Development and Implementation of N-STaR: the Nitrogen-Soil Test for Rice

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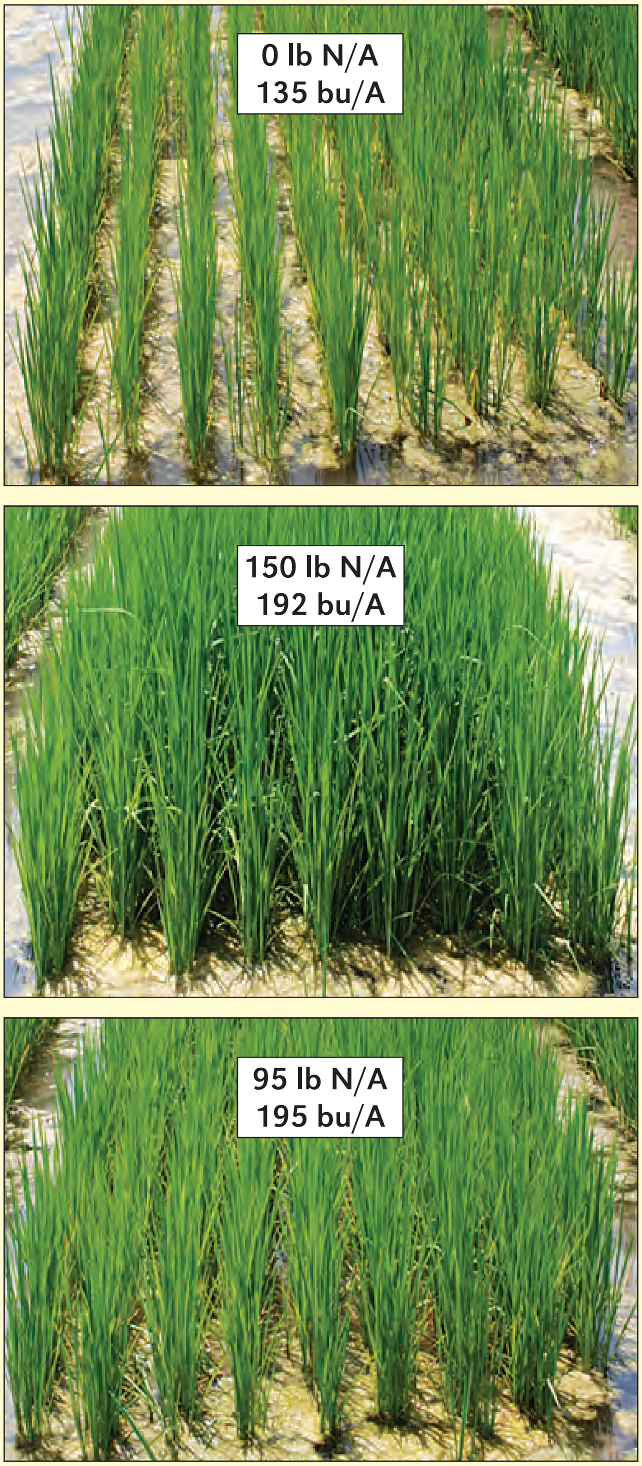
Researchers across the Midsouth U.S. rice producing states of Arkansas, Louisiana, Mississippi and Texas set out to develop a soil-based N test in 2003, which could be used to determine site-specific N fertilizer rate recommendations for rice. The test has now been implemented.



Visual comparison of N rate treatments used in the small-plot validation studies across the Midsouth. Notice the differences in color and rice biomass based on N rate treatment and the corresponding rice yields.

Current N fertilizer recommendations are based on a combination of three factors; soil texture, cultivar, and previous crop. To improve N fertilizer management for Midsouth U.S. rice producers, a stronger emphasis on the soil's ability to supply N should be considered. There have been several papers that focused on alkaline-hydrolyzable N and its use for corn N recommendations (Mulvaney et al., 2001; and Williams et al., 2007), with mixed results on a regional basis. Currently, there is not a reliable soil-based N test for domestic rice producers. Researchers have experimented with soil-based N tests as long as there has been soil fertility research and although some methods have shown promise for rice grown in a greenhouse (Wilson et al., 1994), nothing has stood out as a solid method for predicting rice response to N fertilizer in the field. Identification of a simple soil test to measure the amount of available soil N is becoming more and more important and will be essential for the long-term sustainability of domestic rice production. Benefits of a soil N test are not just about optimizing economic or agronomic returns, but making environmentally sound N fertilizer decisions.

The majority of rice in the Midsouth is produced using a direct-seeded, delayed-flood production system with similar response to N fertilizer on silt loam soils regardless of whether you are in Northern Arkansas or Southern Louisiana. Direct-seeded, delayed flood rice production boasts the highest NUE of any cereal crop when managed properly and can consistently result in values exceeding 75%. Thus, direct-seeded, delayed-flood rice production is the ideal candidate for the development and use of a soil-based N test. The successful correlation and calibration of a newly developed soil test method hinges on three factors; 1) consistent N mineralization, 2) high and consistent NUE and 3) a highly reproducible soil test method that quantifies the forms of N that feed the plant throughout the growing season. Over the past 6 years, researchers collaborated to develop N-STaR: the N-Soil Test for Rice, which will allow field-specific N fertilizer management for Midsouth rice producers.

Initial work with N-STaR centered on the development of a steam distillation technique that could fractionate potentially mineralizable soil-N and offer an alternative to the diffusion method used in the Illinois Soil N Test (ISNT) (Mulvaney et al. 2001; Bushong et al., 2008). Extensive laboratory studies using the ^{15}N tracer identified the specific soil organic N compounds that are being quantified using N-STaR and indicated that amino sugar-N, amino acid-N and NH_4-N were the primary chemical compounds (Roberts et al., 2009). The N compounds quantified using N-STaR are not prone to the loss mechanisms of leaching or denitrification. The relative

Common abbreviations and notes: N = nitrogen; NUE = nitrogen use efficiency; N-STaR = N-Soil Test for Rice; NH_4-N = ammonium-nitrogen.

stability of these soil N fractions coupled with the fact they are the most readily mineralizable-N compounds may account for the high correlation of this soil test method for rice versus a pre-sidedress nitrate test (PSNT) that is commonly used for upland crops. During this same time period, N response field trials were established across the Midsouth in an attempt to begin the process of correlation and calibration. As with any nutrient, the success of a soil test method is only as good as the soil sample taken. Early on, research indicated that a standard 6-in. soil sample was not sufficient to capture the soil N status and accurately predict crop response to N. Soil sampling protocols were adjusted to encompass the entire rooting depth of rice produced on silt loam soils, which literature had shown to be roughly 24 in. Following the increase in soil sampling depth, the accuracy of N-STaR measurements improved considerably. Statistical analysis indicated that the correct sampling depth for rice produced on silt loam soils was 0 to 18-in. and coincided with the effective rooting depth of the rice crop, which is the depth over which the plant can access and assimilate N. Years of research experience identified the need for higher N rates for rice produced on clay soils, and over time it became obvious that N-STaR soil test values were highly related to soil texture and that separate calibration curves would have to be developed for silt loam and clay soils. As silt loam soils comprise the vast majority of rice acreage in the Midsouth, silt loams were the primary focus of our research and currently have the most complete data set.

Over the course of three years, data were obtained from N response trials in Arkansas, Louisiana, Mississippi and Texas (**Figure 1**), but the correlation and calibration curves were not completed until sites were found where there was little to no response to N fertilizer. One of the most difficult aspects of the research was identifying sites that did not respond to N fertilizer and this is partly due to the fact that most silt loam soils in the Midsouth have relatively low organic matter (<2.5%) and amounts of soil residual-N. In the fall of 2008 a completed calibration curve was released for rice produced on silt loam soils (**Figure 2**). The predictive ability for N-STaR, or any soil-based N test, needed to be high due to the responsive nature of rice to N fertilizer, input costs associated with N fertilizer, and the environmental aspects of poorly managed N fertilizer.

Immediately following the completion of the N-STaR calibration curve, research began in replicated, small-plot trials to validate the ability of the soil test to predict site-specific N rates for rice produced on silt loams. Field validation studies were conducted on sites separate from the areas used to develop the correlation and calibration curves and were primarily located in producer fields to mimic real-world settings. During the first year of field validation it became obvious that site-specific N rates using N-STaR often resulted in rice with less biomass and lighter green in color (**see photos**) than rice receiving the standard recommendation of 150 lb N/A. However, results from the small-plot validation studies indicated that yields obtained using N-STaR were similar or higher than the standard practice at 17 of the 18 sites located across Arkansas, Louisiana and Mississippi. Observations made during the small-plot validation studies indicated that disease pressure from sheath blight and false smut were also generally lower in the N-STaR treatments, which provided a site-specific N rate rather than the standard practice of 150 lb N/A. These results provided evidence that N-STaR could predict the N mineralization potential of silt loam soils in the Mississippi River delta and predict the N fertilizer rates required to maximize rice yields. The final step was to evaluate the N-STaR technology in large-scale, commercial production fields.

Figure 1. Relative locations of small-plot N response trials used during the correlation and calibration of N-STaR.

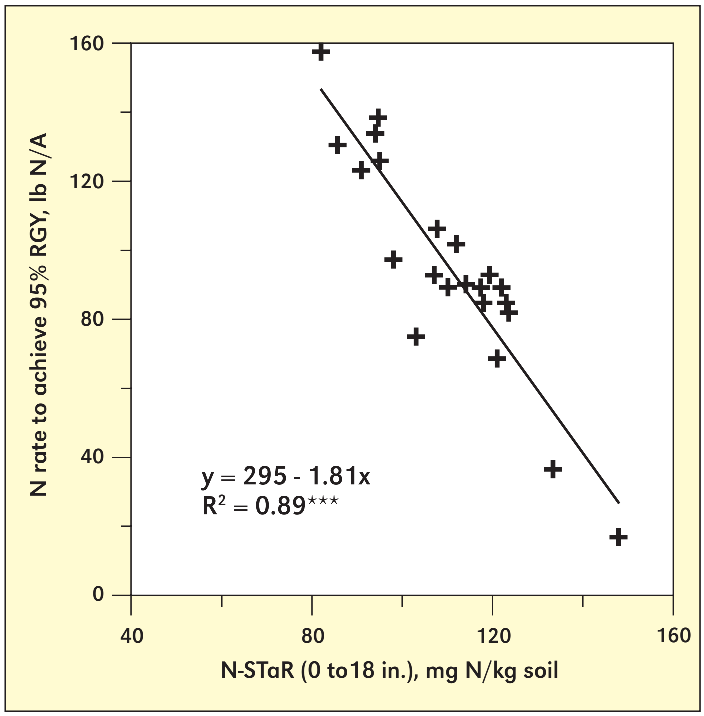


Figure 2. Calibration of N-STaR for the 0 to18 in. depth increment which predicts the N rate required to produce at least 95% relative grain yield for rice grown on silt loam soils.

Large-scale production fields offer a new dimension of field variability error that is not often seen in small-plot research. A number of fields were sampled and analyzed by N-STaR and the determination was made that the 0 to 18-in. soil sample depth required for N-STaR analysis resulted in lower levels of field variability than a traditional 0 to 4-in. soil sample used for routine soil analysis of rice nutrient requirements. During 2011, 17 field-scale strip trials were conducted across the Midsouth US comparing the N-STaR site-specific N rate to the producer practice within a large-scale production field. Treatments were replicated and harvested with a commercial combine, weighed using a weigh wagon, and moisture determined. Statistical analysis indicated that for 15 of the 17 sites, the N-STaR rate recommendation resulted in yields that were equal to or higher than the producer practice. The average N rate reduction across all sites was 55 lb N/A, and in some cases the N rate reduction was as much as 105 lb N/A with no statistical yield difference.

The release of N-STaR for silt loam soils within the Midsouth has been well received by growers. Continuing research with N-STaR will focus on the completion of a correlation and calibration curve for rice produced on clay soils. Other ongoing research is the development of the N-STaR technology for soft red winter wheat production in Arkansas, which indicates the need to sample 6-in. deep and is currently being validated in small-plot trials. The success of N-STaR in rice and wheat promises more efficient N use in Midsouth agriculture. BC

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Mohamed El Gharous Joins Staff of IPNI as Consulting Director of North Africa Program


Dr. Mohamed El Gharous

The International Plant Nutrition Institute (IPNI) is pleased to announce the addition of a new scientific staff member. Dr. Mohamed El Gharous will serve as Consulting Director of IPNI's newly established regional program in North Africa. The program will work collaboratively with the National Agronomic Research Institute (INRA) on projects and activities of mutual interest. Dr. El Gharous will be based in Settat, Morroco.

"The establishment of this program in North Africa marks another milestone for IPNI's regional representation within the African continent," said IPNI President Dr. Terry Roberts. "Mohamed's knowledge of arid and semi-arid agriculture will be a great addition to the knowledge-base of IPNI, and his representation of the North African region will be highly valued by our members and staff."

Dr. El Gharous received a Horticultural Engineer degree (B. Sc.) in 1980 from the Agronomy and Veterinary Hassan II Institute in Rabat, Morroco. He was hired by INRA in Morocco in 1980. Mohamed subsequently received his M.Sc. (Agronomy) in 1987 and his Ph D. (Soil Science) in 1994—both from Oklahoma State University in Stillwater, USA.

Dr. El Gharous's research career began by examining soil fertility for cereals in arid and semi-arid regions. He has since been responsible for coordinating the soil and plant testing laboratory at the Aridoculture Center at Settat (INRA-Settat) as well as research on soil test calibration in arid and semi-arid zones. He has coordinated the cereal and soil management research sub-programs at INRA-Settat, conducted research on soil fertility and fertilization within the aridoculture program, and assisted the management of the Aridoculture Center.

Selected research highlights include following the evolution of P and K in soils under wheat-fallow rotation and quantifying their residual effects; improving fertilizer recommendation techniques in calcareous soils of Morocco; exploring composting and compost effects on soil quality and plant nutrition; defining fertilizer formulas adapted to Moroccan soil and climatic conditions and crops; and adaptation and improvement of soil and plant analyses methods.

Presently, Dr. El Gharous is also Head of the Regional Center for Agricultural Research in Settat; and a member of the Faculty of Science and Technology at the University of Hassan I, Settat, where he lectures and serves as a supervising committee member for a number of graduate student programs. Dr. El Gharous is a nationally recognized expert on the subjects of fertilization, the research programs of INRA-Settat, and Zero-Tillage. He is a member of the Franco-Moroccan joint scientific committee for PRAD Projects (Research Projects in Agriculture for Development), President of the Sports and Cultural Association of Agricultural Research (INRA Club at Settat), and Vice President of the Cultural Association of the Chaouia Ouardigha Region. BC