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Sensor guided nitrogen application can boost up the direct seeded rice production grown in subtropical India

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Abstract
To identify the suitable precision nitrogen management technique for improving growth and yield among the different rice cultivars under direct seeded condition, a field experiment was conducted at Agriculture Research Farm, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India during *Kharif* 2018. The experiment was conducted in split plot design with three rice cultivarssuch as Sabourardhjal, Shushksamrat and Shabhagidhan as main plot treatments and four N management practices as control where no N was applied, fixed time N management (FTNM), real time N management (RTNM) using SPAD meter and adjustable dose of N management (ADNM) through SPAD meter as the sub plot treatments: Results revealed that among the cultivars, the maximum grain yield was obtained in Shushksamrat (3956 kg/ha) which was statistically at par with Shabhagidhan (3752 kg/ha) whereas lowest grain yield was obtained in Sabourardhjal (3213 kg/ha). Among the N management practices, highest grain yield (4177 kg/ha) was recorded in ADNM against 79 kg N/ ha which was at par with grain yield of FTNM (4134 kg/ha) against 100 kg N/ ha. So it can be concluded that using SPAD meter in DSR not only enhanced the production but also can reduced a considerable amount of N application.

Keywords: direct seeded rice, SPAD meter, grain yield, N use efficiency

Introduction
Applying nitrogen (N) fertilizer more than the recommendation is becoming a serious problem in developing countries like India where the recommended dose also found higher than actual demand particularly in rice and wheat (Ghosh *et al*., 2020) [9]. The whole country's food habit depends on either rice or wheat and here the N fertilizer is available in subsidized rate in the market. The most of farmers are small holders and not bearing any risk of crop failure for their hungry stomach. The farmers does not have any issue for the application of N in rice as the fertilizer urea is available at cheapest rate in the market over the other essential macro nutrients. The dark green foliage of rice crop may be the symptoms of healthy plants but not healthy for health and environment (Singh *et al*., 2020) [15]. Considering the sustainability the fertilizer must be applied as per the need at right time with adequate amount. The farmers are very much acquainted with broadcasting of fertilizer which resulted low N use efficiency (NUE) and greater loss of N through volatilization, leaching, runoff and denitrification in rice crop cultivation (Wu *et al*., 2017). The productive NUE is a challenge for developing countries for better environment and sustainable production. It was noted that only India and China alone are about to consume more than 40% of total N consumption in the world (Singh *et al*., 2020) [15] which was due to high subsidy on N fertilizer. Because of subsidized N fertilizer, the farmers are often skip the potassium application in rice crop due to high market price and that much required non subsidized potassic fertilizer sometimes filled by subsidized N fertilizer which leads to very low NUE and environmental pollution through nitrate depletion, eutrophication, ammonia volatilization etc. In rice cultivation technique the farmers are now shifted to direct seeded practice from the conventional puddle transplanted method and here it was noted that the nutrient losses occur more in direct seeded rice (DSR) as compared to the puddle transplanted rice. More than 60% of the world population depends on rice as the main food (Mohanty, 2010) [12] and India is the second largest producer after China with an area about 43.19 Mha with production and productivity of 110.15 Mt and 2.55 t ha^{-1} (Annual report of Ministry of Agriculture and Farmers' Welfare, 2017-18). Though N is one of the vital inputs which plays an important role in growth and production of rice crop but the proper management of N fertilizer is an issue in developing countries (Singh *et al*., 2020) [15].

Generally in Asia, the farmers are very much comfortable with blanket N recommendation with higher dose than the general recommendation to avoid the risk of crop failure (Ghosh *et al*. 2020) [9]. The general recommendation was observed as 100 kg N ha^{-1} for short to medium duration and 120 kg N ha^{-1} for long duration rice cultivars. Despite large amount of N application, the rice crop is about to utilize 30-35% of applied N, which resulted maximum loss, low NUE and affected the natural ecosystems. The farmers are generally applied N in three equal splits such as basal, active tillering and panicle initiation stages for short (115-125 days) to medium duration (130-135 days) rice varieties. However, for long duration (150-155 days) rice cultivars an extra split of N fertilizer before the anthesis was found beneficial for higher production and productivity. It is very important to mention that after anthesis, the N fertilizer recommendation is not applicable due unproductive vegetative growth can be extended the maturity and disrupt the grain formation. The N utilization in DSR technology is also an issue due to more crop weed competition and unpuddled situation though around 30% of total rice cultivated area in India was occupied by DSR (Umashankar *et al*. 2005) [19]. The DSR practice also benefits the environment by reducing greenhouse gases emission which ultimately useful in climate change adaptation and mitigation. In DSR the precise N Assessment according the crop demand is very important for judicious N management and rectifying the NUE. The DSR technique is much differed from the traditional transplanted practice, where inadequate excess broadcasted N fertilizer enhance the crop weed completion and more unutilized N is lost to the environment. The SPAD (Soil Plant Analysis Development) meter or chlorophyll meter is one of the tools of precision farming developed by Konica Minolta company, Japan which can predicts the leaf N content non destructively and accordingly N can be applied as per the need. There are many variable rate applicators to measure the spatial N variability but the SPAD meter is an easy tool to handle and affordable by small holders. Researchers also reported a linear relationship between rice leaf N content and SPAD readings (Zhu *et al*. 2012) [20]. Using SPAD meter the N is applied at certain rate when the observed SPAD is found below the threshold limit. The SPAD index suggests the accurate timing and adjust rate of N fertilizer against the standard recommendation practices (Ghosh *et al*. 2020) [9]. Here through the field experiment the region specific SPAD index for rice crop was notified by the researchers such as for Phillippines and Indonesia it was 32 and 35 for wet and dry season, respectively (IRRI-CREMENT). However in Indo-Gangetic Plain it was 37-37.5 (Balasubramanian *et al*. 2000) [2] and in southern part of India it was recommended as 35 for higher yield and improved N use efficiency (Maiti *et al*. 2004) [11]. The main move is to increase the NUE either by avoidance of excess N or alter any fixed application crop growth stage under standard practices. Considering the cleaner environment the N fertilizer management in DSR is an issue and in this regard the present investigation intends to optimize and identify the critical SPAD and cultivar to allow the precise N management in Indo-Gangetic Plain of eastern India.

Materials and Methods

Experimental site

Field experiment was conducted at research farm of Bihar Agricultural University, Sabour under Indo-Gangetic plain of eastern India during wet season 2018 in *kharif* season. Sabour representing the Agro-climatic Zone III-A which is situated between 25º15′40″ N latitude and 87º2′42″ E longitude at an altitude of 52.73 meter above mean sea level. The experimental plot was engaged with rice-wheat system for last ten years and the soil of the experimental plot was found silty clay loam in texture (22% sand, 49% silt and 29% clay) under Eutrochrepts group The fertility status was recorded as much lower in available N (178.5 kg ha^{-1}) than the critical level (280 kg ha^{-1})with 9.8 kg ha^{-1} of 0.5 M $NaHCO_3$-extractable P (Olsen *et al*. 1954), 129.80 kg ha^{-1} of 1 N NH_4OAc-extractable K (Jackson 1973), neutral in nature (pH = 7.3) and low in cation exchange capacity (10.2 cmol(+) kg^{-1}).The climate of Sabour is characterized by sub-tropical, hot summer, cold winter, and moderate rainfall. December and January months are usually coldest where the mean temperature normally falls as low as 8.2 °C whereas; May and June are the hottest months, having the maximum average temperature of 29.6 °C. The average annual rainfall is about 1207 mm (10 years average), precipitating mostly between middle of June to middle of September. Here in the study the site received around 847.8 mm rainfall from June to October.

Treatment details

The experiment was laid out in split plot design with three replications. The size of individual plot was 6m × 4m. The main plot constituted of three rice cultivars such as Sabour Ardhjal, Shushk Samrat and Shabhagi Dhan. The each main plot was further divided into sub plots having four levels of N management including control *viz*. no N, one treatment with 100% recommended dose of N (100 kg N ha^{-1}) in three equal splits at basal, active tillering i.e. 40 days after sowing (DAS) and before panicle initiation (60 DAS) as fixed time N management (FTNM) in standard practice, the remaining two treatments were based on SPAD threshold greenness as real time N management (RTNM) and adjustable dose N management (ADNM). In RTNM, the 1/3rd recommended dose of N was given at basal and thereafter, 20 kg ha^{-1} in split whenever, the SPAD index of the treated plot was less than 90% of N rich plot (starting from 40 DAS to flower initiation). For the implementation of RTNM, one N rich plot was developed consisting double of the recommended dose of nitrogen (RDN) *viz.* 200 kg N in 3 equal splits at basal, 40 DAS and 60 DAS. However in ADNM, the 1/3rd N of RDN was provided as basal dose and at active tillering and before panicle initiation stages, the N dose was top dressed on the basis of SPAD index having 3 conditions. In first condition, an extra 10 kg Nha^{-1} was top dressed in addition to 20 $kgha^{-1}$ if SPAD index was less than 36 at active tillering and panicle initiation stages; in second condition, 20 $kgha^{-1}$ was applied if the index falls between 36 and 38 at active tillering and panicle initiation stages; in third condition, only 10 $kgha^{-1}$ was top dressed if the SPAD index is more than 38 at active tillering and panicle initiation stages. In ADNM, the application 20 kg Nha^{-1} in split was kept as benchmark. All the treatments received 60 kg P_2O_5 and 40 kg K_2O at the time of sowing. The sources of fertilizers were Urea, Di Ammonium Phosphate and Muriate of Potash.

The treatment details were as follows

Main Plot (Variety)	Sub Plot (N Management)
V1 = SabourArdhjal	N_1 = No N (Control)
V2 = ShushkSamrat	N_2 = 100% RDN as FTNM (100 kg N in three equal split at basal, 40 DAS and 60 DAS
V3 = ShabhagiDhan	N_3 = 1/3rd of RDN at basal and 20 kg N ha^{-1} in split whenever SPAD index of the test plot was<90% of N rich plot as RTNM
	N_4 = 1/3rd of RDN at basal followed by 40 DAS and 60 DAS on the basis of SPAD index as ADNM mentioned below. Condition 1: If SPAD <36, then 20 + 10 kg N/ha; Condition 2: If SPAD 36-38, then 20 kg N/ha; Condition 3: If SPAD >38, then 20-10 kg N/ha

RDN: Recommended Dose of Nitrogen; FTNM: Fixed Time Nitrogen Management; DAS: Days After Sowing; SPAD: Soil Plant Analysis Development; AT: Active Tillering; PI: Panicle Initiation; ADNM: Adjustable Dose of Nitrogen Management.

Chlorophyll Meter

The chlorophyll meter (SPAD-502 Minolta Camera Co., Osaka, Japan) was used in the experiment for canopy chlorophyll concentration index from 40 DAS to flowering at an interval of 10 days for all treatments and replications. The fully expanded and young leaf was used for the measurement and a mean of 15 readings were considered for the representative value. The Readings were recorded on one side of the midrib of the leaf blade between the base and tip.

Crop management and biometric observations

Variety 'Sabourardhjal' used in the investigation which was recommended for medium duration (120-125 days) with an average potential yield about 50-55 q ha^{-1}. The other two varieties were named as 'Shushksamrat' and 'Shabhagidhan' are also short duration cultivars (115-120) with an average yield potential of 35-40 q ha^{-1}.The experimental site was prepared by ploughing the land twice followed by planking in order to easy removal of weeds, root stubbles and other crop residues. The land was leveled manually and bund was made to avoid the seepage of nutrients and to ensure uniform availability of water to the individual plot. Basal dose of fertilizer was applied in each line before the sowing of direct seeded rice. The seeds were sown at row to row spacing of 20 cm after treated with fungicide Bavistin @ 2g kg^{-1} seed. Intercultural operation like hand weeding was done manually at 40 DAS and field was irrigated twice on 10 and 35 DAS and due to regular precipitation and no further irrigation was provided. Each plot was divided into two parts; one part was ear–marked for destructive sampling and the second one was used for yield estimation, plant height and tiller count. Various biometric data *viz*. plant height, tiller count, plant samplings were recorded and collected at time series interval from the ear–marked area of each plot and the economic yield was estimated at the time of harvest. After threshing the grains were dried for 72 hours in hot air over at 70 °C. The total biomass was estimated on oven dry basis and yield was corrected to 12% moisture content. The yield attributes were estimated from each plot at maturity and harvest index was calculated dividing the grain yield by total biomass.

Statistical analysis

The data generated from field experiment were analyzed in split plot design (Cochran and Cox, 1985) [21] in three replications with three main plots and four sub plots by analysis of variance (ANOVA). The significance of different sources of variation was tested by the error mean square of Fisher Snedecor's 'F' test at probability level 0.05. Standard error of mean (SE) and least significant difference (LSD) at 0.05 level of significance were used to compare treatments.

Results and Discussion

Growth and yield attributes

The plant height did not vary significantly among rice cultivars at 100 DAS. Highest plant height was recorded in the FTNM treatment at 100 DAS which was at par with ADNM treatment whereas RTNM has recorded significantly lower plant height compared to FTNM and lowest height was recorded in the control plot. The plant biomass did not vary significantly among rice cultivars at maturity. Among the sub plot treatments ADNM has recorded the highest biomass at maturity which was at par with FTNM but ADNM has saved around 21% fertilizer compared to FTNM treatment. It was because of judicial application of N fertilizer dose based on SPAD meter reading (Gholizadeh *et al*., 2017) [7]. RTNM has achieved significantly lower biomass at maturity when compared to FTNM and ADNM probably because it has received very less amount of N fertilizer (58 kg/ha). Control plot has achieved the lowest biomass among subplot treatments. The interaction effect between rice cultivars and N management practices in growth attributes was found non-significant during the study. The higher dry matter after flowering stage (100 DAS) was accumulated in the Shushksamrat as compared to other cultivars which was reflected in the grain yield and among the subplot treatments, highest dry matter after flowering stage was accumulated in the ADNMsubplot which had recorded the highest grain yield. Peng *et al*. (2012) [13] also suggested that the dry matter accumulation after flowering stage was positively correlated with the grain yield.

The number of panicles m^{-2} and test weight did not show significant effect among the cultivars. But the number of grains has varied significantly. The highest number of grains per panicle (152) was recorded in Sabourardhjal and cultivars Shushksamrat and Shabhagidhan have produced significantly lower number of grains. Sui *et al*. (2013) [18] noticed that Panicle number is the main yield defining factor which can be increased by high N fertilizer application at early vegetative stage. Among the subplot treatments, both FTNM and ADNM have received a fertilizer dose at active tillering stage which resulted in higher number of panicles m^{-2} and highest yield was obtained in ADNM which was statistically at par with FTNM. Among the subplot treatments, FTNM has recorded highest number of panicles m^{-2} (251.6), grains per panicle (153.2) and highest test weight (20.90) which were statistically at par with ADNM whereas all these components were recorded lowest in the control plot. The interaction effect between rice cultivars and N management practices was found to be non significant for all the yield components. However in FTNM, 100 kg N ha^{-1} was applied which is 21% higher than that of ADNM. Although FTNM had received 21%

of higher N fertilizer dose, it didn't show any significant effect on yield attributes. These results are in agreement with the Dinesh *et al.* (2017) [5] who reported that blanket application of N fertilizer didn't show any significant effect on yield attributes compared to need based N application through SPAD meter with the index value of 37. Lee *et al.* (2010) [10] reported that tillers play an important role in determining rice yield and the tiller number is significantly increased by topdressing at the active tillering stage. Significantly lower number of panicles m^{-2} was recorded in RTNM compared to FTNM which was due to very less application of N fertilizer at active tillering stage.

Productivity

Singh *et al.* (2015) [14] observed that for improving yield in rice, N fertilization should be done before sowing/transplanting, at active tillering stage and senor based N fertilization should be done at panicle initiation stage to attain maximum yield. The maximum grain yield was obtained in Shushksamrat (3956 kg/ha) which was statistically at par with Shabhagidhan (3752 kg/ha) whereas lowest grain yield was obtained in Sabourardhjal (3213 kg/ha). Among the subplot treatments, highest grain yield (4177 kg/ha) was recorded in ADNM which was at par with grain yield of FTNM (4134 kg/ha). Here we can observe that ADNM has produced highest grain yield with 21% reduction in N fertilizer when compared to FTNM which implies that application of N fertilizer judiciously based on SPAD index can reduce the use of N fertilizer without reduction in yield. Lowest grain yield was recorded in control plot which didn't receive N fertilizer. These results are in conformity with the statement of Duttarganvi *et al*. (2014) [6] who reported that the maximum yield of 4.40 t/ha was recorded in SPAD-40 threshold value in rice which was statistically on par with the yield recorded in recommended practice with saving of 13% N. The maximum straw yield was obtained in Shabhagidhan (6691 kg/ha) followed by Sabourardhjal (6056 kg/ha). Among the subplot treatments, highest straw yield (6865 kg/ha) was recorded in ADNM which was at par with FTNM (6437 kg/ha) and RTNM (6238 kg/ha). Harvest index was recorded highest in Shushksamrat (41.1) followed by Shabhagidhan (36.0). Harvest index was obtained maximum in FTNM which was statistically at par with ADNM and RTNM. The interaction effect between rice cultivars and N management practices in grain yield, straw yield and harvest index harvest index was found non-significant during the study.

Table 1: Effect of different varieties and N management levels on growth and yield attributes of DSR

Treatments	N rate (kg ha^{-1})	Plant height at 100 DAS	Plant biomass at maturity	Panicles m^{-2}	Grains panicle $^{-1}$	Test weight
Main plot						
Sabourardhjal	59	123.4	9663.7	229.0	151.7	19.4
Shushksamrat	57	121.7	10774.8	236.8	131.7	21.6
Shabhagidhan	61	124.0	10555.0	244.2	133.9	20.2
SEm(±)	-	2.33	254.99	5.01	3.98	0.48
LSD (p=0.05)	-	NS	NS	NS	15.64	NS
Sub plot						
Control	0	103.2	7624.2	222.0	120.1	19.0
FTNM	100	133.2	11670.7	251.6	153.2	20.9
RTNM	58	126.1	10310.0	231.2	137.7	20.9
ADNM	79	129.7	11719.7	241.8	145.3	20.8
SEm(±)	-	2.17	163.35	4.15	3.93	0.42
LSD (p=0.05)	-	6.45	485.33	12.34	11.66	1.26
Interaction	-	NS	NS	NS	NS	NS

FTNM = Fixed time nitrogen management; RTNM = Real Time Nitrogen Management; ADNM = Adjustable Dose of Nitrogen Management; SEm(±) = Standard error of mean; LSD = Least significant difference

Table 2: Effect of different varieties and N management levels on productivity of DSR

Treatments	N rate (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index (%)
Main Plot				
Sabourardhjal	59	3213	6056	34.7
Shushksamrat	57	3956	5627	41.1
Shabhagidhan	61	3752	6691	36.0
SEm(±)	-	141.35	393.77	1.02
LSD (p=0.05)	-	555.01	NS	4.01
Subplot				
Control	0	2662	4958	35.4
FTNM	100	4134	6437	39.2
RTNM	58	3587	6238	36.6
ADNM	79	4177	6865	37.9
SEm(±)	-	90.82	253	0.89
LSD (p=0.05)	-	269.85	752	2.63
Interaction	-	NS	NS	NS

FTNM = Fixed time nitrogen management; RTNM = Real Time Nitrogen Management; ADNM = Adjustable Dose of Nitrogen Management; SEm(±) = Standard error of mean; LSD = Least significant difference

Conclusion

The inadequate N application without any crop canopy sensor may maintain the grain yield but leads toxic environment and unsuitable situation. Here the investigation focused on crop demand basis N application using the SPAD meter in direct seeded rice (DSR) and revealed that SPAD meter can be reliable option for DSR production with less consumption of N fertilizer over the recommended practices. In this study, both the Shushksamrat and Shabhagidhan have performed well under direct seeded condition and growth parameters, yield attributes as well as grain yield obtained in both SPAD based N management as adjustable dose N management (ADNM) and recommended practice as fixed time N management (FTNM) were statistically at par with each other among the sub plot treatments. However, 21% N fertilizer was saved in ADNM as compared to FTNM. The ADNM is a sustainable option for precision N management for improving growth and yield among rice cultivars under direct seeded condition. Based on this study, it can be recommended that N application using SPAD meterin rice is a sustainable option for direct seeded condition to the farmers.

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