Optimizing Maize and Soybean Nutrition in Southern Russia

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Three years after the initiation of the IPNI Global Maize project in southern Russia, a local solution to an Ecological Intensification (EI) management system is proving to be successful model for demonstrating the potential for better yielding and high quality maize and soybean crops compared to those produced with common farm practice.

The Global Maize project of the International Plant Nutrition Institute (IPNI) is an interdisciplinary, international research effort with an overall objective of creating local Ecological Intensification practices for maize production that increase yields at a faster pace than current grower practices (Murrell, 2012). EI production systems also focus on sustainability while satisfying anticipated increases in food demand (Cassman, 1999). An EI system relies on recent research findings on plant nutrient and soil fertility management. Such important goals as putting the right fertilizer source, at the right rate, in the right place, and at the right time (4R Nutrient Stewardship) are all supported by EI management systems. Global Maize project activities began in Russia in 2011 in cooperation with the Southern Federal University (See details at http://research.ipni.net/project/IPNI-2011-RUS-GM41).

A maize-soybean rotation field experiment (A-site) was established in the District of Tselina in Rostov Oblast. The Global Maize Project designates A-sites as those comparing local EI solutions to farm fertilization practice (FP) within split-plot designs. In Tselina, nutrient management system (EI or FP) was tested across the whole plot while the level of N input was tested across the split plots (**Table 1**). This A-site has two experimental areas that allowed both maize and soybean to be grown each season. Maize and soybean were preceded in the field by winter wheat in 2010. The FP N2 treatment in maize represents practices of large scale farms and neighboring ag enterprises; and in soybean these practices are represented by the FP N1 treatment.

Distinguished from A-sites, Global Maize C-sites are single-year field experiments with maize that are conducted simultaneously at several neighboring locations. These short-term experiments examine crop response to N, P and K using nutrient omission plots (**Table 2**). These C-sites used ample nutrient rates to avoid any deficiencies. Maize was preceded in the crop rotation by winter wheat.

All experiments were conducted on a calcareous common chernozem (**Table 3**). The soil had a clay loam texture, high pH, and low OM content. Average initial contents of nitrate-N (NO_3-N) ranged from medium to "increased" (0 to 20 cm soil layer). Soil extraction with 1% ammonium carbonate [$(NH_4)_2CO_3$] found the site to have medium and "increased" levels of available P and K, respectively. For comparison, Olsen P and exchangeable K (1 N ammonium acetate [NH_4OAc] extractable) tests found P to be within the "increased" interpretation class using the proposed ranges for Ukraine (Khristenko and Ivanova, 2012), while exchangeable K was high at all experimental sites.

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; Mo = molybdenum; $ZnSO_4$ = zinc sulfate; Zn = zinc; NH_4NO_3 = ammonium nitrate; KCl = potassium chloride; MAP = monoammonium phosphate; OM = organic matter; ppm = parts per million. IPNI Project: IPNI-2011-RUS-GM41.

Table 1. Fertilizer treatments applied to maize and soybean rotation "A-sites" in Tselina, Rostov.

Treatment	Description
Maize var. Furio (hybrid)	
FP N1	N_9P_{40} applied in spring before planting.
FP N2	$N_{30}P_{40}$ applied in spring before planting.
EI N1	$N_{17}P_{70}K_{40}$ split between a pre-plant ($N_{12}P_{50}K_{20}$) and planting application ($N_5P_{20}K_{20}$) placed 2 cm to the side of the seed.
EI N2	$N_{85}P_{70}K_{40}$ split between a pre-plant ($N_{50}P_{50}K_{20}$), at planting ($N_5P_{20}K_{20}$) placed 2 cm to the side of the seed, and N_{30} side-dressed at the V3 to V5 stage.
Soybean var. Donskaya 9	
FP N1	N_9P_{40} applied in spring before planting
FP N2	$N_{20}P_{40}$ applied in spring before planting
EI N1	$N_{10}P_{45}K_{30}$ applied in spring before planting
EI N2	$N_{30}P_{45}K_{30}$ applied in spring before planting

Sources for N and K were NH_4NO_3 and KCl, respectively. P and K rates are presented as P_2O_5 and K_2O. Rates shown are kg/ha.

Table 2. Fertilizer treatments applied to maize "C-sites" in Tselina, Rostov.

Treatment	Description
Control	No fertilizer
FP	$N_{30}P_{40}$
NPK	$N_{100}P_{80}K_{60}$
PK†	$N_{18}P_{80}K_{60}$
NK	$N_{100}K_{60}$
NP	$N_{100}P_{80}$

†Not a strict PK treatment since MAP was used as the source of P.
Sources for N and K were NH_4NO_3 and KCl, respectively. P and K rates are presented as P_2O_5 and K_2O. Fertilizers were applied in spring before planting maize var. Furio (hybrid). Rates shown are kg/ha.

Results

The highest average yield of maize of 6.95 t/ha was obtained through local EI management and its average improvement over FP was 8% (**Table 4**). Maize responded only slightly to added N in both the EI and FP management systems. The average yield increase due to N ranged from 4 to 6%. This low response may be explained by adequate NO_3-N levels in the soil.

The highest average yield of soybean of 1.96 t/ha was also obtained through EI management and the improvement over FP reached 25% (**Table 5**). The yield response to additional N over the low N treatment, for both the EI and FP management,

Table 3. Initial soil characteristics at the experimental sites, Tselina, Rostov.

Site	Location	OM, %	pH	NH_4-N	NO_3-N	Avail. P†	Olsen P	Avail. K†	Exch. K††
				ppm					
A	SVTU Tselinkiy	2.9	7.9	20	14	10	16	259	384
C	Ag. enterprises	3.2	7.7 to 7.8	14-19	12-16	10-11	16-18	254-276	354-375

†1%$(NH_4)_2CO_3$ extractable. ††1N NH_4OAc extractable.
Weighted averages were calculated for the 0 to 20 cm soil layer based on soil tests for three depths (0 to 5, 5 to 10 and 10 to 20 cm). OM content was measured in 2011 at the C-site.

Table 4. Effect of nutrient management on maize grain yield, A-site, Tselina, Rostov.

Treatment	2011	2012	2013	Average	Yield increase due to N, %
	Yield, t/ha				
FP N1	7.78	6.70	4.03	6.17	-
FP N2	8.12	6.76	4.44	6.44	4
EI N1†	8.33	6.98	4.28	6.53	-
EI N2†	8.78	7.33	4.73	6.95	6
$LSD_{0.05}$	0.27	0.08	0.22		

†Seeds were treated with $ZnSO_4$.

Table 5. Effect of nutrient management on soybean seed yield, A-site, Tselina, Rostov.

Treatment	2011	2012	2013	Average	Yield increase due to N, %
	Yield, t/ha				
FP N1	1.81	1.22	1.68	1.57	-
FP N2	1.86	1.27	1.90	1.68	7
EI N1†	2.06	1.46	2.02	1.85	-
EI N2†	2.21	1.50	2.16	1.96	6
$LSD_{0.05}$	0.11	0.11	0.16		

†Seeds were inoculated and treated with Mo in 2011 and 2012 and treated with Mo in 2013.

Table 6. Effect of nutrient management on soybean seed quality (3-year average), A-site, Tselina, Rostov.

Treatment	Protein	Oil	Protein yield	Oil yield
	%		kg/ha	
FP N1	40.1	18.3	556	248
FP N2	42.4	17.8	629	260
EI N1†	43.4	19.2	706	309
EI N2†	45.6	19.2	789	328

†Seeds were inoculated and treated with Mo in 2011 and 2012 and treated with Mo in 2013.
Protein and oil content are expressed on a dry matter basis.

Table 7. Effect of nutrient management on maize grain yield, C-sites, Tselina, Rostov.

Treatment	2011	2012	2013	Average
	Yield, t/ha			
Control	7.45	6.61	4.78	6.28
FP	8.09	6.95	5.13	6.73
NPK†	8.99	7.50	6.10	7.53
PK†‡	8.29	6.89	5.56	6.91
NK†	7.93	7.17	5.82	6.97
NP†	8.43	7.38	5.94	7.25
$LSD_{0.05}$	0.27	0.09	0.21	

†Seeds were treated with $ZnSO_4$.
‡Not a strict PK treatment since MAP was used as the source of P.

ranged from 6 to 7% and were not significant during all seasons.

Improvements in seed protein were obtained with both EI and FP management treatments that provided extra N fertilizer (**Table 6**). Protein yields were improved as a result of both grain yield increases and protein content improvements. The highest average protein yield of 789 kg/ha was obtained with EI N2. Our three-year studies thus show that application of 30 kg N/ha may be recommended for soybean grown in this southern agro-environmental zone of Rostov to improve protein production.

The highest maize yield from the single-year C-sites was 7.53 t/ha (three-year average), which was produced with the ample NPK treatment (**Table 7**). Grain yield increases over the control and FP were 20 and 12%, respectively. These short-term field experiments suggest maize yield can be increased by up to 10% as a result of increasing N application from 18 to 100 kg N/ha. Maize also showed a consistent yield response to higher P rates—as much as 13% better during the most favorable, highest yielding season of 2011. The following two seasons were less favorable for maize and the P response was less pronounced at 5%. These findings fall in line with expectations for a medium-testing soil.

A significant yield K response in maize of 7% was obtained in the most favorable year of 2011. Maize response to K fertilizer was lower in 2012-2013 at 2 to 3%. These results suggest that a significant maize response to K fertilizer application may be expected when grain yield of about 9 t/ha is formed. It is assumed that K supplying capacity of a calcareous common chernozem having an "increased" level of available K doesn't match plant K requirements in high yielding environments.

Average values for agronomic efficiencies for P (AE_P) and K (AE_K) were 7.0 and 4.7 kg grain/kg P_2O_5 or K_2O, respectively. These values are quite high considering the ample nutrient rates applied. Under the current price scenario, it is estimated that P and K fertilizer use in maize would be profitable with AE_P and AE_K values above 6.2 and 2.7 kg grain/kg P_2O_5 or K_2O, respectively. We took into consideration the average grain prices at farm gate in the fourth quarter of 2013 and the average prices for MAP and standard KCl in the first quarter of 2014 excluding the costs of fertilizer delivery to the farm, fertilizer application, and additional harvesting and drying for the added grain yield.

Global maize A-site showing maize plots comparing FP (top left) and EI (top right) on July 2013; and soybean plots in August 2011 (left to right) Drs. Nosov, Kuprov and Biryukova.

Summary

Optimization of plant nutrition with macro- and micronutrients is very important in improving productivity of maize and soybean grown in Southern Russia. This three-year field experiment showed that a local EI management system contributed to 8% and 25% more grain production for maize and soybean, respectively, compared to FP. In soybean, an EI system that included 30 kg N/ha also improved the protein content of harvested seeds. Profit analysis from nutrient omission C-sites revealed that the selected "ample" P and K rates were profitable under moderate and above-medium levels of available P and K, respectively. BC

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