Comparison of the Two Methods for the Analysis of Petiole Nitrate Nitrogen Concentration in Irrigated Cotton

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Abstract

A study was conducted in Arizona in 1997 with the objective of analyzing the accuracy of a recently developed portable nitrate meter (Cardy meter) to effectively measure petiole nitrate-nitrogen (NO_3-N) in irrigated cotton (Gossypium ssp.). This task was accomplished by performing correlation and linear regression analyses on NO_3-N concentrations of cotton petiole sap, as measured by the Cardy meter, against the standard procedure NO_3-N analysis, as measured by an ion selective electrode (ISE). Results revealed that the NO_3-N concentrations of petiole sap were highly correlated with dried petiole NO_3-N (pearson correlation coefficient = 0.96, $P < 0.0001$). A regression equation with an $r^2 = 0.92$ was derived: $Y = 9.96X - 1170.86$, where X and Y are NO_3-N in petiole sap (ppm) and dried petioles (ppm), respectively. These results suggest that the sap analysis using the Cardy meter is a potentially valuable tool to monitor the in-season N status of irrigated cotton.

Introduction

Efficient nitrogen (N) management is essential to achieving optimum yields in cotton (Gossypium spp.) production. Due to the dynamic nature of cotton growth, decisions need to be made promptly and effectively regarding N rates and times of applications. For instance, N in excess of that needed for optimum lint yield can lead to excessive vegetative growth and delayed maturity (Tewolde et. al, 1995). Deficiencies experienced at the time of maximum crop demand can result in lint yield reductions. A technique available to managing in-season N inputs efficiently in terms of economic, agronomic, and environmental concerns can be accomplished by monitoring the in season NO_3-N status of the plant using petiole analysis.

Gardner and Tucker (1967) first established the foundation for the utilization of petioles as a N management tool for irrigated cotton in the desert Southwest. The traditional method of petiole NO_3-N analysis to determine plant N status involves numerous steps, which can be costly and time-consuming (Baker and Smith, 1969). A portable NO_3^- selective electrode (hereafter referred to as the Cardy meter) has recently been developed that can directly measure NO_3^- present in fresh samples of expressed petiole sap. This Cardy meter offers immediate results of in-season crop N status. Therefore, adjustments in N fertilization can be made before the crop experiences N deficiencies or excessive N applications are made that may lead to enhanced vegetative growth, yield reductions, and/or delayed maturity.

The accuracy of portable NO_3^- meters has been examined in the past by testing the correlation between NO_3-N concentrations determined by sap analysis and NO_3-N concentrations determined by dried petiole analysis. Hodges and Baker (1993) used cotton to compare the differences in the two methods. They found good correlations (r = 0.88) for early sampling periods, but poor correlations for late sampling periods. They found that the NO_3-N concentrations measured in the petiole sap extracts increased relative to those measured in the dried petioles during later stages of growth, and concluded that this may be a result of the decrease in moisture content in mature cotton plants. Hartz et al. (1994) compared petiole sap NO_3-N using a portable electrode with conventional dry tissue analysis for several vegetable crops and obtained r^2 values ranging from 0.65 to 0.89. Due to the slope of the regression line differing significantly among crops, Hartz et al (1994) emphasized the importance of determining the relationship for each crop of interest. Kubota (1996) conducted a study towards evaluating the accuracy of sap test for cauliflower and broccoli petiole NO_3-N determination in comparison to conventional dry tissue analysis. The design included 3 irrigation rates and 4 N applications. Regression coefficients for the 3 irrigation rates did not differ significantly ($P < 0.05$), thus the relationship between sap NO_3-N and dried petiole NO_3-N was not effected by differences in crop water status.

Potential problems associated with the Cardy meter may result from poor calibration, environmental conditions, and maintenance. Initial experiments performed by Hodges and Baker, (1993) revealed that the meters were very sensitive to temperature and sunlight. Life of the meter's sensor pads will vary depending on environment and care. For example, initial measurements performed under laboratory conditions in this study revealed that the sensor pads may need replacement after approximately 260 samples.

In 1997, a study was initiated with the objective of analyzing the accuracy of the Cardy meter to effectively measure NO_3-N in cotton petioles grown under irrigated conditions in the desert Southwest.

Materials and Methods

Field experiments evaluating various rates of N applications were used as sampling sites in 1997. The experiments being conducted at these sites offered a wide gradient in N fertility regimes and petiole NO_3-N concentrations. These experiments consisted of a N and PIX_{TM} (N-PIX) experiment conducted at the University of Arizona Marana Agricultural Center (MAR), and N management experiments at both the MAR and Maricopa Agricultural Center (MAC). Both Upland cotton (G. hirsutum L., var. DPL 33B) and American Pima (G. barbadense L., var Pima S-7) were sampled at MAC. At MAR, only Upland cotton (DPL 33B and STV 474) was sampled.

Routine petiole sampling from each experimental unit was performed on approximate 14 day intervals, from as early as the occurrence of the seventh node through cut-out. Petioles were sampled from the uppermost, fully expanded mature leaf, which generally fell in the vicinity of the fourth or fifth node below the terminal. Approximately 50 petioles were randomly collected from each plot, mixed thoroughly, and divided into two portions, dry and fresh. Fresh petioles were immediately stored in sealed plastic bags, and transported on ice in an insulated cooler from the field to the laboratory. The tissue of the fresh petioles was subsequently crushed with a rolling pin to extract sap, which was used for determining NO_3-N concentrations. Four to five drops of the extracted sap were placed directly on the sensor pad of a Cardy nitrate meter for analyses (Horiba, Ltd., Kyoto, Japan). Two Cardy meters were used simultaneously to assess improve accuracy and precision of measurement. The Cardy meters were recalibrated using a two point calibration after every ten measurements or sooner if large differences between the two Cardy meters were observed. Potassium nitrate (KNO_3) standards of 150 and 2000 ppm NO_3^- were used to perform the calibrations. Nitrate measurements as determined by the Cardy meter were converted to NO_3-N for subsequent regression analysis.

Dry petioles were oven dried at 65 ° C for 24 hours and then ground to pass a 425 µm (40 mesh) screen for prior to analysis. Dried petiole samples were extracted with a 0.025 M $Al_2(SO_4)_3$ buffer solution containing 10 mg NO_3-N L^{-1}. The extraction process involved the addition of 40 ml of the extracting solution to 400 mg of dried sample and shaking the mixture for 15 minutes. Nitrate-N concentrations of the filtered extract were determined by use of an ion selective electrode (ISE) for NO_3-N. Regression and correlation analyses between the dry and fresh methods for NO_3-N determination were performed in accordance to procedures outlined by Gomez & Gomez (1984) and the SAS Institute (SAS, 1996).

Results and Discussion

Correlation and linear regression analyses were performed on NO_3-N concentrations of cotton petiole sap, as measured by the Cardy meter, against dried petiole NO_3-N, as measured by the ISE. The results revealed that NO_3-N concentrations of petiole sap were highly correlated with dried petiole NO_3-N throughout the season (pearson correlation coefficient = 0.96, $P < 0.0001$). The linear regression equation (Equation 1) was shown to be highly significant ($P < 0.0001$):

$$Y = 9.96X - 1170.86 \ (n = 279, r^2 = 0.92) \qquad \text{(Eq.1)}$$

where Y refers to the NO_3-N in the dried petiole tissue (ppm), and X refers to the NO_3-N in the petiole sap (ppm). The standard errors of the slope and intercept are ± 0.0413 and ± 235, respectively. Both the slope and intercept are highly significant with $P < 0.0001$

In contrast to Hodges and Baker (1993), the NO_3-N concentrations in the petiole sap extracts measured in this study showed a consistent, positive linear relationship with the dried petiole measurements throughout the entire season (Fig.1). In this study, we conducted petiole sampling from the occurrence of the seventh node to cut-out, which provided samples with a range of 213.5 to 22, 485 ppm NO_3-N.

In conclusion, these results demonstrate that sap NO_3-N concentrations as determined by the Cardy meter were well correlated with dried petiole NO_3-N analyzed by the traditional laboratory method using dry, ground petioles. Therefore, the quick sap analysis using the Cardy meter is a potentially valuable tool to monitor the in-season N status of irrigated cotton in Arizona.

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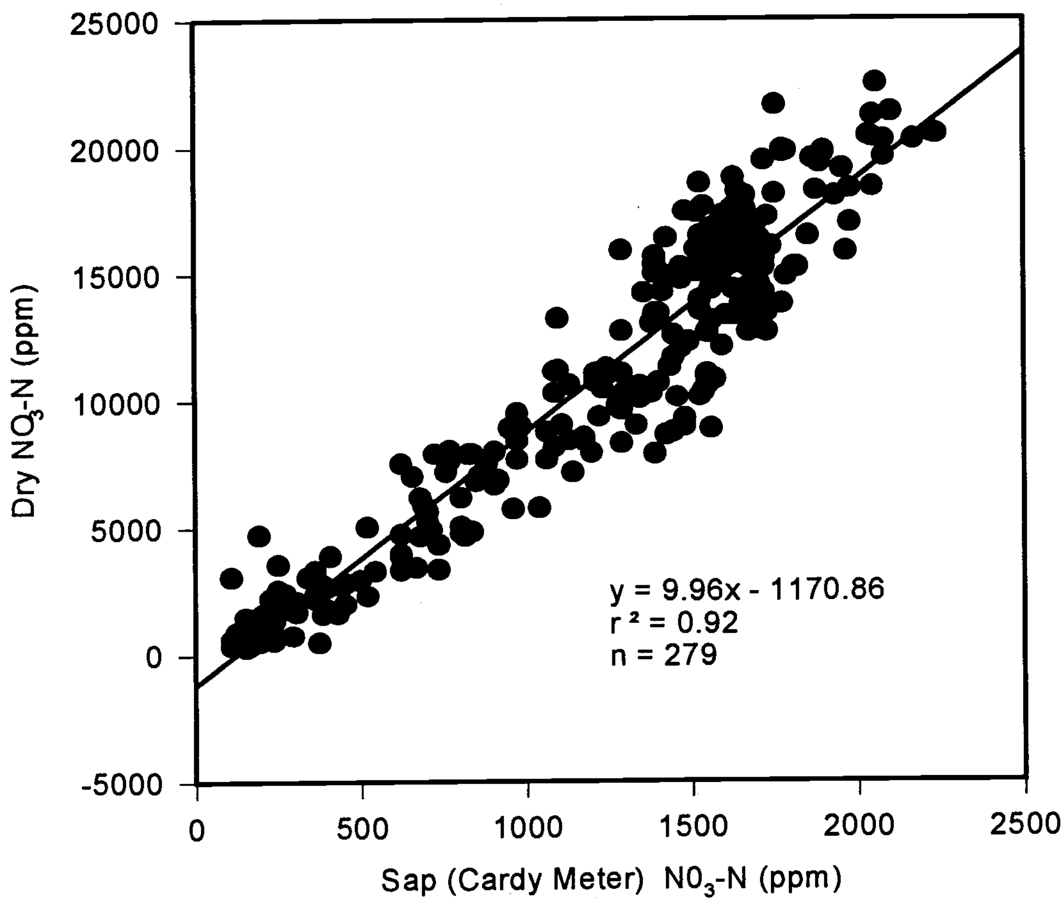

Fig.1. Dry NO_3-N (ppm) vs. Sap NO_3-N (ppm)