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Precision nitrogen management in wet direct seeded Sali rice through green seeker, leaf colour chart and nano nitrogen

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Abstract
A field experiment was carried out at Instructional cum Research farm, Assam Agricultural University, Jorhat to study the performance of direct seeded *sali* rice under different nitrogen management practices *viz.*, green seeker, leaf colour chart and nano nitrogen during *kharif* season of 2021. The experiment consisted of ten different nitrogen management techniques. The experiment was laid out in randomized block design (RBD) with three replications. The rice variety "Ranjit Sub1" was sown on 16 July, 2021 and harvested on 30th November, 2021.The results of the experiment revealed that application of 20 kg Nha^{-1} as basal + 15 kg ha^{-1} N through LCC when LCC ≤ 5 twice starting from 21 DAS + rest green seeker guided resulted in the highest physiological parameters, growth parameters in all growth stages, yield attributing parameters, grain yield (4.88 t ha^{-1}) and straw yield (6.36t ha^{-1}) and harvest index. Besides, 120 kg Nha^{-1} applied as per recommended method (60kg basal+ 30kg at active tillering + 30kg at PI) significantly influenced all the growth parameters at 30DAS. In terms economics, application of 20 kg N ha^{-1} as basal + 15 kg ha^{-1} N through LCC when LCC ≤ 5 twice starting from 21 DAS + rest green seeker guided resulted in the highest gross return of ₹ 1,34,420.83 ha^{-1}, net return (₹ 89,824.43 ha^{-1}) and B:C (2.01), followed by treatment consisted of application of 20 kg Nha^{-1} basal + 20 kg Nha^{-1}at 21 DAS + green seeker guided with gross return (₹ 1,28,158.75 ha^{-1}), net return (₹ 83,714.25 ha^{-1}) and B:C (1.88). The study suggests that application of site-specific nitrogen management with the help of green seeker and leaf colour chart can increase the yield of direct seeded rice in the most economical way with efficient utilization of nutrient.

Keywords: Direct seeded rice, green seeker, leaf colour chart, nano urea, site specific nitrogen management

Introduction
Among the cereals, rice is the most popular staple meal consumed by more than half of the world's population, particularly in Asia and Africa (Langaro *et al.*, 2016) [13]. After sugarcane and maize, it is the agricultural product with the third-highest global production (509 MT milled rice in 2021-2022). More than one-fifth of the calories consumed worldwide are obtained from rice, which also provides around 22% of the world's supply of calories and 17% of its proteins (Carrijo *et al.*, 2017) [4]. Among the nations that cultivate rice, India has the biggest area (44.8 million hectares), followed by China and Indonesia. There are mainly two methods of rice cultivation *viz.*, direct seeded and transplanting. Now a days, more emphasis is given in direct seeding instead of transplanted rice.

Direct seeded rice (DSR) is a method of rice culture that avoids preparing nursery beds or using transplanting techniques in favour of directly spreading germinated rice seeds into a levelled field. Puddling in transplanted rice can have negative effects on the growth and yield of subsequent crops due to its negative effects on soil physical properties, which include poor soil structure, insufficient permeability in the subsurface layer, and soil compaction (Gathala *et al.*, 2011) [6]. Due to water and labour shortages as well as weather changes, production of conventional puddled transplanted rice is severely affected (Pathak *et al.*, 2011) [18].

Also, in comparison to transplanted rice, wet direct-seeded rice has a 10.8% greater grain yield and a global warming potential that is 60.4% lower (Ye Tao *et al*., 2016) [22].

Out of all the production practices, fertilizer management especially nitrogen is very much important to obtain a good harvest. Nitrogen is the primary fertilizer for nutrition of plants. About 40% of India's total nitrogen use is accounted by nitrogen applied to rice alone (Mohanty *et al*., 2023) [16]. The majority of farmers are using nitrogenous fertiliser to rice in accordance with general guidelines for sizable geographic areas with comparable climatic conditions and topographies. To prevent yield loss due to nitrogen shortage, farmers frequently use fertiliser nitrogen in considerably higher quantities than the general guidelines. Broad-based blanket recommendations always result in the application of fertiliser N more than the need of the crop in many fields due to the significant temporal and field-to-field variability in soil N availability, limiting the effective use of fertiliser N. (Dobermann *et al*., 2003, Liu *et al.*, 2020, Baral *et al*., 2020) [5, 14, 3]. Since there is no transplanting shock when seeds are sown directly, the crop grows quickly at first, which could lead to a nitrogen shortage later on. In the case of rice, adequate nitrogen management is crucial to preventing this problem, and site-specific nitrogen management is desirable. The nitrogen use efficiency must be high enough to provide the best possible use of nitrogen.

Split applications of N might slow down the fast release of nitrogen (Majumdar *et al*., 2000) [15]. The mix of the fertilizer, as well as the rate and timing of application, can also have an impact on relative recoveries and the degree of N loss. The crop-need-based method to managing nitrogen (N) accounts for variations in the N content of the soil as well as the additional nitrogen fertiliser needs of crops. Near-infrared leaf N analyses, chlorophyll metres, leaf colour charts, crop canopy reflectance sensors and remote sensing are some of the methods used to evaluate the degree of greenness (Giller *et al*., 2004) [7]. To achieve high nitrogen use efficiency (NUE), a fertilizer N management strategy based on visible and near-infrared spectral response from plant canopies i.e. a green seeker optical sensor and Leaf Colour Chart (LCC) are used. The Leaf Colour Chart (LCC) is used to determine the N fertilizer needs of rice crops. Regardless of the amount of N applied, LCC is a perfect, affordable and environment friendly technique for maximising nitrogen use efficiency (Konwar, 2020) [10]. It detects leaf colour intensity, which is connected to leaf N status in rice, and is simple to use for real-time N management (Balasubramanian *et al.*, 1999) [2]. Although research on the precise application of nitrogen with LCC has been done in various parts of the country, much have not been done in the north-eastern region of India. So, to determine the timing of N application in rice based on crop need, a straightforward and affordable method with low skill requirements by the farmer is to be studied.

Materials and Methods

The field experiment was carried out during the kharif season of 2021 at Instructional-cum-Research (ICR) farm of Assam Agricultural University, Jorhat. The experimental site is situated at 26°71′N latitude, 94°18′E longitude and at an altitude of 87 m above mean sea level. During the experimental period i.e. from standard meteorological week (SMW) 29 to 48, total rainfall was about 563.60mm out of which highest rainfall were observed during SMW 32 with total precipitation of 113.40mm. The weekly average maximum temperature ranged from 24.39 °C to 35.59 °C and minimum temperature from 8.48 °C to 25.83 °C. The texture of the site was sandy loam with 66.29% sand, 17.24% silt and 16.47% clay. In case of chemical properties of the soil, soil was slightly acidic with a pH of 5.5 and having 0.59% organic carbon. In case of available nitrogen, phosphorus and potassium the soil was having medium nitrogen (287.62 kg ha^{-1}) and low phosphorus (21.5 kg ha^{-1}) and potassium (116.33 kg ha^{-1}). The experiment included 10 numbers of treatments that were replicated 3 times which include the following treatments. T_1: Control (No added nitrogen); T_2: 30 kg Nha^{-1} as basal + 15 kg Nha^{-1} at active tillering + 15 kg Nha^{-1} at PI; T_3: No basal N + N application @2ml L^{-1} through nano-urea at 21, 35 and 50 DAS; T_4: No basal N + 15 $kgha^{-1}$ N through LCC when LCC ≤ 5 from 21 DAS; T_5: 20 kg Nha^{-1} as basal + 15 $kgha^{-1}$ N through LCC when LCC ≤ 5 from 21 DAS; T_6: No basal N + 15 kg ha^{-1}N through LCC when LCC ≤ 5 twice starting from 21 DAS + rest green seeker guided; T_7: 20 kg N ha^{-1}as basal + 15 kg ha^{-1} N through LCC when LCC ≤ 5 twice starting from 21; DAS + rest green seeker guided; T_8: No basal N + 20 kg N ha^{-1}at 21 DAS + green seeker guided; T_9: 20 kg N ha^{-1}basal + 20 kg N ha^{-1}at 21 DAS + green seeker guided; T_{10}: 120 kg N ha^{-1}applied as per recommended method (60kg basal+ 30kg at active tillering + 30kg at PI). The experiment was carried out in randomize block design. Each treatment was replicated three times and was allocated randomly.

Nitrogenous fertilizer in the form of urea were applied according to the treatments. The LCC scores of ≤5 was compared with the fixed time recommended N rate of 60 kg ha^{-1}. In the recommended N rate treatment, N was applied in 2:1:1 ratio at the time of sowing as basal (30 kg ha^{-1}), maximum tillering (15 kg ha^{-1}) and panicle initiation stages (15 kg ha^{-1}), respectively. So, 15 kg was taken as a split application of N as per the LCC value (Konwar, 2020) [10]. LCC readings were taken from 21 DAS at 7-10 days interval till 50% flowering. The Normalize difference vegetation index (NDVI) value was calculated with the help of green seeker by moving the sensor manually over the crop canopy at a speed of 0.5 m sec^{-1} with the trigger pulled. The readings were taken at an interval of 3 days at a height of 60-120 cm from crop canopy. The NDVI value of plots with different treatment were compared with the nitrogen rich plot. When the NDVI value were found comparatively less than that of nitrogen rich plot, nitrogen was applied in terms of urea as per requirement based on the fertilization estimation chart by taking maximum yield as 6 t ha^{-1}. The amount of nitrogen requirement was calculated from the fertilizer estimation chart mentioned in Trimble guidelines.

Results and Discussion

Crop growth rate and Leaf area index

At 0 to 30DAS, T_{10} resulted in the highest value for crop growth rate 3.28 gm^{-2} day^{-1} which was statistically at par with T_7(3.26 gm^{-2} day^{-1}), T_5 (3.25 gm^{-2} day^{-1}) andT_9(3.25 gm^{-2} day^{-1}). At 30-60 DAS, 60-90 DAS, 90-120 DAS and 120 DAS to harvest, treatment T_7 resulted the highest crop growth rate of 9.45 gm^{-2} day^{-1}, 11.91 gm^{-2} day^{-1}, 13.64 gm^{-2} day^{-1} and 7.07 gm^{-2} day^{-1}, respectively in these growth stages. It is shown in the Fig. 1. In case of leaf area index (LAI), at 30DAS, among the treatments T_{10} registered the highest leaf area index of 1.19 and it was statistically at par with T_9 (1.15) followed by T_7 (1.05). But in case of 60 DAS, 90 DAS and 120 DAS, T_7 resulted the highest leaf area index of 4.37, 5.28 and 4.31, respectively. These data are presented in the Fig. 2. Since dry matter accumulation is influenced by growth parameters *viz*., plant height, number of tillers, leaf area index etc. and these parameters were also found to be the highest in case of T_7 in the experiment. Increase in dry matter accumulation might be due to higher amount of nitrogen throughout the crop cycle in split doses as per crop requirement and its higher uptake by the crop results in effective growth of plants. These findings were in support with the results proposed by Jayanthi *et al*., (2007) [9], Kumar and Haefele (2013) [11] and Ajmal *et al*., (2020) [1].

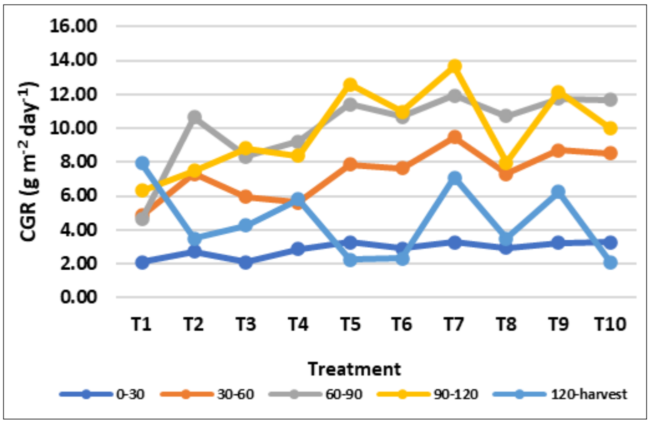

Fig 1: Effect of nitrogen management techniques on crop growth rate

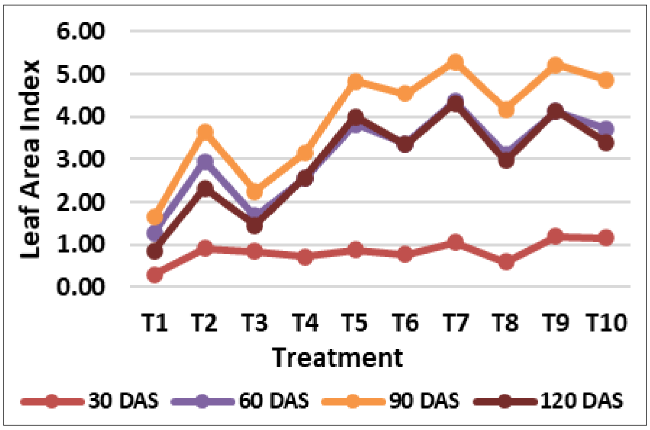

Fig 2: Effect of nitrogen management techniques on leaf area index

Yield attributes

At the time of harvest, the treatment with application of 20kg Nha^{-1} as basal + 15kgha^{-1} N through LCC when LCC ≤ 5 twice starting from 21DAS + green seeker guided (T_7) resulted in the highest number of effective tillers (291.67 m^{-2}) which was statistically at par with T_9 (287.67 m^{-2}), T_5 (285.33 m^{-2}) and T_8(281.67 m^{-2}). In case of panicle length T_7 resulted the highest value for panicle length (24.33 cm) which was significantly higher than the others. Among the treatments, T_7 resulted in the highest value for total number of grains per panicle (152.33) which was significantly higher than the other treatments. Similarly, T_7resulted in the highest value for filled grains per panicle (142.20) which was statistically at par with T_9 (138.20) and T_{10} (138.13). In the experiment, it was observed that percent filled grains were non-significant among the treatments. However, the highest percent filled grains (93.80%) was found in T_{10} followed by T_7 (93.24%) and T_5 (93.17%). In case of test weight, the highest test weight (22.54 g) was found in T_7 which was statistically at par with T_9 (21.62 g) and T_5 (21.21 g). (Table 1). In T_7, almost 21% increase in number of effective tillers per square meter, 7.8% in panicle length, 14.18% in total grains per panicle, 14.2% in filled grains per panicle and 16 5% increase in test weight were recorded as compared to no nitrogen treatment i.e. T_1. Such results might be due to timely availability and higher uptake of nitrogen in T_7 as compared to other treatments where nutrients were applied as basal, no basal or in one or two splits as per requirement of the crop. Similar findings were also reported by Kumari *et al.*, (2000) [12] and Pandey *et al.*, (2000) [17].

Table 1: Effect of nitrogen management techniques on yield attributing characters of wet direct-seeded *sali* rice

Treatment	Number of effective tillers per square meter	Panicle length (cm)	Total grains per panicle	Filled grains per panicle	Filled grain percentage (%)	Test weight (g)
T_1	230.33	22.43	134.53	122.03	90.74	18.81
T_2	252.67	22.80	136.93	124.03	90.56	20.66
T_3	273.67	21.77	131.03	119.27	91.05	19.92
T_4	276.33	22.43	132.93	118.67	89.26	19.68
T_5	285.33	23.80	144.63	134.73	93.17	21.21
T_6	276.67	22.87	140.13	129.83	92.68	20.34
T_7	291.67	24.33	152.53	142.20	93.24	22.54
T_8	281.67	22.57	135.33	125.17	92.49	20.64
T_9	287.67	23.63	148.77	138.20	92.92	21.62
T_{10}	282.00	23.07	147.37	138.13	93.80	20.97
S. Em. (±)	3.81	0.09	0.89	1.84	1.43	0.47
CD(P=0.05)	11.02	0.25	2.57	5.33	NS	1.36

Yield and harvest index (HI)

Among the various nitrogen management treatments, treatment T_7 resulted in the highest grain yield of 4.88t ha^{-1} and it was statistically at par with T_9 (4.54 t ha^{-1}). In case of straw yield, T_9 recorded in the highest straw yield (6.45t ha^{-1}) which was statistically at par with T_7 (6.36t ha^{-1}), T_{10} (6.03t ha^{-1}), T_6 (5.97t ha^{-1}), T_2 (5.93 t ha^{-1}), T_5 (5.91 t ha^{-1}) and T_3 (5.85 t ha^{-1}).Among all the treatments, T_7 recorded the highest value for harvest index (43.40%) which was statistically significant over the HI recorded from all other N management treatments and was followed by T_9 (41.31%), T_{10} (40.72%) and T_5(40.19%) (Table 2). This increase in yield might be due to application of nitrogen through LCC and green seeker in split doses at times when it was needed. These results were in accordance with the findings of Sathiya *et al.*, (2009) [21], Gurupadappa *et al.*, (2020) [8], Premalatha and Angadi (2005) [19], Sah *et al.*, (2019) [20].

Table 2: Effect of nitrogen management techniques on grain yield, straw yield and harvest index of wet direct-seeded *sali* rice

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
T_1	3.17	5.39	37.04
T_2	3.87	5.93	39.51
T_3	3.57	5.85	37.83
T_4	3.69	5.68	39.39
T_5	3.98	5.91	40.19
T_6	3.82	5.97	39.06
T_7	4.88	6.36	43.40
T_8	3.80	5.66	40.19
T_9	4.54	6.45	41.31
T_{10}	4.14	6.03	40.72
S. Em. (±)	1.56	2.11	0.40
CD(P=0.05)	4.51	6.11	1.17

Benefit-cost ratio

The data stated that among the various nitrogen management techniques, T_{10} resulted in the highest cost of cultivation of ₹ 45204.00 ha^{-1} followed by T_7 (₹ 44596.40 ha^{-1}), T_5 (₹ 44444.50 ha^{-1}) and T_9 (₹ 44444.50 ha^{-1}). In case of gross return, the highest gross return was observed in T_7 (₹ 134420.83 ha^{-1}) followed by T_9(₹ 128158.75 ha^{-1}). It was obtained that the highest net return (₹ 89824.43 ha^{-1}) was found with T_7 followed by T_9 (₹ 83714.25 ha^{-1}). However, the lowest cost of cultivation, gross return and net return was observed in T_1i.e., ₹ 42600.00

ha^{-1}, ₹ 94280.28 ha^{-1} and ₹ 51680.28 ha^{-1}, respectively, followed by T_3 i.e. (₹ 43120.00 ha^{-1}, ₹ 104834.68 ha^{-1} and₹ 61714.68 ha^{-1}, respectively. Among the various nitrogen management techniques, T_7 recorded the highest benefit-cost ratio of 2.01 followed by T_9 (1.88) and T_5 (1.55). However, the lowest benefit-cost ratio (1.21) was observed in T_1 followed by T_4 (1.42). These data are presented in the Table 3.

Table 3: Effect of nitrogen management techniques on cost of cultivation, gross return, net return and benefit-cost ratio of wet direct-seeded *sali* rice

Treatment	Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	B:C
T_1	42600	94280.28	51680.28	1.21
T_2	43900	111606.86	67706.86	1.54
T_3	43120	104834.68	61714.68	1.43
T_4	43900	106455.04	62555.04	1.42
T_5	44444.5	113544.44	69099.94	1.55
T_6	44119	110805.28	66686.28	1.51
T_7	44596.4	134420.83	89824.43	2.01
T_8	44119	108553.57	64434.57	1.46
T_9	44444.5	128158.75	83714.25	1.88
T_{10}	45204	117574.78	72370.78	1.60

Conclusion

The present study identified that the combined use of leaf colour chart and green seeker helps in precision nitrogen application at right time and right quantity in wet direct seeded s*ali* rice. From the study it was observed that the combined nitrogen application with the help of green seeker and leaf colour chart positively enhance the growth parameters, yield attributing parameters and ultimately the yield of rice. It is also found to be most economical among the treatments. From the study we can conclude that application of nitrogen through leaf colour chart and green seeker helps in real time nitrogen management in the crop field. Nitrogenous fertilizers can also be applied in the rice field with the help of green seeker alone which was also found to be efficient. Since these findings are from only one year of investigation, further experimentation for few more years may be required to derive a valid conclusion before forwarding it for recommendation to the farming community.

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