Current Agriculture Research Journal Vol. **4**(1), 54-61 (2016)

Chlorophyll Meter-Based Dynamic Nitrogen Management in Wheat (*Triticum aestivum* L.) Under Subtropical Environment

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http://dx.doi.org/10.12944/CARJ.4.1.05

(Received: April 24, 2016; Accepted: May 17, 2016)

ABSTRACT

Injudicious use of nitrogen fertilizer is very commonly practice in tropical and subtropical regions. SPAD *(Soil-Plant Analysis Development) chlorophyll* meter-based nitrogen top-dressing may reduce the risk of under or over application. Considering this, the study was conducted to measure the relative advantage of dynamic methods of nitrogen fertilization over conventional method in wheat field. For this, conventional nitrogen (CN) treatments i.e. CN_{60}, CN_{90}, CN_{120}, CN_{150} at 60, 90, 120 and 150 kg ha^{-1} were compared with four chlorophyll meter-based dynamic nitrogen (DN) treatments i.e. DN_{80}, DN_{90}, DN_{120}, DN_{100} at 80, 90, 120 and 100 kg ha^{-1} nitrogen. Irrespective of treatments, SPAD meter readings remained above 45 (threshold value) beyond 50 days after seeding, but plant performance varied depending on the methods and doses used in nitrogen top-dressing. Treatment CN_{150} performed better displaying the highest SPAD values, total dry matter production, leaf area index, crop growth rate and net assimilation rate resulting to the highest grain yield (5.10 t/ha) in wheat. The plant performance in DN_{120}, DN_{100}, DN_{90} and CN_{120} treatments were statistically similar to that of CN_{150} in respect of all most all plant characters studied. Comparing with CN treatments, DN treatments resulted in better plant growth and grain yield at the same level of nitrogen fertilizer. This is because of maintaining need-based fertilizer at early stage of wheat and application of appropriate amount of nitrogen fertilizer in each time in DN treatments compared to CN treatments. The result suggests that chlorophyll meter can be effectively used for real time nitrogen top-dressing to increase productivity of wheat.

Keywords: SPAD, Chlorophyll Meter, Nitrogen, Top-dressing, Wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the third most-produced cereal after maize and rice and staple food of millions of people in the world[1]. Fertilizer nitrogen (N) is the most essential plant nutrient required comparatively a larger amount than other elements in wheat. However, judicious use of this nutrient requires its synchronized application with crop requirement[2]. In absence of synchronization, plants grow vigorously that reduces N fertilizer use efficiency[3,4]. The optimized N fertilization can synchronize N demand of wheat and thus N application rates drastically reduce without any yield losses[5]. Rahman *et al*[6]. suggested to establish an appropriate N management practice to improve N use efficiency in wheat owing to save our soil from being using over or under doses of fertilizer. The SPAD chlorophyll meter potentially offers a useful nondestructive and handheld system of evaluating plant chlorophyll status[7]. It is evident that much of leaf N is involved in enzymes associated with chlorophyll and the evaluation of chlorophyll content using SPAD meter could provide an indirect assessment of leaf N content[8].

In recent years, it showed that the split top-dressing of N fertilization and indirect assessment of N through SPAD chlorophyll meter may improve N use efficiency and enhance productivity of wheat [9,11]. Time and rate of N fertilizer top-dressing has a significant role in higher productivity of the crop. The usual practice of applying higher quantity of N fertilizer as basal dose reduces the availability of nitrogen at peak growth of the crop resulting in low yield. For fine tuning of N management in the farmer's field having high variability in fertility condition under subtropical environment and to reduce the risk of under and over N fertilization, SPAD meter-based real time N application could be effective and popular to the farmers. Lopez-Bellido *et, al*[12]. observed the potential of using SPAD meter in predicting fertilizer N requirements in wheat. However, its potentiality in determining the precision level of N requirement in wheat field is not widely tried in the subtropical regions. Considering these, the study was undertaken to compare different conventional and SPAD meter-based dynamic methods of N fertilization and to precise the conventional methods for maximizing wheat yield.

MATERIALS AND METHODS

The experiment was conducted at the Field Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706 from December, 2012 to March, 2013. This region is characterized by a subtropical climate having hot summer (May-August) and mild winter (December-February). It belongs to Agro Ecological Zone 28 at geographic coordinates $24^0$05' N latitude and $90^0$16¢ E longitude with an elevation of 8.4 m above the mean sea level. The crop tested in the experiment was widely cultivated wheat variety BARI Gom-27 in Bangladesh. The experiment was laid out in a Randomized Complete Block Design with four replications. The unit plot size was 3×2 m. There were eight treatments of which four were conventional nitrogen (CN) management viz. (1) CN_{60} = 60 kg ha^{-1} N (2) CN_{90} = 90 kg ha^{-1} N (3) CN_{120} = 120 kg ha^{-1} N and (4) CN_{150} = 150 kg ha^{-1} N and four were dynamic nitrogen (DN) management: viz. (1) DN_{80} = 20 kg ha^{-1} N in each time started from 18 days after sowing (DAS) and for four times total amount was 80 kg ha^{-1} N, (2) DN_{90} = 30 kg N ha^{-1} in each time started from 19 DAS and for three times total amount was 90 kg ha^{-1} N, (3) DN_{120} = 40 kg N ha^{-1} in each time started from 20 DAS and for three times total amount was 120 kg ha^{-1} N and (4) DN_{100} = 50 kg N ha^{-1} in each time started from 24 DAS and for two times total amount was 100 kg ha^{-1} N. In CN treatments, one third of nitrogen was applied as basal application and the rest of the nitrogen was applied at 25 and 50 days after sowing (DAS) as top dress. In DN, supplied N application was done when the SPAD value fell down the critical value of 45 as suggested by Barraclough and Kyte[13].

Seeds were placed continuously in lines by making narrow and shallow furrows with iron tine and covered properly. The crop was terminally harvested around four months after sowing. The data refer to growth and physiological parameters as well as yield and yield attributes. Among the physiological parameters, SPAD value over time and corresponding leaf chlorophyll content, dry matter production, leaf area index, crop growth rate and net assimilation rate were recorded. The yield data viz. 1000-seed weight, the number of tillers per m^2, spike length, the number of spikelet per spike and the number of grains per spike and the grain yield were recorded when the plant attained full maturity. Twelve wheat plants were selected randomly from each plot at 17 DAS excluding border area and SPAD value was taken from middle portion of the latest fully developed leaf by using Minolta chlorophyll meter (Model: SPAD-502, Minolta Co. Ltd., Japan). Thus SPAD values were taken from each plot at 3 days interval up to 84 DAS. Collected data were subjected to statistical analysis. Arithmetic mean values of the different plots, those experiencing conventional and dynamic nitrogen supplements were compared to evaluate the difference in the plant performance by employing Least significance difference (LSD). MSTAT-C and SPSS program were used to perform statistical analysis.

RESULTS AND DISCUSSION

SPAD chlorophyll meter reading

SPAD reading was markedly influenced by N treatments (Figure 1). In DN treatments, nitrogen fertilizer applied when SPAD value falls below 45. SPAD meter reading was found to increase one-week after application of N fertilizer. Before 42 DAS, fluctuating of SPAD meter reading occurred irrespective of treatments, but DN treatments maintained comparatively higher SPAD values over CN treatments having same rate of N fertilizer. After 45 DAS, SPAD reading increased up to anthesis stage with the progress of plant age, thereafter it declined regardless of treatments. The maximum SPAD reading was observed in CN_{150} followed by CN_{120} and DN_{120} treatment. The treatments CN_{150} and DN_{100} showed the highest SPAD values up to 51 DAS. Thereafter, SPAD readings in DN_{100} gradually fell down but remained above 45. In rice, different doses of nitrogen fertilizer showed significant effect on SPAD meter reading at different growth stages[14].

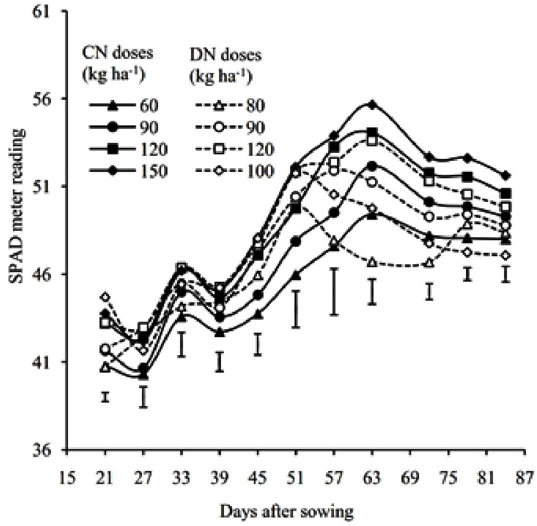

Fig. 1: SPAD meter readings at different days after sowing of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management. Vertical lines represent LSD at 5% level of significance

Wheat responded most to nitrogen fertilizer at maximum tillering stage when SPAD reading fell below 44[15]. However, SPAD value more than 45 was reported excess consumption of nitrogen uptake in spring wheat[16].

Total dry matter production

Total dry matter (TDM) production progressively increased over times and varied depending on the doses of N fertilizer and management systems (Table 1). The increasing rate of TDM production was high during 70 to 90 DAS and thereafter, it slowed down and continued till maturity. It might be due to decrease in photosynthetic capacity of the plants, and shedding and discoloration of leaves by damaging chlorophyll. Plants grown under CN_{150} treatment produced the highest TDM, which was significantly higher than those grown under other treatments. Chandurkar *et al*[17]. and Bellido *et al*[18]. also reported that TDM increased up to 150 kg N ha^{-1} in wheat. Except CN_{150} treatment, DN treated plants produced comparatively higher TDM at same rate of N application indicating better nitrogen uptake in DN management. However, at low N rate both CN and CN management had no additional benefit.

Table 1: Total dry matter production at different days after sowing of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management

Treatments	Total dry matter (g m^{-2}) Days after sowing 71	81	91	101	111
CN application (kg ha^{-1})					
60	1041	1180	1371	1465	1496
90	1138	1309	1546	1665	1703
120	1253	1444	1721	1854	1902
150	1398	1607	1933	2091	2152
DN application (kg ha^{-1})					
80	1077	1226	1444	1545	1580
90	1182	1365	1613	1737	1779
120	1308	1507	1804	1945	1997
100	1203	1359	1585	1697	1724
LSD (5%)	51.01	60.01	88.6	102	101.4
CV %	2.89	2.97	3.7	3.97	3.85

CN = Conventional nitrogen, DN = Dynamic nitrogen, LSD = Least significance difference at 5% level of significance, CV = Coefficient of variation.

Leaf area index

Leaf area index (LAI) gradually decreased from 71 DAS to 91 DAS irrespective of nitrogen treatments (Figure 2). The treatment CN_{150} showed the highest LAI which is statistically identical with that of the treatment DN_{120} at different DAS. Kibe *et al*[19]. also reported that an exponential increase in nitrogen fertilizer increased LAI. The most remarkable

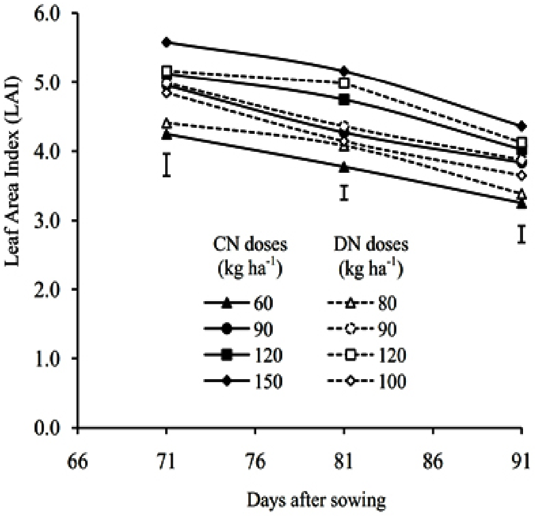

Fig. 2: Leaf area index at different days after sowing of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management. Vertical lines represent LSD at 5% level of significance

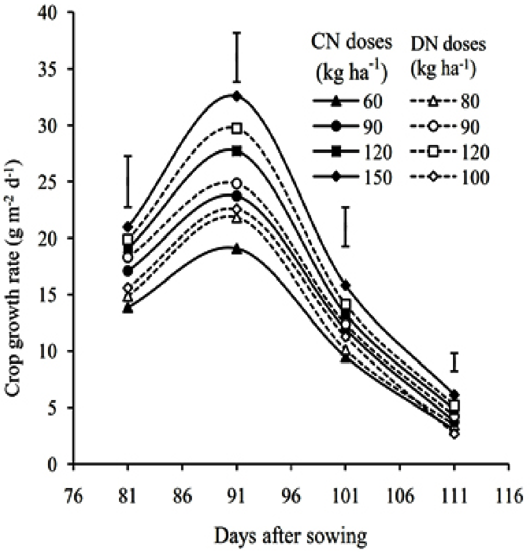

Fig. 3: Crop growth rate (CGR) at different days after sowing of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management. Vertical lines represent LSD at 5% level of significance

responses of plants were the maintenance of higher LAI in DN treatments compared to CN treatments for 90 or 120 Kg ha^{-1} N application. This implies that SPAD meter-based real time fertilizer increased LAI most likely to higher N efficiency in DN fertilization.

Crop growth rate

Crop growth rate (CGR) varied significantly for different fertilizer N treatments (Figure 3). Among the treatments, CN_{150} maintained the highest CGR throughout and statistically similar with the treatments CN_{120}, DN_{120} and DN_{90} at 81, 91 and 101 days after sowing. At 111 DAS, CN_{150} exhibited the highest value, but dissimilar to other treatments. The results obtained by Rahman[20] are also in agreement with this, where CGR was high for using 120 and 160 kg N ha^{-1}. Kibe *et al*[19]. explained the fact that CGR increased with the increasing rate of N fertilizer in wheat because of accelerating the activities of meristems and increasing the function of protoplasm. Inadequate N in CN_{60}, DN_{80}, CN_{90} and DN_{100} treatments is probably a stressful condition responsible for disturbing the physiological function of plant resulting to inadequate leaf formation and development, and consequently may have less photosynthesis. Inadequate growth and development during the stressful conditions have also been reported by Vibhuti *et al*[21].; and Shahi *et al*[22,23]. in wheat and rice crops, respectively. This may results in reduced dry matter production and ultimately CGR was not satisfactory. Comparing the treatment CN_{120} with DN_{20}, the CGR was apparently higher in DN_{120} than CN_{120}. This indicates that dynamic N application increased nutrient use efficiency (NUE) in wheat.

Net assimilation rate

Net assimilation rate (NAR) varied significantly with varying degrees of N fertilization (Figure 4). Regardless of treatments, NAR increased linearly from early growth stage and reached maximum at 81 DAS and then gradually declined. It reveals that NAR was high for high N rate which is most common in various studies[24,25]. However, treatment CN_{150} showed the highest NAR than other treatments presumably because of producing more leaf area that may respond to harvest more light and accumulate more dry matter. Comparing with CN treatments, DN treatments having same rate of N fertilizer showed higher NAR. This result suggests that plant need-based fertilizer application increased NUE by enhancing leaf photosynthesis. Generally, increased NAR is attributed to enhanced photosynthetic capacity of leaves with improved nutrition of the plants[26].

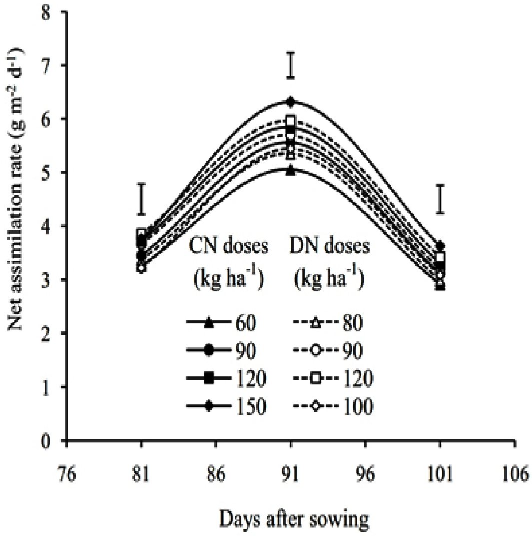

Fig. 4: Net assimilation rate (NAR) at different days after sowing of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management. Vertical lines represent LSD at 5% level of significance

Yield attributes and grain yield

The grain yield of wheat is increased significantly as a result of the positive contribution of all yield contributing characters i.e. grains per spike, spike length, spikelets per spike and grain weight (Table 2). In general, the grain yield increased with increasing N rates. Nitrogen receiving from the treatment CN_{150} resulted in the highest grain yield (5.10 t ha^{-1}) that was statistically similar with those produced in treatments DN_{120}, CN_{120}, DN_{100} and DN_{90},and significantly higher than those of all other conventional and dynamic treatments. The results of the highest yield are in agreement with many studies[27, 28 ,29] where it is reported that N application @ 150 kg ha^{-1} produced the highest wheat yield. The lowest yield (4.25 t ha^{-1}) was found from the CN_{60} treatment. Although CN_{90} and DN_{90} contained the same amount of nitrogen, the grain yield of DN_{90} was much higher than CN_{90}. In case of other treatments i.e. $CN_{90,}$ DN_{80} and CN_{60}, the late top-dressing with inadequate N fertilizer at vegetative stage inhibited plant growth and development.

Table 2: Grains per spike, spike length and spikelets per spike, grain weight and grain yield of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management

Treat ment	Grain sno./ spike	Spike length (cm)	Spikelet no./ spike	1000- seed wt. (gm.)	Grain yield (kg ha^{-1})
CN appli -cation (kg ha^{-1})					
60	39.33	9.79	16.65	42.94	4.25
90	40.53	10.01	16.93	43.65	4.45
120	43.58	10.47	18.23	44.52	4.94
150	46.03	10.90	18.88	44.89	5.10
DN application (kg ha^{-1})					
80	41.13	9.99	17.70	43.25	4.36
90	42.18	10.21	17.78	43.67	4.91
120	43.45	10.53	18.45	44.66	5.02
100	41.58	10.13	17.68	43.97	4.87
LSD	1.78	0.41	1.15	0.38	0.40
CV (%)	2.87	2.71	4.40	0.59	5.74

CN = Conventional nitrogen, DN = Dynamic nitrogen, LSD = Least significance difference at 5% level of significance, CV = Coefficient of variation

Correlation between grain yield and SPAD meter reading

The correlation coefficient between wheat grain yield and SPAD values is presented in Table 3. The SPAD meter readings at different days after sowing are positively correlated with grain yield. A positive association between chlorophyll meter reading and grain yield is reported in many studies[30] [31]. SPAD meter readings as an estimate of leaf chlorophyll content correlate with grain yield as accurately as leaf N concentrations[15] [32]. This study reveals that SPAD meter readings at 33 and 45 DAS were highly correlated (r_{33} = 0.74 and r_{45} = 0.79) with the grain yield. Correlation coefficients were low at 27 and 39 DAS as SPAD values dropped (Figure 1). Interestingly, except conventional N management at 150 kg ha^{-1}, all DN fertilizer management maintained higher SPAD values up to 45 DAS. The maintenance of need-based fertilizer at early stage of the crop as well as appropriate amount of N application in each time in DN_{120} treatment gave better yield and almost similar to CN_{150} but higher compared to CN_{120}.

Table 3: Correlation matrix between grain yield and SPAD meter readings of wheat grown under conventional nitrogen (CN) and dynamic nitrogen (DN) management

Parameter	Y	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Y	1										
X1	0.68**	1									
X2	0.51**	0.37*	1								
X3	0.74**	0.60**	0.52**	1							
X4	0.54**	0.64**	0.49**	0.39*	1						
X5	0.79**	0.73**	0.63**	0.60**	0.74**	1					
X6	0.63**	0.66**	0.53**	0.41*	0.71**	0.89**	1				
X7	0.67**	0.52**	0.29	0.50**	0.52**	0.53**	0.58**	1			
X8	0.59**	0.52**	0.17	0.57**	0.37*	0.40*	0.38*	0.78**	1		
X9	0.51**	0.43*	0.20	0.57**	0.22	0.35*	0.33	0.67**	0.91**	1	
X10	0.39*	0.16	0.18	0.44*	0.33	0.25	0.27	0.66**	0.79**	0.78**	1

Here, wheat grain yield= Y(t/ha) and X1, X2, X3, X4, X5, X6, X7, X8, X9 and X10 are the SPAD readings at 21, 27, 33, 39, 45, 51, 57, 63, 72, & 84 DAS respectively, * and ** indicate significance at 5 and 1% respectively.

CONCLUSION

From the study, it reveals that SPAD chlorophyll meter helps to quantify leaf greenness in wheat. Thus meter values should be maintained 45 at early stages, and appropriate amount of N fertilizer should be top-dressed to facilitate growth and development towards higher grain production. It also affirms that chlorophyll meter-based N management saved significant amount of nitrogen without significant yield loss. Therefore, SPAD chlorophyll meter can be a useful tool to the farmers of subtropical region for maintaining judicious use of N fertilizer and sustainability of growing wheat.

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