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Influence of optical sensor based precision nitrogen management on yield, nutrient uptake and available nutrient status of aerobic rice (*Oryza sativa* L.)

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Abstract
Nitrogen (N) nutrition in aerobic rice is gaining importance because of its role in increasing productivity and the large quantities of this major nutrient that are uptake by crop. A field experiment was conducted at Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra, Bengaluru during *kharif* 2017 to improve yield, nutrient uptake and available nutrient status after harvest of aerobic rice as influenced by precision nitrogen management practices through crop sensors. Nitrogen nutrition was done based on sensor readings, which are taken for indexing nitrogen content in aerobic rice. The experimental results revealed that, significantly higher grain yield (7353 kg ha^{-1}) and straw yield (9151 kg ha^{-1}). Higher total nutrient uptake of nitrogen (135.8 kg ha^{-1}), phosphorus (23.04 kg ha^{-1}) and potassium uptake (117.7 kg ha^{-1}) were recorded with the application of nitrogen based on SPAD sufficiency index 96-100 per cent as compared to package of practices. After harvest of aerobic rice application of nitrogen based STCR for targeted yield of 8 t ha^{-1} was recorded significantly higher soil available nitrogen (334 kg N ha^{-1}) and application of nitrogen based on SPAD threshold 35 recorded higher available phosphorus and potassium (36.41 and 209 kg P_2O_5 & K_2O ha^{-1}, respectively) compared to rest of the treatments.

Keywords: Aerobic rice, green seeker, optical sensors, SPAD, sufficiency index

1. Introduction

Rice (*Oryza sativa* L.) is the world's most important foremost cereal grain. It is one of the major staple food for Asian countries, more than 90 per cent of rice which is produced and also consumed in Asia. India is the major rice producing country after china in the world and contributing about 20 per cent of world rice production. India stands first in rice cropped area (43.78 m ha) and second in production (118.43 m t) with productivity of 2705 kg ha^{-1}. In Karnataka rice is grown in an area of 1.38 m ha and production of 3.81 m t with a productivity of 3084 kg ha^{-1} (Anon., 2020) [2].

Nitrogen fertilization is one of the major agronomic practice that affects the yield and quality of rice crop, which requires at early and mid tillering stages to maximize the panicle number and reproductive stage to produce optimum spikelets per panicle and percentage filled spikelets (Sathiya and Ramesh, 2009) [17]. To improve the nitrogen use efficiencies various practices are followed such as use of nitrification inhibitor controlled release nitrogenous fertilizer, deep placement of nitrogenous fertilizers *etc*., There are also different types of gadgets available for improving nitrogen use efficiency such as leaf colour chart (LCC) and crop sensors like SPAD meter and GreenSeeker, which can indirectly estimate crop N status of the growing crops and help to define time and quantity of in-season fertilizer N top dressings in aerobic rice. Supplemental N fertilizer applications are thus synchronized with crop demand.

The current approaches to detect soil and plant N levels are soil-testing, visual diagnosis and foliar analysis. However, these conventional approaches are time consuming, expensive; require considerable effort for soil collection or plant sampling, processing and results are not immediately available. Therefore, to provide appropriate recommendations of spatial N applications, it is necessary to use several tools simultaneously, such as crop and soil sensors, to achieve reliable measurements of N availability from soil and crops need. The evaluation of nitrogen use efficiency (NUE) in agriculture is an important way to evaluate the density of N applied and its role in yield.

Because crop responses to N application depend on the organic matter in the soil, strategies of N management in cereal crops that include reliable predictions of the response index in each season that could increase NUE. In this scenario, sensors are becoming more prevalent in agricultural lands. Using variable rate applicator, it is possible to detect variability in crops and make rapid decisions in the field. Some sensors allow real time changes in agricultural practices by detecting variability and responding to that variability.
Spectral properties of rice leaves measured through visual comparison, such as reading the intensity of green colour of leaves using a leaf colour chart (Bijay-Singh *et al*., 2002) [3] or by measuring absorbance of light in red wavelength using chlorophyll (SPAD) meter (Peng *et al.*, 1995) [12] can be used for managing crop demand-driven need-based fertilizer N application in rice. These tools provide instantaneous results and have been demonstrated to schedule need-based fertilizer N applications in rice (Bijay-Singh *et al.*, 2002 and Varinderpal-Singh *et al*., 2010) [3].
Sensors utilize the optical characteristics of plants and their associated vigor and health properties. The application of optical sensors in agriculture has advanced rapidly in the recent years. These sensors use visible and near-infrared (NIR) spectral response from plant canopies to detect N stress. Chlorophyll contained in the palisade layer of the leaf absorbs 70 to 90 per cent of all incident light in the red wavelength band. Reflectance of the NIR electromagnetic spectrum (720-1300 nm) depends upon mesophyll cells which scatter and reflect as much as 60 per cent of all incident NIR radiation (Puneet Sharma, 2011) [14]. Spectral vegetation indices such as the normalized difference vegetation index (NDVI) have been shown to be useful for indirectly obtaining information such as photosynthetic efficiency, productivity potential and potential yield (Raun *et al*., 2001) [16]. These spectral properties of leaves can prove to be a helpful guide in managing crop demand-driven need-based fertilizer N application but there is a need to establish simplified criteria in a more rational manner. Yield potential for a crop is identified using a vegetative index known as NDVI (normalized difference vegetative index) and an environmental factor. Nitrogen (N) is then recommended based on yield potential and the responsiveness of the crop to additional nitrogen. Keeping these points in view the present study on yield, nutrient uptake and available nutrient status after harvest of aerobic rice as influenced by precision nitrogen management practices through crop sensors was undertaken.

2. Material and Methods

A field experiment was conducted at ZARS, UAS, Bengaluru during *kharif* 2017. The site is located at 12^0 51' N latitude and 77^0 35' E longitudes with at an altitude of 930 m above mean sea level (MSL). The soil of the experimental site was red sandy loam. The initial pH was 6.10 and organic carbon (0.52%). The available nitrogen, phosphorus and potassium were 323.13, 32.18 and 263.33 kg N, P_2O_5 & K_2O ha^{-1}, respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with nine treatments and replicated thrice. Treatments involving, T_1: Nitrogen management through SPAD sufficiency index 90-95 per cent, T_2: Nitrogen management through SPAD sufficiency index 96-100 per cent, T_3: Nitrogen management through SPAD-35, N 25, T_4: Nitrogen management through SPAD-40, N 25, T_5: Green Seeker based nitrogen management, T_6: Nitrogen management through SSNM for targeted yield of 8 t ha^{-1}, T_7: STCR based N management for targeted yield of 8 t ha^{-1}, T_8: Recommended dose of N as per package of practices and T_9: Absolute control. The land was brought to fine tilth before sowing by ploughing twice with tractor drawn disc plough and passing cultivator and two harrowing. Irrigation provided through drip system including pump, filter units, main line, sub lines and laterals were installed. In line laterals of 16 mm size within lines spaced at 45 cm apart with 4 lph capacities were laid out at a distance of 60 cm apart and there by lateral spacing of 60 cm was fixed. Seeds of aerobic rice cultivar MAS 946-1 (two seeds per hill) were dibbled maintaining 25 cm inter and intra row spacing. The required fertilizer was calculated and applied as per the treatments. In case of SPAD and GreenSeeker based nitrogen management, 25 per cent of the recommended dose of nitrogen was applied as basal along with full dose of P_2O_5 and K_2O. Remaining nitrogen was supplied as per the treatments. In case of STCR 50 per cent of the nitrogen was applied as basal and remaining 50 per cent N was applied at 30 and 60 DAS along with recommended P_2O_5 and K_2O were applied at the time of sowing. In case of SSNM 50 per cent of the nitrogen was applied as basal and remaining 50 per cent N was applied at three equal splits at 30, 45 and 60 DAS along with recommended P_2O_5 and K_2O were applied at the time of sowing. In case of recommended practices, nitrogen (100 kg ha^{-1}) was applied as per package of practices. Recommended dose of FYM (10 t ha^{-1}) was applied to all the treatments except in case of absolute control and mixed into the soil two week before sowing. Irrigation was provided through drip and soil moisture maintained at field capacity throughout the crop growth period. Irrigation was withheld 10 days before the crop attained maturity. Crop was harvested and threshed, the grain and straw yield are recorded from net plot. The yield per ha was calculated from the net plot yield and expressed in kg ha^{-1}. The data was statistically analyzed by following standard procedure (Gomez and Gomez, 1984) [7].

Nutrient uptake by aerobic rice calculated by following formulas

$$\text{Nitrogen Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen concentration (\%)} \times \text{dry weight (kg ha}^{-1}\text{)}}{100}$$

$$\text{Phosphorus Uptake (kg ha}^{-1}\text{)} = \frac{\text{Phosphorus concentration (\%)} \times \text{dry weight (kg ha}^{-1}\text{)}}{100}$$

$$\text{Potassium Uptake (kg ha}^{-1}\text{)} = \frac{\text{Potassium concentration (\%)} \times \text{dry weight (kg ha}^{-1}\text{)}}{100}$$

3. Result and Discussion

3.1 Effect of sensor-based precision nitrogen management on grain and straw yield of aerobic rice

The grain yield expression is basically a function of absolute infrastructure and seed development activity of plant (Pandey *et al*., 1991) [11]. The grain yield is a principal criterion for evaluating efficiency of various treatments because ultimate effects of experimental variables are reflected in the final crop yield. Grain and straw yield (kg ha^{-1}) of the aerobic rice was significantly influenced with precision nitrogen management practices (Table 1). Significantly higher grain yield was recorded with the application of nitrogen based on SPAD sufficiency index 96-100 per cent (7353 kg ha^{-1}) as compared to N recommended package of practices (6753 kg ha^{-1}). Which was found to be statistically on par with GreenSeeker based nitrogen management (7258 kg ha^{-1}), nitrogen management through SSNM for targeted yield of 8 t ha^{-1} (7006 kg ha-1) and STCR based N management for targeted yield of 8 t ha^{-1} (6911 kg ha^{-1}). Significantly lower grain yield was noticed in absolute control (2995 kg ha^{-1}). Significantly higher straw yield was noticed with nitrogen management through SPAD sufficiency index 96-100 per cent (9151 kg ha^{-1}) over absolute control (4576 kgha^{-1}) and was on par to all other treatments, followed by GreenSeeker based N management and N management through SSNM for targeted yield of 8 t ha^{-1} (9088 and 9025 kg ha^{-1}) (Table 1).

Rice grain yield is a manifestation of yield attributes *viz*., number of productive tillers per hill, higher panicle length, number of grains per panicle and 1000 grain weight. Significantly higher grain and straw yield was obtained with application of nitrogen based on SPAD sufficiency index 96-100 per cent. This was due to increased nitrogen fertilization up to panicle initiation stage, this could be attributed to higher uptake of nitrogen and efficient utilization of nitrogen by crop resulting in better vegetative growth and dry matter accumulation in source, then translocated to sink. This resulted in higher yield attributes like productive tillers per hill, filled grains per panicle, panicle length and panicle weight and these lead to higher grain yield (Khavita and Balasubramanian, 2008) [9]. Manzoor *et al*. (2006) [10] observed that there was increasing trend in plant height, productive tillers per hill, panicle length, grains per panicle, 1000 grain weight and rice grain yield with application of nitrogen from 0 kg N ha^{-1} up to 175 kg N ha^{-1}. The increased grain yield with nitrogen management through SPAD sufficiency index96-100 per cent was mainly due to superior yield parameters *viz*., number of productive tillers per hill (36.1), panicle length (24.5 cm), panicle weight(4.13 g panicle-1), 1000 seed weight (25.07 g), number of grains per panicle (168.9) and filled grains per panicle (156.8). These yield attributing parameters helped to get significantly higher grain yield. Higher yield attributes was attributed by higher plant height, increased number of tillers and higher total dry matter accumulation. Application of nitrogen in split doses using precision tools enabled to supply nitrogen in time to time, there by enhanced uptake of nitrogen in turn increased leaf area and leaf area index. This facilitated in higher drymatter production and better partitioning into reproductive parts due to higher photosynthetic activity resulted from better growth parameters of aerobic rice. This is inconformity with the findings of Bijay-Singh *et al*. (2002) [3], Ghosh *et al*. (2013) [6] and Suresh *et al*. (2017) [19]. The yield and yield parameter of the aerobic rice varied significantly due to difference in the growth parameters which were ultimately affected by time and levels of nitrogen applied. Since the economic yield is a portion of the total biological yield of crops, accumulation of total dry matter helps in enhancement of economical yield (Puneet Sharma, 2011) [14].

Assessment of straw yield in different treatments indicated that higher straw yield was observed with application of nitrogen in five splits based on SPAD sufficiency index 96-100 per cent, which was attributed to higher leaf area and total number of tillers resulting in elevated dry matter production. The lower grain and straw yield recorded in absolute control was in agreement with the results of Prabhudev *et al*. (2017) [13] who opined that low level of nutrients in soil lead to reduced growth and yield attributes. Significantly higher yield attributing components are directly influencing the superior grain yield.

3.1.1 Harvest index (HI): Harvest index indicates the percentage of dry matter partitioned and accumulated in the economic portion. Harvest index was crop genetic makeup and thus plant not altered with external management. The results revealed that, lower harvest index was recorded with absolute control (0.40). Higher harvest index value of (0.45) was registered with the application of nitrogen based on SPAD sufficiency index 96-100 per cent. This was mainly due to higher economic yield.

3.2 Effect of sensor-based precision nitrogen management on total nutrient uptake in aerobic rice

Results revealed that, precision nitrogen management though SPAD sufficiency index 96-100 per cent recorded more nutrient uptake than other treatments (Table 2). Application of nitrogen based SPAD sufficiency index 96-100 per cent was recorded significantly higher uptake of nitrogen, phosphorous and potassium (135.8, 23.04 and 117.7 kg ha^{-1}, respectively) over RDN applied as per package of practices (118.2, 19.94 and 104.4 kg ha^{-1}). However, it was on par with GreenSeeker based nitrogen management (131.3, 22.71 and 114.1 kg ha^{-1}), *nitrogen management through SSNM for targeted yield of 8 t ha^{-1} (127.1, 22.13, 111.4 kg ha^{-1}) and STCR based N management for targeted yield of 8 t ha^{-1} (125.4, 22.11 and 110.0 kg ha^{-1}) uptake of* nitrogen, phosphorous and potassium respectively . Significantly lower uptake of nitrogen, phosphorous and potassium by uptake was observed with absolute control (49.1, 8.50 and 48.5 kg ha^{-1}, respectively).

Application of nitrogen as per crop demand increased the growth attributes like plant height, number of tillers per hill, leaf area and dry matter accumulation ultimately higher biomass production due to higher uptake of nutrients. This increased the metabolic activity of the plant, leading to greater accumulation of dry matter and it's partitioning consequently the grain yield (Hussain *et al*., 2005) [8]. Higher grain yield related to higher photosynthetic efficiency, which was mainly attributed to higher nutrient uptake and assimilation in source and translocation to the sink. Nitrogen is a constituent of chlorophyll, proteins, enzymes, hormones, vitamins, alkaloid etc. Phosphorus is a constituent of sugars, phosphates, nucleotides, nucleic acids. Potassium is most important cation not only with regard to its content in plant tissue but also its role in physiological and biochemical functions in imparting drought tolerance in plants (Pushpa *et al*., 2007) [15]. Higher uptake of nitrogen, phosphorus and potassium registered with nitrogen applied based on SPAD sufficiency index 96-100 per cent with fixed dose of 25 kg N ha^{-1} in split doses up to panicle initiation stage was attributed to higher dry matter production and yield. Application of nitrogen at panicle initiation stage resulted in higher uptake of nitrogen compared to other treatments, wherein nitrogen was applied up to 45 and 60 DAS. Which helped in obtaining higher plant vigour and yield attributes coupled with more photosynthetically active leaf area. The present findings are in close association with the results observed by Shekara (2008) [18], Ghosh *et al*. (2013) [6], Anil *et al*. (2014) [1] and Suresh *et al*. (2017) [19].

3.3 Nitrogen use efficiency in aerobic rice as influenced precision nitrogen management practices

Nitrogen use efficiency (NUE) under different precision nitrogen management practices for aerobic rice was estimated in terms of recovery efficiency (RE), agronomic efficiency (AE) and physiological efficiency (Table 3). Nitrogen management through SPAD-35, N_{25} recorded significantly higher nitrogen use efficiency (84.48), recovery efficiency (76.43 per cent), agronomic efficiency (44.55) and physiological efficiency for applied nitrogen (58.29) than other treatments. It was mainly because of application of lower quantity nitrogen as per the crop demand and higher yield per unit quantity of nitrogen was reduced. Achievable levels of RE depend on crop demand for N, supply of N from indigenous sources, fertilizer rate, timing product and mode of application. Recovery efficiency depends on the congruence between plant demand and nutrient release from fertilizer and is affected by the application method (amount, timing, placement and N form) and factors that determine the size of the crop nutrient sink (genotype, climate, plant density and abiotic/biotic stresses *etc*.). Agronomic efficiency is a product of nutrient recovery from mineral or organic fertilizer (RE) and the efficiency with which the plant uses each additional unit of nutrient (PE). It depends on management practices that effect RE and AE. Peng and Cassman (1998) demonstrated that recovery efficiency of top-dressed urea during panicle initiation stage could be as by as 78 per cent. Higher recovery and agronomic efficiency values observed with the treatment SPAD-35, N_{25} based nitrogen management was due to application of lesser quantity of fertilizer nitrogen and higher grain yield per unit quantity of nitrogen.

3.4 Available nutrient status of soil after harvest of aerobic rice

Precision nitrogen management practices showed the significant influence on soil available nutrients status (Table 4**)**. Application of nitrogen based STCR for targeted yield of 8 t ha^{-1} was recorded significantly higher soil available nitrogen (334 kg N ha^{-1}) and application of nitrogen based on SPAD threshold 35 recorded higher available phosphorus and potassium (36.41 and 209 kg P_2O_5 & K_2O ha^{-1}, respectively). Significantly lower available N, P_2O_5 and K_2O kg ha^{-1} recorded with absolute control (269, 12.40 and 181 kg ha^{-1}, respectively).

Table 1: Grain yield, straw yield and harvest index of aerobic rice as influenced by precision nitrogen management practices

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
T_1: Nitrogen management through SPAD sufficiency index 90-95%	6859	8772	0.44
T_2: Nitrogen management through SPAD sufficiency index 96-100%	7353	9151	0.45
T_3: Nitrogen management through SPAD-35, N_{25}	6336	8520	0.43
T_4: Nitrogen management through SPAD-40, N_{25}	6848	8804	0.44
T_5: Green Seeker based nitrogen management	7258	9088	0.44
T_6: Nitrogen management through SSNM for targeted yield of 8 t ha^{-1}	7006	9025	0.44
T_7: STCR based N management for targeted yield of 8 t ha^{-1}	6911	8993	0.44
T_8: Recommended dose of N as per package of practices	6753	8615	0.44
T_9: Absolute control	2995	4576	0.40
S.Em+	161	304	0.01
CD at 5%	482	911	NS

SPAD: Soil Plant Analysis Development, SSNM: Site Specific Nutrient Management, STCR: Soil Test Crop Response

Table 2: Nitrogen, phosphorus and potassium uptake by aerobic rice as influenced by precision nitrogen management practices

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T_1: Nitrogen management through SPAD sufficiency index 90-95%	119.7	20.40	107.7
T_2: Nitrogen management through SPAD sufficiency index 96-100%	135.8	23.04	117.7
T_3: Nitrogen management through SPAD-35, N_{25}	106.4	18.99	101.2
T_4: Nitrogen management through SPAD-40, N_{25}	119.4	20.34	107.5
T_5: Green Seeker based nitrogen management	131.3	22.71	114.1
T_6: Nitrogen management through SSNM for targeted yield of 8 t ha^{-1}	127.1	22.13	111.4
T_7: STCR based N management for targeted yield of 8 t ha^{-1}	125.4	22.11	110.0
T_8: Recommended dose of N as per package of practices	118.2	19.94	104.4
T_9: Absolute control	49.1	8.50	48.3
S.Em+	4.7	1.26	3.7
CD at 5%	14.1	3.79	11.1

SPAD: Soil Plant Analysis Development, SSNM: Site Specific Nutrient Management, STCR: Soil Test Crop Response

Table 3: Nitrogen use efficiency (NUE), recovery efficiency (RE), agronomic efficiency (AE) of nitrogen and physiological efficiency (PE) as influenced by precision nitrogen management practices

Treatments	NUE (kg grain ka^{-1} N applied)	RE (%)	AE^{N} (kg grain ka^{-1} N applied)	PE (kg grain kg^{-1} N uptake)
T_1: Nitrogen management through SPAD sufficiency index 90-95%	68.59	70.55	38.64	54.77
T_2: Nitrogen management through SPAD sufficiency index 96-100%	42.02	49.53	24.90	50.28
T_3: Nitrogen management through SPAD-35, N_{25}	84.48	76.43	44.55	58.29
T_4: Nitrogen management through SPAD-40, N_{25}	68.48	70.27	38.53	54.83
T_5: Green Seeker based nitrogen management	58.07	65.74	34.11	51.88
T_6: Nitrogen management through SSNM for target of 8 t ha^{-1}	43.79	48.74	25.07	51.43
T_7: STCR based N management for target of 8 t ha^{-1}	47.66	52.59	27.01	51.36

T_8: Recommended dose of N as per package of practices	67.53	69.08	37.58	54.41
T_9: Absolute control	0.00	0.00	0.00	0.00
S.Em+	3.38	4.38	1.48	3.08
CD at 5%	10.14	13.12	4.45	9.23

SPAD: Soil Plant Analysis Development, SSNM: Site Specific Nutrient Management, STCR: Soil Test Crop Response

Table 4: Available nutrients in soil as influenced by precision nitrogen management practices after harvest of aerobic rice

Treatments	Nitrogen (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1: Nitrogen management through SPAD sufficiency index 90-95%	292	34.30	194
T_2: Nitrogen management through SPAD sufficiency index 96-100%	326	30.22	184
T_3: Nitrogen management through SPAD-35, N_{25}	286	36.41	209
T_4: Nitrogen management through SPAD-40, N_{25}	294	33.79	195
T_5: Green Seeker based nitrogen management	312	31.43	186
T_6: Nitrogen management through SSNM for targeted yield of 8 t ha^{-1}	328	33.21	187
T_7: STCR based N management for targeted yield of 8 t ha^{-1}	334	33.58	190
T_8: Recommended dose of N as per package of practices	289	35.32	196
T_9: Absolute control	269	12.40	181
S.Em+	13	1.37	194
CD at 5%	40	4.10	184

SPAD: Soil Plant Analysis Development, SSNM: Site Specific Nutrient Management, STCR: Soil Test Crop Response

4. Conclusion

Higher grain yield (7353 kg ha^{-1}), straw yield (9151 kg ha^{-1}) and harvest index (0.45) was recorded with the application of nitrogen based on SPAD sufficiency index 96-100 per cent as compared to RDN as per package of practices (42.21 g hill^{-1}, 6753, and 8615 kg ha^{-1}, respectively). Higher total uptake of nitrogen, phosphorus and potassium were also recorded with nitrogen management through SPAD sufficiency index 96-100 per cent (135.8, 23.04 and 117.7 kg ha^{-1}, respectively) as compared to RDN as per package of practices (118.2, 19.94 and 104.4 kg ha^{-1}, respectively). Higher recovery efficiency, agronomic efficiency of N and physiological efficiency were observed in nitrogen management through SPAD-35, N_{25} (76.43, 44.55 and 59.16 per cent, respectively).

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