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Influence of precision nitrogen management through crop sensors on growth and yield of aerobic rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted during *kharif* 2017 at Zonal Agricultural Research Station, UAS, Bengaluru in sandy loam soil. The experiment was laid out in RCBD with nine treatments, replicated thrice and cultivar used was MAS 946-1. The results revealed that nitrogen management through SPAD sufficiency index 96-100 per cent recorded significantly higher plant height (72.2 cm), number of tillers (45.8 hill^{-1}), leaf area (2813 cm^2 hill^{-1}), total dry matter (136.2 g hill^{-1}), higher productive tillers hill^{-1} (36.1), panicle length (24.5 cm), test weight (25.07 g) and total number of filled grains panicle^{-1} (156.8) with least chaffyness (8.42 %) ultimately resulted in higher grain (7353 kg ha^{-1}) and straw yield (9151 kg ha^{-1}). The nitrogen management through SPAD sufficiency index 96-100 per cent recorded higher gross returns (□ 124021 ha^{-1}) and net returns (□ 75062 ha^{-1}). Whereas, higher B: C ratio found with Green Seeker based nitrogen management (2.56).

Keywords: Precision nitrogen management, crop sensors, aerobic rice, Green Seeker

Introduction
Rice (*Oryza sativa* L.) is the world's most important major 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. It is third most important among the agricultural commodity with production of 741.5 m t after sugarcane and maize. India is the major rice producing country after china in the world and contributing about 20 per cent of world rice production. India stand first in rice cropped area (43.19 m ha) and second in production (110.15 m t) with productivity of 2550 kg ha^{-1}. In Karnataka rice is grown in an area of 1.01 m ha and production of 2.54 m t with a productivity of 2522 kg ha^{-1} (Anon., 2017) [1].

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. The blanket fertilizer recommendation consisting three split applications of preset rates of total fertilizer N during the growing season of aerobic rice is commonly used by the farmers for managing N fertilizer. Large field-to-field variability of soil N supply, agro-climatic conditions and varietal differences restrict efficient use of fertilizer N.

High grain yields can only be obtained by ensuring adequate nitrogen assimilation by plants in the course of growing season. It is the most widely used fertilizer nutrient in rice and its consumption has increased substantially during the past decades. However, the fertilizer N use efficiency by rice is very low as partial factor productivity has decreased exponentially since 1965. The main reason for low N use efficiency is inefficient splitting of N doses coupled with N applications in excess of crop requirements and extent of fertilizer N loss through leaching, ammonia volatilization and runoff loss. Sound N management practices need to be established and followed to improve N use efficiency, leading to higher grain yield levels and minimal fertilizer N loss to the environment.

In the mid-eighties and early nineties, the emphasis was shifted from reducing N losses to matching crop N demand with fertilizer N supply for achieving high N use efficiency (Buresh, 2007) and the research since then has been oriented more towards finding means and ways to apply fertilizer N in real-time using crop demand-driven and field-specific needs. 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) or by measuring absorbance of light in red wavelength using chlorophyll (SPAD) meter (Peng *et al.*, 1995) 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.

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. 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. 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.

The purpose of this study was to establishment of SPAD sufficiency index and SPAD threshold values in aerobic rice, which is a pre-requisite for managing SPAD guided need-based fertilizer N applications. To use optical sensors for guiding fertilizer N application, an attempt was made to establish threshold NDVI value using Green Seeker that may facilitate the growers to use of optical sensors for making instant fertilizer N application decisions and to improve growers' knowledge for effective nitrogen (N) management. The overall goal is to improve the nitrogen use efficiency and increase crop productivity in a sustained manner. Keeping these above facts, the present study was conducted to standardize the precision nitrogen management practices using crop sensors and to know their effects on growth and yield of aerobic rice.

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 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 includes, 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 thereby lateral spacing of 60 cm was fixed. There were 17 aerobic rice rows at a distance of 25 cm apart in each treatment extending to 4.25 m length. 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 Green Seeker 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 SSNM and STCR 50 per cent of the nitrogen was applied as basal and the balance 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 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. Weed managed with one hand weeding at 25 DAS followed by inter cultivation to control the weeds. Plant population was maintained in all the treatments by thinning out of excess seedlings at 15 DAS and leaving one seedling per spot. Healthy crop stand was ensured by adopting need-based crop protection and recommended packages of practices. Five plants were selected at random and tagged. These plants were used for recording plant height (cm), number of tillers, leaf area, leaf area index and dry matter accumulation. Leaf area was measured using leaf area meter and LAI was calculated as ratio of leaf area per plant to area occupied by the plant. Yield attributes like, number of productive tillers, panicle length, panicle weight, test weight, number of grains per panicle, number of filled grains per panicle, grain and straw yield were recorded. The data was statistically analyzed by following standard procedure (Gomez and Gomez, 1984) [6].

Results and Discussion

Growth parameters of aerobic rice

Growth parameters of aerobic rice were significantly influenced by precision nitrogen management practices (Table 1). Significantly higher plant height (72. cm), maximum number of tillers (45.8 $hill^{-1}$), leaf area (2813 cm^2 $hill^{-1}$), LAI (4.50) and total dry matter production (136.2 g $plant^{-1}$) at harvest were recorded in treatment receiving nitrogen management through SPAD sufficiency index 96-100 per cent and it was found on par with Green Seeker based nitrogen management, nitrogen management through SSNM for targeted yield of 8 t ha^{-1}. Similar trend was observed with plant height, number of leaves, leaf area, LAI and total dry matter production. SPAD reading recorded significantly higher in nitrogen management through SPAD sufficiency index 96-100 per cent (45.5) and it was on par with Green Seeker based nitrogen management (43.5) at 75 DAS compared to other treatments. Significantly lower growth parameters were recorded in absolute control.

An optimum plant height is claimed to be positively correlated with productivity of plant. The plant height helps to increase the dry matter production and was increased with successive increase in nutrient levels required to achieve the higher grain yield. The increased plant height was due to synchrony in application of nitrogen with crop nitrogen demand which resulted increased cell division and elongation which increased inter nodal length in turn higher plant height. Similar observations were made by Puneet Sharma (2011) [13] and Suresh *et al*. (2017) [14]. Leaf area increased due to synchronization of applied nitrogen between crop demand and supply leads to development of more and more chlorophyll pigments. This in turn increases specific leaf weight and resulted in higher light interception, root development, leaves development and plant height resulted in better dry matter production and distribution in the plant parts especially in panicles and better yield and yield components. These results are in conformity with the findings of El-habbal *et al.* (2010) [4] in wheat and Ghosh *et al*. (2013) [5] in rice. Increased SPAD readings was due to application of nitrogen synchronizing with crop demand enhanced growth, leaf turgidity as well as chlorophyll content and improved the efficiencies of applied fertilizers. The results are in accordance with the findings of Nagarjun (2015) [11] in maize and Suresh *et al*. (2017) [14] in rice. The chlorophyll content regulates the photosynthetic efficiency. Application of nitrogen based on SPAD sufficiency index 96-100 per cent increased the SPAD chlorophyll meter readings and NDVI values. Increase in SPAD chlorophyll meter readings indicates production of appreciable amount of chlorophyll in the leaves. These results were also in conformity with Maiti (2004) [9], Yinkun *et al*. (2014) [15] and Bijay-Singh *et al*. (2015) [2].

This increase in total dry matter was due to higher growth parameter *viz*., plant height, more number of tillers and enhanced photosynthetic leaf area. This is achieved due to synchronization of applied nitrogen between crop demand and supply which involves in chlorophyll synthesis there by higher synthesis of more chlorophyll pigments. Similar findings were also reported by Hussain *et al.* (2005) [7].

Yield and yield attributes of aerobic rice

Yield attributes like, number of productive tillers per hill, panicle length, panicle weight, test weight, number of grains per panicle, number of filled grains per panicle as well as grain yield and straw yield of aerobic rice were favorably influenced by precision nitrogen management practices (Table 2).

The data revealed that, application of nitrogen based on SPAD sufficiency index 96-100 per cent recorded significantly higher number of productive tillers per hill (36.1), panicle length (24.5 cm), panicle weight (4.13 g), test weight (25.07 g), number grains per panicle (168.9) and filled grains per panicle (156.8) as compared to rest of the treatments and it was on par with Green Seeker based nitrogen management (34.9, 24.1 cm, 4.00 g, 25.03 g, 164.4 and 150.0, respectively), nitrogen management through SSNM for targeted yield of 8 t ha^{-1} (33.5, 23.8 cm, 3.90 g, 25 g, 162.6 and 147.8, respectively) and STCR based nitrogen management for the targeted yield of 8 t ha^{-1} (33.1, 23.4 cm, 3.87 g, 24.90 g, 157.7 and 143.1, respectively). Absolute control recorded significantly lower number of productive tillers per hill (18.6), panicle length (19.3 cm), panicle weight (1.87 g), test weight (22.53 g), number grains per panicle (90.6) and filled grains per panicle (76.7). The results are in conformity with the findings of Khavita and Balasubrananian (2008) [8], Puneet Sharma (2011) [13], Bijay-Singh *et al*. (2015) [2] and Suresh *et al*. (2017) [14]. The elevated values of yield attributing characters could be ascribed to the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency for photosynthates to sink. This higher yield attributes under precision nutrient management practices were further due to improved growth attributes viz., plant height, number of tillers, leaf area and SPAD values which reflected in significantly higher total dry matter accumulation.

The data on grain yield (Table 3) revealed that, significantly higher grain yield (7353 kg ha^{-1}) was recorded with the application of nitrogen based on SPAD sufficiency index 96-100 per cent and it was on par with Green Seeker 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 nitrogen management for the targeted yield of 8 t ha^{-1} (6911 kg ha^{-1}). Significantly lower grain yield of 2995 kg ha^{-1} was recorded with absolute control. Similar trend was noticed with respect to straw yield.

Significantly higher grain yield of aerobic rice in precision nitrogen management practices was mainly due to superior yield parameters (Table 2) *viz*., number of productive tillers hill^{-1} (36.1), panicle length (24.5 cm), panicle weight (4.13 g panicle^{-1}), 1000 seed weight (25.07 g), number of grains panicle^{-1} (168.9) and filled grains panicle^{-1} (156.8). These yield attributing parameters helped to get higher grain yield (Table 2). Puneet Sharma (2011) [13], Ghosh *et al*. (2013) [5], Prabhudev *et al*. (2017) [12] and Suresh *et al*. (2017) [14]. The enhanced values of yield attributing characters could be ascribed to the tendency of nitrogen in accelerating growth, photosynthetic activity and translocation efficiency for photosynthates. Further, higher grain and straw yield of aerobic rice was mainly due to better translocation of photosynthates from source to sink and higher growth attributing characters like more number of tillers, leaf area and higher dry matter production and its accumulation into different parts of plant and yield attributing characters like, number of productive tillers hill^{-1}, panicle weight, test weight and more number of filled grains panicle^{-1} with less chaffy grains. These results are in accordance with the findings of Ghosh *et al*. (2013) [5] and Suresh *et al*. (2017) [14] who indicated that application of nutrients based on crop demand enhanced the productivity of rice. Mohanty *et al.* (2015) [12], Ramanjit *et al*. (2015) [11] who reported that, GreenSeeker based nitrogen management practices recorded significantly higher yield and yield attributes in rice, cotton, sweet corn and maize, respectively.

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 kg ha^{-1}) and was on par to all other treatments, followed by Green Seeker based nitrogen management and nitrogen management through SSNM for targeted yield of 8 t ha^{-1} (9088 and 9025 kg ha^{-1}) (Table III). Higher straw yield mainly due to higher growth parameter *viz*., plant height, number of tillers, leaf area per hill and higher total dry matter production per hill (Table I).

In the present investigation harvest index did not found to be significantly differed due to precision nitrogen management practices (Table 3). However, a higher value of harvest index (0.45) was observed in nitrogen management through SPAD sufficiency index 96-100 per cent as compared to absolute control (0.40).

Application of nitrogen based on SPAD sufficiency index 96-100 per cent besides providing higher grain yield was also recorded higher net returns (□ 75062 ha^{-1}), however higher B:C ratio was obtained in Green Seeker based nitrogen management. Higher net returns mainly due to higher grain and straw yield than compared to rest of the treatments, however due to higher labor wages and cost incurred in urea which pose to lower B:C ratio (2.53) than compared to Green Seeker based nitrogen management (2.56).

From the study, it can be concluded that nitrogen management through SPAD sufficiency index 96-100 per cent, Green Seeker based nitrogen management and precision nitrogen management through SSNM and STCR for targeted yield of 8 t ha^{-1} are the best precision nitrogen management practices in aerobic rice for realizing higher grain yield.

Table 1: Growth parameters of aerobic rice at harvest as influenced by precision nitrogen management practices

Treatments	Plant height (cm)	Number of tillers hill^{-1}	Leaf area (cm^2 hill^{-1})	LAI	Dry matter production (g hill^{-1})	SPAD readings	Green Seeker (NDVI)
T$_1$	66.1	40.5	2113	3.38	120.6	41.8	0.67
T$_2$	72.2	45.8	2813	4.50	136.2	45.5	0.74
T$_3$	62.3	37.1	1707	2.73	103.7	37.9	0.63
T$_4$	66.0	40.3	2042	3.27	120.0	41.2	0.67
T$_5$	70.6	45.0	2787	4.46	133.9	43.5	0.73
T$_6$	69.4	44.4	2685	4.30	129.9	43.3	0.72
T$_7$	68.8	44.0	2607	4.17	128.4	42.9	0.70
T$_8$	65.3	39.9	1966	3.15	117.2	41.6	0.68
T$_9$	50.3	26.3	721	1.15	72.0	36.1	0.53
S.Em$\pm$	2.0	1.8	79	0.13	4.0	1.0	0.02
CD at 5%	5.9	5.3	237	0.38	12.1	3.1	0.05

T$_1$: Nitrogen management through SPAD sufficiency index 90-95 %
T$_2$: Nitrogen management through SPAD sufficiency index 96-100 %
T$_3$: Nitrogen management through SPAD-35, N$_{25}$
T$_4$: Nitrogen management through SPAD-40, N$_{25}$
T$_5$: GreenSeeker 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
T$_9$: Absolute control

Table 2: Yield attributes aerobic rice as influenced by precision nitrogen management practices

Treatments	Number of productive tillers hill^{-1}	Panicle length (cm)	Panicle weight (g)	1000 seed weight (g)	Number of grains panicle^{-1}	Number of filled grains panicle^{-1}
T$_1$	29.9	22.9	3.70	24.69	152.0	134.9
T$_2$	36.1	24.5	4.13	25.07	168.9	156.8
T$_3$	25.3	21.6	3.38	23.57	133.6	113.1
T$_4$	28.9	22.7	3.69	24.67	151.4	133.6
T$_5$	34.9	24.1	4.00	25.03	164.4	150.0
T$_6$	33.5	23.8	3.90	25.00	162.6	147.8
T$_7$	33.1	23.4	3.87	24.90	157.7	143.1
T$_8$	27.2	22.6	3.59	24.33	148.3	131.6
T$_9$	18.6	19.3	1.87	22.53	90.6	76.7
S.Em$\pm$	1.3	0.4	0.10	0.50	4.7	5.0
CD at 5%	3.9	1.2	0.29	1.51	14.0	14.8

T$_1$: Nitrogen management through SPAD sufficiency index 90-95 %
T$_2$: Nitrogen management through SPAD sufficiency index 96-100 %
T$_3$: Nitrogen management through SPAD-35, N$_{25}$
T$_4$: Nitrogen management through SPAD-40, N$_{25}$
T$_5$: GreenSeeker 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
T$_9$: Absolute control

Table 3: Grain, straw yield, harvest index (HI) and economics of aerobic rice as influenced by precision nitrogen management practices

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI	Goss returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
T$_1$	6859	8772	0.44	116043	68407	2.44
T$_2$	7353	9151	0.45	124021	75062	2.53
T$_3$	6336	8520	0.43	107820	60691	2.29
T$_4$	6848	8804	0.44	115926	68290	2.43
T$_5$	7258	9088	0.44	122502	74558	2.56
T$_6$	7006	9025	0.44	118627	70253	2.45
T$_7$	6911	8993	0.44	117154	69164	2.44
T$_8$	6753	8615	0.44	114217	66781	2.41
T$_9$	2995	4576	0.40	51789	18096	1.54
S.Em$\pm$	161	304	0.01	NA	NA	NA
CD at 5%	482	911	NS			

T$_1$: Nitrogen management through SPAD sufficiency index 90-95 %
T$_2$: Nitrogen management through SPAD sufficiency index 96-100 %
T$_3$: Nitrogen management through SPAD-35, N$_{25}$
T$_4$: Nitrogen management through SPAD-40, N$_{25}$
T$_5$: GreenSeeker 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
T$_9$: Absolute control

Conclusion

Application of nitrogen based on SPAD sufficiency index 96-100 per cent helped in obtaining higher grain yield, straw yield and net returns. However, benefit cost ratio found more in case of Green Seeker based nitrogen management due to reduced cost incurred in nitrogen fertilizer.

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