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RESEARCH PAPER

Use of chlorophyll meter and optical sensors for nitrogen management in direct seeded rice

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Abstract: The field experiment was conducted at Agricultural Research Station, Siruguppa during *kharif* 2016 to assess the feasibility of chlorophyll meter (SPAD) and optical sensor (Green seeker) for nitrogen management in dry direct seeded rice (DSR). The experiment was laid out in randomized complete block design with eight treatments and three replications. Treatments included variable rates of nitrogen *i.e.* 0%, 50%, 100% and 150% of the recommended N along with recommended P and K. The above set of treatments was studied in combination with and without FYM @ 101 ha^{-1}. The periodic observations on plant growth parameters and recordings of crop sensors data was made at 15 days intervals from 30 to 105 DAS. Moreover, the laboratory estimation of leaf chlorophyll and leaf N content was also made on the same day. The correlation coefficients of sensor readings showed a strong correlation with the plant growth parameters, leaf chlorophyll and leaf N content estimated at different days of crop growth period and ultimately with the grain yield of DSR. Thus, indicating that there is every chance in better utility of crop sensor readings in nitrogen management by developing threshold limits for these values.

Key words: Chlorophyll meter, Direct seeded rice, Green seeker, Nitrogen

Introduction

Paddy (*Oryza saliva* L.) is the principle food crop of South and South eastern countries and provides food for more than half of the global population. Usually, paddy is cultivated under transplanted submerged condition over a large area. In recent past direct dry sowing of rice

Direct Seeded Rice (DSR) is gaining momentum owing to its advantages of less water requirement over transplanted method since it does not require puddling and no standing water.

Nitrogen, the key element that governs the crop yield to a larger extent; nitrogen fertilization plays a key role in plant physiological process and influence sink size there by increasing the grain yield of rice (Somasundaram *et al*., 2002). Moreover, the nitrogen in soil is more dynamic and its losses through various mechanisms particularly under submerged rice ecosystem may leads to its low use efficiency which is the most important yield limiting factor as for as paddy cultivation is concerned. Indian soils are very low in available nitrogen status and all the nitrogen required by the crop has to be supplied mainly through inorganic fertilizers. On the other hand, continuous and indiscriminate use of large quantities of chemical fertilizers over the years resulted in the deterioration of the soil quality and the environment. Nitrogen management in rice is becoming more important as concerns grows more about the high cost of their inputs and nitrate pollution of the surface and ground water in the agricultural areas (Xue *et al.,* 2008). Effective management of fertilizers, particularly N remains a major challenge to researchers and producers. Hence, adoption of wise management practices by timely application based on the crop requirement is very much need of the hour, to answer the questions of when, where and how much fertilizer nutrient need to be applied, we require a monitoring technique to evaluate the nutrient availability and crop requirement. The technique needs to be quick, effective and inexpensive, and should allow on the spot decision making (Patil, 2009). The methods of fertilizer recommendation based on the soil and plant analysis are very laborious and are time consuming.

In order to reduce the drudgery of the laboratory analysis, scientists have exploited crop sensor technology that gives information on the nitrogen need of a crop based on the leaf optical property. Since, leaf greenness and/or leaf N content is closely related to photosynthesis rate and biomass production, and is a sensitive indicator of changes in crop N demand during the growing season. Chlorophyll meter (SPAD) and green seekers are such devices which can be effective in optimization and recommendation of nitrogen. The SPAD meter is a hand held, simple, quick and non-destructive in-situ tool for measuring relative content of chlorophyll in leaf that is directly proportional to leaf N content.

Hence, the SPAD chlorophyll meter is used to diagnose the N status in crops and determine the right time of N application (Ladha *et al*., 2000). The SPAD meter measures how much of the light of a certain wavelength is absorbed (chlorophyll molecules) by the leaf sample. The instrument measures transmission of red light at 650 nm, at which chlorophyll absorbs light, and transmission of infrared light at 940 nm. at which no absorption occurs.

Similarly, Normalized Difference Vegetation Index (NDVI) is a unit measured by an optical sensor which is based on the reflectance at red and near infrared (NIR) regions these values can obtained by using a hand held device. Green Seeker TM (N Tech Industries Inc., Ukiah, CA, USA). NDVI measurements can range from -1 to 1, with higher values indicating better plant health.

At the same time, evaluation of these devices for their suitability and utility in the field of agriculture for better correlation of crop yields is also need to be addressed at the earliest for their wider acceptability.

Material and methods

A field experiment was carried out during *kharif* 2016 at Agricultural Research Station, Siruguppa which is under the jurisdiction of University of Agricultural Sciences, Raichur. The experimental soil was deep black with clay texture having alkaline pH (8.54) and low EC (0.18 dS m^{-1}). The CEC of soil was (39.2 cmol (p+) kg^{-1}) and medium in soil organic carbon content (6.10 g kg^{-1}), low in available nitrogen (172.35 kg ha^{-1}), medium in available phosphorous (33.03 kg ha^{-1}) and potassium (248.41 kg ha^{-1}). The concentrations of DTPA exlractable micronutrients *viz.,* zinc, iron, copper and manganese were 0.79, 9.73, 2.05 and 4.18 mg kg^{-1} respectively. The RDF @ 150:75:75 N, P_20_5, K_20 kg ha^{-1} is being used for the direct seeded rice also. The treatments selected for the study included variable rates of nitrogen *viz.,* at 50%, 100% and 150% of recommended N with each receiving recommended doses of P and K. One absolute control (No NPK or FYM) was also included. These four treatments were tried with FYM (@ I0 t ha^{-1}) and without FYM. Therefore, a total of eight treatments were laid out in a randomized complete block design with three replications. After the preparation of the land FYM was incorporated one day before the sowing. The rice variety selected was S1RI-1253, direct sowing of seeds was made in the dry soil after the receipt of sufficient rain fall through SW-monsoon. Complete dose of P and K. were applied at 30 DAS, while N was supplied at 3 splits *i.e.,* 30, 45 and 60 DAS, nutrients were applied through urea, DAP and MOP and standard package of practices were followed to manage the pest and diseases and weeds in order to keep the crop healthy. The optimum soil moisture was maintained throughout the experimentation using both canal and bore well waters as and when required. Observations of SPAD meters and Green seekers were recorded at 15 days interval from 30 DAS to 105 DAS, on the same day leaf chlorophyll and leaf nitrogen was analyzed by collecting the upper fully expanded leaves.

The relative values for chlorophyll content in leaves was recorded using chlorophyll meter (Model: SPAD plus 502) designed by Spectrum Technologies, Inc. About 5 to 6 recordings of observations were made at the middle of each leaf using top 2-3 leaves from each randomly selected plant and averaged. Such measurements were made on about 5 to 6 plants randomly chosen in each plot which is averaged and expressed as SPAD value for each respective treatment.

Normalized Difference Vegetation Index (NDVI) was calculated from the visible and near infrared light reflected by vegetation. The NDVI is an index calculated based on the radiation of remote sensing reflection bands:

$$NDVI = \frac{NIR-VIS}{NIR+VIS}$$

Where, VIS and N1R stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively.

The Green Seeker hand held optical sensor unit (Trimble Navigation Limited, Sunnyvale, CA, USA) was used for NDVI measurement in the study. The sensor emits brief bursts of red and infrared light and then measures the amount of each that is reflected back. The instrument was held 60-120 cm above the plant canopy and moved around the plot randomly along the crop canopy to measure the average NDVI value for each plot. The observations were recorded at 30, 45,60, 75, 90 and 105 DAS.

The periodic estimation of total chlorophyll content of the fully matured leaves was determined by following dimethyl SUlfoxide (DMSO) method as devised by Hiscox and lsraelstam (1979).

A set of leaves which were collected for the estimation of leaf chlorophyll content were used for the periodic estimation of leaf nitrogen after drying in a hot air oven at 60 °C and powdering in a grinder fitted with stainless steel blades. The powdered sample was digested using sulphuric acid and salicylic acid with catalytic mixture and N content was determined by Micro Kjeldahl distillation as explained by Piper (1966).

The crop was harvested at physiological maturity after 150 days of sowing and grain and straw yields were recorded after the crop harvest.

Results and discussion

SPAD and NDVI recordings

The SPAD readings and NDVI values of DSR recorded at different periods of crop growth showed an increasing trend with the increase in the nitrogen rate among various treatments. Among different growth stages, the observed values for both SPAD and NDVI were tend to increase with the crop growth stages irrespective of treatments and the highest values were observed at 75 DAS and thereafter there was a decline (Table 1). It is well established that the chlorophyll present in the plant leaves is closely related to the nutritional condition of the plant. On the other hand, SPAD and NDVI readings are relative indicators of the plant leaf health. The SPAD value will increase in proportion to the amount of nitrogen present in the leaf. In general, higher the SPAD value is an indicative of a healthier plant. Among the various treatments, the treatments that received increased N applications have shown the higher SPAD values. Similarly, Rosolem and Mellis (2010) have also observed higher SPAD readings due to increased nitrogen application in paddy while Schlemmer *et al.* (2005) have noticed similar observations in corn. Similarly, the increase in NDVI values was attributed to the increase in the chlorophyll content which is the resultant of increased nitrogen in leaves. Moreover, there was decline in SPAD and NDVI values recorded after 75 DAS, which may be attributed to the ageing of leaves and decrease in greenness (Harrell *et al.,* 2011).

Per leaf chlorophyll (mg g^{-1}) and Leaf nitrogen content (%)

Per similar to the NDVI and SPAD readings same trend was also observed with the leaf chlorophyll content. The comparison of leaf chlorophyll values among different crop growth stages irrespective of treatments indicated a slight positive change as the crop grows and it attains higher values at 75 DAS and thereafter

Table 1. SPAD readings and NDVI values recorded al different days of DSR

Treatment	SPAD readings						NDVI values					
	30	45	60	75	90	105	30	45	60	75	90	105
T_1	37.10	33.38	36.65	32.29	28.57	26.91	0.19	0.40	0.31	0.36	0-30	0.35
T_2	33.57	33.20	34.52	34.51	28.86	27.68	0.22	0.49	0.31	0.39	0.35	0.37
T_3	35.05	37.66	45.83	53.32	29.61	28.12	0.23	0.48	0.55	0.64	0.52	0.49
T_4	31.22	38.87	43.20	45.35	31.20	31.02	0.20	0.52	0.52	0.55	0.50	0.47
T_5	35.29	40.46	45.77	59.84	35.62	35.67	0.21	0.47	0.53	0.67	0.65	0.62
T_6	31.91	41.71	47.19	55.29	34.73	34.04	0.21	0.51	0.58	0.67	0.60	0.59
T_7	34.15	46.53	60.44	64.94	39.98	38.47	0.21	0.48	0.61	0.71	0.64	0.67
T_8	33.61	49.20	59.32	64.86	40.56	37.59	0.20	0.50	0.65	0.70	0.64	0.70
S.Em±	1.99	0.53	4.09	134	1.08	0.95	0.01	0.03	0.02	0.03	0.02	0.02
C.D. at 5 %	NS	1.60	12.42	4.08	3.26	2.88	NS	NS	0.07	0.08	0.03	0.06

Note: T_1 : Absolute control, T_2: FYM a 10 t ha^{-1}, T_3: 50% RUN & rec. doses of PK.
T_4 :T_3, +FYM@ 10 t ha^{-1}. T_5: 100% RON & rec. doses of PK. T_6:T_5 + FYM@ 10 I ha^{-1}.
T_7: 150% RUN & rec.doses of PK, T_8, T_7 + FYM @ 10 t ha^{-1}

Table 2. Average chlorophyll content and leaf nitrogen conlenl of DSR estimated al different days of sowing (DAS) as influenced by various treatments

	Chlorophyll content (mg g^{-1})						Leaf nitrogen content (%)					
	30	45	60	75	90	105	30	45	60	75	90	105
T_1	1.84	1.77	2.06	1.69	1.57	1.16	2.63	2.17	1.76	1.62	1.65	1.08
T_2	1.86	1.69	2.07	1.68	1.48	1.03	2.85	2.17	1.66	1.59	1.45	1.07
T_3	1.89	1.81	2.42	2.76	2.11	1.25	2.88	2.02	2.14	1.58	1.82	1.07
T_4	1.78	1.81	2.62	2.83	2.33	1.33	2.38	2.31	2.05	1.72	1.92	1.16
T_5	1.85	2.14	2.74	3.47	2.48	1.41	2.53	2.23	2.38	2.11	2.28	1.41
T_6	1.85	2.25	2.80	3.39	2.99	1.33	2.70	2.43	2.55	2.09	2.19	1.60
T_7	1.82	2.00	3.56	4.20	4.01	1.30	3.00	2.64	2.82	2.47	2.32	1.86
T_8	1.91	2.11	3.32	4.19	4.19	1.34	3.07	2.50	2.73	2.39	2.55	1.89
S.Em±	0.02	0.16	0.13	0.09	0.19	0.04	0.21	0.13	0.09	0.08	0.12	0.03
C.D. at 5 %	NS	NS	0.40	0.26	0.58	0.12	NS	NS	0.27	0.24	0.38	0.09

Note: T_1 : Absolute control, T_2: FYM a 10 t ha^{-1}, T_3: 50% RUN & rec. doses of PK.
T_4 : T_3, +FYM@ 10 t ha^{-1}. T_5: 100% RON & rec. doses of PK. T_6: T_5 + FYM@ 10 I ha^{-1}.
T_7: 150% RUN & rec.doses of PK, T_8: T_7 + FYM @ 10 t ha^{-1}

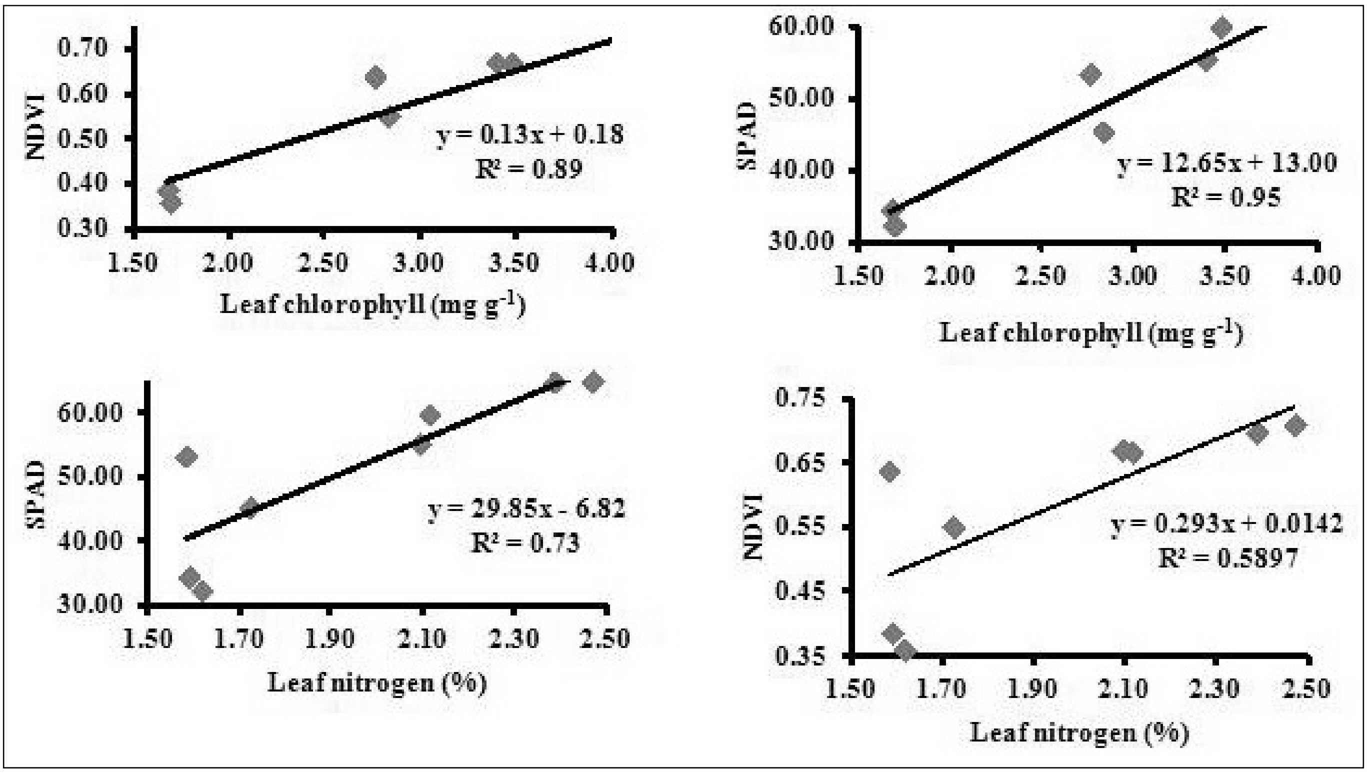
it showed a decline (Table 2). These trends are in conformity with the observations of Ghosh *et al.* (2004) and Mahajan *et al.* (2011) who have reported the increase in the chlorophyll content with the increase in the N doses.

In the case of leaf nitrogen content, among the different crop growth stages the highest was recorded at 30 DAS and there after the N concentration decreased marginally and it was lowest at 105 DAS irrespective of treatments. On the other hand, the leaf nitrogen content showed a linear increase with the treatments that received variable N application rates (Table 2).

When we consider all the above discussed parameters together, in the present study in general, irrespective of treatments we have noticed a comparatively higher values at 75 DAS and also observed a positive trend with the nitrogen rate of application. It is obvious that the ageing and senescence of leaves and translocation of the nitrogen from vegetative parts to the reproductive part, may lead to decline in values of these parameters collected at subsequent growth stages of the crop after 75 DAS. For the better understanding of the relation between these parameters the correlation is obtained for the observations collected at 75 DAS and is presented in Figure 1.

Table 3. Correlation coefficients between biochemical and biophysical parameters of paddy crop recorded at different crop growth periods during the experimentation

Parameters	30 DAS	45 DAS	60DAS	75 DAS	90 DAS	105 DAS
			SPAD			
NDVI	0.01	0.40	0.89	0.98	0.85	0.96
Chlorophyll	0.33	0.72	0.97	0.76	0.96	0.74
Nitrogen	0.16	0.82	0.95	0.86	0.94	0.94
			NDVI			
Chlorophyll	0.45	0.26	0.87	0.77	0.82	0.79
Nitrogen	0.38	0.34	0.92	0.77	0.92	0.91
			Chlorophyll			
Nitrogen	0.71	0.47	0.96	0.47	0.92	0.58



Correlation coefficient between SPAD readings, NDVI values, leaf chlorophyll and nitrogen content of DSR

The correlation coefficients between the various parameters were presented in Table 3. In general, the coefficient values were found to be positive. However, the higher correlation coefficients among the above parameters were observed at 60, 75 and 90 DAS.

The positive correlation may be due to the fact that all these parameters are inter related to each other as they are dependent on the nitrogen concentration in the leaf and in turn on the nitrogen application rate. Similar to our results, a positive correlation was also observed by Suresh (2013) while studying nitrogen dynamics and its relation with biochemical and biophysical parameters in paddy. Further. Islam *et al.* (2009) also observed a close positive relationship of SPAD value with chlorophyll and leaf nitrogen content. While, Jones *et al.* (2007) found a strong correlations between NDVI and chlorophyll yield ($r^2 = 0.92$). Similarly, in wheat, a positive correlation among leaf SPAD, canopy NDVI and chlorophyll content and leaf N was observed by Hao, *et al.* (2010).

Grain and Straw yield of DSR

The grain and straw yields obtained after the harvest of the crop are presented in Table 4 and both the grain and straw yields were increased with the increase in the rate of nitrogen application.

Correlation

All the parameters assessed in the present study have shown a positive correlation with the paddy yield (Table 5), and it was strong at 75 DAS. The simple regression equations obtained for NDVI value Y=l I3I6.70X-2475.30, (r^2=0.97) and for SPAD reading Y=122.37X-2137.59, (^=0.95). It is obvious that the nitrogen as a major nutrient can inlluence leaf N and Chlorophyll content consequently SPAD and NDVI values, ultimately the final yield. Similar observations were made by Suresh, 2013 in paddy and by Kailou *et al.*, 2014, Ali *et al.*, 2014 and Syeda *et al.*, 2014 in different crops. The decline in the relationship between grain yield and NDVI values at later stages of growth can be attributed to canopy closure (Harrell *et al.,* 2011).

Table 4. Grain and straw yield under Direct Seeded Rice

Treatment	Grain (kg ha^{-1})	Straw (kg ha^{-1})
T_1	1686	2994
T_2	1789	3641
T_3	4318	6336
T_4	4003	6824
T_5	4752	7045
T_6	5106	7549
T_7	5776	8369
T_8	5690	8432
S.Em±	139.05	271.42
C.D. at 5 %	421.76	823.28

Table 5. Correlation coefficients of various parameters of DSR recorded at different intervals with the grain yield

DAS	NDVI	SPAD	Chlorophyll	Leaf N
30	0.01	-0.36	0.33	0.16
45	0.40	0.92	0.72	0.82
60	0.89	0.91	0.97	0.95
75	0.98	0.97	0.76	0.86
90	0.85	0.86	0.96	0.94
105	0.96	0.88	0.74	0.94

Conclusion

Response of the paddy to the applied nitrogen was positive and this was reciprocated in the biophysical and biochemical observations collected at critical growth periods and higher grain yields were possible from the treatments with increased rate nitrogen application. At the same time, the observations at critical growth periods from crop sensors such as SPAD and NDVI values can be utilized for the better nitrogen management and monitoring of crop health and yield predictions. Thus, future research works should focus to develop threshold limits for SPAD and NDVI values for better nitrogen management with the objective of increasing its use efficiency in paddy as well as in other crops.

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