Increasing late N availability throughout new products to soybean crops

Dr. Ricardo Melgar

Report 2009 to Fluid Fertilizer Foundation

Introduction

Nitrogen requirement of legumes can be met by both mineral assimilation and symbiotic nitrogen fixation. The plant N requirement may not be met during early vegetative and later productive phases by N2 fixation. Symbiotic fixation begins only after nodule formation, which is preceded by the colonization of the rhizosphere and the infection of legume roots by Rhizobium. Thus, mineral N may be a critical source of N for grain legumes during both the early vegetative and late reproductive periods. The period of high N requirement for soybean is from R3 to the R6 growth stages. Harper (1974) reported that 25 to 60 % of the N in a mature soybean comes from N fixation and the other 40 to 75 % comes from the soil. The contributions of symbiotic and mineral N sources to total plant N are determined by legume N requirement and mineral N supply provided an effective Rhizobium symbiosis is ensured. When mineral N uptake is less than the N requirement, N2 fixation potential can be considered to be equal to the aggregate of per day deficits in mineral N uptake during the legume growth cycle. Several researches indicated positives responses (Sorenson and Penas, 1978; Touchon and Rickerl, 1986) to N fertilization in soybean. Some American authors, Gascho (1991), Flannery (1986) Oplinger (1991), and Wood et al. (1993) reported that N fertilizer applied at the R1 to R5 growth stages increased soybean yields. Wesley et al (1998) in Kansas reported significant increases to N fertilizer supplied as urea or UAN in soybean under irrigation. But extensive work carried out along the Midwest US show controversial results (Barker and Sawyer 2005) . In Pampean region of Argentina, we had some small but consistent response to N applied as ready available sources applied by hand at R1 (data not published).

Although it might be some evidences for late application responses, operational is difficult to manage when fertilizer has to be applied on a dense soybean crop. Under Argentinean conditions, broadcasting urea is not possible since spreaders are not common and of low working capacity. Other sources like ammonium nitrate are forbidden by actual regulations. However, some use of UAN and NS solutions are of increasing use among famers.

Given the development of fluid fertilization and availability of fluid application equipment in particular, there is the possibility of delivering fluid N fertilizers by dribbling or knifing at a phonological moment when soybean canopy is small enough to allow the traffic of terrestrial applicators. However, that moment may be too early if ready available N is applied, that may stop or slow down severely the symbiotic fixation process.

New products developed by industry technological advances may help to allocate fluid N products at a time of planting or shortly afterwards, when farm equipment terrestrial can move over the fields. This could be a cost effective measure of higher efficiency than foliar sprays and cheaper than flying urea, otherwise impossible unless N cold be applied by fertigation.

By using slow/controlled release fertilizers, which may delay between 30 to 60 days its render of mineral N to crops coupled with that early moment, the timing of N availability may offer a better synchronization with N demand without jeopardizing N fixation. Also, urea with a urease inhibitor would prevent N losses by volatilization as NH3 but also at the same time to avoid adding readily available N as in the case of UAN.

Having fertilizer-N available at late stages of soybean, when fixed N would not be enough to support high yields on soybeans would boost grain yields without affecting symbiotically fixed N.

The objective of this work was to evaluate the effect of increasing late N availability by improving placement/product combinations of fluid N sources on soybean grain yields and N uptake.

Materials and Methods

One experiment was set in five locations of Pergamino area, located at north Pampean region of Argentina. However, due

One experiment was conducted in the 2008-2009 season with soybean and carried out at four locations. The experiments were in farmer's fields and experimental station of INTA at Pergamino. The locations where the trials on wheat were installed were: Mercedes (Corrientes Prov.), Crespo (Entre Rios Prov.) Ocampo (Buenos Aires Prov.) and Acevedo near Pergamino city. Another experiment was located in the experimental station of INTA, near Pergamino city, but the sown failed to the extreme drought of the season, precluding the possibility of repeating the sown. The tables 1 and 2 below show some agronomic characteristics and soil test values of the top 0-20 cm.

Table 1. Soil fertility characteristics of topsoil of the experimental sites.

Site	*Location*	*pH*	*OM*	*P-Bray*	*S-SO4*	*N-NO3*
			%	...... mg/kg		
Mercedes	Corrientes	5,8	2,32	7,2	--	--
Crespo	Entre Rios	6,9	3,39	14,2	9,9	--
Ocampo	NO Bs.As.	5,5	3,38	11,5	12,1	25,3
Acevedo	NO Bs.As.	7,1	2,97	13,9	7,8	2,7

Table 2. Agronomic characteristics and management dates of the experiments.

Site	Previous crop	Variety /Hybrid	Sowing Date	Starter N-P-K-S	N Application
Mercedes (Ctes.)	Pasture	DM 4800	Nov 9	14-37-30	-
Crespo (ER)	Corn	A4700	Nov 12	0-37-0	
Ocampo (Bs.As.)	Corn	ADM 4200	Nov 30	0-46-0	
Acevedo (Bs.As.)	Soybean	ADM 50048	Dec 1	0-47-0	

The experiment evaluated four N combinations of source/placement treatments and compared with a check that did not receive fertilizers and with a control that received a readily available N source (ammonium nitrate: 33-0-0) applied at time of maximum uptake, were broadcast by hand at R1 stage, making a total of ten treatments.

Sources to be evaluated are slow or controlled release N products, as follow:

- Nitamin®, provided by GPA, a fluid fertilizer with 30 % N, of which 60 % is slow release, and 40 % of N is in amidic form (urea);
- Nitamin Nfusion ™ , provided by GPA[1], a fluid fertilizer with 22 % N, of which 94 % is slow release and the rest being urea;
- A concentrated urea solution (20% N);
- Idem but with the addition of 0.5% of Agrotain®[2], (n-btpt, an urease inhibitor);

Fluid applications were performed by two methods: 1) Dribbling and 2) Knifing in subsurface bands. A mechanical pump and an applicator bar that holds the nozzles and hoses that deliver the fertilizer blend stream every 0.52 m across the width of the plots at a speed proportional rate by pumping through a hose that fall freely over the soil or is attached to a knife that lead the fluid at 5 cm below soil surface.

The rate for all N applications was 40 kg N/ha.

All these sources were applied and placed at the best timing in order to minimize the possibility of interfering with the symbiotic process. Thus, Urea solutions (c & d) , Nitamin ® (a) and Nitamin NFusion™ (b) were knifed and placed at 5 cm below and aside the rows (2" x 2") at V3 stage.

---

[1] GPA: Georgia Pacific Ltd. Atlanta GA

[2] Agrotain Internacional, St. Louis, MO

	Treatment	% N	Timing	Placement
1	Check (No N Fertilizer)	--	--	--
2	Control (Ammonium Nitrate)	33	R1	Broadcast
3	Nitamin®,	29	V3	Knifed 5 cm x 5 cm
4	Nitamin Nfusion	27	V3	Knifed 5 cm x 5 cm
5	Urea solution	22	V3	Knifed 5 cm x 5 cm
6	Idem 5 + 0.5% of Agrotain®	22	V3	Knifed 5 cm x 5 cm
7	Nitamin®,	29	V3	Dribbled
8	Nitamin Nfusion TM	27	V3	Dribbled
9	Urea solution	22	V3	Dribbled
10	Idem 5 + 0.5% of Agrotain®	22	V3	Dribbled

All these treatments were allocated in a randomized block design with four replications. Plots will be 6 rows spaced 0.52 m of 10 m length.

The crops were inoculated and properly fertilized at planting with enough P and S to prevent any possible shortage of essential nutrients.

Harvest occurred at physiological maturity and grain yield was evaluated by cutting plants of four lineal segments within the plot, each one covering 0,5 m2 making a total area of 2 m^2. The whole aboveground plants were weighed before threshing to evaluate total aboveground dry matter. After threshing, a sample of grain and residues was taken to evaluate humidity content in grain and stover. Plot grain yield was expressed in kg/ha at 13,5 % humidity

Grain analyses for N concentration were performed using Kjeldhal technique and protein was calculated used a local factor of 5,71. Nitrogen uptake by grain in kg /ha was calculated as a product of grain yield and N concentration. By subtracting the values of the check, the partial N efficiency for each of the treatment was calculated as increase in grain N accumulation that results from the application of a given rate of fertilizer N.

Statistical Analysis

The soybean yield data was statistically analyzed considering the site and treatment and its interaction as well according to the following model:

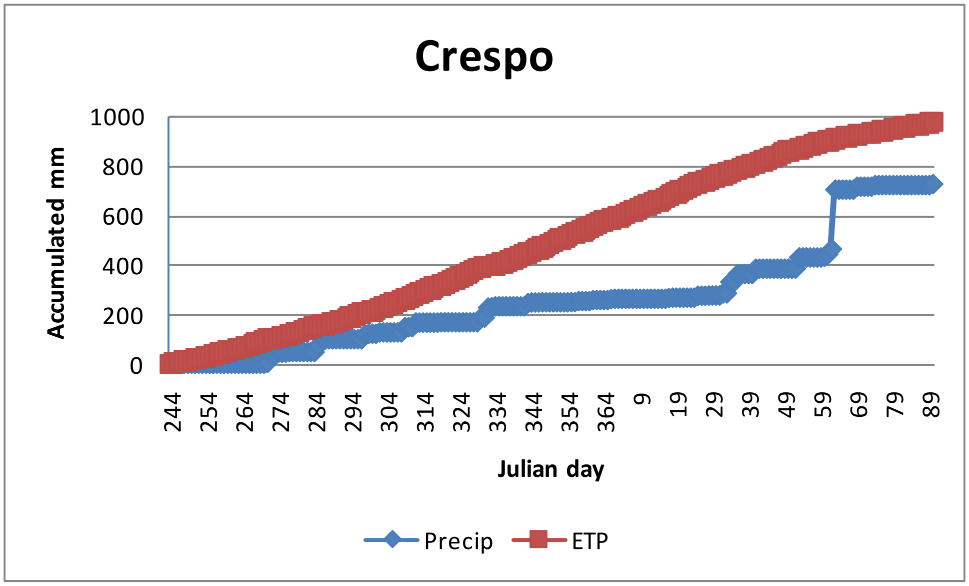
$$Y_{ijk} = \mu + \alpha_i + \beta_{j(i)} + \gamma_k + \alpha\gamma_{ik} + \varepsilon_{ijk}$$

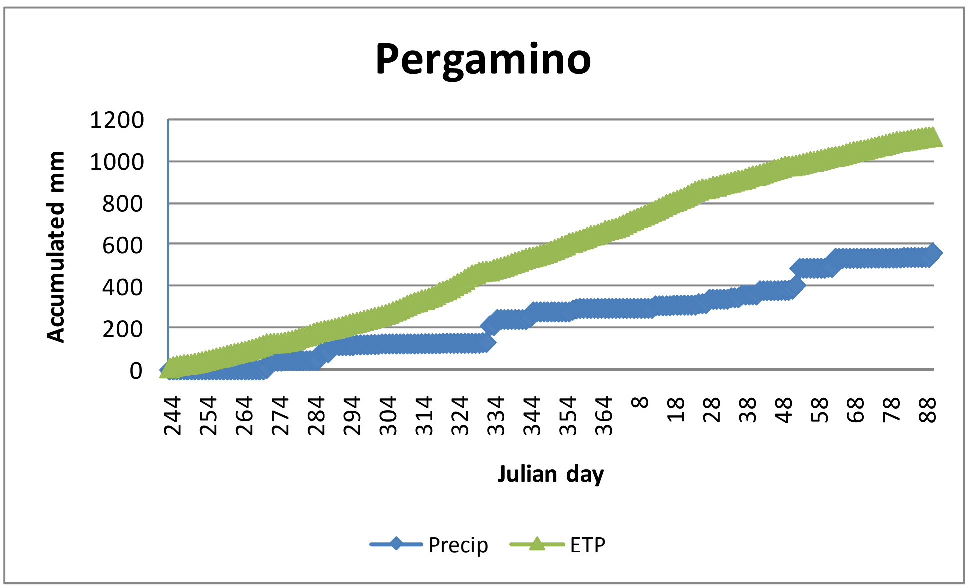
Where μ is the overall mean and ε is the experimental error, α, β, and γ are estimators for the site, block and treatment effects respectively. When grain yield were analyzed by site, the corresponding effect and its interactions were withdrawn from the model. Some treatments comparisons were performed as single orthogonal contrast. All data were analyzed using the general lineal model procedures of the SAS statistical software (SAS Institute Inc., 1999-2001).

Results and discussion

The whole region was affected by one of the worst drought that prevented to attain normal yields and treatment performance. The figure 1 show the accumulated rainfall compared to past year and normal long term climatic series. Specially Pergamino area and Crespo, during the growing time of the soybean crops.

Figure 1. Accumulated precipitation and evapotranspiration from September 1 2008 to March 31, 2009 at INTA Exp. Stations of Parana (Crespo), and Pergamino.





Notwithstanding, the soybean yielded some grain in all sites and show a reasonable nodulation, and it is assumed that N fixations performed according the weather restrictions.

There were strong differences in yield among sites due to the weather pattern . While Pergamino area show Acevedo one of the lowest yield ever observed (1244 kg/ha) the yields at the other locations show a parallel with the rainfall received during the growing cycle. Only slightly more than Acevedo was obtained at Ocampo (2058 kg/ha) while the northern locations were in the range of 2,2 t/ha (Mercedes and Crespo respectively 2238 and 2209 kg/ha).

These yield locations resulted in a different response to treatments, with a rather an almost significant statistical interaction (pr > F : 0,09). Due to this differential response, the table 3 and 4 present the grain and biomass yields by site. In spite of the differences in sites, some tendency is observed with sources and incorporation of fertilizers (Fig 2). In general grain yields and differences due to treatments, that were paralleled with biomass yield and differences.

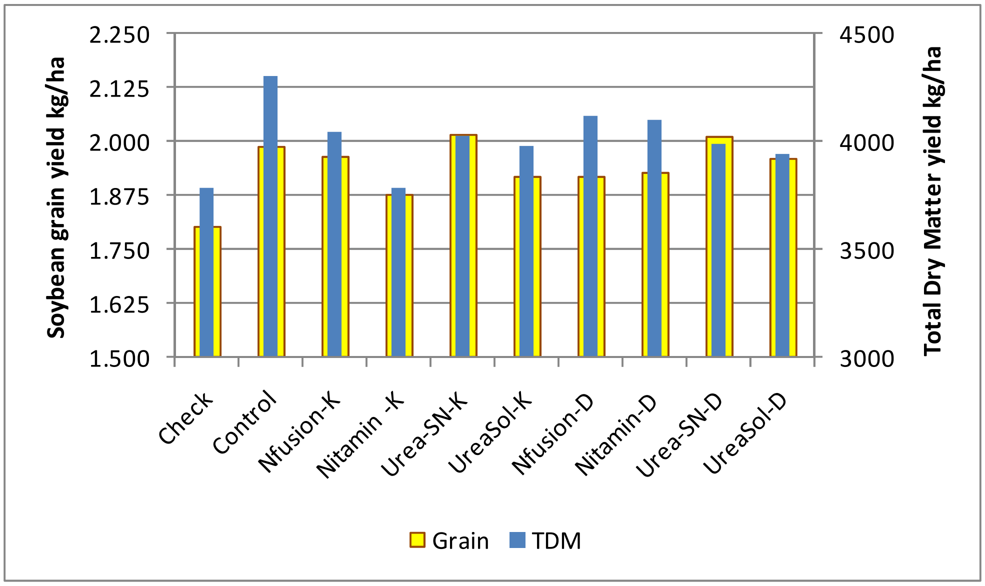
Table 3. Treatment means and summary of statistical analysis for soybean grain yields across sites in 2008/09.

Treatment / Placement	Acevedo	Crespo	Mercedes	Ocampo
		Kg /ha		
Check - No N --	1.471	1.953	1.825	1.963
Control – AN Broadcast	1.265	2.250	2.255	2.171
Nfusion Knifed	1.237	2.165	2.380	2.077
Nitamin Knifed	1.014	2.318	2.268	1.898
Urea solution Knifed	1.159	2.328	2.513	2.066
Urea Sol + n-BTPT Knifed	1.037	2.188	2.333	2.116
Nfusion Dribbled	1.157	2.203	2.340	1.968
Nitamin Dribbled	1.509	2.238	1.955	2.003
Urea solution Dribbled	1.324	2.355	2.055	2.312
Urea Sol + n-BTPT Dribbled	1.272	2.385	2.170	2.007
Pr> F $_{treatment}$	0,53	0,36	0,07	0,32
LSD $_{5\%}$	497	337	426	314
CV %	27,5	10,37	13,3	10,5

Table 4. Treatment means and summary of statistical analysis for total aboveground dry matter yields across sites in 2008/09.

Treatment Placement	Acevedo	Crespo	Mercedes	Ocampo
Check - No N --	2778	4190	4048	4130
Control – AN Broadcast	2383	4980	5305	4553
Nfusion Knifed	2218	4778	5085	4100
Nitamin Knifed	1913	5335	4035	3855
Urea solution Knifed	2185	5170	4845	3900
Urea Sol + n-BTPT Knifed	1905	4775	5135	4100
Nfusion Dribbled	2183	4855	5435	4010
Nitamin Dribbled	2858	4968	4468	4125
Urea solution Dribbled	2498	5183	3748	4510
Urea Sol + n-BTPT Dribbled	2393	5335	4203	3825
Pr> F $_{treatment}$	0,45	0,14	0,002	0,14
LSD $_{5\%}$	919	760	887	748
CV %	27,1	10,6	13,2	12,5

Fig. 2. Treatment means pooling locations for grain and total dry matter yields



A variable trait quite more affected by fertilizer treatments were protein content in grains. The table 5 shows the treatment means of protein concentration in grain of each site. The values show a good tendency in sources for both dribbled and knifed method of application. Control treatment that received AN show a rather high level comparable to better treatments. On the other hand, the check depicts a rather low value (Fig.3).

There were not significant correlation between the grain yields and protein content of grains and the relationship was inverse, that is higher protein with lower yields (r =-0,28 ns). When transforming the protein values into N%, and estimating the N uptake in grains, the tendency in differences among treatments is replicated.

Table 5. Treatment means of soybean protein content across locations. Each number is a single composite sample of grains of the four replications.

	Acevedo	Ocampo	Crespo	Mercedes
	.... % Protein			
Nfusion Knifed	37,2	37,5	36,1	37,0
Nitamin Knifed	38,2	37,9	38,1	36,9
Urea solution Knifed	38,2	38,9	36,9	36,2
Urea Sol + n-BTPT Knifed	37,5	36,7	36,7	37,2
Nfusion Dribbled	36,2	37,8	36,8	36,4
Nitamin Dribbled	39,0	39,1	37,2	36,3
Urea solution Dribbled	38,0	38,6	36,0	36,4
Urea Sol + n-BTPT Dribbled	37,3	36,5	36,3	37,0
Nfusion Knifed	37,2	37,4	35,9	35,9
Nitamin Knifed	38,7	38,2	36,4	36,2

Fig. 3. Treatment means pooling locations for protein content in soybean.

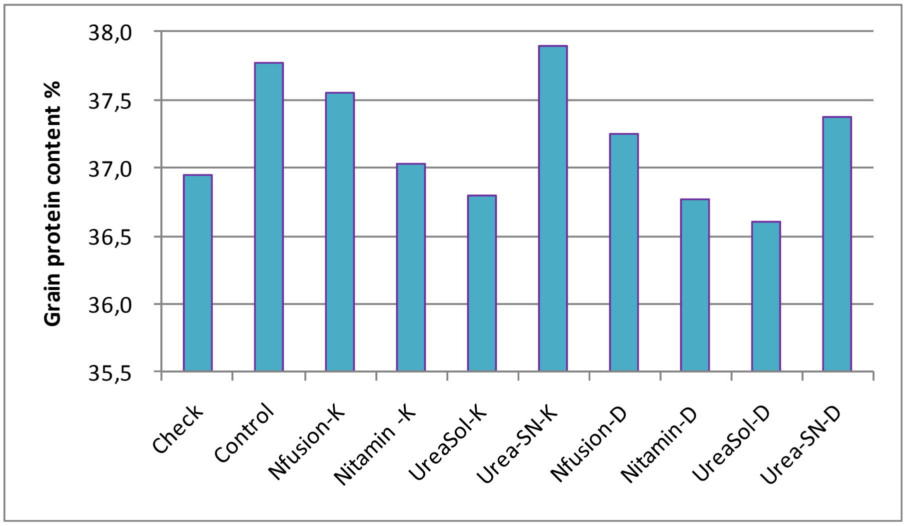
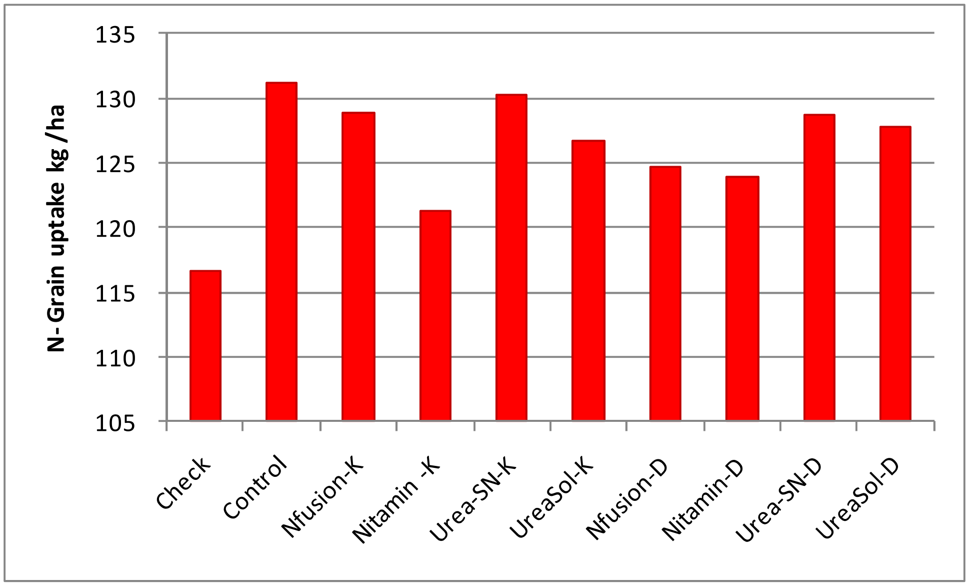


Fig. 4. Treatment means pooling locations for grain N uptake in soybean.



Final considerations

The severe lack of rains during the critical periods of filling grains prevented the attain of a high yield that could stress the N symbiotic capacity to supply N to crops. Therefore, N was of ample abundance for the limited grain and biomass yields obtained.

Unfortunately, we were not able to set a trial under irrigation, which could enhance the possibility of enlarge differences between check and fertilizer treated soybean.

We expect that a next season, with a different weather pattern, especially under a higher precipitation scenario, the treatment differences would allow reaching a more conclusive effect.

References

Ebelhar S. A. and A. H. Anderson. 2005. Late-Season Nitrogen Fertilizer Application. Effects on Irrigated Soybean Yields. Crop Sci.

Barker D.W. and J. E. Sawyer. 2005. Nitrogen Application to Soybean at Early Reproductive Development. Agron. J. 97:615-619 (2005).

Harper, J.E. 1974. Soil and symbiotic requirements for optimum soybean production. Crop. Sci. 14:255-260.

Flannery, R.L. 1986 Plant food uptake in a maximum yield soybean study. Better Crops Plant Food. Fall: 6-7.

Gascho, G.J. 1991. Late season nitrogen application for soybean. p. 96-114. In Proc. Symp. Fluid Fert. Found., Scottsdale, AZ. 4-6 Mar. Fluid Fertilizer Foundation, Manchester, MO.

Oplinger, E.S. 1991. Soybean fertilization with nitrogen, calcium and boron solutions. p. 185-193. In Proc. Symp. Fluid Fert. Found., Scottsdale, AZ. 4-6 Mar. Fluid Fertilizer Foundation. Manchester, MO.

Sorenson, R.C. and E.J. Penas. 1978. Nitrogen fertilization of soybean. Agron. J. 70:213-216.

Touchton, J. T., and D.H. Rickerl. 1986. Soybean growth and yield response to starter fertilizers. Soil Sci. Soc. Am. J. 50:234-237.

Wesley, T.L., R.E. Lamond, V.L. Martin, and S.R. Duncan. 1998. Effects of late season nitrogen fertilizer on irrigated soybean yield and composition. J. Prod. Agric. 11: 331-336.

Wood, C.W., H.A. Torbert and D.B. Weaver. 1993. Nitrogen fertilizer effects on soybean growth, yield and seed composition. J. Prod. Agri. 6:354-360.