International Symposium “Root Research and Applications”
RootRAP, 2–4 September 2009, Boku – Vienna, Austria

Root and nodule efficiency in soybean (*Glycine max* (L) Merr.) in differing conditions of water and nitrogen supply

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ABSTRACT

Irrigation and nitrogen fertilization are important agricultural practices to increase soybean yield and quality. Irrigation and late N supply in soybean were tested in a two-year field trial in a silty-loam soil, to evaluate their effects on root growth, nodule activity and isoflavone accumulation in seed of two soybean varieties. The unusual nitrogen fertilization in soybean aimed at covering declining nitrate-reductase and still low nitrogenase-reductase activities. Root profiles of volumetric root length density (RLD) and diameter were revealed at harvest by auger sampling. Morphological features of nodules, such as section area, axis and perimeter, were detected by image analysis, and their activity estimated as foliar ureides. Irrigation had contrasting effects on root growth in two considered varieties, but generally increased seed yield, with some positive influence on seed quality. In conditions of optimal water availability, seed protein contents increased, as well as number of nodules and their efficiency (i.e., foliar ureides).

KEYWORDS: Nodule size, seed protein, root length density, root diameter.

INTRODUCTION

In the European Union and American continent, soybean is the most important dietary protein constituent in livestock rearing. Soybean production is also very important for human health (Lacombe et al., 2000). Various agronomic practices, such as irrigation and nitrogen fertilization, can modify plant root growth and qualitative characteristics of seeds. This study evaluates root variables, such as RLD (Root Length Density), root and nodule diameter in relation to leaf ureide production and seed protein content in two varieties in conditions of diverse irrigation and nitrogen supply .

MATERIALS AND METHODS

A two-year field trial was carried out in 2006 and 2007 at the experimental farm of the University of Padova at Legnaro (NE Italy). Two cultivars, Ales and Nikir, were cultivated in a split split-plot experimental design with four replicates. These cultivars had diverse attitudes in protein concentration, Ales with low and Nikir with high protein tenor. Two different irrigation regimes were applied: optimal water supply (100% of ETm, maximum evapotranspiration) and rainfed (controls). Nitrogen was supplied in R3 (first year) and R1 phases (second year). The reason for supplying nitrogen was to improve N nutrition when nitrate reductase activity is presumed to fall and nitrogenase has not reached its peak. Foliar ureides were measured in the R5 phase in both varieties by the Herridge method (Herridge et al., 1982). Nodules were spread on a white background and photographed with a digital camera, and images were analyzed with Image-J open-source software, revealing their main geometric features (i.e., number, major and minor axes, perimeter, section area). At harvest, a soil core, 1 m deep and 7 cm in diameter, was taken

from each plot, splitting root profiles into 10-cm long sub-samples. Samples were then washed and roots collected in a sieve. Variables such as RLD (Root Length Density) and root diameter were measured by image analysis (KS 300 software, Zeiss, Germany) in 300-DPI resolution images acquired through a flatbed scanner (HP 4C). Protein tenor was measured according to N Kjeldahl×6.25.

RESULTS AND DISCUSSION

Nikir was confirmed as having a higher protein tenor than Ales (43% vs. 42%, $P<0.05$)), but the varieties had very similar yields. Water supply had the effect of increasing yield (main effect, irrigated vs. rainfed: 4.7 and 4.0 t ha^{-1}). As consequence of irrigation, Ales markedly increased its RLD in the top 0.3-m depth (8.2 vs. 5.8 cm cm^{-3} of rainfed), unlike Nikir, which had higher RLD in rainfed conditions (8.3 vs. 7.0 cm cm^{-3}) (Figure 1). Generally, irrigation caused a decrease in nodule size (main effect on nodule diameter: rainfed vs. irrigated, 5.46 vs. 5.0 mm) and an increase in nodule number (3-fold higher) and root diameter (+30%). In particular, root diameter in the top 0.3 m was found to be positively correlated with seed protein content ($R^2>0.39$). RLD was weakly related to seed protein, expect for root densities in the 0.4-0.5 depth interval, where the correlation was significant ($R^2=0.2$). As regards fertilization, late N application had a generally smaller effect than irrigation, and only a decreased nodule size was observed. The effect of N application on seed protein was negative when applied in the R1 phase (2^{nd} year) (-4%) and positive when applied later (R3 phase, 1^{st} year) (+5%). Lastly, leaf ureide concentration was found positively associated with RLD and nodule size.

These results suggest that, in soybean, root variables are very sensitive to agronomic practices, with an important effect on seed quality. In particular, root diameter and occasionally root length density are positively correlated with seed protein. In general, the effect of irrigation prevailed over that of nitrogen, with the possibility of a negative effect of N in the earlier application (at R1). Behaviour was different among varieties in relation to development of root apparatus in conditions of irrigation.

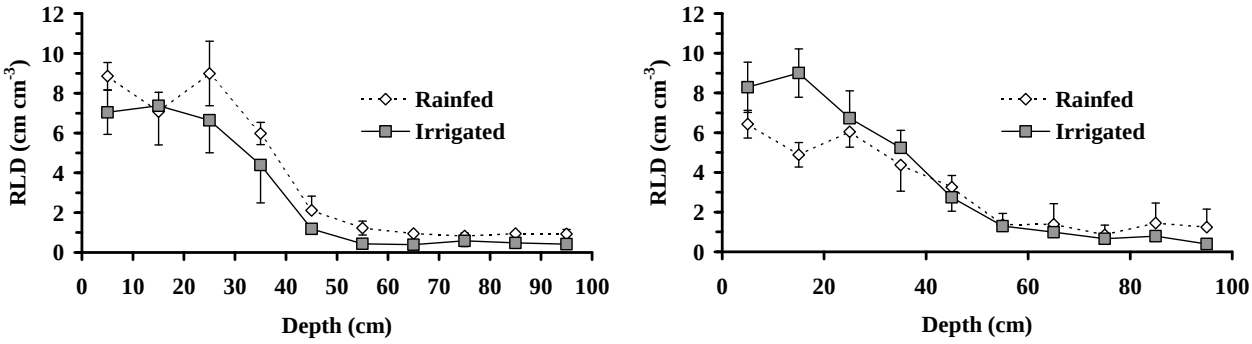

Figure 1: Root length density (± S.E.) in two soybean varieties, Nikir (left) and Ales (right), in varying irrigation regimes and without N application.

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