Improving Mid-Season Nitrogen Recommendations for Winter Wheat Using Soil Moisture Data

By Olga Walsh, Yumiko Kanke, D.E. Edmonds, and W.R. Raun

Nitrogen sensor technology has significantly advanced the understanding of site-specific N management in crop production. Combining sensor information with other important yield affecting data has the potential to further improve the capabilities of this technology. Scientists at Oklahoma State University (OSU) are developing means of incorporating soil moisture into winter wheat yield potential determinations, and ultimately N management decisions.

Soil water availability and fertility status are among the major factors limiting crop production worldwide. Soil moisture (SM) is the amount of water that is contained within the soil pores, and it is a key factor affecting yield.

Establishment of automated, high-density SM networks offers effective technology to generate high-quality SM data sets. Recognizing the importance of SM for agriculture and other disciplines, numerous research institutions across the USA are dedicated to collecting and managing SM information. The Climate Prediction Center of the National Weather Center database (http://www.cpc.ncep.noaa.gov/), the Automated Weather Data Network of the High Plains Regional Climate Center in Nebraska (http://www.hprcc.unl.edu), and the Illinois State Water Survey (http://www.sws.uiuc.edu/warm/) are examples of such automated networks that offer climatological data on temperature, precipitation, and SM for the USA.

The Oklahoma Climatological Survey's Oklahoma Mesonet (OM) (Brock et al., 1995) is an automated statewide network designed to measure the environment at the size and duration of mesoscale weather events. Soil moisture data at four depths – 2 in., 10 in., 24 in., and 30 in. (5, 25, 60, and 75 cm) – are collected every 10 minutes at over 100 remote meteorological stations. Data are available at the OM website: >http://www.mesonet.org/<.

Many authors proposed that accurate SM information could be vital for estimating crop yield potential (YP) and making fertilizer recommendations. Carlson et al. (1995) noted that lack of homogeneity in soil water content is apparent and indicates the need for evaluation of factors affecting SM spatial and temporal variability. Gillies et al. (1997) also stated that knowing soil water content is important when evaluating crop YP mid-season. It is not unusual for SM levels to vary significantly both site-to-site and year-to-year. Thus, spatial and temporal variability in SM should be accounted for when estimating YP and making fertilizer recommendations. Results by Kumar et al. (2006) illustrated that YP estimates could be improved using Normalized Difference Vegetative Index (NDVI) data combined with SM data in a grain sorghum experiment.

Sensor-Based N Rate Calculator

The Sensor-Based Nitrogen Rate Calculator (SBNRC), developed at OSU, is an on-line tool available at the N use efficiency (NUE) website: >http://nue.okstate.edu/<. The SBNRC enables producers to estimate in-season YP, and to determine

Abbreviations and notes for this article: N = nitrogen; OM = organic matter.

On-line view of Sensor Based Nitrogen Rate Calculator (SBNRC) available at >www.nue.okstate.edu<.

optimum N fertilization application rates based on predicted YP and crop responsiveness. The SBNRC entails using GreenSeeker™ technology to measure crop canopy reflectance and calculate NDVI. Canopy reflectance readings are collected mid-season (Feekes 5 growth stage for winter wheat). The sensor is designed to illuminate the light in both red (650nm) and NIR (770nm) bands and to register the fraction of the emitted light returned from the canopy to the sensor. NDVI is highly correlated with plant vigor, leaf chlorophyll content, and plant N status. Response Index (RI) is determined by comparing the NDVI values from the representative area within a field to the NDVI values obtained from an N-rich strip (NRS) (Mullen et al., 2003). The NRS is simply a strip within a field to which N fertilizer was applied to create a non-limiting environment. Comparing the NDVI's from non-limiting NRS to the NDVI's from the rest of the field provides valuable information about the crop's N status and helps to make a decision about how much, if any, fertilizer N must be applied to satisfy crop needs. In-Season Estimated Yield (INSEY) is calculated as NDVI (Feekes 5) divided by growing degree days (GDD)>0 (Lukina et al., 2001; Raun et al., 2001). The INSEY index serves as an indicator of the rate of plant N uptake (Raun et al., 2002). Using NDVI allows accounting for spatial and temporal variability existing within the field.

Soil Moisture and SBNRC

The soil fertility group at OSU is currently striving to further refine the winter wheat algorithm for SBNRC by incorporating SM at the time of sensing into the algorithm. At-

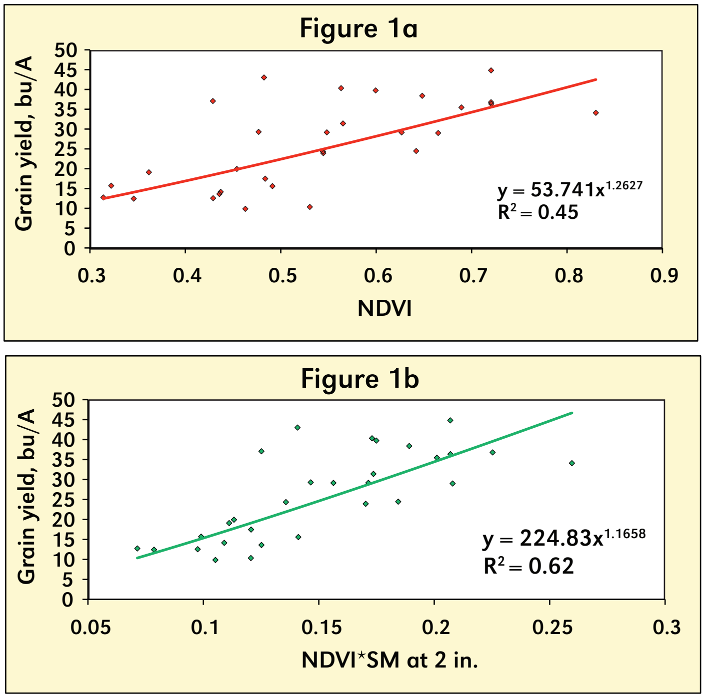

Figure 1. Normalized Difference Vegetative Index (NDVI) (a, top) and NDVI*SM at 2 in. (b, bottom) as a predictor of winter wheat grain yield at Stillwater, Oklahoma (2001-2006).

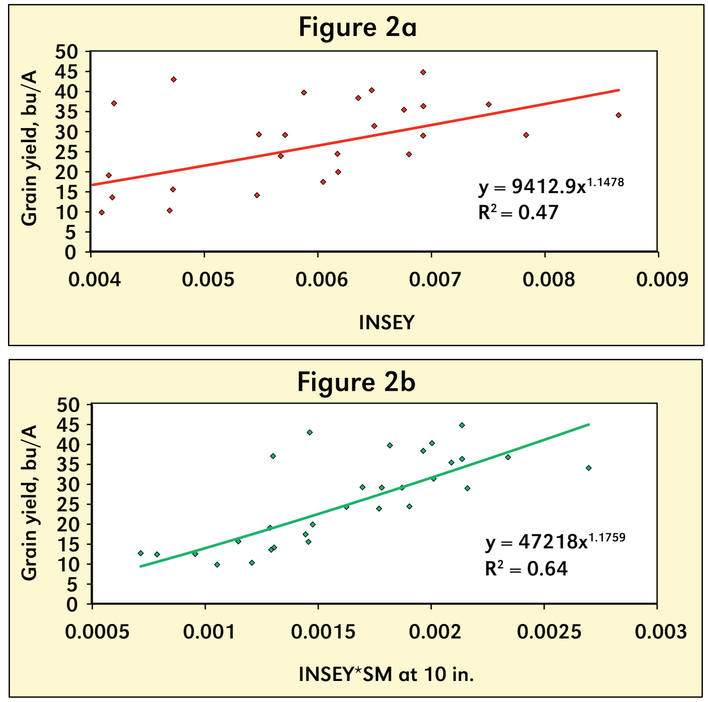

Figure 2. In-Season Estimated Yield (INSEY) (a, top) and INSEY*SM at 10 in. (b, bottom) as a predictor of winter wheat grain yield at Stillwater, Oklahoma (2001-2006).

sensing knowledge of the amount of water present in the soil profile will help to more accurately predict YP. This should in turn improve N recommendations.

Statistical analysis was carried out to assess the value of SM data in YP estimation. Simple correlation analysis between 24 variables, including SM, NDVI*SM, INSEY*SM, and wheat grain yield were performed using yield data from long-term OSU experiments near Lahoma and Stillwater, Oklahoma, and SM data provided by the OM. The SM values at sensing, and a month average SM around sensing date at four depths (2, 10, 24 and 30 in.) were used in the analysis.

Results showed that SM at sensing and a month average SM around sensing date were generally highly correlated ($p < 0.001$) with grain yield at both sites. At Lahoma, 17 of 24 variables (excluding SM at sensing at 10, 24, and 30 in., and a month average SM around sensing date at all four depths) were significantly correlated with grain yield ($p < 0.001$). While there was no relationship observed between grain yield and the variables reflecting only SM at this site, all the variables combining both vegetative and SM characteristics (NDVI*SM and INSEY*SM) were significantly correlated ($P < 0.001$) with yield. At Stillwater, 22 of total 24 variables (excluding a month average SM around sensing date at 24 and 30 in. depths) were significantly correlated with wheat yield ($p < 0.001$). Trend analysis showed that higher correlation values (R^2) were generally observed with combination of indices (NDVI*SM and INSEY*SM) compared to NDVI and INSEY alone (**Figures 1 and 2**), suggesting that indices that combine both SM and the vegetative crop characteristics could help to more accurately estimate winter wheat YP.

Our SBNRC approach makes fertilizer N recommendations based on crop YP, thus increasing the accuracy of the YP estimation. Using SM data has the potential to substantially improve N recommendations and management decisions. BC

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