Can We Improve Nitrogen Management for Sunflower?

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The correct diagnosis of soil N availability for sunflower is critical to deciding the right N rate for maximum seed yield and adequate oil and protein concentration.
Use of local sensors to characterize in-crop N status will complement any soil N diagnosis.

Nitrogen is the main nutrient that affects yield and seed quality of sunflower. Oil concentration determines the commercial quality of the seeds, while protein concentration is key to sunflower by-products. Increases of 1% in seed protein would generate increases of up to 5% in by-products. Nitrogen deficiency decreases leaf area and photosynthetic rate, and consequently radiation interception and use efficiency (Massignam et al., 2009). Adequate soil N availability is necessary to achieve high oil and protein concentration in the seeds; however, excessive levels can decrease the percentage of oil. Therefore, accurate N diagnosis methods are needed.

The most widely used diagnostic method for N in Argentinian sunflower is based on determining N availability at planting (NA), which includes pre-plant soil nitrate-N (NO_3-N) at 0 to 60 cm depth (PPSNT) plus fertilizer N (FN). Several critical thresholds have been proposed to maximize seed yield and define the production and economic optimum NA (i.e., PONA and EONA). However, NA has low predictive performance in regions with excessive water, before or after sampling, because of nitrate leaching losses. Furthermore, this method does not consider the contribution of N by mineralization during the growing season. Under a similar situation, the soil nitrate-N test at the 6-leaf stage (6-leaf SNT) has been proposed for maize (Magdoff et al., 1984), although this method does not define the economic optimum N rate.

Soil N diagnosis could be complemented with sensors measuring transmittance (Minolta SPAD 502®) and reflectance (GreenSeeker®), which might characterize the N status of the crop at 6-leaf and 12-leaf stages (V6 and V12, Schneiter and Miller, 1981). While both sensors have been successfully tested in different crops (wheat, corn, potatoes, etc.), no information is available for sunflower. The Minolta SPAD 502 sensor determines leaf greenness (LG) while the GreenSeeker sensor determines a vegetation index (NDVI). As these sensors are affected by several factors (genotype, management conditions, etc.), it is recommended to relativize the measurements with reference areas without N limitation, defining an N sufficiency index (NSI) for the Minolta SPAD 502, and a relative NDVI (NDVIr) for the GreenSeeker.

This article outlines a series of field experiments that: 1) evaluate the effect of N on seed yield and protein and oil concentration, 2) assess the predictive performance of NA, 3) determine the PONA and EONA, and 4) evaluate the predictive performance of N diagnosis methods based on determining the NSI and NDVIr.

Abbreviations and notes: N = nitrogen.

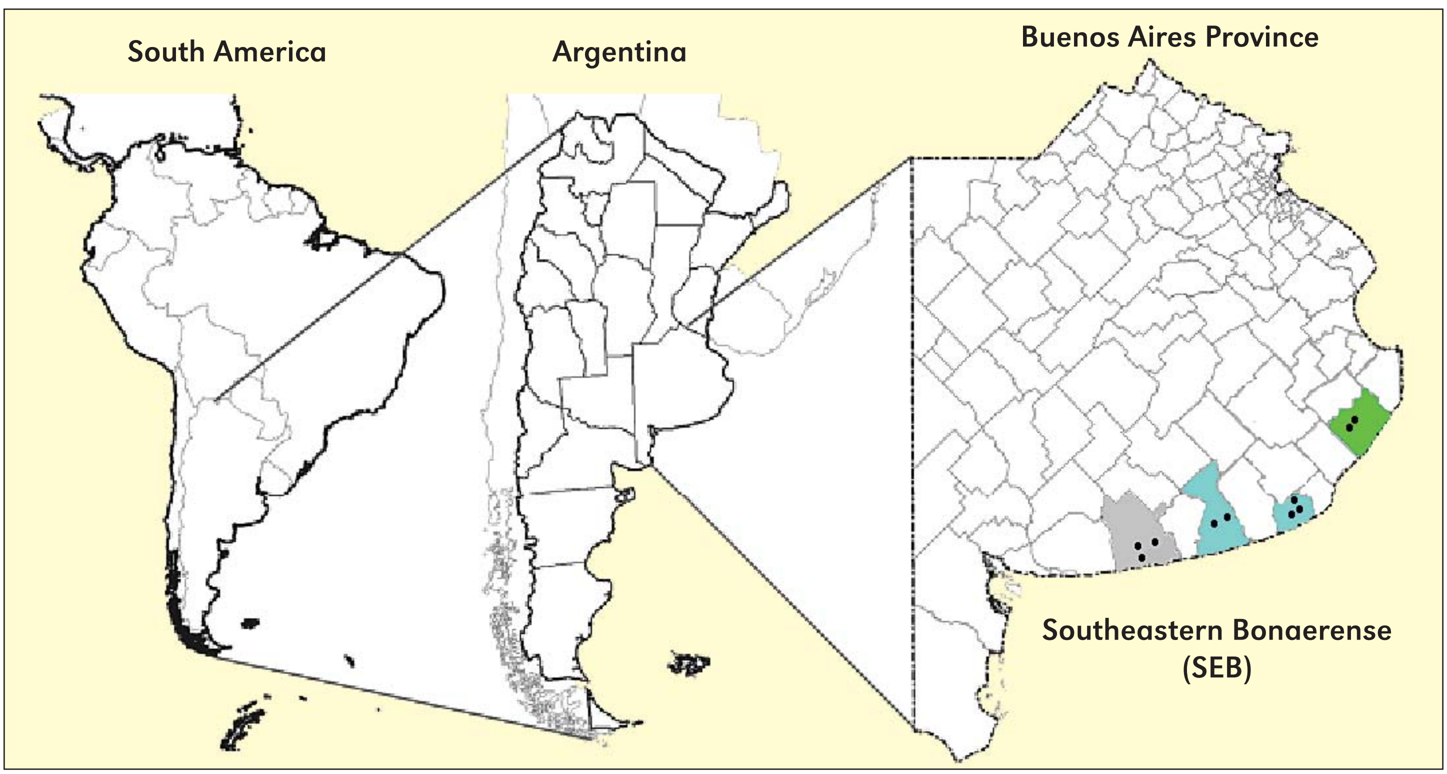

Figure 1. Location of sunflower experimental sites in the 2014-15 season. Green area: Gral. Madariaga. Blue area: Miramar-Mechongué-Necochea. Grey area: Tres Arroyos.

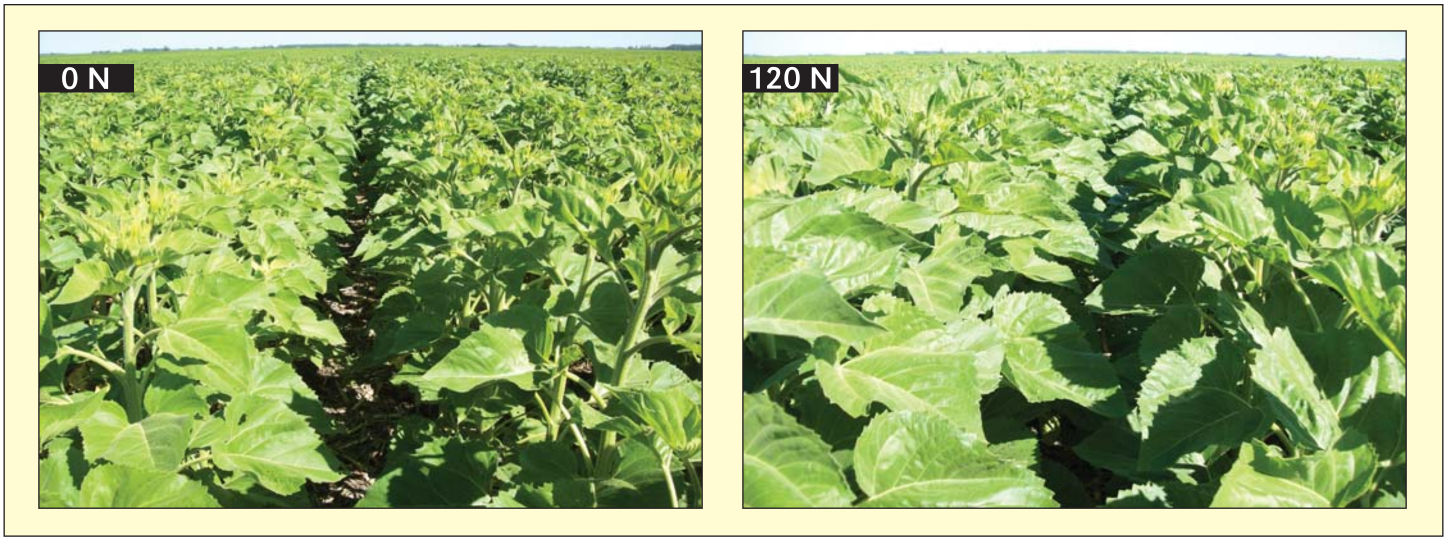

Figure 2. Plots without N application (left) and with 120 kg N/ha (right).

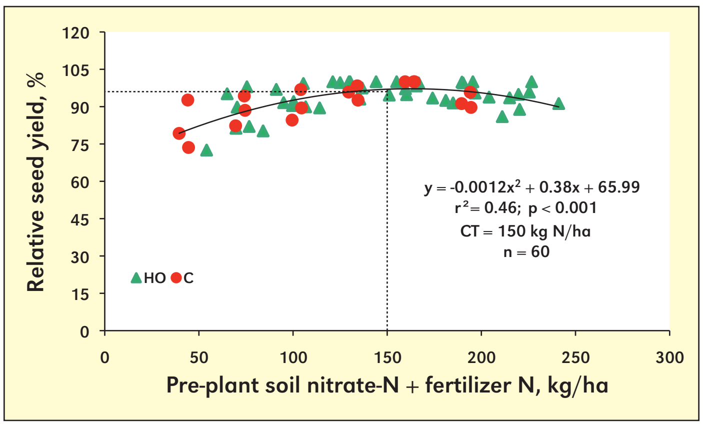

Figure 3. Relative seed yield (RSY) as a function of N availability at planting. CT = critical threshold for 95% RSY. HO = high oleic hybrids. C = conventional hybrids. n = number of cases.

Field Experiments

During the 2014-2015 season, 10 N fertilization experiments were carried out in southwestern Buenos Aires province (Argentina), evaluating N rates (0 to 120 kg N/ha), under environments with different soil and weather conditions (**Figure 1**). The predominant soils are prairie soils without and with a calcareous layer, with sandy loam to sandy clay loam texture. Soil Bray P1, organic matter, and pH (0 to 20 cm) were 12.4 ± 4.0 mg/kg, 5.1 ± 1.2%, and 5.9 ± 0.3, respectively. Sunflower genotypes include high oleic (HO) (n = 7), and conventional (C) (n = 3) hybrids.

Seed Yield and Quality

Average seed yield was 3,540 ± 484 kg/ha and N response 590 ± 208 kg/ha. Seed yield responses to N were significant at five sites. Nitrogen fertilization increases leaf area development, which resulted in an increase in radiation interception by the crop (**Figure 2**).

The HO hybrids had lower percentages of oil and higher percentages of protein than the C hybrids (54.2 vs. 55.7% and 15.1% vs. 12.0%, respectively). Nitrogen application did not affect seed oil concentration (HO: 0N = 54.4% vs. 120 kg N/ha = 54.0%; C: 0N = 55.2% vs. 120 kg N/ha = 55.7%). However,

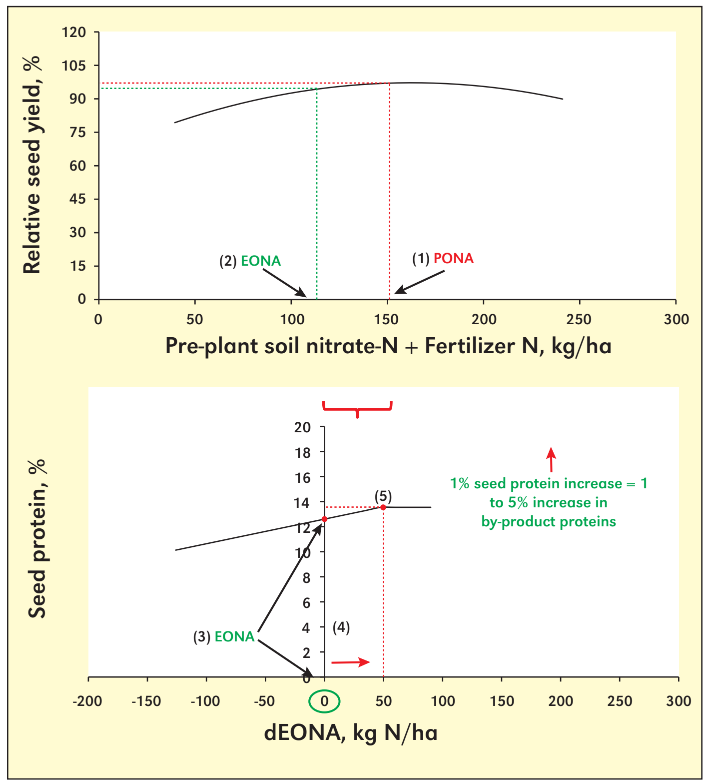

Figure 4. Relationships between relative seed yield (RSY) and N availability at planting (top), and seed protein and the differential economic optimum N availability (dEONA) for conventional hybrids. Production optimum N availability (PONA) [1] indicates the production optimum N availability, and EONA [2] the economic optimum N availability, [3] shows the seed protein level at dEONA, [4] is the increase in N rate above EONA to maximize seed protein, [5] is the optimum seed protein level.

seed protein concentration increased, on average, by 1.9% and 2.5% with the highest N rate for HO and C hybrids, respectively. Therefore, the protein/oil ratio increased linearly with N application. In summary, N application did not affect seed oil concentration, but would increase seed and by-products protein concentration.

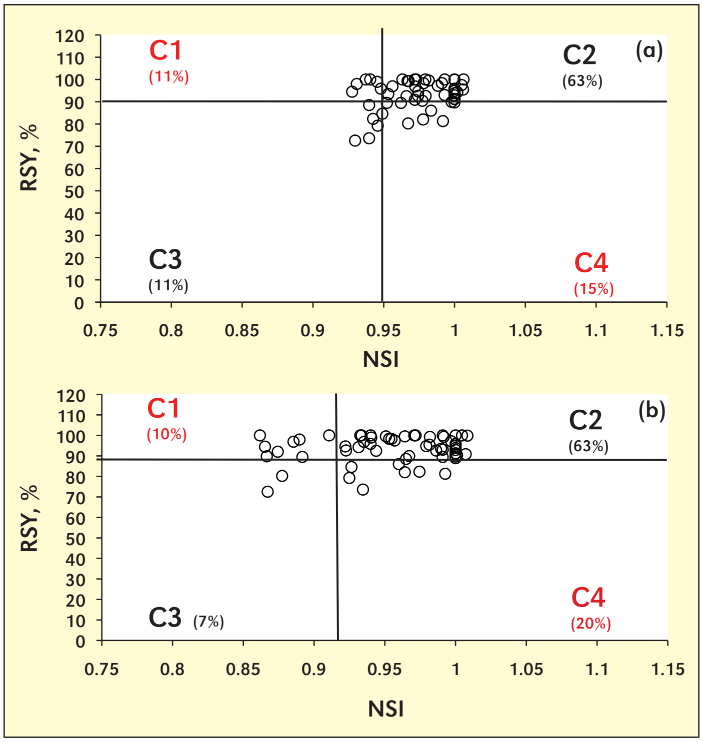

Figure 5. Relative seed yield (RSY) as a function of NSI at sunflower stages V_6 (a) and V_{12} (b) (Schneiter and Miller, 1981). The vertical lines indicate the critical threshold for N sufficiency index (NSI), while the horizontal lines indicate 90% of RSY. Quadrants C1 and C4 show incorrect diagnosis, and quadrants C2 and C3 show correct diagnosis. Data between parentheses represent the percentage of cases in each quadrant over the total number of cases.

Diagnosing N Needs

Nitrogen availability at planting (NA = PPSNT+FN) explained 46% of the variation in relative seed yields (RSY) (**Figure 3**). According to this model, a maximum seed yield of 4,000 kg/ha would be reached with NA of 150 kg N/ha, 37.5 kg of available N per t seed. No relationship was found between RSY and 6-leaf SNT, probably because of excessive water (120 mm) before soil sampling.

Considering a price ratio of 4.5 kg sunflower seed per kg N (4.5:1 ratio), the EONA averaged 110 kg N/ha for both genotypes (i.e., 40 kg N/ha less than the PONA). However, seed protein concentration increased with higher NA than the EONA. This situation would create potential bonuses of protein pellets and flour in the international market. In this study, it was determined that the application of 48 and 90 kg N/ha above the EONA (differential EONA, dEONA) in genotypes C and HO would maximize the concentration of protein in seed, reaching values of 13.6 and 16.5%, respectively. **Figure 4** shows an example for C genotypes relating the diagnosis method based on NA with the RSY; and dEONA to maximize the percentage of protein. The application of about 48 kg N/ha above the EONA (dEONA = 0) allowed seed protein to increase by nearly 1%, and by-product proteins by 5%.

The NSI was affected by N application at both stages, V6 and V12, while fertilization only affected NDVIr at V12. Moreover, significant relationships between NSI and NA were observed (r^2 of 0.39 and 0.42 at V6 and V12, respectively). Relationships of NA and NDVIr were also significant, but to a lesser magnitude (r^2 = 0.13 and 0.17, for V6 and V12, respectively). This would indicate that NDVIr did not properly relate to N availability. Moreover, using the quadrant methodology (Cate and Nelson, 1965), the NSI correctly diagnosed 74% and 70% of the points (quadrants C2 + C3) for V6 and V12, respectively (critical threshold: 0.95 and 0.92, respectively) (**Figure 5a** and **5b**). Although both sensors contributed to the diagnosis of N deficiency in sunflower, SPAD showed a better performance compared to GreenSeeker.

Summary

Nitrogen application in sunflower would increase seed yield and seed protein concentration without affecting seed oil concentration. Moreover, NA (PPSNT + FN) allowed the determination of optimum N availability for seed yield and maximized seed protein concentration, which would increase the quality of the flour and pellets. Meanwhile, the SPAD measurements have proved to be a tool that could complement soil N diagnosis and requires further investigation for practical use. BC

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