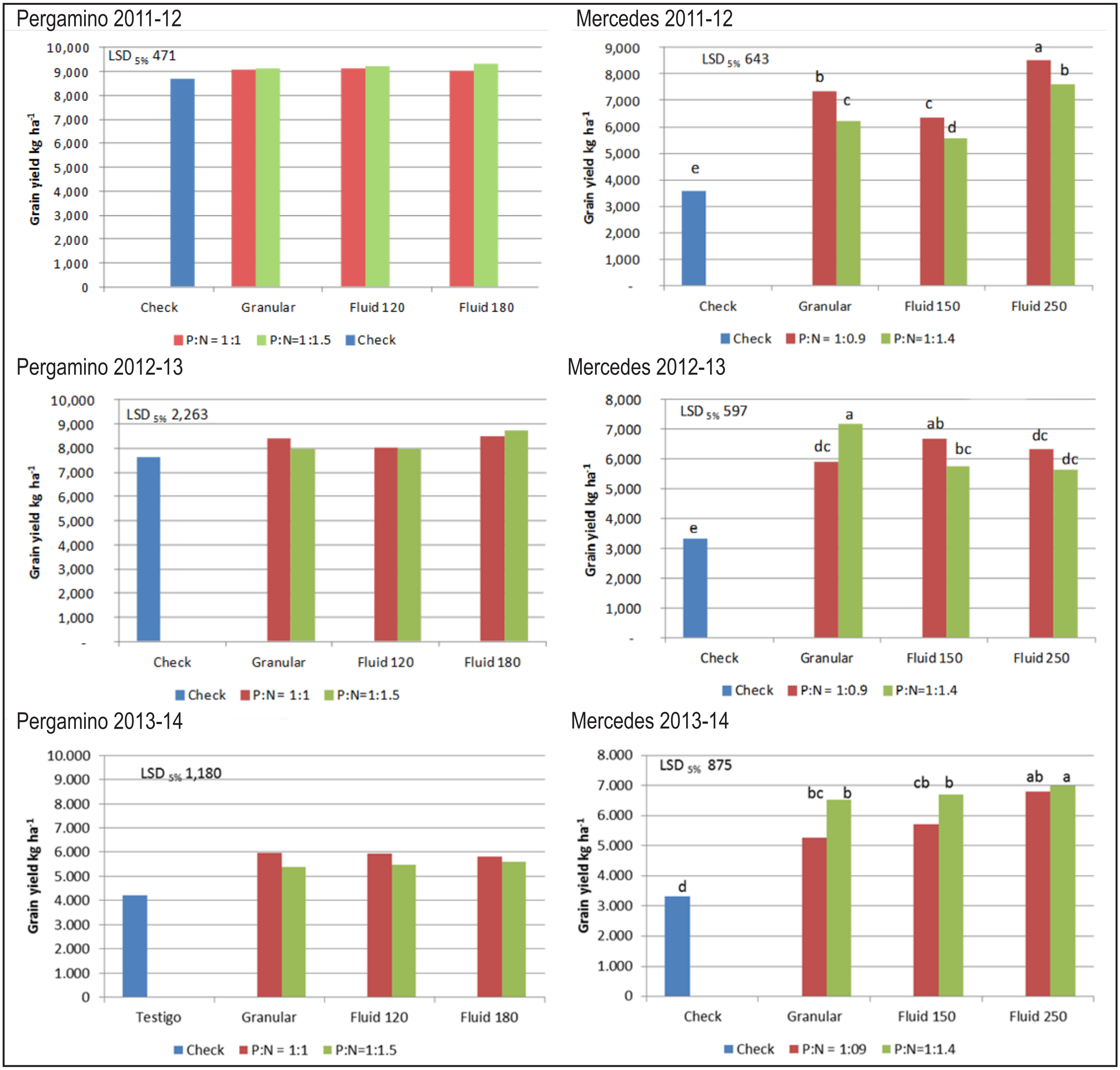

Figure 2. *Treatment means of grain yields of corn affected by the different base fertilizer at planting across locations and years. (P_2O_5 is shown as P).*

Table 6. Applied and removal of P_2O_5 (shown as P) and S averaged across the three years in Pergamino trials compared to mean relative yields.

Treatments		Applied	Removal		Relative	Applied/Removal ratio	
Fertilizer/Rate	P_2O_5:N ratio	P_2O_5 - S	P_2O_5	S	yield	P_2O_5	S
		kg ha^{-1}	kg ha^{-1}			%	
Granular 1	1:1	18 – 6	29,7	7,8	100%	61%	77%
Fluid 1	1:1	22 – 7	29,2	7,7	98%	75%	91%
Fluid 2	1:1	33 – 11	28,9	7,6	97%	114%	145%
Granular 2	1:1.5	26 - 4	28,5	7,5	96%	91%	53%
Fluid 1	1:1.5	29 – 5	29,4	7,7	99%	99%	65%
Fluid 2	1:1.5	44 - 7	29,7	7,8	100%	148%	89%

Table 7. Applied and removal of phosphorus (as P_2O_5) and potassium (as K_2O) averaged across the three years in Mercedes trials compared to mean relative yields.

Treatments		Applied	Removal		Relative	Applied/Removal Ratio	
Fertilizer/Rate	P_2O_5:N ratio	P_2O_5-K_2O	P_2O_5	K_2O	yield	P_2O_5	K_2O
		kg ha^{-1}	kg ha^{-1}			%	
Granular 1	1:0.9	18 - 12	23,5	29,6	86%	77%	40%
Fluid 1	1:0.9	18 - 12	23,8	30,0	87%	76%	40%
Fluid 2	1:0.9	31 - 21	27,4	34,6	100%	113%	61%
Granular 2	1:1.4	29 - 10	25,3	31,9	92%	115%	31%
Fluid 1	1:1.4	28 - 9	22,8	28,8	83%	123%	31%
Fluid 2	1:1.4	46-16	25,6	32,4	94%	179%	49%

effect of starter rate significant. Similarly, only in one trial was the granular source superior to fluid at same rate and P:N ratio.

All evaluated grades were able to supply enough P or S to achieve a reasonable replacement percentage (application vs. removal) but not of K in Mercedes, where the need of K in the starter is clearly demonstrated.

Given the responses to P, S, and K, the recommended amount to be supplied should be enough to cover the crop requirements, rather than looking at N:P ratio in the blend, since N demand can be later satisfied.

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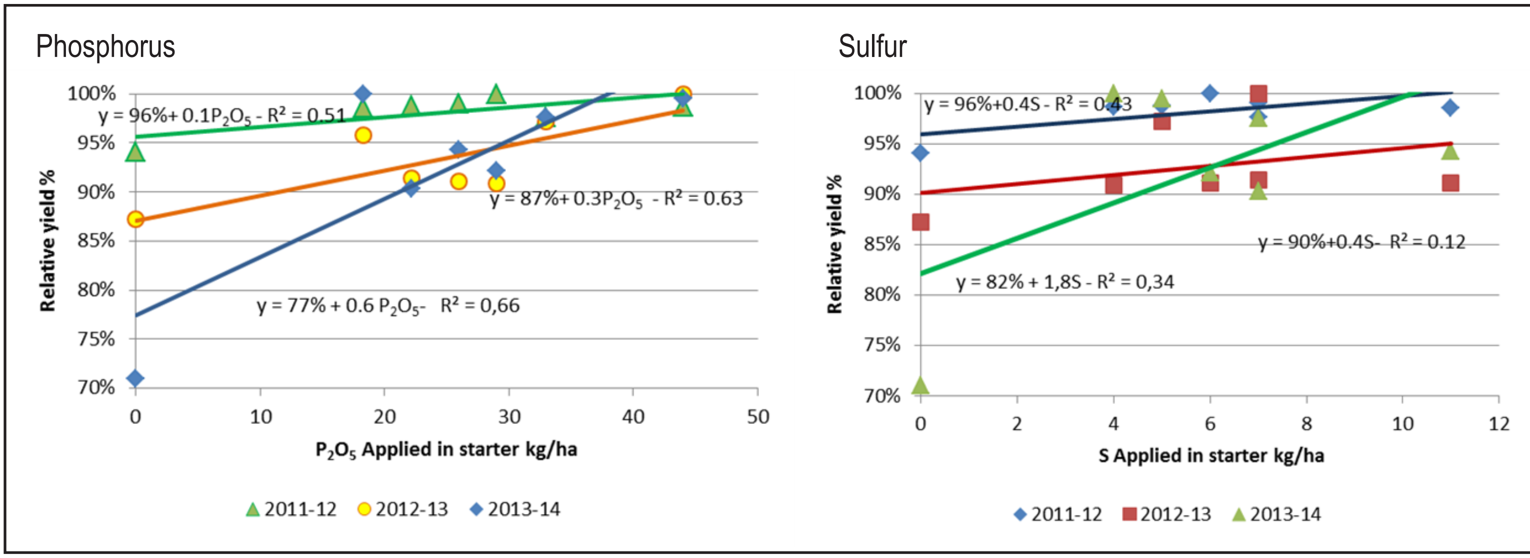

Figure 3. *Response to phosphorus and sulfur in Pergamino trials.*

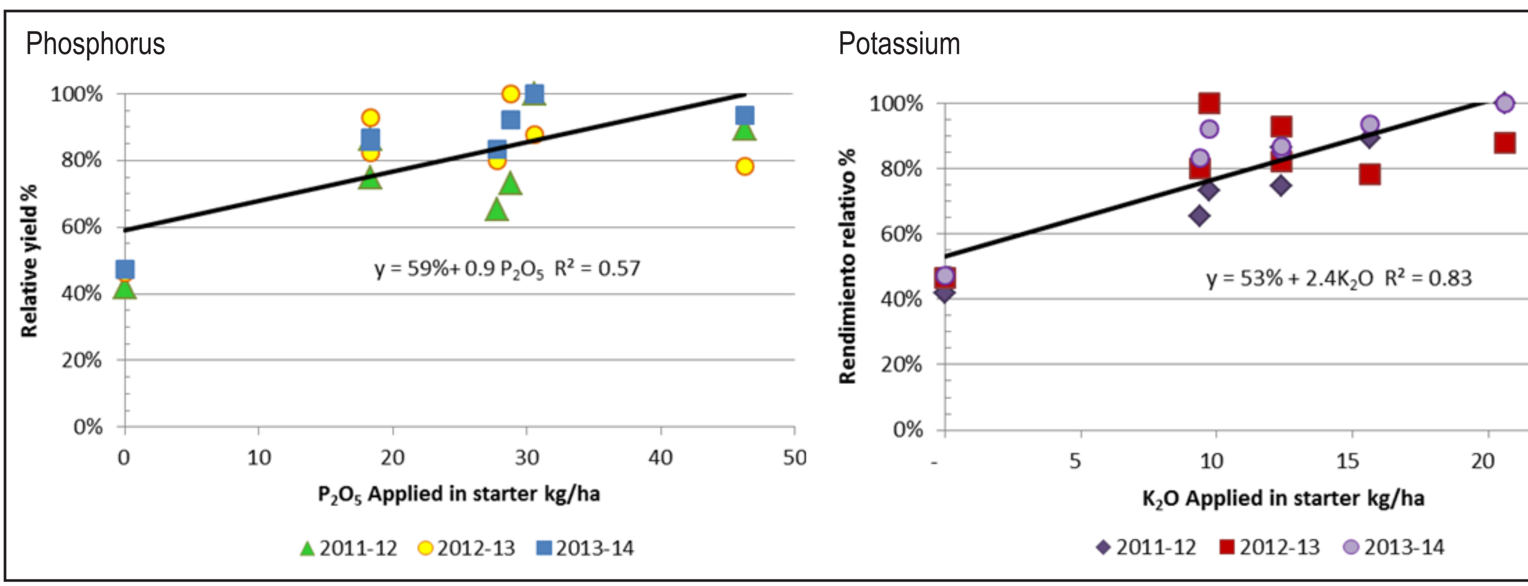

Figure 4. *Response to phosphorus and potassium in Mercedes trials.*