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USE OF A CHLOROPHYLL METER TO EVALUATE THE NITROGEN STATUS OF DRYLAND WINTER WHEAT

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ABSTRACT: Chlorophyll meter leaf readings were compared to grain yield, leaf N concentration and soil NH_4-N plus NO_3-N levels from N rate studies for dryland winter wheat. Soil N tests and wheat leaf N concentrations have been taken in the spring at the late tillering stage (Feekes 5) to document a crop N deficiency and to make fertilizer N recommendations. The chlorophyll meter offers another possible technique to estimate crop N status and determine the need for additional N fertilizer. Results with the chlorophyll meter indicate a positive association between chlorophyll meter readings and grain yield, leaf N concentration and soil NH_4-N plus NO_3-N. Additional tests are needed to evaluate other factors such as differences among locations, cultivars, soil moisture and profile N status.

INTRODUCTION

The value of soil tests prior to planting to evaluate fertilizer-N requirements for dryland winter wheat (*Triticum aestivum* L.) has been well established in Colorado. Many fertility experiments on dryland winter wheat have been integrated in cultivar performance trials since 1981 (Follett et al., 1987). Uniform areas adjacent to the cultivar trials were selected and soil samples were taken to a depth of 60 cm. As customary, samples were divided into surface samples (0-30

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cm) for routine (soil pH, P, K, nitrate-N, and salts) and subsoil samples (30-60 cm) for nitrate-N determination. The soil tests were then utilized to determine fertilizer-N recommendations.

The value of spring soil tests has been recently evaluated (Russell et al., 1987 and Vaughan et al., 1990a). Spring application of part, or perhaps all, of the N fertilizer to dryland winter wheat may offer advantages to applying fall only N-application. A major advantage of spring-N application is that it allows spring evaluation of stand and stored soil moisture before applying N fertilizer. An additional advantage is that of a shorter period of capital tie-up with spring-N application compared to fall fertilization. Research conducted in Colorado has shown that spring applied N is equal to, and in some cases superior to fall application for increasing winter wheat grain yield and protein content (Russell et al., 1987 and Vaughan et al., 1990a). These results indicate dryland wheat producers can use either fall or spring timing to apply fertilizer-N.

Use of soil and/or leaf tissue testing for determining crop N deficiency is widely accepted in the Great Plains. Soil samples taken to a depth of 60 cm have been used to develop a spring-N fertilizer recommendation model (Table 1). Likewise, fertilizer N recommendations can be made with leaf tissue-N tests at the plant growth state of Feekes 5 (Table 2). The primary problem with spring soil tests or leaf tissue tests is the time required for sampling, laboratory analysis and interpretation, and fertilizer-N recommendation by a farm advisor. The turn around time for this service must be very fast or it will be too late to make a profitable spring fertilizer-N application.

Measurement of chlorophyll content of wheat leaves by using a meter offers an opportunity to evaluate springtime crop-N status and thereby determine the need for additional fertilizer-N application without costly delays. The speed of data collection and ease of operation associated with chlorophyll meters makes them an ideal N-management tool if their output could be appropriately related to either the existing spring soil- or leaf tissue-tests described above. The chlorophyll meter has been evaluated for other crops. Studies reported in the literature used a light-weight, hand-held meter for measuring the chlorophyll content of leaves without causing damage to plants; specifically a meter developed by the Soil-Plant Analyses Development (SPAD) Section of Minolta Camera Company (Ramsey,

TABLE 1. Fertilizer Recommendation Model Based on NH_4-N plus NO_3-N (0-60 cm) for Dryland Winter Wheat.

Grain yield goal	Soil N level, kg ha^{-1}			
	<70	70-113	114-179	>180
kg ha^{-1}	Spring N kg ha^{-1}			
<2000	22	0	0	0
2000-3610	44	22	0	0
3611-4000	66	66	44	22
>4001	66	66	66	44

Source: Vaughan, et al., 1990a

TABLE 2. Fertilizer Recommendation Model Based on Feekes 5 Leaf N Concentration for Dryland Winter Wheat.

Grain yield goal	Leaf N level, g kg^{-1}		
	<34	35-38	>39
kg ha^{-1}	Spring N kg ha^{-1}		
<3170	22	0	0
3171-3700	66	44	22
>3701	66	66	44

Source: Vaughan, et al., 1990a

NJ)[3]. The newest model (SPAD 502) determines relative amount of chlorophyll present by measuring leaf transmittance in two wavelength regions.

Turner and Jund (1991) used the SPAD 502 chlorophyll meter to predict nitrogen topdress requirements for semidwarf `Lemont' rice (*Oryza sativa* L.) grown in research plots on several soils and locations in Texas. They observed decreased yields of rice as chlorophyll meter readings, measured on the most recently matured leaf at prepanicle initiation or panicle differentiation stages, decreased below 40. Their data indicated that the SPAD 502 chlorophyll meter can be used to quickly assess the need for N-topdressing during prepanicle initiation and panicle differentiation growth stages of rice.

Schepers et al. (1992) used the SPAD 502 chlorophyll meter to compare corn (*Zea mays* L.) leaf disk N concentrations to chlorophyll meter readings at silking for a variety of hybrids at several locations, but that calibration of chlorophyll meter readings to crop N status may not be possible because of unique "greenness" characteristics of various hybrids. Schepers et al. (1992) reported that normalization procedures may allow standardization of leaf tissue-N concentrations across hybrids, locations, and growth stages. However, they also observed that timing of N-fertilization confounded calibration of chlorophyll meter readings and made interpretation difficult. Their data indicated that, although critical levels for corn leaf-N have been established, chlorophyll meter readings at anthesis are equally well or better correlated with yields than are leaf-N concentrations.

Recently, Piekielek and Fox (1992) investigated the use of the SPAD 502 chlorophyll meter to predict sidedress N requirements for corn in Pennsylvania. Their results indicate that other site factors besides N availability affect the accuracy of using leaf chlorophyll as a N test. Among factors that may need to be considered are plant stress from disease, insect damage, cold temperatures, plant population, and organic vs inorganic N inputs as they may influence soil N availability in the subsequent portion of the year. They concluded that the accuracy of the use of SPAD readings to identify fields that will respond to sidedress N applications is similar to the pre-sidedress soil NO_3-N test with the convenience of the SPAD test being a major benefit.

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3. Trade and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by the authors or USDA.

The objective of this research is to quantify relationships between yield, leaf N concentration, soil tests and the SPAD 502 chlorophyll meter readings for dryland winter wheat production. Specific goals were to evaluate the potential for calibration of chlorophyll meter readings with soil tests for N and leaf N concentration for the purpose of evaluating crop N status and predicting need for N fertilization.

METHODS AND MATERIALS

Four existing replicated N rate studies in Colorado were used to compare yield, leaf N concentration, soil tests and SPAD 502 chlorophyll meter readings of dryland winter wheat. The four sites are designated as Akron 1, Akron 2, Punkin Center, and Willard. The Akron 1 study was located on a Platner loam (fine, montmorillonitic, mesic Aridic Paleustoll) and the Akron 2 study was located on a Weld silt loam (fine-loamy, mesic Aridic Paleustoll). The Punkin Center study was located on a Ascalon sandy loam (fine-Ioamy, mixed mesic Aridic Argiustoll). The Willard study was located on a Weld silt Ioam (fine-Ioamy, montmonillinic, mesic Aridic Paleustoll).

The N fertilizer rates for the Akron 1 location were 0, 28, 56, 84, and 112 kg/ha. The N fertilizer rates for the Akron 2 location were 0, 34, and 68 kg/ha. The Punkin Center and Willard studies both had N fertilizer rates of 0, 22, 44, and 68 kg/ha and 20 kg/ha P prior to planting. The two Akron locations had P fertilizer applied as suggested by soil tests. The wheat cultivar TAM 107 was grown at all locations.

Readings were taken using the SPAD 502 chlorophyll meter at mid-length on the uppermost fully expanded leaf from approximately 20 randomly selected plants (Figure 1). Readings were avoided that would be directly on the leaf midrib. The leaf was removed from the plant by detachment at the leaf collar to facilitate ease of taking chlorophyll meter readings. The leaf was then saved for determination of leaf N concentration. Optimum growth stage to sample for N concentration in the leaf of winter wheat is between late tillering (Feekes 5) and early jointing (Feekes 7) (Vaughan et al., 1990b). The wheat plants were sampled April 17 to 19 at approximately Feekes 5. This growth stage is just after tillering and before the first node is detectable. The leaf sheaths are strongly erect at this stage of growth. Nitrogen concentrations of leaf tissue were determined by automated combustion analysis using a Carlo Erba C/N analyzer (Haake Buchler Instruments Inc.,

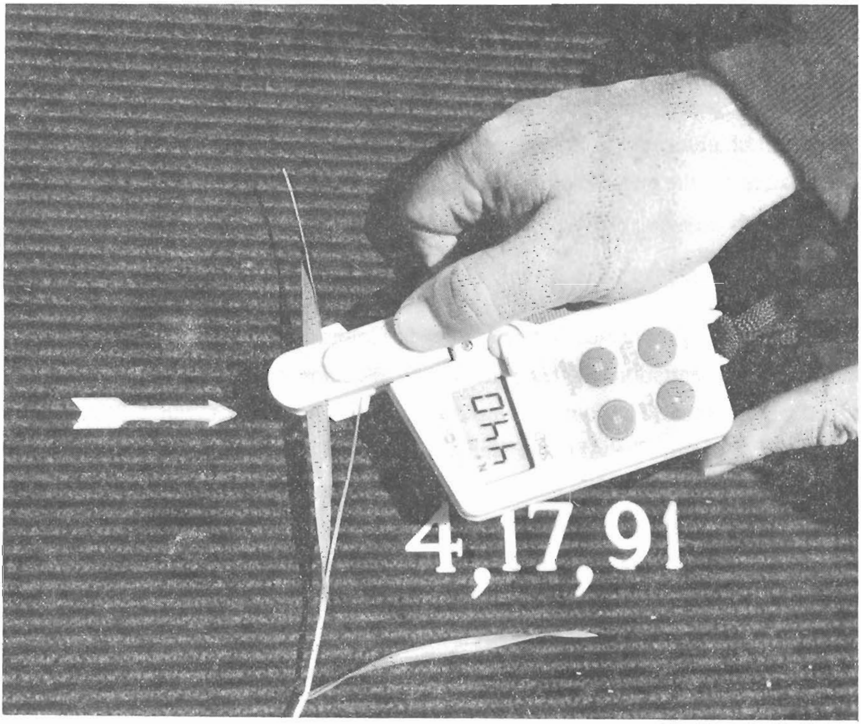

FIGURE 1. Placement of the SPAD 502 Chlorophyll Meter at the Mid-Length on the Uppermost Fully Expanded Leaf at Feekes 5 Growth Stage.

Saddle Brook, NJ)[3] (Marshall and Whitehead, 1985). Soil samples for NH_4-N and NO_3-N analysis were taken from each plot at the same time leaf samples were removed for meter readings and leaf N analysis. Soil samples were air-dried, ground to pass a 2-mm screen, extracted with 1 mol/L KCl, and analyzed for available NO_3-N and NH_4-N by a Technicon Autoanalyzer (Technicon, Tarryton, NY)[3].

RESULTS AND DISCUSSION

In general, chlorophyll meter readings are expected to increase as soil-N availability increases. Crop growth stage, differences in water availability among locations and soil type under dryland farming conditions, and other soil nutrient (especially phosphorus) availability may influence calibration of the SPAD 502 meter. Dryland climatic conditions may be especially important when comparing meter readings taken at an early spring growth stage to grain yields. However, it is very important to obtain chlorophyll meter readings at an early growth stage (Feekes 5) while the wheat is still sufficiently early to respond to topdress-N fertilizer and to expect an economic yield response. Chlorophyll meter readings, grain yield, leaf N, and soil NH_4-N plus NO_3-N for the four locations are shown in Table 3. Comparison of soil-N levels shown in Table 1 with those shown in Table 3 indicate that spring-N application should have benefitted crop yields for the 0, 28, 56, and 84 kg/ha N-rate treatments for Akron 1 site, but would have only benefitted the 0 N-rate at the Akron 2 site. Spring-N application should have benefitted crop yields for all N-rate treatments at both the Punkin Center and Willard sites. Measured level of soil mineral N (NH_4-N + NO_3-N) levels in the top 60 cm of the 84 kg/ha N-rate at the Akron 1 site appears to be an outlying data point when compared to the applied N-rate, chlorophyll meter reading, yield, and leaf-N measurements (Table 3). It may be that a sufficient amount of residual-N resided below the 60 cm depth to cause the resulting yields and other measurements, as may also be possible for the 0 N-rate at the Akron 2 site. However, since reanalyses of soil samples for the 84 kg/ha N-rate at the Akron 1 site produced essentially the same as the original analyses, the point will be treated as an anomaly for the purposes of this discussion.

Comparison of leaf-N levels in Table 2 with those in Table 3 indicate that spring-N application would have benefitted crop yields for the 0, 28, and 56 kg/ha N-rate treatment for the Akron 1 site, but would not have benefitted the N-rate treatments at the Akron 2 site. Spring-N application should have benefitted crop yields for at least the 0, 22, and 44 kg/ha N-rate treatments and possibly all treatments at both the Punkin Center and Willard sites.

Comparison of chlorophyll meter readings and yield responses to fall-applied fertilizer N in Table 3 show that meter readings and yields both significantly increased as N rate increased at the Akron 1 site, with a leveling off of meter readings at about 42 to 44 with increasing N-rates above 56 kg N/ha. Meter readings ranged from 42 to above 46 at the Akron 2 site, with a significant increase between the 0 and 68 kg/ha Nrate treatments, but no significant yield responses to fertilizer N were observed. At the Punkin Center site meter readings ranged from about 43 to 48 and increased significantly with increasing N rate up

TABLE 3. Effect of N Rate on Chlorophyll Meter Reading, Grain Yield, Leaf N, and NH_4-N plus NO_3-N for Dryland Winter Wheat at Four Locations.

N Rate	Meter Reading	Grain Yield	Leaf	NH_4-N + NO_3-N 0 - 60 cm
kg ha^{-1}		kg ha^{-1}	g kg^{-1}	kg ha^{-1}
Akron 1 location				
0	36.3	2442	28	34
28	38.7	3343	31	43
56	41.9	4116	34	97
84	43.3	4466	38	57
112	44.2	4352	38	158
LSD (.05)	3.2	1217	6	9
Akron 2 location				
0	42.5	4385	43	79
34	43.8	4890	43	150
68	46.5	4419	43	191
LSD (.05)	1.9	NS	NS	NS
Punkin Center location				
0	42.8	2993	34	35
22	44.8	3249	36	43
44	48.2	3410	38	50
68	48.3	3471	39	59
LSD (.05)	2.5	NS	3	16
Willard location				
0	46.4	3941	34	32
22	48.1	4116	36	53
44	48.9	4076	36	56
68	50.4	4231	37	73
LSD (.05)	1.7	128	NS	19

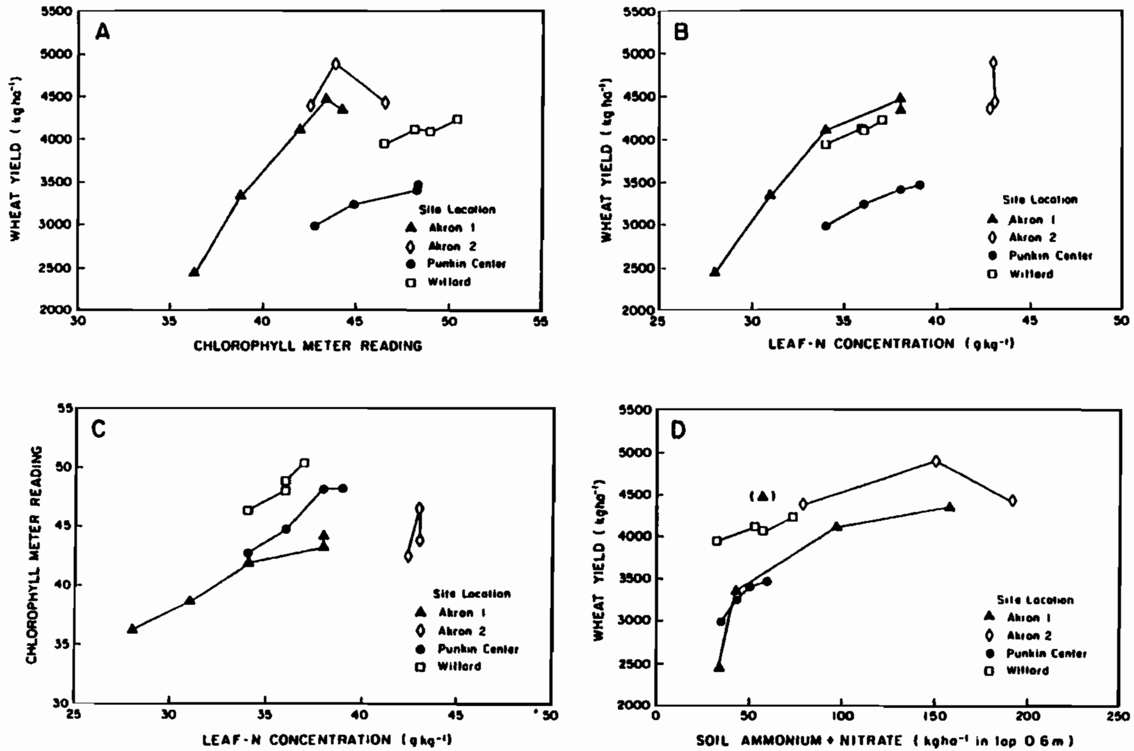

FIGURE 2. 2A. Comparison of Chlorophyll Meter Readings and Yield of Wheat; 2B. Comparison of Leaf N Concentration and the Yield of Wheat; 2C. Comparison of Chlorophyll Meter Readings and Leaf N Concentrations for Wheat; 2D. Effect of Soil NH_4-N + NO_3-N on Yield of Wheat.

to 44 kg/ha N. Significant yield responses to fertilizer N were not observed because of the large variance in the grain yield data. At the Willard site, meter readings ranged from about 46 to 50 and increased significantly with increasing N rates up to 44 kg/ha N. Grain yield responses were similar with a significant increase between the 0 to the 22 kg/ha N-rate treatments and an additional increase between the 44 and 68 kg/ha Nrate treatments.

Chlorophyll meter readings and yield responses for all four locations are shown in Figure 2. The Punkin Center and Willard locations had higher meter readings and apparently lower yield potential than did the two Akron sites. There was a general linearity between leaf N concentrations and wheat yield for all locations except the Akron 2 location (Figure 2B). Likewise, there was general linearity between leaf N concentrations and chlorophyll meter readings for three of the four locations (Figure 2C). The Akron 2 location had a high N-fertility level (NH_4-N + NO_3-N). Thus, leaf N concentration remained constant at 43 g/kg (Table 3). In general, as the soil-mineral N level increased, grain yield increased (Figure 2D). Again, because of the high fertility level, the yield response was not significant for the Akron 2 location (Table 3).

CONCLUSION

In general, calibration of the SPAD 502 chlorophyll meter against grain yield, leaf N or available soil N (NH_4-N + NO_3-N) is possible. However, factors such as location, cultural practices, moisture availability, soil profile N and cultivar differences may have an effect on leaf greenness and the resulting chlorophyll meter readings. In the current study a grain yield response might be expected for a meter reading of less than about 42. However, a significant yield response was observed at the Willard site with a meter reading of 50 compared to meter reading of 48 or less. Because a chlorophyll meter provides a unitless indication of leaf greenness, utilization of this technology will likely require normalizing the data relative to a check on an adequately fertilized area of the field.

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