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ADJUSTING IN-SEASON NITROGEN FERTILIZER RATE FOR SILAGE CORN WITH REAL-TIME SENSING

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ABSTRACT

Nitrogen management has tremendous implications on crop productivity, quality and environmental stewardship. Sufficient nitrogen is needed to achieve optimum yield and quality. Soil and in-season plant tissue testing for nitrogen status are time consuming and expensive. Real time sensing of plant nitrogen status can be a useful tool in managing nitrogen inputs. Very good correlations were observed between chlorophyll meter measurements and relative plant nitrogen status. In-season nitrogen fertilizer recommendations can be made from meter reading differences between a well fertilized reference area and the rest of the field. An algorithm was developed for in-season nitrogen fertilizer rate recommendations.

Keywords: *corn silage, nitrogen, remote sensing, Zea mays*

INTRODUCTION

Nitrogen fertilizer is the most used and often the most mismanaged nutrient input. Nitrogen management has tremendous implications on crop productivity, quality and environmental stewardship. Sufficient nitrogen is needed for optimum yield and quality. Soil and in-season plant tissue testing for nitrogen status are time consuming and expensive. Real time sensing of plant nitrogen status can be a useful tool in managing nitrogen inputs. Very good correlations have been observed between remotely sensed crop nitrogen status, in-season nitrogen fertilizer recommendations and yield for other locations. However, these other regions do not match the high input, irrigated, high yield potential conditions for crop production in the southern San Joaquin Valley. The objectives of this project are to assess the reliability of remotely sensed non-destructive plant nitrogen measurements to wet chemistry data from sampled plant tissue and develop in-season nitrogen recommendations based on remotely sensed data for improved nitrogen use efficiency.

The Southern San Joaquin Valley produced 9.5 million metric tons of corn valued at 403 million dollars from 139 thousand hectares in 2011. Corn is typically a heavy nitrogen user. An estimated 57 thousand metric tons of nitrogen was used. While nitrogen requirements for optimum crop production are well established the appropriate rate and timing of individual nitrogen applications are not always accurately accomplished. The nitrogen requirement can be accurately determining by knowing the available soil nitrogen and the amount of added nitrogen in conjunction with tissue tests. This method is expensive and time consuming and rarely performed. Additionally, much of the corn silage acreage is fertilized with manure and irrigated with dairy lagoon water. However, an accurate and thorough measurement of nitrogen levels in manure and lagoon water even when conducted is widely variable. The over application of nitrogen has the potential to dramatically impact ground water through leaching and surface water from runoff. The use of remote sensing to determine nitrogen status in the plant is a quick method for determining if any additional nitrogen is required to produce optimum yield and quality.

Commercially available products to remotely sense plant nitrogen content use either reflectance or light transmittance/absorbance. The reflectance method uses ambient and reflected light in the 700 and 840 nm wavelengths to calculate a relative chlorophyll index. A hand held device can measure areas from 1.5 inch to 4.5 inch diameter. This is the same methodology that is incorporated in on-the-go vehicle mounted, aerial or satellite imagery. The transmittance/absorbance method requires that the device be clamped on a leaf and utilizes the 650 and 940 nm wavelengths to determine a relative chlorophyll index.

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Varvel, et al [1] were able to identify nitrogen deficient corn plants with a chlorophyll meter but found no differences between adequately to excessively fertilized plants. Research conducted in Pennsylvania [2] utilized the ratio between readings taken from a field and the well fertilized reference area to determine nitrogen fertilizer need. No nitrogen fertilizer would be recommended if the ratio was 0.95 or greater. It then used the relative SPAD reading as a multiplier along with manure application and leaf stage. These figures are then used to add to or subtract from an initial N fertilizer recommendation of 310 kg ha^{-1}. In Iowa, research [3] recommendations are for no added N fertilizer if the ratio is greater than 0.97 and up 112 kg N ha^{-1} if the ratio is less than 0.88. Purdue University recommendation [4] uses 0.95 as the application threshold then further states that "meter readings… do not tell us how much additional N should be applied…" Barker and Sawyer [5] developed a quadratic plateau regression model to determine the economic optimum nitrogen rate. All of these studies were conducted without irrigation. Potential yield and optimum nitrogen rate varied from year to year as rainfall amounts differed. Corn silage production is irrigated in the San Joaquin Valley, thus most corn production in this area does not experience moisture stress under normal irrigation management. Schmidt, et al [6] found good correlation between transmittance/absorbance meter readings and economic optimum nitrogen rate. In a recent study, Scharf et al [7] found sensor-based variable rate nitrogen applications increased corn yield and reduced N fertilizer application rate compared to the farmer's chosen constant N rate.

Murdock, et al [8] developed the formula $N = 6 + (7*D)$ for wheat grown in Kentucky where N = lbs. of N per acre to be applied at Feekes 5 and D = the difference in meter reading between the well fertilized reference area and the field. Research that this author [9] conducted for wheat in the southern San Joaquin Valley resulted in the formula $N = 35 + (12*D)$. The growing conditions, varieties and yield potential for wheat in the San Joaquin Valley are very different from other parts of the nation. The same is true of corn and other crops. Research using chlorophyll meters in corn, and other crops has been conducted in other locations. Considering the growing conditions in the San Joaquin Valley and the different varieties that are grown here it is very likely that formulas for these crops developed elsewhere are not accurate for this area.

MATERIALS AND METHODS

Plots were established at the UCCE Kern Research Farm in the southern San Joaquin Valley in 2011 and 2012. A randomized complete block factorial design with three replications was used. This location provided low initial nitrogen plot areas. Plots were four 76-cm rows by 7.6 meters. Corn (*Zea mays* L.) was planted in April and harvested in July. Irrigation was sufficient to not be a limiting factor. Treatments included nitrogen applications of 0, 112, 224, and 336 kg nitrogen per hectare applied at planting only and the same rate at planting with additional nitrogen fertilizer at growth stage V8 to total 336 kg N per hectare. Soil nitrogen level was tested before planting and after harvest. Plant nitrogen status was measured at growth stage V8 and VT. Plant nitrogen measurements were made by reflectance, transmittance/absorbance, and wet chemistry.

The two products used to remotely sense plant nitrogen content use either reflectance or light transmittance/absorbance. The reflectance method uses ambient and reflected light in the 660 and 840 nm wavelengths to calculate a relative chlorophyll index. This instrument is the Spectrum® FieldScout® CM 1000 NDVI Meter. The hand held device can measure areas from 1.5 inch to 4.5 inch diameter. This is the same methodology that is incorporated in aerial or satellite imagery. "Normalized difference vegetation index" or NDVI measurements were made with the instrument about 2 feet above the crop canopy with a 45 or 90 degree angle to the canopy. Measurements from reflected light are abbreviated CM 1000 45 or CM 1000 90 for the different angles. The CM 1000 NDVI meter displays the NDVI calculation (-1.0 to 1.0).

The transmittance/absorbance instruments are the Konica ®Minolta® SPAD 502 Plus, and the Opti-Sciences® CCM-200. These meters are clamped on a leaf and utilize the 650 and 940 nm wavelengths and 653 and 931 nm wavelengths, respectively, to determine a relative chlorophyll index. Measurements were made at different locations on the plant leaf to determine the most representative spot, data not shown. Data shown was measured at the midpoint between the leaf tip and collar. The SPAD meter readings are a relative index (-9.99 to 199.9) calculated from NDVI times a constant whereas the CCM meter readings are the ratio of readings (653 nm divided by 931) thus the scale is different.

RESULTS AND DISCUSSIONS

Corn silage yield increased as at planting nitrogen fertilizer rate increased (Table 1). The highest nitrogen fertilizer rate did not exceed normal application rates in the southern San Joaquin Valley. Yield response to added nitrogen fertilizer can be described by the equation (Fig. 1):

$$\text{Corn Silage Yield (Mt ha}^{-1}\text{)} = 0.07 * \text{N Rate (kg ha}^{-1}\text{)} + 46.6 \quad (1)$$

Ear leaf nitrogen concentration and silage yield were not significantly different for the treatments where the total nitrogen application was the same (Table 1). In this study, the split application of nitrogen fertilizer did not improve nitrogen use efficiency. Irrigation did not exceed evapotranspiration thus nitrogen fertilizer did not move beyond the rooting zone.

Table 1: Corn N concentration and silage yield at 70% moisture.

N Rate					
At Planting [kg ha^{-1}]	Side Dress [kg ha^{-1}]	Ear Leaf N [g kg^{-1}]	Yield [mt ha^{-1}]	V8 N without side dress N [g kg^{-1}]	Yield without side dress N [mt ha^{-1}]
0	336	32.9	68.0	26.6 b	44.2 c
112	224	32.6	67.2	42.5 a	57.4 b
224	336	31.8	68.6	43.8 a	63.4 ab
336	0	31.4	69.3	52.7 a	68.2 a
LSD $_{0.05}$		ns	ns	12.4	1.2
CV %		5.4	7.3	16.6	8.7

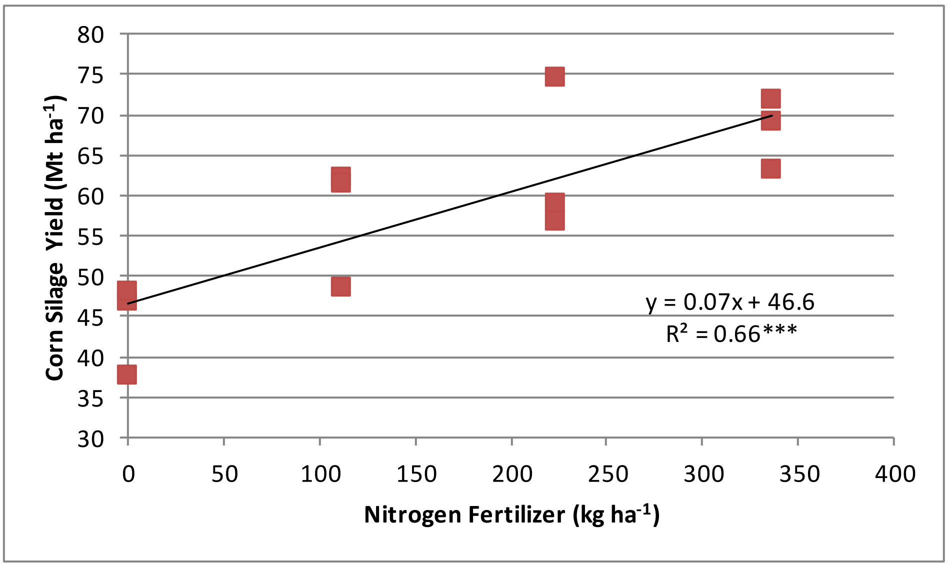

Fig. 1: Corn silage yield response to at planting nitrogen fertilizer application.

Chlorophyll readings utilizing the CM 1000 NDVI meter at growth stage V8 were not significantly different (Table 2). This meter uses a slightly different wave length than the CM 1000 chlorophyll meter (660 vs 700 nm). It is not known to this author what difference the slight variation in wave length made. Other research [8], [9] were able to measure differences with this type of meter. There were good correlations between meter readings from the SPAD and CCM 200 meters (Fig. 2.)

Table 2: CM 1000 NDVI meter readings.

At planting N rate	5/20	6/16
0	0.86	0.84
112	0.91	0.87
224	0.88	0.85
336	0.89	0.83
LSD $_{0.05}$	ns	ns
CV %	5.4	3.6

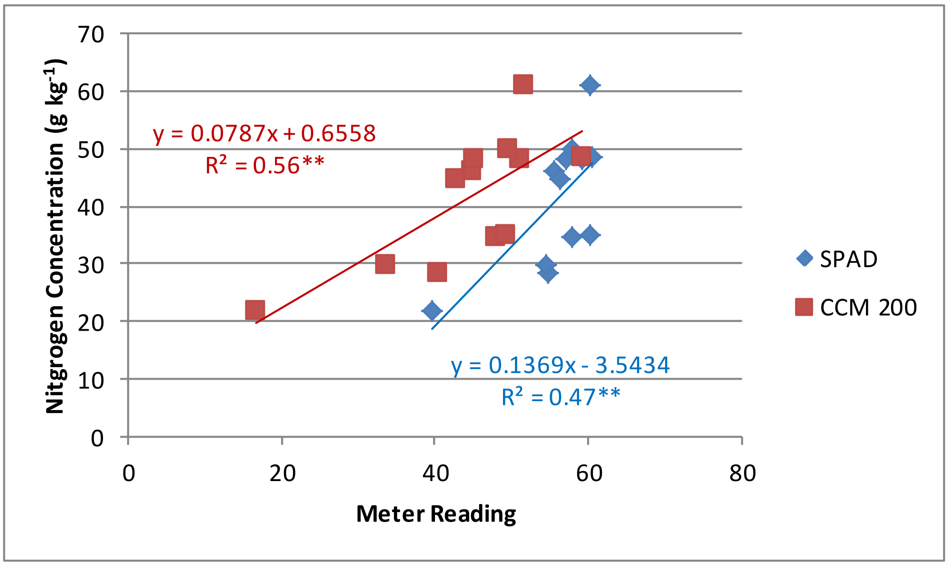

Fig. 2: V8 Nitrogen Concentration versus Meter Reading.

The difference between the meter reading of the well fertilized treatment and the other treatments was calculated. Very good correlations were observed between meter reading differences from the CCM 200 and SPAD instruments and nitrogen recommendation, R^2>0.89 and 0.90, respectively (Fig. 3). Because the internal calculation and constant are different between the meters the slope of each equation is different.

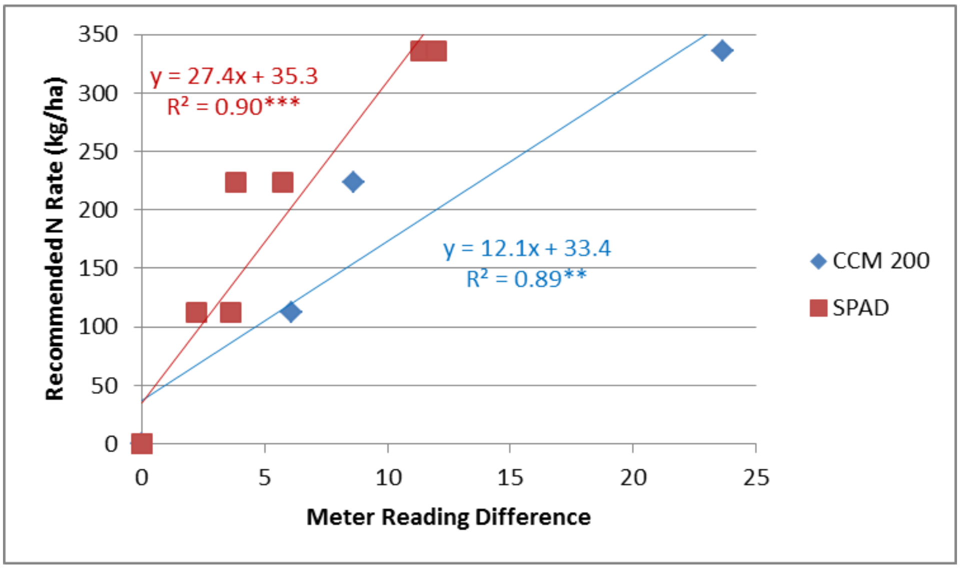

Fig. 3: SPAD and CCM 200 meter readings versus recommended N rate.

CONCLUSIONS

Early spring sampling of corn plants can provide useful information on plant nitrogen status and the need for additional nitrogen fertilizer. The use of chlorophyll meters provides quick and accurate information needed for nitrogen fertilizer recommendations.

Side dress nitrogen fertilizer recommendation is as follows:

Apply the expected full nitrogen fertilizer rate on a reference area with actively growing plants at least three weeks prior to sampling. The reference area should be representative of the field and can be several small areas throughout the field or a strip through the field. At growth stage V8 to V10, compare the readings from the reference areas to readings from the remainder of the field. Because individual plants vary, at least 30 readings should be made throughout the field and reference area. Make the measurements at the mid-point of the leaf on the upper most leaf that has a collar exposed. The difference between the average of the readings will give an indication of the need for additional nitrogen fertilizer.

The side dress nitrogen fertilizer rate calculation is:

$$N = 27 * dSPAD + 35 \quad (2)$$

N = Recommended Nitrogen Rate in kg N ha^{-1}
dSPAD = Difference in SPAD meter reading between the reference area and the measured crop area

or

$$N = 12 * dCCM + 35 \quad (3)$$

N = Recommended Nitrogen Rate in kg N ha^{-1}
dCCM = Difference in CCM 200 meter reading between the reference area and the measured crop area.

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