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CARDY METER, AN EFFECTIVE TOOL FOR QUICK ASSESSMENT OF COTTON N AND K LEVELS

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Introduction

The increased cost of cotton (*Gossypium hirsutum* L.) production paired with low commodity prices necessitates more efficient nutrient management for the crop. The ability to monitor nitrogen (N) and potassium (K) levels throughout the growing season allowing detected deficiencies to be corrected on a timely bases improves the possibility of achieving optimal yields. Petiole analysis is available to the producer from university and independent labs as a tool to monitor crop nutrient levels during the growing season. A common problem of traditional lab analysis is the lack of timely results to the crop advisor.

Sampling and conducting the petiole analysis the same day can eliminate this time lag. One method of same day analyses is the utilizing of Cardy portable electrode-based ion meters (Horiba, Ltd., Kyoto, Japan). The Cardy NO_3-N and K ion meters offer crop advisors the ability to quickly evaluate crop N and K levels relative to growing conditions. Cardy meters have been widely used in vegetable production with NO_3-N and K thresholds established for several crops (Maynard and Hochmuth, 1997). During the past decade several researchers (Burmester and Mullins, 1994; Hodges and Baker, 1993; and Smith, et al. 1997) have investigated the utility of Cardy meters as diagnostic tools in cotton.

Hodges and Baker (1993) found that routine lab analysis and the Cardy meter measurements were strongly correlated (r=0.88) although a change in the slope of the correlation equation was noted with increasing time. A major problem in the correlation process is the extraction of petiole sap after bloom. Because of this, these researchers suggested that the meters would be useful for early season measurements and for evaluating problem areas in fields. Burmester and Mullins (1994) obtained similar results when evaluating the K meter for in-field measurements. Contradictory to the earlier study the K correlations between lab analysis and Cardy meter were poor (R^2=0.08 or less) in all but the bloom sampling period (R^2=0.53). These poor correlations were attributed to the difficulty in obtaining sap extract as the plant matured. Burmester and Mullins concluded that the best use for the Cardy meters would be early season before the petioles hardened.

As with any diagnostic tool there are potential problems associated with the Cardy meter. In addition to improper calibration, environmental conditions, and maintenance issues Hodges and Baker (1993) found the meters to be highly sensitive to high temperature and sunlight. Smith, et al. (1997) conducted a trial to analyze the accuracy of the Cardy meter to effectively measure NO_3-N in irrigated cotton. As with previous correlation experiments, petioles were randomly sampled and divided into two samples, one for Cardy meter analysis and one for the standard lab analysis. Correlation and linear regression analysis were conducted on NO_3-N concentrations as measured by the Cardy Meter versus the standard lab analysis. The two NO_3-N petiole analysis methods were highly correlated (Pearson correlation coefficient = 0.96, P<0.0001) throughout the growing season. A highly significant (P< 0.0001) linear regression equation was derived: Y = 9.96X – 1170.86 (n = 279, R^2=0.92), where X and Y are NO_3-N concentrations (ppm) for Cardy meters and standard lab analysis, respectively. Their results suggest that the Cardy meters can be a valuable diagnostic tool to monitor NO_3-N levels in cotton.

This study was continued to evaluate the NO_3-N and K Cardy meters as an in-field diagnostic tool for cotton production. The study was conducted in several locations across the cotton belt. The Cardy meter N and K determinations were to be correlated with N and K values determined by the University of Arkansas lab at Marianna, AR.

Material and Methods

Strategic locations (five in 2001 and seven in 2002), based on soil type, were selected from seventeen possible locations selected for a regional fertility trial. This regional evaluation consisted of four or five treatments, depending on the year and location. The locations were selected in an attempt to encompass many of the annual environmental fluctuations that potentially affect cotton production. Agronomic data by location is reported in Table 1.

Petioles were sampled weekly from the two center plot rows of each treatment. The sampling period began one week before bloom and continued trough cutout. From each plot, approximately 20-30 petioles were sampled from upper-most mature leaf, generally the fourth node from the top. These petioles were collected from each treatment of only one replication (which was rotated weekly) and the samples sent to the University of Arkansas (UA) Soil Test Laboratory for a standard NO_3-N and K determination, Procedures PL-0002 and PL-0001, respectively.

Prior to each sampling, both N and K Cardy meters were calibrated in accordance with the instructions and the standards provided with each meter. Fresh petioles were cut approximately ½" in lengths and placed in a garlic press for sap extraction. The sap was squeezed either into a small beaker or directly onto the meter. The final reading was an average of several readings. As the crop matured, it was necessary to place the petioles in a freezer for approximately 20 minutes to rupture the cell walls, which facilitated sap extraction.

Regression and correlation analysis between the Cardy meter and UA lab analysis were performed for both the NO_3-N and K concentrations in accordance with procedures outlined by the SAS Institute (SAS, 1997).

Results and Discussion

Correlation analyses were performed by location and across locations by sampling date for each year and combined but is not reported in this paper.

The results from the 2001 study demonstrated that Cardy meter NO_3-N and K concentrations (ppm) were linear correlated with the UA concentrations. The linear regression equations derived across the five locations for NO_3-N and K, respectively, were: N = 0.2273AN + 918.54 (n=384, R^2=0.36), where N and AN are NO_3-N concentrations (ppm) for the Cardy meter and UA lab analysis, respectively; and K = 505.68AK + 1375.7 (n=384, R^2=0.55), where K and AK are K concentrations for the Cardy meter (ppm) and UA lab analysis (%), respectively. Differences were exhibited in the linear relationships for both the NO_3-N and K concentrations among the five locations and may have been due to differences in sampling technique, environmental conditions, or variety.

Three additional locations were added to the study in 2002 for a total of seven locations (one 2001 site dropped out of the 2002 study) (Table 1) in order to better define the relationship between Cardy Meter and UA lab analysis. Linear, quadratic, and cubic regression analyses were performed on NO_3-N concentrations (ppm) of cotton petiole sap, as measured by the Cardy meter, versus the NO_3-N ppm as measured by the UA Procedure PL-0002 for each year and combined across years. The best fitting regression equation of the two years data collected from all locations are reported in Table 2 where N refers to the Cardy meter NO_3-N ppm levels, and AN refers to the Arkansas lab NO_3-N ppm levels. Similar regression analyses were also performed on the K concentrations (ppm and %) as measured by the Cardy meter and the UA Procedure PL-0001, respectively. The best fitting regression equations and levels of significance for each location are reported in Table 3 where K refers to the Cardy meter K ppm levels, and AK refers to the UA lab K % levels.

Evaluating the data across locations and years a highly significant ($P<0.0001$) quadratic regression equation was derived: N = 356.40 + 0.136AN – 0.0000029AN^2 (n=625, R^2=0.52), where N and AN are NO_3-N concentrations (ppm) for the Cardy meter and UA lab analysis, respectively (Fig. 1). Similarly, a highly significant ($P<0.0001$) quadratic regression equation was derived: K = 1294.52 + 929.15AK – 59.40AK^2 (n=619, R^2=0.31), where K and AK are K concentrations for the Cardy meter (ppm) and UA lab analysis (%), respectively (Fig. 2). Increasing the amount of data points results in relationships that are curvilinear which is more reflective of the N and K demand curves in cotton than a linear equation. In general, all locations had a better fit to the data for NO_3-N readings than K readings as indicated by the R^2 values for each location except for Lubbock, TX (Tables 2 & 3). It is likely that K readings are more impacted by variety and environmental conditions than the NO_3-N readings, therefore the lower R^2 values exhibited (Table 3).

Conclusion

The results demonstrate that the cotton petiole NO_3-N and K concentrations (ppm) as measured by the respective Cardy meters show a positive curvilinear relationship with the UA lab concentrations. These curvilinear relationships indicate that the Cardy meters can be used as an effective diagnostic tool to monitor N and K concentrations throughout the growth season. Therefore, this diagnostic tool should improve nutrient management by crop advisors for not only cotton but also several crops.

Literature Cited

Burmester, C.H., and G.L. Mullins. 1994. Evaluation of a compact ion meter for in-field measurement of potassium in cotton petioles. Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN. p. 1574.

Hodges, S.C., and S. Baker. 1993. Correlation of plant sap extracts of nitrate-N and K with dries petiole extracts. Proc. Beltwide Cotton Conf. National Cotton Council, Memphis, TN. p. 1335-1337.

Maynard, D.N., and G.J. Hochmuth. 1997. Knott's handbook for vegetable growers. 4th ed. John Wiley and Sons, New York.

SAS Institute. 1997. SAS/STAT: Procedures. Release 6.12 ed. SAS Inst., Cary, NC.

Smith, J.H., J.C. Silvertooth, and E.R. Norton. 1998. Comparison of the two methods for the analysis of petiole nitrate nitrogen concentration in irrigated cotton. Pub. AZ1006. College of Ag., Univ. of Arizona, Tucson, AZ.

Table 1. Locations and agronomic information.

	2001		2002	
Location	**Variety**	**Planting Date**	**Variety**	**Planting Date**
Rowher, AR	STV747	6/05/01	STV474	4/23/02
Portageville, MO	BXN 47	5/25/01	PM 1218 BR	5/13/02
Verona, MS	SG501BR	5/09/01	SG501BR	5/16/02
Las Cruces, NM	-	-	Acala 1517-99	4/15/02
Altus, OK	-	-	DPL655BR	5/09/02
Florence, SC	DPL458BR	4/24/01	DPL458BR	4/18/02
Jackson, TN	-	-	PM 501	5/07/02
Lubbock, TX	PM 2326RR	5/17/01	-	-

Table 2. NO_3-N quadratic regression equations and test of significance for all locations across years.

Location	Equation	R^2	n	Intercept	Slope
Rowher, AR	$N = 301.72 + 0.100\ AN - 0.0000018\ AN^2$	0.54	196	P<0.0001	P<0.0001
Portageville, MO	$N = 217.45 + 0.179\ AN - 0.0000046\ AN^2$	0.79	153	P<0.0001	P<0.0001
Verona, MS	$N = 486.79 + 0.170\ AN - 0.0000056\ AN^2$	0.36	72	P<0.0014	P<0.0001
Las Cruces, NM	$N = 102.31 + 0.261\ AN - 0.0000092\ AN^2$	0.88	40	P<0.2242	P<0.0001
Altus, OK	$N = 568.97 + 0.127\ AN - 0.0000021\ AN^2$	0.77	36	P<0.0003	P<0.0001
Florence, SC	$N = 358.99 + 0.141\ AN - 0.0000040\ AN^2$	0.77	60	P<0.0001	P<0.0001
Jackson, TN	$N = 322.75 + 0.105\ AN - 0.0000029\ AN^2$	0.82	28	P<0.0001	P<0.0001
Lubbock, TX	$N = 275.92 + 0.375\ AN - 0.0000015\ AN^2$	0.25	40	P<0.6757	P<0.0066

Table 3. K linear or quadratic regression equations and test of significance for all locations across years.

Location	Equation	R^2	n	Intercept	Slope
Rowher, AR	$K = 1402.42 + 838.56\ AK - 67.74\ AK^2$	0.17	196	P<0.0020	P<0.0001
Portageville, MO	$K = 925.69 + 1294.88\ AK - 124.57\ AK^2$	0.35	148	P<0.0045	P<0.0001
Verona, MS	$K = 879.03 + 1297.05\ AK - 145.86\ AK^2$	0.35	72	P<0.0802	P<0.0006
Las Cruces, NM	$K = -1245.72 + 3019.82\ AK - 283.73\ AK^2$	0.15	40	P<0.6848	P<0.0263
Altus, OK	$K = 3060.12 + 275.93\ AK$	0.12	36	P<0.0001	P<0.0400
Florence, SC	$K = 4680.22 + 79.38\ AK$	0.02	60	P<0.0001	P<0.2809
Jackson, TN	$K = -5489.08 + 4030.08\ AK - 347.44\ AK^2$	0.18	23	P<0.3174	P<0.0481
Lubbock, TX	$K = 1669.50 + 447.77\ AK$	0.27	40	P<0.0218	P<0.0006

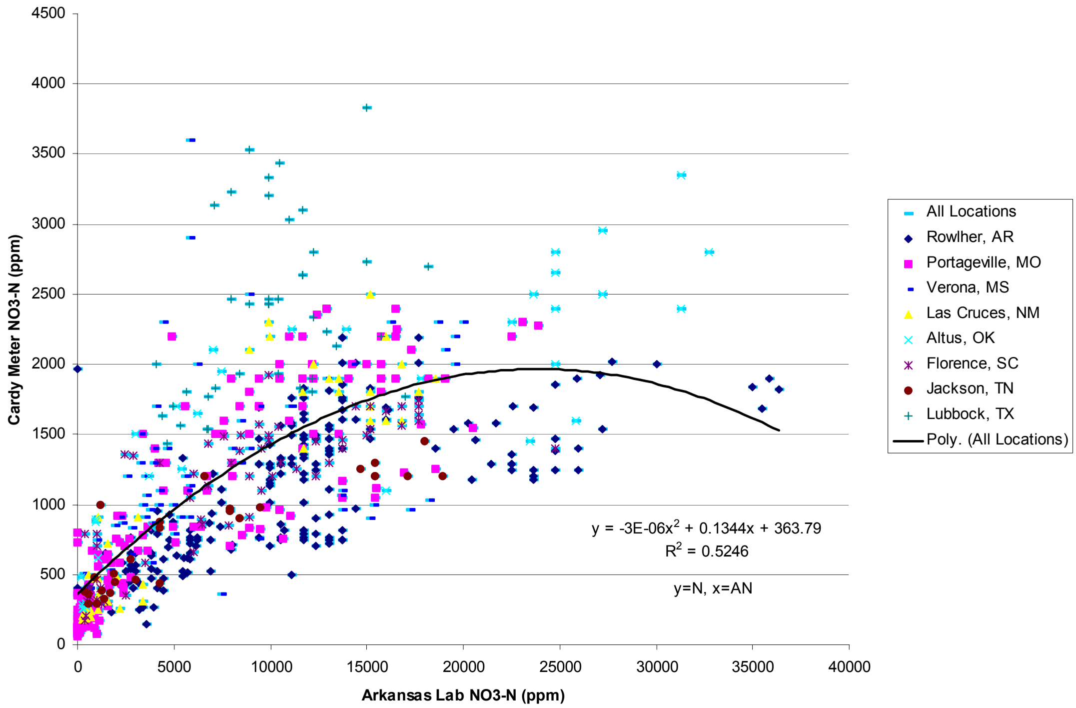

Figure 1. Quadratic regression across locations and years for Cardy meter NO_3-N (ppm) vs. Arkansas Lab NO_3-N (ppm).

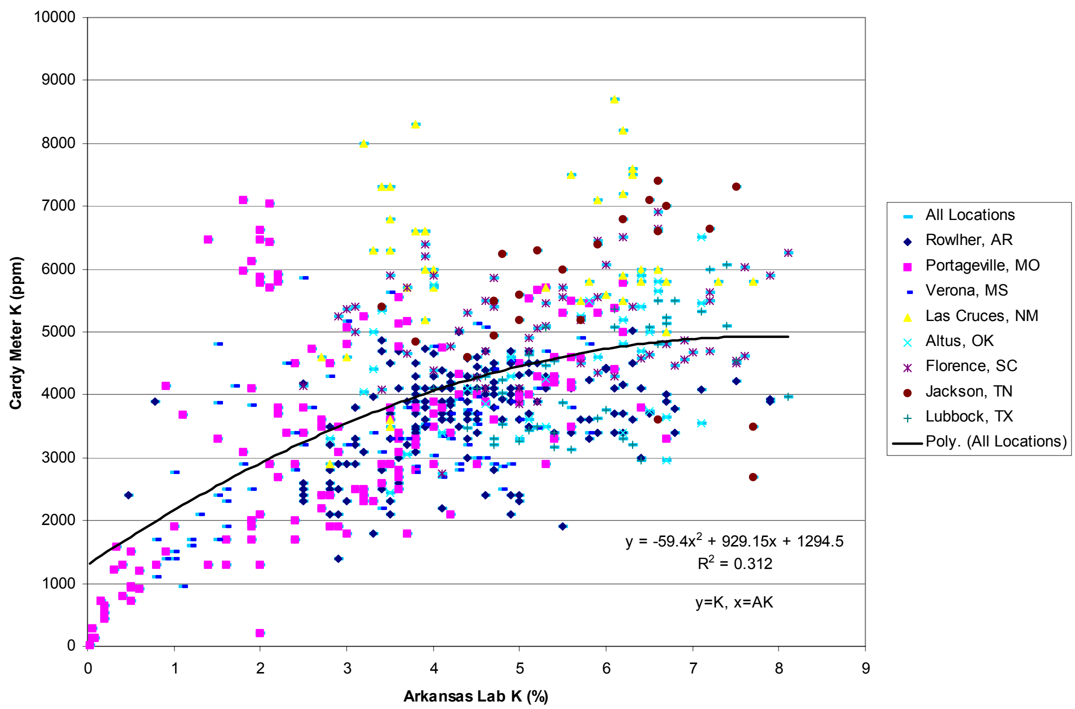

Figure 2. Quadratic regression across locations and years for Cardy meter K (ppm) vs. Arkansas Lab K (%).