Effect of site specific nitrogen management on grain quality and productivity of *kharif* rice

Abstract

A field study was carried out during *kharif* at the Agronomy Main Research Farm, Department of Agronomy, College of Agriculture, OUAT, Bhubaneswar with the crop rice. The experiment was laid out in randomized complete block design with twelve site specific nitrogen management practices i.e. T_1-RDF (80:40:40 kg N:P_2O_5:K_2O ha^{-1}),T_2 - 20 kg N ha^{-1} at LCC score <4 with no basal N,T_3 - 20 kg N ha^{-1} at LCC score <4 with 20 kg N ha^{-1} at basal,T_4 - 20 g N ha^{-1} at SPAD value <35 with no basal N, T_5- 20 kg N ha^{-1} at SPAD value <35 with 20 kg N ha^{-1} at basal, T_6- 20 kg N ha^{-1} at Green seeker (GS) >1.25 RI with no basal N, T_7- 20 kg N ha^{-1} at Green seeker (GS) >1.25 RI with 20 kg N ha^{-1} at basal, T_8- 150 kg N ha^{-1} (N rich strip plot), T_9- N omission plot, T_{10}- STBN, T_{11}- INM (20 kg N ha^{-1} as FYM at basal + 40 kg N ha^{-1} at tillering + 20 kg N ha^{-1} at PI stage), T_{12}- Organic nutrient (FYM 10t ha^{-1} at basal + 2t ha^{-1} VC top dressing). The result of the experiment revealed thatprotein and carbohydrate yield were higher with application of 20 kg N ha^{-1} at Green seeker (GS) >1.25 RI with 20 kg N ha^{-1} at basal (410.4 and 4135.1 kg ha^{-1}, respectively) followed by the treatment receiving 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal(395.5 and 3977.2 kg ha^{-1}, respectively). Application of 20 kg N ha^{-1} at Green seeker (GS) >1.25 RI with 20 kg N ha^{-1} at basal recorded significantly higher grain yield (5.68 t ha^{-1}), straw yield (6.57 t ha^{-1}) and harvest index (47 %) followed by 20 kg N ha^{-1} at SPAD value <35 with 20 kg N ha^{-1} at basal.

Key words: LCC, SPAD, Green seeker, INM, STBN, Protein and Carbohydrate

1. Introduction

Rice *(Oryza sativa* L.) is the staple food for more than half of the world's population. About 90% of rice grown in the world is produced and consumed in the Asia-Pacific Region. India is the second highest rice producing countries of the world after China.

Nitrogen, an important major nutrient for crop growth, plays a crucial role in determining crop productivity. Adequate nitrogen supply stimulates the synthesis of chlorophyll, the green pigment responsible for photosynthesis. Chlorophyll captures sunlight and converts it into energy, enabling plants to produce carbohydrates and support vegetative growth. It is a critical component of photosynthetic machinery, as it is required for the synthesis of proteins and enzymes involved in photosynthesis.

Among various reasons for the low productivity, inefficient utilization of nitrogen is considered to be the most leading factor. With rice yield increasing, the rate of chemical fertilizer applied especially nitrogen is continuously increasing. Nitrogen use rate has become too high and nitrogen use efficiency (NUE) has come down to low. The majority of farmers in India apply nitrogen fertilizer as blanket recommendations of 60–120 kg N ha^{-1} or higher. Novel N-management techniques based on leaf priorities are introduced in different premier rice research institutes for real-time N management different types of decision support tools, such as the leaf color chart (LCC), soil plant analysis development (SPAD) chlorophyll meter and Green Seeker (GS) optical sensors have been introduced. By implementing site-specific nitrogen management strategies, farmers can optimize nitrogen application rates based on the specific needs of different areas within a rice field. This approach takes into account factors such as soil fertility, crop demand, and environmental conditions, allowing for more precise and efficient nitrogen fertilizer application. Adequate nitrogen availability in the soil promotes the production of proteins in plants, leading to higher protein content in the grain. Conversely, insufficient nitrogen supply can limit protein synthesis, resulting in lower protein content.Carbohydrates, such as starches and sugars, are also influenced by nitrogen availability. Nitrogen affects the balance between vegetative and reproductive growth in plants. When nitrogen is limited, plants tend to allocate more resources to grain production, leading to higher carbohydrate content in the grain. Conversely, excessive nitrogen can stimulate vegetative growth at the expense of grain filling, resulting in lower carbohydrate content. So, optimal use nitrogen fertilizer can lead to improved grain quality, with higher protein content and well-developed carbohydrate reserves, which are essential for various food and feed applications.Also, properly managing nitrogen application based on site-specific factors such as soil nutrient levels, crop requirements and growth stages can result in increased rice productivity.Therefore, the field experiment on "Effect of site specific nitrogen management on grain quality and productivity of *kharif* rice" was conducted for monitoring crop responses with the objective of improve grain quality and productivity.

2. Materials and methods

The present investigation entitled "Effect of site specific nitrogen management on grain quality and productivity of *kharif* rice" was conducted during the *kharif* season of 2021 and 2022 (consecutively for two years) at Agronomy Main Research Farm of Odisha University of Agriculture and Technology, Bhubaneswar, Odisha. The soil of the experimental site was acidic and sandy loam in texture, low in available nitrogen (194.3 kg ha^{-1}) and organic carbon (0.53 %), medium in available phosphorus (18.3 kg ha^{-1}) and medium in available potassium (185.3 kg ha^{-1}) with *p*H of 5.82 and EC of 0.21 dSm^{-1}. The rice variety was taken MTU-1075 (Pushyami).Treatments consisted of twelve site specific nitrogen management practices in *kharif* rice i.e. T_1 - RDF (N_2:P_2O_5:K_2O::80:40:40 kg ha^{-1}), T_2 - 20 Kg N ha^{-1} at LCC score <4 with no basal N, T_3 - 20 Kg N ha^{-1} at LCC score <4 with 20 Kg N ha^{-1} at basal, T_4 - 20 Kg N ha^{-1} at SPAD value <35 with no basal N, T_5- 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal, T_6- 20 Kg N ha^{-1} at Green seeker (GS) >1.25 RI with no basal N, T_7- 20 Kg N ha^{-1} at Green seeker (GS) >1.25 RI with 20 Kg N ha^{-1} at basal, T_8- 150 Kg N ha^{-1}(Sufficient level of N2), T_9- nitrogen omission plot, T_{10}- STBN (N_2:P_2O_5:K_2O::100:40:40 kg ha^{-1}), T_{11}- integrated nutrient management (20 Kg N as FYM at basal + 40 Kg N at tillering + 20 kg N at PI stage) and T_{12}- organic nutrient management (FYM 10t ha^{-1} at basal + 2t ha^{-1} VC top dressing). The experiment was conducted in randomized complete block design for rice with three replications.

2.1 Estimation of protein content and protein yield

Protein content in grain of paddy was calculated by multiplying the nitrogen content of grain with a factor 6.25 (Tsen and Martin, 1971). Protein yield was measured by multiplying protein content (%) with grain yield of rice and expressed in kg ha^{-1}.

2.2 Carbohydrate content and yield

The iodine colorimetric method was used for estimating the carbohydrate content, specifically starch, in rice grains. The starch present in rice grain reacted with iodine and resulting in the formation of a blue-black complex.After the colorimetric reaction, the absorbance of the complex was measured at a wavelength 620 nm using a spectrophotometer. This starch concentration was converted to carbohydrate content value by considering the conversion factor 0.85 for starch to carbohydrates. Carbohydrateyield was measured by multiplying Carbohydratecontent (%) with grain yield of rice and expressed in kg ha^{-1}.

2.3 Grain and straw yield

The crop was harvested on maturity (80-85% of the grains turned straw yellow) from the net plot leaving the border plants of 0.5 m in each end and 2 rows from each side. The produce of individual net plot was left in the field for drying for three days and then threshed separately treatment wise. The grain and straw yields were recorded after final sun drying for 3-4 days to maintain moisture content of about 10% in grains and 14% in straw. The values were converted to ton ha^{-1}.

2.4 Harvest index (HI)

It denotes the ratio of economic yield (grain yield) to biological yield (grain + straw) as per Donald and Hamblin (1976).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t/ ha)}}{\text{(Grain + straw yield)(t/ha)}} \text{X } 100$$

3. Results and discussion

Observations on protein and carbohydrate content, protein and carbohydrate yield and productivity of rice in *kharif* were taken during course of study. The detailed experimental findings of "Effect of site specific nitrogen management on grain quality and productivity of *kharif* rice" on above mentioned characters are given below

3.1 Protein content

Results of protein content of rice are presented in Table 1 and fig 1. Among different sitespecific nitrogen management practices to rice, nitrogen omission plot resulted significantly superior crude protein content (7.78 and 7.68 %) in both the years of experiment followed by the treatment receiving organic nutrient (7.68 and 7.64 %),150 Kg N ha^{-1} (7.72 and 7.54 %) and RDF (7.55 and 7.47 %) in 2021 and 2022 respectively. Pooled analysis suggested that nitrogen omission plot recorded higher protein content by 2.9 and 6.9 % over RDF and STBN.Lowest protein content was found in the treatment receiving 20 Kg N ha^{-1}at LCC score <4 with 20 Kg N

ha^{-1}at basal (7.06,7.14 and 7.10 % in 2021, 2022 and pooled analysis respectively).This result was in conformity with Choudhury and Kennedy, 2004.

Table 1. Protein content and Carbohydrate content in grain of rice as influenced by Site specific nitrogen management

Treatments	Protein content (%)			Carbohydrate content (%)		
	2021	2022	Pooled	2021	2022	Pooled
RDF	7.55	7.47	7.51	71.32	71.22	71.27
LCC BN-0	7.46	7.41	7.44	70.71	71.97	71.34
LCC BN-20	7.06	7.14	7.10	73.91	73.76	73.84
SPAD BN-0	7.44	7.38	7.41	72.40	71.24	71.82
SPAD BN-20	7.11	7.21	7.16	71.98	72.12	72.05
GS BN-0	7.31	7.32	7.32	72.06	71.93	72.00
GS BN-20	7.07	7.22	7.15	71.46	72.61	72.04
N-150	7.72	7.54	7.63	70.65	70.76	70.71
N-0	7.78	7.68	7.73	68.83	69.12	68.98
STBN	7.20	7.35	7.28	71.86	71.91	71.89
INM	7.12	7.22	7.17	72.08	71.96	72.02
ORGANIC	7.68	7.64	7.66	70.10	70.52	70.31
SEm (±)	0.157	0.146	0.153	0.330	0.351	0.334
CD (0.05)	0.46	0.43	0.45	0.97	1.03	0.98

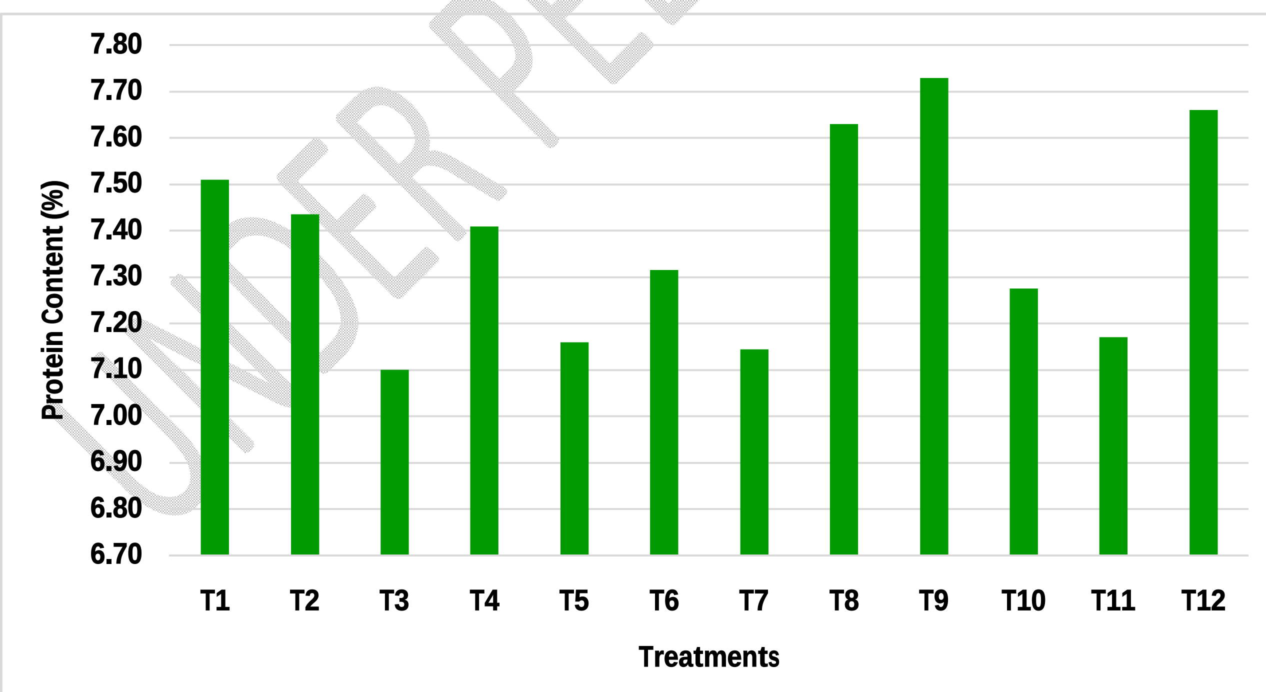

Fig 1. Protein content in grain of rice as influenced by Site specific nitrogen management

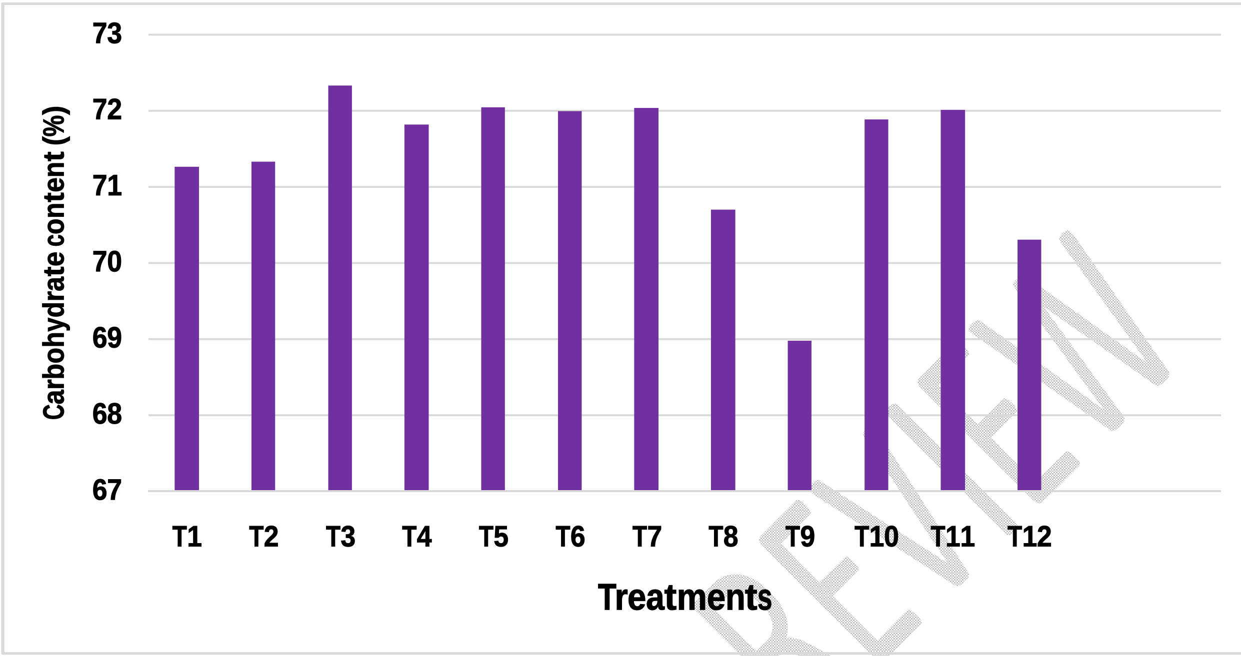

Fig 2. Carbohydrate content in grain of rice as influenced by Site specific nitrogen management

3.2 Carbohydrate content

Results of carbohydrate content of rice are presented in Table 1 and fig 2. Among different site specific nitrogen management practices to rice, application of 20 Kg N ha^{-1} at LCC score <4 with 20 Kg N ha^{-1} at basal resulted significantly superior carbohydrate content (73.91 and 73.76 %) in both the years of experiment followed by the treatment receiving 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal (71.98 and 72.12 %), 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with 20 Kg N ha^{-1} at basal (71.46 and 72.61 %) and INM (71.96 and 72.02 %) in 2021 and 2022 respectively. Pooled analysis suggested that application of 20 Kg N ha^{-1} at LCC score <4 with 20 Kg N ha^{-1} at basal resulted higher carbohydrate content by 3.6 and 2.7 % over RDF (N_2:P_2O_5:K_2O::80:40:40 kg ha^{-1}) and STBN (N_2:P_2O_5:K_2O::100:40:40 kg ha^{-1}). Lowest carbohydrate content was found in the nitrogen omission plot (68.83, 69.12 and 68.98 %) in 2021, 2022 and pooled analysis respectively)(Mohanta*et al.*, 2021).

Table 2. Protein yield and carbohydrate yield in grain of rice as influenced by Site specific nitrogen management

Treatments	Protein yield (kg ha^{-1})			Carbohydrate yield (kg ha^{-1})		
	2021	2022	Pooled	2021	2022	Pooled
RDF	336.7	351.8	344.7	3180.9	3354.5	3271.3
LCC BN-0	353.6	366.8	360.8	3351.7	3562.5	3460.0
LCC BN-20	357.9	373.4	365.7	3747.2	3857.6	3802.8
SPAD BN-0	360.1	372.0	366.1	3504.2	3590.5	3547.9
SPAD BN-20	385.4	404.5	395.2	3901.3	4045.9	3977.2
GS BN-0	357.5	372.6	365.3	3523.7	3661.2	3592.8
GS BN-20	401.6	419.5	410.4	4058.9	4218.6	4135.1
N-150	332.7	327.2	330.4	3045.0	3071.0	3061.7
N-0	242.0	201.2	221.9	2140.6	1810.9	1979.7
STBN	360.7	364.6	363.3	3600.2	3566.7	3587.3
INM	373.8	387.0	380.7	3784.2	3857.1	3824.3
ORGANIC	280.3	306.4	293.4	2558.7	2827.9	2692.9
SEm (±)	6.21	5.36	6.48	86.52	72.37	77.45
CD (0.05)	18.4	15.7	19.1	253.1	212.8	225.6

3.4 Protein yield

Data on protein and carbohydrate yield influenced by site specific nitrogen management practices are depicted in Table 2. Among various nitrogen management practices, higher protein yield (401.6 and 419.5 kg ha^{-1}) was recorded by application of application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal closely followed by 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal(385.4 and 404.5 kg ha^{-1}) in 2021 and 2022, respectively. Pooled analysis showed that application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal had 84.9% increase in protein yield over nitrogen omission plot which gave the lowest values during both years of study.Studies had shown that moderate nitrogen fertilization can increase the protein content of rice grains, while excessive nitrogen application can have a negative effect on protein content (Chen *et al.*, 2020). Similarly, carbohydrate yield was recorded highest (4058.9 and 4218.6 kg ha^{-1}) with the application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal in 2021 and 2022, respectively. Pooled analysis showed that application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal gave 26.4 and 15.3% more carbohydrate yield than RDF and STBN, respectively. Nitrogen omission plot had the lowest carbohydrate yield (1979.7 kg ha^{-1}). Studies had shown that Green seeker based nitrogen management provided the right amount of nitrogen precisely when it was needed, supporting the energy demands for carbohydrate synthesis, transport, and storage in developing rice grains. This optimization of grain filling could positively impact carbohydrate yield(Mohanta*et al.*, 2021).

3.5 Grain yield

Data with respect to grain yield as influenced by different site specific nitrogen management treatments are depicted in Table 3. The results showed that different treatments had significant impact on grain yield during both the years of experiment and pooled analysis. The treatment receiving application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal recorded significantly higher grain yield (5.68 and 5.81 t ha^{-1}) than any other treatments and was at par with application of 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal(5.42 and 5.61 t ha^{-1}) in 2021 and 2022, respectively. Pooled analysis showed that significantly higher grain yield (5.74 t ha^{-1}) resulted from application of 20 Kg N ha^{-1} at GS >1.25 Response index with 20 Kg N ha^{-1} at basal over all other treatment. Further results showed that the treatment receiving 20 Kg N ha^{-1}at SPAD value <35 with 20 Kg N ha^{-1}at basal and INM (20 Kg N as FYM at basal + 40 Kg N at tillering + 20 kg N at PI stage) were at par with each other. There were 25.1, 15.0, 8.1 and 49.9 % increase in grain yield of 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with 20 Kg N ha^{-1} at basal over RDF, STBN, INM plot and organic nutrient management plot, respectively. Lowest values were obtained from the treatment receiving nitrogen omission plot during both years of study and pooled analysis. Studies have shown that green seeker-based nitrogen management can lead to higher grain yields than the recommended dose of fertilizer. The reason behind the higher grain yield in green seeker-based nitrogen management is that it allows for more precise application of nitrogen fertilizer, reducing the risk of over-fertilization or under-fertilization. Over-fertilization can lead to nitrogen leaching, which can contaminate groundwater and surface water, while under-fertilization can result in reduced crop yield. Green seeker technology allows farmers to apply the right amount of nitrogen fertilizer at the right time, leading to better crop growth and higher yields (Franzen *et al.*, 2010, Singh *et al.*, 2018, Mandal *et al.*, 2019 and Baral*et al.*, 2021). Further results showed that the treatment receiving 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal and INM (20 Kg N as FYM at basal + 40 Kg N at tillering + 20 kg N at PI stage) were at par with each other. The reason behind the similar grain yield in SPAD-based nitrogen management and INM is that both approaches aim to optimize nitrogen management based on the plant's nitrogen status. SPAD technology allows farmers to measure the plant's nitrogen status in real-time, enabling them to adjust the nitrogen application rate accordingly. INM, on the other hand, combines various nitrogen management methods to optimize the availability and utilization of nitrogen by the plant. Both approaches aim to provide the plant with the right amount of nitrogen at the right time, leading to better crop growth and yield. This result is supported by Lafond *et al.*, 2008and Chen *et al.*, 2020.

3.6 Straw yield

Data on straw yield presented in Table 3, indicated that different site specific nitrogen management influenced straw yield of rice during both the years of study and in pooled analysis. Significantly higher straw yield (6.48 and 6.57 t ha^{-1}) in 2021 and 2022, respectively, were observed due to application of 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with 20 Kg N ha^{-1} at basal than any other treatments and were at par with 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal (6.35 and 6.54 t ha^{-1}), in respective years. Pooled analysis revealed that significantly higher straw yield (6.57 t ha^{-1}) was recorded due to application of 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with 20 Kg N ha^{-1} at basal which was 16.3, 8.1and 22.8 % higher than RDF, STBN and organic management, respectively. This may be due to green seeker technology allows farmers to measure the plant's nitrogen status in real-time and adjust the nitrogen application rate accordingly, leading to better nitrogen use efficiency and plant growth. RDF, SPAD-based nitrogen management, and INM, on the other hand, may result in over or under application of nitrogen, leading to suboptimal plant growth and lower straw yield (Singh *et al.*, 2011and Liu *et al.*, 2016).

Table 3. Grain yield and straw yield of rice as influenced by Site specific nitrogen management

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			HI (%)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
RDF	4.46	4.71	4.59	5.62	5.68	5.65	44.2	45.3	44.8
LCC BN-0	4.74	4.95	4.85	5.76	5.89	5.83	45.1	45.7	45.4
LCC BN-20	5.07	5.23	5.15	6.22	6.32	6.27	44.9	45.3	45.1
SPAD BN-0	4.84	5.04	4.94	5.72	5.94	5.83	45.8	45.9	45.9
SPAD BN-20	5.42	5.61	5.52	6.35	6.54	6.45	46.0	46.2	46.1
GS BN-0	4.89	5.09	4.99	5.87	6.14	6.01	45.4	45.3	45.4
GS BN-20	5.68	5.81	5.74	6.48	6.65	6.57	46.7	46.6	46.7
N-150	4.31	4.34	4.33	6.33	6.38	6.36	40.5	40.5	40.5

N-0	3.11	2.62	2.87	4.23	4.31	4.27	37.7	37.8	37.8
STBN	5.01	4.96	4.99	6.04	6.12	6.08	45.3	44.8	45.1
INM	5.25	5.36	5.31	6.24	6.33	6.29	45.7	45.9	45.8
ORGANIC	3.65	4.01	3.83	5.24	5.45	5.35	42.4	43.6	43.0
SEm (±)	0.12	0.08	0.11	0.09	0.07	0.06	0.31	0.28	0.28
CD (0.05)	0.35	0.24	0.34	0.26	0.21	0.17	0.91	0.84	0.83

3.7 Harvest index

Data on harvest index of rice is presented in Table 3. Among various site specific nitrogen management practices followed, significantly higher harvest index (46.7 and 46.6 %) was recorded with application of 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with 20 Kg N ha^{-1} at basal and was at par with application of 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal and application of 20 Kg N ha^{-1} at Green seeker (GS) >1.25 Response index with no basal N in 2021 and 2022. Lowest harvest index was obtained from nitrogen omission plot (37.7 and 37.8 %) in respective years. One possible reason for the higher harvest index in green seeker-based nitrogen management is the improved plant nitrogen use efficiency. Green seeker technology allows farmers to measure the plant's nitrogen status in real-time and adjust the nitrogen application rate accordingly, leading to better nitrogen use efficiency and plant growth. This may result in a higher proportion of the plant's biomass being allocated to the grain, leading to higher harvest index. This result is in conformity with Liu *et al.*, 2016 and Swamy *et al.*, 2016.

4. Conclusion

From the above study, it is concluded that site specific nitrogen management consisting of 20 kg N ha^{-1} as basal along with application of 20 kg N ha^{-1} as per Green seeker value (> 1.25 Response index) combined with phosphorus and potassium based on soil test recommendation, produced the maximum protein yield (410.4 kg ha^{-1}), Carbohydrate yield (4135.1 kg ha^{-1}),grain yield of 5.74 t ha^{-1}, straw yield of 6.57 t ha^{-1} with harvest index 47% and highest protein and carbohydrate yield (410.4 and 4135.1 kg ha^{-1}, respectively).

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