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CHLOROPHYLL METER READINGS IN CORN AS AFFECTED BY PLANT SPACING

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ABSTRACT: Heightened environmental consciousness has increased the perceived need to improve nitrogen (N) use efficiency by crops. Synchronizing fertilizer N availability with maximum crop N uptake has been proposed as a way to improve N-use efficiency and protect ground water quality. Chlorophyll meters (Minolta SPAD 502) have the potential to conveniently evaluate the N status of corn (*Zea mays* L.) and help improve N management. A potential problem with the use of chlorophyll meters is the effect of within-row plant spacing on meter reading variability. Chlorophyll meter readings and leaf N concentration of irrigated corn at anthesis and grain yield at harvest were measured on plants grouped into eight within-row plant spacing categories. Leaf N concentration was not affected by plant spacings, but chlorophyll meter readings and grain yield per plant increased as plant competition decreased and N fertilizer rate increased. These data indicate that avoiding plants having extreme spacings can greatly increase precision when using chlorophyll meters to evaluate the N status of corn.

INTRODUCTION

Increased environmental consciousness has resulted in the need for improved N management in crop production. Chlorophyll meters have been identified as a convenient tool for evaluating the N status of corn because good relationships between chlorophyll content and N status have been established (1,2). In general, chlorophyll meter readings and leaf greenness increase as N availability to the plant increases.

Obvious concern when collecting any type of plant data includes how a given plant represents the general population. This specifically relates to the number of observations required to detect differences for a given level of precision. The number of observations required is influenced by many factors contributing to the variability in data within fields or, more specifically, the variability within individual leaves.

Differences in spatial area available to individual plants maybe one source of sample variation for chlorophyll meter readings. Non-uniform distance between plants has been identified as one factor related to reduced grain yields in corn (3). Variable plant stand leads to unequal light interception which is important because of the positive relationship between intercepted radiation by a corn canopy and grain yield (4,5,6). It has also been demonstrated that an increase in intercepted radiation increases N accumulation in plants (4,6).

The objectives of this study were to evaluate the effect of within-row plant spacing on chlorophyll meter readings and to develop plant selection and sampling guidelines that can improve the sensitivity of the chlorophyll meter for evaluating the N status of corn.

MATERIALS AND METHODS

The study was conducted on 12-row plots (9.1 m by 61 m long) at two N rates (67 and 134 kg N/ha as sidedress anhydrous ammonia) on a furrow-irrigated Wood River silt loam (fine, montmorillonitic mesic typic arguistolls). Four replicates of each plot were planted to Pioneer brand hybrid 3379 at 69,000 seeds/ha. Hail damage and other factors reduced the stand to 60,500 plants/ha before the plants reached the R4 growth stage as defined by Hanway (7). At the R4 growth stage, the distance between individual plants was measured along 22-m lengths of the center eight rows within each plot.

A single chlorophyll meter reading was taken at R4 on the ear leaf of each plant at mid-length and midway between the edge and the midrid. A single 1-cm

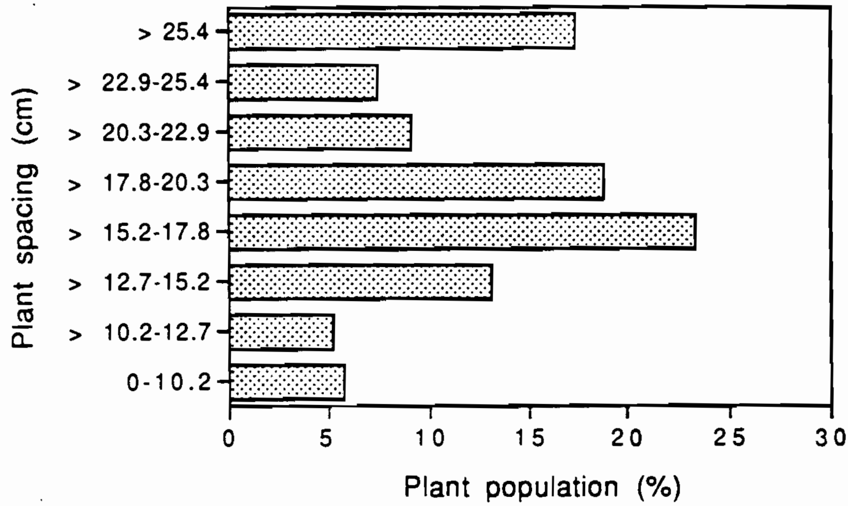

FIGURE 1. Frequency distribution of plants among eight space availability categories.

diameter leaf disk was collected from the same leaf and area using a leaf punch (Precision Machine Company, Lincoln, NE). Dried leaf disks were ground for five minutes using a Spex model 8000 mixer/mill (SPEX Industires, Inc., Edison, NJ.), and leaf N concentrations were determined using a Carlo Erba model NA 1500 CHN analyzer as described by Schepers et al. (8).

Each of the total 5,616 plants was assigned to one of eight within-row plant spacing categories where the linear space available to each plant was defined as the mean distance to the two nearest plants (Fig. 1). To compensate for uneven numbers of observations in each category, weighted regression analyses were used to describe the relationships between mean available plant spacing and mean chlorophyll readings observed within each spacing category (9). Similar relationships were described for leaf N concentrations.

An estimate of variation for chlorophyll meter readings resulting from non-uniform plant spacing is described in the results and discussion section. Corn grain from individual plants within a spacing category was combined for yield

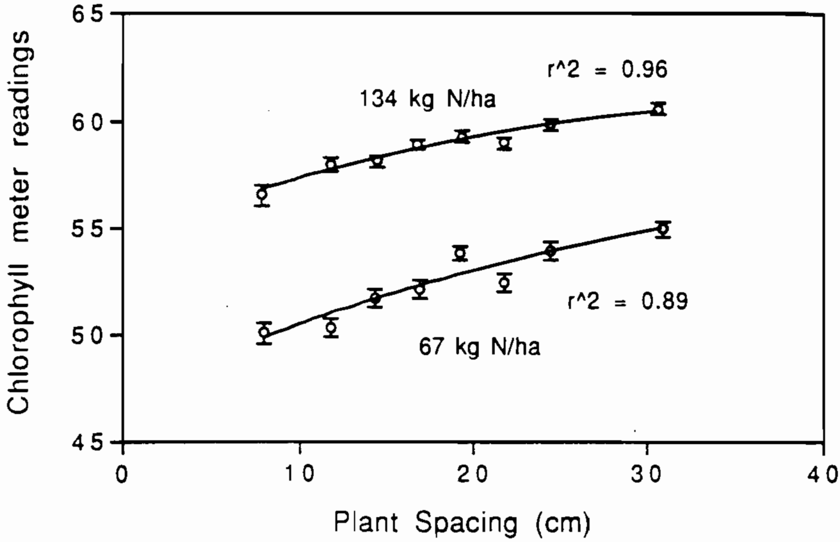

FIGURE 2. Relationships between mean space for each category and mean chlorophyll meter readings observed within each space-availability category. The standard error of the mean for a given N rate is presented with the standard error bars.

analysis. Shelled grain moisture was determined using a moisture meter and yields were adjusted to 15.5% moisture.

RESULTS AND DISCUSSION

Corn yields averaged 8.0 and 9.5 Mg/ha for and 67 and 134 kg/ha N rates, respectively. The observed difference in yields indicated N was deficient at the 67 kg N/ha rate of N application ($p<0.01$). Chlorophyll meter readings averaged 52.9 and 59.0 units at the R4 growth stage for the 67 and 134 kg N/ha rates of N application, respectively ($p<0.01$). These observations are consistent with earlier reports (10) that indicated chlorophyll meters could be used to evaluate the N status of corn.

Chlorophyll meter readings increased as within-row plant spacing or N rates increased (Fig. 2). The effects of plant spacing are important because the range in

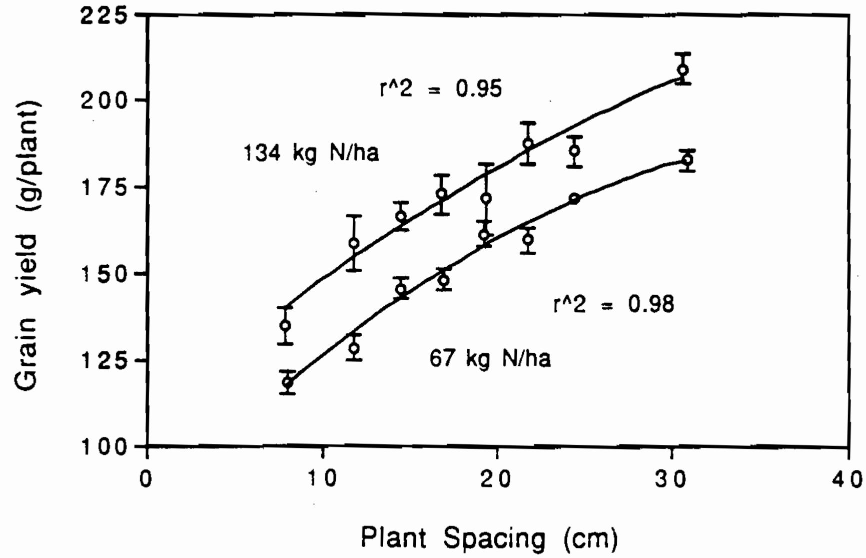

FIGURE 3. Relationships between mean space for each category and mean grain yield per cent observed within each space-availability category. The standard error of the mean for a given N rate is presented with the standard error bars.

chlorophyll meter readings due to plant spacing within a fertilizer rate was approximately the same magnitude as the difference in chlorophyll meter readings due to the difference in N rate (*i.e.*, 67 kg N/ha) at a given plant spacing. Although the effects of plant spacing and N rate on chlorophyll meter readings are independent (Fig. 2), they could easily be confounded under field conditions.

The effect of N rate and plant spacings on chlorophyll meter readings carried over to grain yield (Fig. 3). The effect of within-row plant spacing on yields could be explained by, i) a positive relationship between intercepted radiation by the corn canopy and grain yields (4,5,6), ii) an increase in N accumulation associated with increased radiation interception (4,6) iii) and/or increased volume of soil available for exploration by each plant. It should be noted that the yields per plant were not directly correlated to yields per hectare because increases in area per plant impose restrictions on the number of plants per hectare.

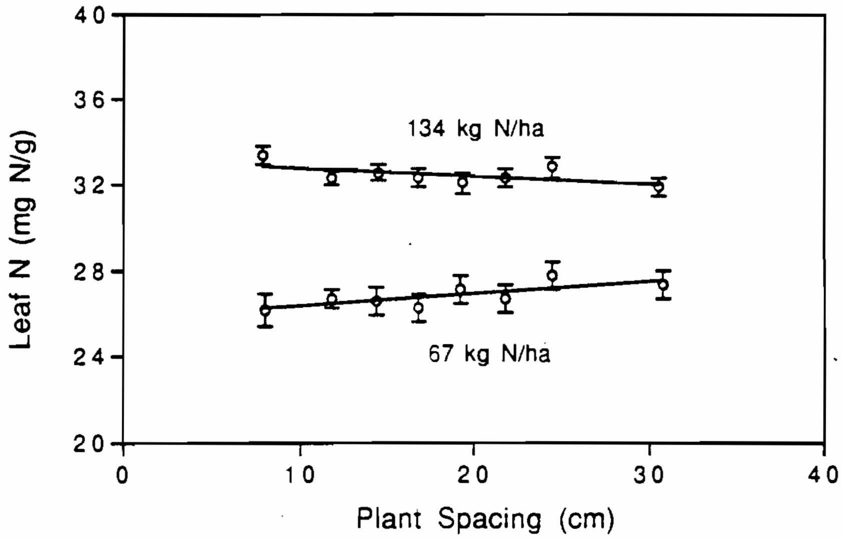

FIGURE 4. Relationships between mean space for each category and mean leaf N observed within each space-availability category. The standard error of the mean for a given N rate is presented with the standard error bars.

Regression analysis indicated plant spacing within a N rate did not have a significant effect (p>0.05) on leaf N concentrations (Fig. 4). Comparing this observation with results in Figure 2 indicates plant spacing had a greater effect on chlorophyll meter readings than leaf N concentrations. Apparently individual plant yield was more strongly influenced by light interception than N rate. Even at the lower N rate the widely spaced plants were not able to compensate very well in terms of leaf N concentration. These observations suggest the presence of an extensive rooting system that effectively overlaps and minimizes the conceptual benefit of more widely spaced plants having greater nutrient availability. Although leaf N concentrations did not increase with increasing light (*i.e.*. larger spacings), this does not mean plants with less competition did not take up more N. Increasing plant available space increased the specific leaf weight (data not shown), which is defined as the mass of tissue per unit surface area. If the mass per surface area increases and the N concentration remains constant, a larger mass of N must be

Table 1. Calculated number of chlorophyll meter readings required to attain various levels of desired precision for atypical plant population around a mean of 19.1 cm.

Plant space	N rate	Desired precision			
		0.2	1.0	2.0	4.0
cm	kg N/ha	Meter readings required			
19.1 ± 1.3	67	92	4	1	1
19.1 ± 1.3	134	47	2	1	1
19.1 ± 3.9	67	357	20	7	1
19.1 ± 3.9	134	183	14	4	1
19.1 ± 6.4	67	895	47	17	2
19.1 ± 6.4	134	427	36	9	2
19.1 ± 8.9	67	1644	88	32	4
19.1 ± 8.9	134	790	66	16	4
19.1 ± 11.5	67	2195	123	44	5
19.1 ± 11.5	134	1111	88	22	5
Total population	67	4013	215	77	10
	134	1931	161	40	9

present per unit surface area. This would be consistent with the increased yield resulting from larger plant spaces within a given N rate.

An estimate of variation for chlorophyll meter readings resulting from non-uniform plant spacing was made using predicted chlorophyll meter readings for each plant based on its individual spacing (Fig. 2). This was achieved by using the regression relationship between mean plant space for each category and mean chlorophyll meter readings for each category within a N rate (see Fig. 2) to assign predicted chlorophyll meter readings to the actual plant spaces recorded for plants within each plot. This enabled us to evaluate variances resulting from only plant space differences because they are predicted values from the actual plant population. This approach eliminated variations between plants, leaves, and spots on leaves. The variance for the predicted chlorophyll meter readings within a given plant spacing category was calculated for both N rates. Using these variances in Stein's two-stage test (11), an estimate was formed for the number of readings required to attain several levels of precision.

Based on data presented above, avoiding plants with atypical spacings should reduce uncertainties associated with assessment of crop N status. The net effect of sample variation can also be decreased by increasing the sample number. For example, the number of samples required to attain a precision of ±2.0 chlorophyll meter reading units decreased by over a factor of 2 when only sampling plants having spacings in the range of 10.2 to 28.0 cm (19.1±8.9 cm) as compared to plants randomly sampled from the total population (Table 1). By sampling plants in the 19.1±8.9 cm range, less than 15% of the plant population was excluded. This example is relevant because the results of on going studies suggest that a precision of ±2.0 meter reading units (*i.e.* 3 to 5%) is a reasonable expectation to detect agronomically significant N deficiencies. By simply eliminating outlier plant spacings within a population, a precision of ±2.0 meter reading units could be obtained by taking 30 readings, the maximum number of readings retained by the chlorophyll meter.

The relationships between precision and number of observations required for a desired precision at various plant spacing intervals are illustrated in Table 1. The only source of variability considered was the effect of within-row plant spacing on the precision of chlorophyll meter readings because these relationships were calculated from the trends shown in Figure 2. Additional studies are needed to evaluate the effects of spatial variability in soil N availability and the variability in chlorophyll meter readings in leaves of a given plant.

CONCLUSION

The results of this study confirm earlier reports that the chlorophyll meter shows promise as an effective tool for evaluating the N status of corn. Chlorophyll meter readings for irrigated corn increased with increasing plant spacing. The results also show that the performance of the chlorophyll meter can be significantly improved by avoiding plants having atypical spacing. The benefits of avoiding atypical plants were much greater for the chlorophyll meter than for leaf N concentration determined by conventional leaf tissue analysis. Leaf N concentration may be less sensitive to plant competition than chlorophyll meter readings because of changes in specific leaf weight which increased with increasing plant space.

REFERENCES:

1. Wolfe, D. W., D. W. Henderson, T. C. Hsiao, and A. Alvino. 1988. Interactive water and nitrogen effects on senescence of maize. II. Photosynthetic decline and longevity of individual leaves. Agron. J. 80:865-870.

2. Lohry, R. D. 1989. Effect of N fertilizer rate and nitrapyrin on leaf chlorophyll, leaf N concentration, and yield of three irrigated maize hybrids in Nebraska. PhD. Dissertation. University of Nebraska, Lincoln, NE.

3. Krall, J. M., H. A. Esechie, R. J. Raney, S. Clark, G. Teneyk, M. Lundquist, N. E. Humburg, L. S. Axthelm, A. D. Dayton, and R. L. Vanderlip. 1977. Influence of within-row variability in plant spacing on corn grain yield. Agron. J. 69:797-799.

4. Ottman, M. J. and L. F. Welch. 1988. Supplemental radiation effects on senescence, plant nutrients, and yield of field-grown corn. Agron. J. 80:619-626.

5. Winter, S.R. and J. W. Pendleton. 1970. Results of changing light and temperature regimes in a corn field and temperature effects on apparent photosynthesis of individual leaves. Agron. J. 62:181-184.

6. Chan, W. and A. F. MacKenzie. 1972. Effects of shading and nitrogen on growth of corn (*Zea mays* L.) under field conditions. Plant Soil 36:59-70.

7. Hanway, J. J. 1982. How a Corn Plant Develops. Iowa Cooperative Extension Service Special Report 48.

8. Schepers, J. S., D. D. Francis, and M. T. Thompson. 1989. Simultaneous determination of total C, total N, and ^{15}N on soil and plant material. Commun. Soil Plant Anal. 20:949- 960.

9. SAS Institute Inc. 1985. SAS User's Guide: Statistics, 1985 edition. SAS Institute Inc., Cary, NC.

10. Schepers, J. S., D. D. Francis, and F.E. Below. 1992. Comparison of corn leaf N concentration and chlorophyll meter readings. Commun. Soil Sci. Plant Anal. 23(17-20):2173-2187.

11. Steel, R.G.D. and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach, 2nd edition. McGrawHill Book Co., New York, NY.