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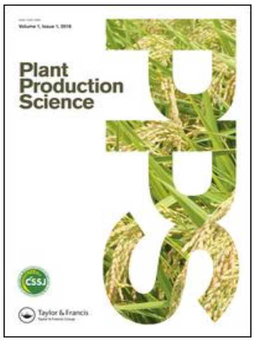

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Effect of Leaf Phosphorus and Potassium Concentration on Chlorophyll Meter Reading in Rice

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Abstract : Chlorophyll meter (SPAD) is a convenient tool to estimate leaf nitrogen (N) concentration of rice plants. There is no information on the effects of leaf phosphorus (P) and potassium (K) concentration on SPAD readings and on the relationship between SPAD values and leaf N concentration in the literature. In 1996 dry season, cv IR72 was grown at the International Rice Research Institute (IRRI) and the Philippine Rice Research Institute (PhilRice) under various N, P and K fertilizer combinations. SPAD measurements were made on the topmost fully expanded leaves at mid-tillering and panicle initiation. The leaves were then detached, dried and analyzed for N, P and K. The SPAD values were highly correlated with leaf N concentration ($r=0.93$ to 0.96). Fertilizer-K application did not affect SPAD values, leaf N concentration, or the relationship between the two. Phosphorus deficiency reduced leaf N concentration at mid-tillering, but increased leaf N concentration at panicle initiation when the same amount of N was applied. The SPAD values were 1 to 2 units greater for zero-P plants than P-treated plants at a given leaf N concentration at mid-tillering. At panicle initiation, the relationship between SPAD values and leaf N concentration was not significantly affected by leaf P status. These results suggest that a different regression equation between SPAD values and leaf N concentration should be used to estimate leaf N concentration of P-deficient and P-sufficient rice leaves at vegetative stage using a SPAD.

Key words : Chlorophyll meter, Leaf K concentration, Leaf N concentration, Leaf P concentration, Rice (*Oryza sativa* L.).

The chlorophyll meter (SPAD) provides a simple, quick, and nondestructive method for estimating leaf chlorophyll content (Watanabe et al., 1980). Since much of the leaf nitrogen (N) is in enzymes associated with chlorophyll, SPAD has become a popular means for estimating leaf N (Chapman and Barreto, 1997). The SPAD has been used to predict the need for additional N fertilizer in rice (Turner and Jund, 1991; Garcia et al., 1996; Peng et al., 1996), maize (Piekielek and Fox, 1992; Piekielek et al., 1995) and wheat (Fox et al., 1994).

Peng et al. (1992) reported that leaf thickness as reflected by specific leaf weight (SLW) affected the estimation of leaf N concentration using SPAD. Dividing SPAD values by SLW greatly improved the prediction of leaf N concentration across growth stages and cultivars in rice (Peng et al., 1993) and maize (Chapman and Barreto, 1997).

Phosphorus (P) and potassium (K) deficiency are widespread in irrigated rice systems in Asia mainly due to negative P and K balances resulting from increased grain yield and crop intensification and inadequate application of P and K fertilizers (De Datta, 1983; De Datta and Mikkelsen, 1985; Dobermann et al., 1998). The symptoms of P and K deficiency include stunted plants, short and dark green leaves (Yoshida, 1981; De Datta and Mikkelsen, 1985). However, P deficient leaves are erect while K deficient leaves are droopy. The morphological changes of P and K deficient leaves may affect SPAD readings and such information is not available in the literature. The objective of this study was to determine the effects of leaf P and K concentration on SPAD readings and on the relationship between SPAD values and leaf N concentration.

Materials and Methods

Field experiments were conducted at two sites in the Philippines during the 1996 dry season: the International Rice Research Institute (IRRI) farm, Los Baños, Laguna and the Philippine Rice Research Institute (PhilRice) farm, Muñoz, Nueva Ecija. An indica semidwarf rice cultivar IR72 was grown in both sites. Fourteen-d-old seedlings were transplanted on 31 January at IRRI and 21 January at PhilRice. Hill spacing was 0.2×0.2 m with five seedlings per hill. Plot size was 21 m^2.

Seven and six fertilizer treatments were arranged in a randomized complete block design with four and three replications at IRRI and PhilRice, respectively (Tables 1 and 2). In P-treated plots, 25 kg P ha^{-1} at IRRI and 30

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Abbreviation : IRRI, International Rice Research Institute; K, potassium; N, nitrogen; P, phosphorus; PhilRice, Philippine Rice Research Institute; SLW, specific leaf weight; SPAD, chlorophyll meter.

Table 1. Effects of N, P, and K fertilizers on chlorophyll meter (SPAD) readings, leaf N, P and K concentration and specific leaf weight (SLW) at mid-tillering. IRRI farm, Los Baños, Laguna, 1996 dry season.

Fertilizer input (kg ha^{-1})				Leaf concentration (g kg^{-1})			SLW
N	P	K	SPAD	N	P	K	(g m^{-2})
0	0	0	30.7	34.1	2.0	21.5	37.8
0	25	0	32.0	36.1	3.0	22.0	37.3
0	0	40	31.8	35.0	2.5	22.3	39.6
210	0	0	38.0	44.9	1.5	20.8	39.2
210	25	0	38.9	49.0	3.7	23.4	36.1
210	0	40	37.5	43.8	1.4	20.6	36.8
210	25	40	38.9	48.9	3.5	23.6	37.6
LSD (0.05)			1.1	1.8	0.3	1.0	2.4

Table 2. Effects of N, P, and K fertilizers on chlorophyll meter (SPAD) readings, and leaf N, P and K concentration at mid-tillering. PhilRice farm, Muñoz, Nueva Ecija, 1996 dry season.

Fertilizer input (kg ha^{-1})				Leaf concentration (g kg^{-1})		
N	P	K	SPAD	N	P	K
0	0	0	33.3	34.8	1.3	15.1
0	30	50	29.0	31.1	2.9	19.1
210	0	0	34.2	37.2	1.3	13.2
210	30	0	36.3	43.2	3.1	10.1
210	0	50	34.8	38.2	1.2	16.4
210	30	50	34.6	42.9	2.9	21.0
LSD (0.05)			1.8	2.3	0.3	1.5

kg P ha^{-1} at PhilRice as single superphosphate was applied and incorporated 1 day before transplanting. In K-treated plots, 40 kg K ha^{-1} at IRRI and 50 kg K ha^{-1} at PhilRice as KCl was applied and incorporated 1 day before transplanting. The N-fertilized plots received a total of 210 kg N ha^{-1} as urea. Nitrogen was applied in four splits (60 kg as basal, 60 kg at mid-tillering, 60 kg at panicle initiation, and 30 kg at flowering). Mid-tillering was defined as the mid-way between transplanting and panicle initiation. Standard cultural management practices were followed. Fields were flooded 4 days after transplanting and a floodwater depth of 5 to 10 cm was maintained until 7 d before physiological maturity when fields were drained. Diseases and pests were intensively controlled to avoid any crop damage.

A chlorophyll meter (SPAD-502, Minolta Co.) was used to take readings at mid-tillering and panicle initiation. At each sampling date, five uppermost fully expanded leaves were selected in each plot. Three SPAD readings were taken around the midpoint of each leaf blade, 30 mm apart, on one side of the midrib. Fifteen SPAD readings were averaged to represent the mean SPAD value of each plot. After SPAD readings were recorded, the five leaves were detached and pooled for measuring area, dry weight, N, P and K concentration at IRRI, but only N, P and K concentration at PhilRice. Leaf area was measured by a leaf area meter (LI-3000, Li-Cor). Dry weight was determined after oven-drying at 70°C to constant weight. Specific leaf weight was calculated as the ratio of dry weight to leaf area. Leaf N concentration was determined by micro-Kjeldahl digestion and distillation (Bremner, 1965). Leaf P concentration was determined colorimetrically as reduced phosphomolybdate at 625 nm using the Technicon AutoAnalyzer II (Technicon Irand Limited). Leaf K concentration was measured using atomic absorption spectrophotometry (Yoshida et al., 1976). Mean comparisons were made using the LSD (0.05) based on ANOVA (SAS, 1985).

Results and Discussion

Chlorophyll meter readings and leaf N concentration at mid-tillering and panicle initiation responded significantly to fertilizer-N applications at both sites (Tables 1 to 4). The differences in SPAD values and leaf N concentration between N-treated and zero-N plots were greater at panicle initiation than at mid-tillering. Fertilizer-P application increased leaf P concentration

Table 3. Effects of N, P, and K fertilizers on chlorophyll meter (SPAD) readings, leaf N, P and K concentration, and specific leaf weight (SLW) at panicle initiation. IRRI farm, Los Baños, Laguna, 1996 DS.

Fertilizer input (kg ha^{-1})				Leaf concentration (g kg^{-1})			SLW
N	P	K	SPAD	N	P	K	(g m^{-2})
0	0	0	30.3	26.0	2.2	20.3	47.9
0	25	0	31.6	25.3	2.7	19.2	49.7
0	0	40	29.8	26.2	2.6	19.9	48.1
210	0	0	38.8	39.5	1.4	21.5	45.8
210	25	0	36.4	36.9	2.7	22.1	43.7
210	0	40	38.8	40.3	1.3	21.4	46.5
210	25	40	37.3	37.8	2.8	23.6	44.8
LSD (0.05)			1.6	1.3	0.2	1.0	1.9

Table 4. Effects of N, P, and K fertilizers on chlorophyll meter (SPAD) readings, and leaf N, P and K concentration at panicle initiation. PhilRice farm, Muñoz, Nueva Ecija, 1996 dry season.

Fertilizer input (kg ha^{-1})				Leaf concentration (g kg^{-1})		
N	P	K	SPAD	N	P	K
0	0	0	31.2	26.9	1.6	16.5
0	30	50	29.8	24.6	2.7	16.1
210	0	0	41.9	40.6	1.2	14.6
210	30	0	38.0	36.6	2.9	9.9
210	0	50	40.9	38.6	1.2	17.2
210	30	50	36.4	35.7	3.0	18.4
LSD (0.05)			1.9	1.3	0.1	1.2

significantly. The critical leaf P concentration is 1.0 g kg^{-1} during vegetative growth in rice (Yoshida, 1981), however, P deficiency may be suspected when leaf P concentration is below 2.0 g kg^{-1} (Tanaka and Yoshida, 1970). Plants in both sites maintained leaf P concentration above the critical level of 1.0 g kg^{-1} at the two growth stages (Tables 1 to 4). When N was not applied, P application was necessary only at PhilRice to maintain leaf P concentration above 2.0 g kg^{-1}. With N application, P application was necessary at both IRRI and PhilRice to maintain leaf P concentration above 2.0 g kg^{-1}.

The critical leaf K concentration is 12 g kg^{-1} at mid-tillering, 10 at maximum tillering and 8 at panicle initiation (Mikkelsen, 1983). These critical K levels may vary slightly depending on growing condition and the measurement method of leaf K concentration. At IRRI, leaf K concentration did not respond to fertilizer-K application (Tables 1 and 3). Leaf K concentration was greater than or close to 20 g kg^{-1} in all treatments at both growth stages. This was because of high indigenous soil K supply and additional K inputs from irrigation water at IRRI farm (Dobermann et al., 1996). At PhilRice, significant differences in leaf K concentration between K-treated and zero-K plants were observed, except for zero-N plots at panicle initiation (Tables 2 and 4). Leaf K concentration of plants that received N and P fertilizers but no K fertilizer was close to the critical K concentration at PhilRice.

At mid-tillering, P-treated plants had significantly higher leaf N concentration than the zero-P plants when N was applied (Tables 1 and 2). Phosphorus deficiency might limit root function and N uptake ability of root systems at this stage. At panicle initiation, however, it was reversed and P application significantly reduced leaf N concentration in N-treated plots (Tables 3 and 4). At panicle initiation, crop growth rate is higher and leaf N concentration is lower than at mid-tillering due to dilution (Dingkuhn et al., 1990). Phosphorus deficiency might limit crop growth rate and reduced the magnitude of tissue N dilution from mid-tillering to panicle initiation.

About 90% of variation in SPAD values was explained by leaf N concentration at both mid-tillering and panicle initiation (Fig. 1). At mid-tillering, the effect of P fertilizer on SPAD values was relatively small and inconsistent as compared to its effect on leaf N concentration (Tables 1 and 2). Phosphorus deficiency did not reduce

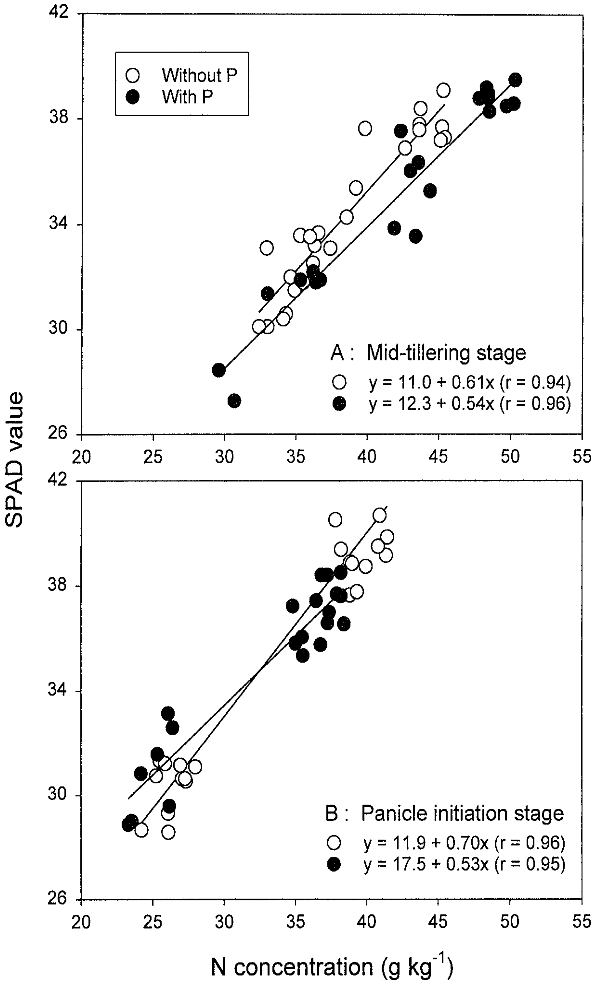

Fig. 1. Relationship between chlorophyll meter (SPAD) readings and leaf N concentration at mid-tillering (A) and panicle initiation (B) stages in plants with and without fertilizer-P application. Data were taken from all fertilizer treatments at IRRI farm and PhilRice farm in 1996 dry season. The P-treated plots received 25 kg P ha^{-1} at IRRI and 30 kg P ha^{-1} at PhilRice.

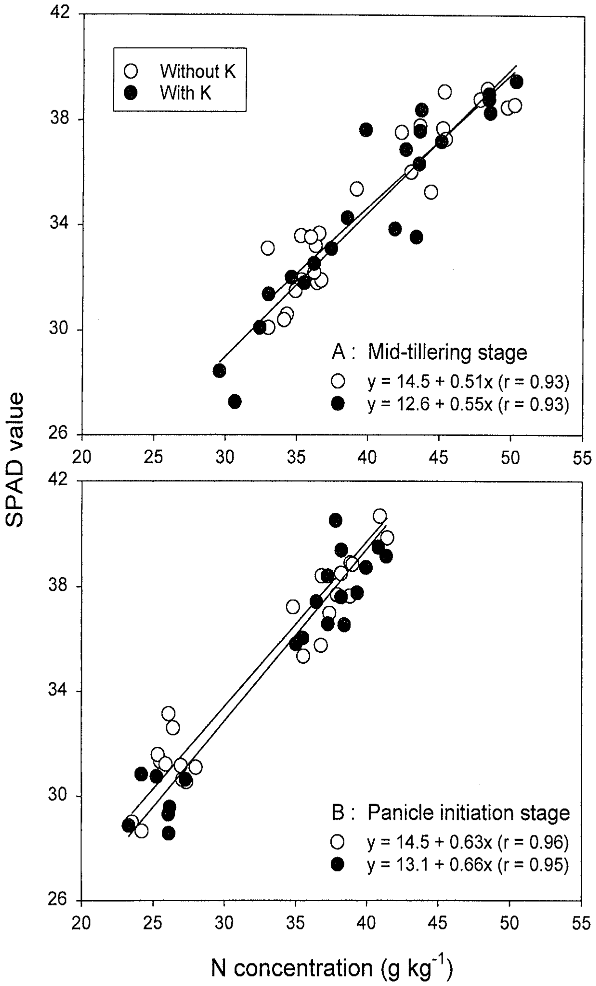

Fig. 2. Relationship between chlorophyll meter (SPAD) readings and leaf N concentration at mid-tillering (A) and panicle initiation (B) stages in plants with and without fertilizer-K application. Data were taken from all fertilizer treatments at IRRI farm and PhilRice farm in 1996 dry season. The K-treated plots received 40 kg K ha^{-1} at IRRI and 50 kg K ha^{-1} at PhilRice.

SPAD values and leaf N concentration proportionally. Fig. 1A indicates that SPAD values were 1 to 2 units greater for zero-P plants than P-treated plants at a given leaf N concentration at mid-tillering. The P-deficient plants usually have dark green leaves in the vegetative stage (Yoshida, 1981 ; De Datta and Mikkelsen, 1985). The dark green leaves may result in high SPAD values independently from leaf N concentration.

At panicle initiation, P application reduced SPAD values in N-treated plants, especially at PhilRice (Tables 3 and 4). Phosphorus deficiency increased leaf N concentration and SPAD values proportionally. This is supported by the fact that the relationship between SPAD values and leaf N concentration was the same for P-treated and zero-P plants at panicle initiation (Fig. 1B).

Thick leaf increases SPAD values without increasing leaf N concentration (Peng et al., 1992). Specific leaf weight is associated with leaf thickness (Pettigrew et al., 1993). The effect of P fertilizer on SLW was small and inconsistent (Tables 1 and 3). Therefore, higher SPAD values of zero-P plants at the same leaf N concentration was not associated with the differences in leaf thickness between zero-P and P-treated plants.

The effect of fertilizer K on SPAD values and leaf N concentration can not be determined at IRRI since plants did not respond significantly to K treatment in terms of leaf K concentration (Tables 1 and 3). At PhilRice, fertilizer K had no effect on leaf N concentration or SPAD values although it had significant effect on leaf K concentration (Tables 2 to 4). For example, fertilizer treatment with N and P but without K input had leaf K concentration close to the critical level of 10 g kg^{-1}. Leaf K concentration of plants that received N, P and K fertilizers was close to 20 g kg^{-1}. The SPAD values and leaf N concentration of these two treatments were similar. The relationship between SPAD values and leaf N concentration was the same for K-treated and zero-K plants at mid-tillering and panicle initiation (Fig. 2).

In conclusion, SPAD values were closely correlated with leaf N concentration. Phosphorus deficiency reduced leaf N concentration at mid-tillering, but increased leaf N concentration at panicle initiation when the same amount of N was applied. At mid-tillering, phosphorus deficiency did not reduce SPAD values and leaf N concentration proportionally. The SPAD values were 1 to 2 units greater for zero-P plants than P-treated plants at a given leaf N concentration at mid-tillering. The difference of 1 to 2 units in SPAD values is relatively small compared with the error of SPAD measurements under most field conditions. It may not be a concern when SPAD is used to determine the need for N application at mid-tillering in the fields where P is limited. However, if SPAD is used to accurately estimate leaf N concentration in an experiment, a different regression equation between SPAD values and leaf N concentration should be used for P-deficient and P-sufficient rice leaves at vegetative stage. At panicle initiation, the relationship between SPAD values and leaf N concentration was not significantly affected by leaf P status. Leaf K concentration did not affect leaf N concentration, SPAD values, or the relationship between the two.

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