Nutrient Management for a No-Till Rotation in the Pampas: Three Years of Field Trials

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Crop economics can be improved by high yield crop management. Advantages include reduced impact of fixed costs and increased profit margins. Adequate crop nutrition optimizes the use efficiency of all resources and inputs involved in crop production. Knowledge of the extent of nutrient deficiencies pinpoints one set of the barriers to maximum economic yields.

No-tillage is a best management practice that has expanded rapidly in the last 10 years in Argentina. With approximately 12 million hectares (M ha) in the 2000/01 growing season under the no-till production system, it has allowed higher and more stable crop yields than conventional tillage systems due to improved soil organic matter content, greater soil water retention, and better soil structure. As Argentina's farmers develop high-yielding production systems including use of improved technologies such as no-tillage, crop nutrient requirements increase and new nutrient limitations may develop.

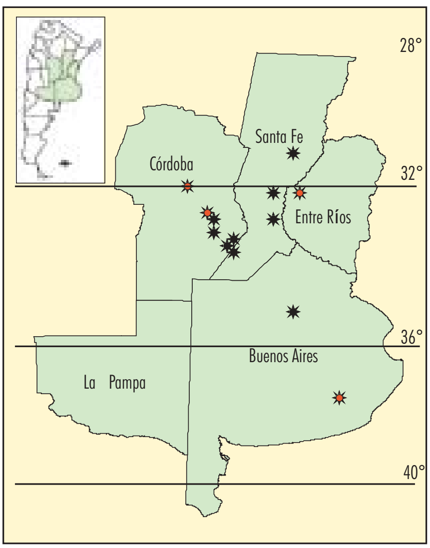

Figure 1. Location of the experimental sites in the Pampean region of Argentina (Provinces of Buenos Aires, Santa Fe, Córdoba, Entre Ríos, and La Pampa). Black dots indicate the sites started in 1999 under wheat, and red dots represent sites started in 2000 under corn. Map generated with ArcView© from INTA-Aeroterra (1995).

In 1999, AAPRESID (a farmer organization dedicated to innovative conservation tillage methods) initiated a study on nutrient management of field crops under no-tillage rotations in the Pampas region. The main objectives were to: evaluate deficiencies and responses to nitrogen (N), phosphorus (P), sulfur (S), potassium (K), magnesium (Mg), boron (B), copper (Cu), and zinc (Zn), under a wheat/double crop soybean-corn-soybean rotation; and to determine maximum grain yields without nutrient limitations. This article summarizes results of grain yields of the first three years of the project, that includes a complete rotation with the four crops.

Thirteen trials on farm fields having stabilized no-tillage systems were established in the provinces of Buenos Aires, Córdoba, Santa Fe, and Entre Ríos (**Figure 1**, **Table 1**). Nine of the experiments were established in 1999/00 under wheat/soybeans, and four were established in 2000/01 under corn. Soils

Table 1. Experimental sites, years under no-tillage (NT), and previous crop at the beginning of the study.

Site	Province	Farmer	Years under NT	Previous crop
Bragado [1]	Buenos Aires	Spelanzón	8	Corn
Cafferata [1]	Santa Fe	Ambrogio	4	Soybeans
Corral de Bustos [1]	Córdoba	Ghio	8	Corn
Leones [1]	Córdoba	Fogante	10	Soybeans
Los Surgentes [1]	Córdoba	Pellizón	1	Soybeans
Maciel [1]	Santa Fe	Berra	2	Corn
Monte Buey [1]	Córdoba	Romagnoli	11	Soybeans
San Carlos [1]	Santa Fe	Colussi	3	Corn
San Justo [1]	Santa Fe	Fabbro	2	Soybeans
Noetinger [2]	Córdoba	Fogante	2	Wheat/soybeans
Paraná [2]	Entre Ríos	A. Protestante	5	Soybeans
Pilar [2]	Córdoba	Borletto-Barrilli	5	Wheat/soybeans
Tandil [2]	Buenos Aires	El Hervidero	3	Wheat

[1]Sites started in 1999 (wheat/soybeans). [2]Sites started in 2000 (corn).

were Argiudolls, except at Bragado and Pilar, which were Hapludolls. Crop management was similar to that provided to the whole field site by farmers. Wheat, soybean, and corn cultivars at each trial were selected according to their adaptation to the area and yield potential.

The fertilizer treatments—varying nutrient combinations plus an unfertilized check—are listed in **Table 2**. Treatment strips were 5 to 15 m wide and 50 to 300 m long, and were arranged in randomized complete block design within a complete block. Fertilizer application rates were determined from grain removal data for expected yield. Treatment 6 was omitted at San Carlos and San Justo. Rates of N were reduced for full season soybeans (2001), which were treated with a double rate of *Bradyrhizobium* inoculant. Fertilizer treatments were applied annually before planting by banding below and to the side of the seed row for wheat (1999), corn (2000), and soybeans (2001).

Soil sampling to a 20 cm depth was carried out prior to wheat planting, and at selected sites and years, prior to corn and soybean planting. Leaf analysis was performed for selected sites and treatments by collecting flag leaves of wheat at anthesis, and ear leaves of corn at silking. Grain was harvested by farm-scale equipment and yields are reported at commercial grain moisture contents, (i.e., 13.5% moisture for wheat and soybean and 14.5% for corn). Analysis of variance and means separation by the Least Significant Difference (LSD) test were performed for each crop data set when appropriate.

Soil analysis for the nine wheat sites (1999), and four corn sites (2000) are provided (**Table 3**). Soil organic matter (SOM) content ranged from 2.4 to 5.7%, and soil pH from 5.5 to 6.7.

Soil nitrate-N (NO_3-N) and sulfate-S availability

Table 2. Fertilization treatments applied to trials.

Treatment	Application rates, kg/ha
Check	—
NP	150 kg N [1] + 30 kg P
NPS	150 kg N [1] + 30 kg P + 22 kg S
NPSK	150 kg N [1] + 30 kg P + 22 kg S + 50 kg K
NPSKMg	150 kg N [1] + 30 kg P + 22 kg S + 50 kg K + 11 kg Mg
Complete	150 kg N [1] + 30 kg P + 44 kg S + 36 kg K + 22 kg Mg + 2 kg B + 2kg Cu + 4 kg Zn

[1]For soybeans (2001), the amount of N applied was 34 kg/ha.

Table 3. Soil analysis at the 13 experimental sites, 0 to 20 cm depth.

Site	SOM	P	NO_3-N	SO_4-S	pH	Ca	Mg	K	B	Cu	Fe	Mn	Zn
	%	- - - ppm	- - -			- - meq/100 g	- -		- - - - - - - ppm				- - - - - - -
Cafferata[1]	3.3	12	26	5	5.7	9.8	2.4	1.6	0.7	2.0	93	118	1.6
Maciel[1]	2.4	20	12	7	6.1	7.1	1.8	1.2	1.1	1.9	85	154	1.0
San Carlos[1]	2.6	19	14	5	5.7	8.2	2.0	1.0	0.6	2.2	97	155	1.1
San Justo[1]	2.6	14	32	5	5.5	7.4	1.6	1.0	0.7	1.7	102	160	1.5
Leones[1]	2.6	19	18	6	5.8	11.5	3.1	1.9	0.8	2.4	69	122	1.1
Corral de Bustos[1]	3.4	22	21	5	5.8	10.8	2.5	1.9	1.0	2.2	82	122	1.5
Los Surgentes[1]	3	28	16	5	5.6	11.3	2.7	1.8	0.6	2.6	86	117	1.5
Monte Buey[1]	2.8	19	17	6	5.7	10.9	2.8	1.9	0.6	2.0	75	77	1.2
Bragado[1]	4.2	7	17	6	5.6	9	2.1	1.4	0.7	1.9	111	90	2.6
Noetinger[2]	3.0	20	14	7	6.1	10	2.7	2.0	0.9	1.7	56	87	1.0
Paraná[2]	4.0	11	13	–	6.6	–	–	–	–	–	–	–	–
Pilar[2]	2.3	26	16	7	6.7	11	2.5	2.7	1.2	1.5	36	78	0.7
Tandil[2]	5.7	33	8	7	5.9	14	1.9	1.9	1.0	1.4	85	28	2.9

[1]Sites started in 1999 (wheat/soybeans). [2]Sites started in 2000 (corn).

were both low at wheat and corn planting. Bray P-1 was low, less than 15 parts per million (ppm) at four sites, medium (15 to 20 ppm) at six sites, and high (more than 20 ppm P) at four sites. Exchangeable calcium (Ca), Mg, and K were above those considered critical for grain production as were soil test Cu, iron (Fe), and manganese (Mn). Boron availability was medium at nine sites and adequate at four sites. Soil Zn content was low at one site, adequate at 10 sites, and high at two sites.

Soil analysis in the second year of experimentation failed to show residual effects from year-1 fertilization for N, K, Mg, S, B, Cu, or Zn fertilization (data not shown). Bray P-1 was extremely variable among treatments and years (data not shown).

Average grain yields for wheat, doublecrop soybeans, corn, and full season soybeans are provided (Table 4). Total grain production, the sum of all four crop yields, and a relative production index, a comparison of the check (100) is also given.

Wheat yields varied from 2,000 to 4,120 kg/ha for the check treatment, and between 2,610 and 5,420 kg/ha for the various fertilizer treatments. A significant difference between the check and the fertilized treatments was determined, but no difference existed among fertilized treatments. The average response to NP fertilization was 1,120 kg/ha (+36%). This response was associated with low NO_3-N availability at planting, and for the Bragado, Cafferata, and San Justo sites, low Bray P-1 levels. Higher yields were observed at Cafferata, because of S application (i.e., NPS treatment), and at Bragado because of application of potassium chloride (KCl) and sulfate of potash magnesia.

Doublecrop soybean yields were affected by drought as rainfall during the months of December 1999 and January 2000 averaged only 226 mm for all seven sites. There were no significant differences between treatments as check yields varied between 1,810 and 3,240 kg/ha, while fertilized plots averaged between 1,580 and 3,260 kg/ha. Yields of the NP treatments tended to be lower than check yields, but application of S raised yield to the same level of the check (**Table 4**). A tendency for lower yields in doublecropped soybeans following NP fertilized wheat

Table 4. Average grain yields for the six treatments of the four crops.

Crop	Number of sites	Check	Grain yield				
			NP	NPS	NPSK	NPSKMg	Complete
		-------------------- kg/ha --------------------					
Wheat (1999)	9	3,090 b	4,220 a	4,170 a	4,330 a	4,390 a	4,710 a
Soybeans (1999/00)	7	2,520	2,220	2,490	2,460	2,490	2,570
Corn (2000)	10	5,620 b	9,000 a	10,100 a	10,100 a	10,200 a	10,100 a
Soybeans (2001)	10	3,860	4,020	4,240	4,140	4,330	4,310
Total production		15,100	19,400	21,000	21,000	21,400	21,700
Relative index		100	129	139	139	142	144

For Wheat 1999 and Corn 2000, values for each treatment followed by the same letter are not significantly different at a probability level of 5%. LSD values of 887 and 2,538 kg/ha for wheat and corn, respectively.

was observed in this and other experiments in the northern Pampas. It is speculated to be a result of: a) greater water consumption by the fertilized wheat crop compared to the check, with less soil water available for soybeans at initial vegetative stages after wheat, and b) an "induced" S deficiency generated by greater S consumption of the previous NP fertilized wheat crop as compared to the unfertilized check.

The last hypothesis is supported by the fact that S fertilization in the previous wheat crop (NPS treatment in these trials), usually equaled or exceeded the yields of soybean check plots.

Corn yields benefited from excellent climatic conditions, with the average precipitation being 526 mm from October to February for all 10 sites. Check yields varied between 1,230 and 9,550 kg/ha, while fertilized yields ranged from 3,510 to 12,200 kg/ha. There were significant differences between the check and the fertilized treatments, but no difference amongst fertilized treatments. Response to NP averaged 3,370 kg/ha, a 60% grain yield increase over the check yield, which was related to low soil NO_3-N and/or Bray P-1 at planting. Sites at Cafferata, San Justo, Corral de Bustos, Los Surgentes, and Paraná also showed yield increases due to S fertilization (data not shown).

Full season soybean yields varied between 2,370 and 5,160 kg/ha for the check treatments, and between 2,850 and 6,120 kg/ha for the fertilized treatments. There were no significant differences between treatments in the overall analysis. Observations at individual sites showed that P application increased yields by 480 and 1,080 kg/ha at San Justo and Cafferata, respectively, according to their low Bray P levels. Sites at Cafferata, San Justo, Los Surgentes, and San Carlos showed increases of 330 to 760 kg/ha because of S fertilization.

Nitrogen and P concentrations for ear leaves of corn for checks were lower than the critical levels suggested by international references. Fertilization with N and P increased these concentrations above critical levels (**Table 5**). Similarly, NP concentrations for wheat were lower in the checks compared to fertilized plots. Concentrations of B and Cu for wheat, and B and Mg for corn were below international standards, while Mg concentrations for wheat, and K and S concentrations for corn were close to standard international critical levels. All other nutrients were at concentrations well above critical levels. Significant relationships were found between corn yield and leaf N and P

Table 5. Average nutrient concentration of flag leaves of wheat (1999) at anthesis, and ear leaves of corn (2000) at silking for the six treatments evaluated.

Treatment	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	%						ppm				
Wheat 1999											
Check	2.9	0.25	1.7	0.40	0.13	0.24	4	3	146	33	14
NP	3.4	0.27	1.8	0.52	0.14	0.29	4	3	140	53	15
NPS	3.2	0.26	1.8	0.46	0.13	0.30	4	2	139	48	14
NPSKCl	3.5	0.27	1.8	0.50	0.13	0.32	4	2	135	48	14
NPSKMg	3.5	0.27	1.9	0.50	0.13	0.33	4	2	124	53	14
NPSMgK micros	3.4	0.27	1.9	0.49	0.13	0.35	7	2	134	52	15
Corn 2000											
Check	1.9	0.21	1.6	0.55	0.16	0.18	12	8	158	40	28
NP	3.0	0.33	1.7	0.59	0.19	0.20	13	13	166	88	35
NPS	3.0	0.32	1.6	0.60	0.22	0.23	13	14	190	81	30
NPSKCl	3.1	0.32	1.7	0.60	0.21	0.24	12	14	187	80	28
NPSKMg	3.2	0.35	1.7	0.62	0.21	0.22	13	15	187	79	29
NPSMgK micros	3.1	0.34	1.7	0.61	0.21	0.25	14	14	192	84	29

concentrations considering all sites and treatments (**Figure 2**). Corn grain yields of 11,000 kg/ha could be reached with N and P concentrations of 3.4 and 0.36%, respectively.

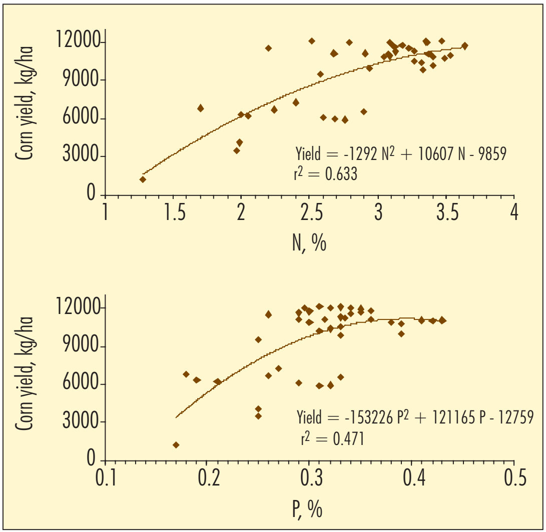

Figure 2. Relationship between corn yield and N and P concentration in the ear leaf at silking. Data include all sites and treatments (n = 42).

Conclusions

Fertilization with N and P increased the total average grain production of the four crop, 3-year rotation by 29%. The NP effect was significant for wheat and corn, but not for doublecropped or full season soybeans. Application of S increased total grain production over NP fertilization alone by an average of 10%; however, this increase was not statistically significant (p=0.05) in any of the four crops. Responses to other nutrients were not significant, although some crop-specific tendencies were occasionally observed at some sites.

Analysis of this 3-year rotation shows the importance of a fertilization management strategy for the complete rotation and not just for a particular crop. A new cycle of the 3-year rotation started in 2002/03 and will provide more information on long-term fertilization management for high-yields under no-tillage in the Pampas, particularly improvement of NPS fertilization management. **BCI**

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