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Growth analysis and grain yield of rice (*Oryza sativa* L.) varieties under green manure based integrated nutrient management

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ABSTRACT

Field experiments were conducted at Bhubaneswar, Odisha during kharif seasons of 2018 and 2019 to study the growth behavior of rice varieties under nutrient management practices. Six treatment combinations comprising of three nutrient management (100% Soil Test Based Nitrogen Recommendation (STBNR), 75% STBNR + in situ green manuring (dhaincha) and 50% STBNR + in situ green manuring of dhaincha) and two rice varieties (Manaswinee of 125d duration and Hasanta of 145d duration) were tried in randomized complete block design (RCBD) with four replications. The results showed that crop growth rate (CGR) was significantly influenced by both nutrient management practices and varieties. Pooled over the years, application of 75% STBNR + green manuring of dhaincha exhibited the maximum CGR of 11.33 and 20.80 g/m^2/day during 30-60 and 60-90 DAT, respectively and which were superior to 100% STBNR and 50% STBNR + green manuring of dhaincha. Similarly, rice cv. 'Hasanta' recorded CGR of 10.98 and 20.42 g/m^2/day during 30-60 and 60-90 DAT, respectively, which were higher over cv. 'Manaswinee'. The maximum relative growth rate (RGR) of 23.77 mg/g/day was registered with 50% STBNR + green manuring of dhaincha, being at par with 75% STBNR + green manuring of dhaincha during 60-90 DAT. Application of 75% STBNR + green manuring of dhaincha recorded the maximum Net assimilation rate (NAR) of 3.41 and 4.26 g/m^2 leaf area/day during 30-60 and 60-90 DAT, respectively. Both cultivars were equally effective for RGR and NAR. The treatment trend for physiological indices led to higher grain yield under 75% STBNR + green manuring of dhaincha among nutrient management practices and cv. 'Hasanta' between rice varieties. Grain yield and the three physiological indices were positively correlated, but the correlation coefficient values were significant for CGR and NAR.

Key words: Crop growth rate, relative growth rate, net assimilation rate, correlation

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food grain crop of India, being grown in 44.2 Mha area with annual production of 116.5 Mt and productivity of 2.64 t/ha (DES, GOI, 2020). Though we are self sufficient in production of rice, the projected demand of the grain can only be met by maintaining steady increase in production over the years, which is necessarily to come from increased productivity i.e., almost double of the current level. Nitrogen is the kingpin in improving the crop productivity, in general. Being a cereal crop, the nitrogen requirement of rice is very high *i.e.,* 20 kg N per tonne of economic product. On the other hand, fertilizer-N is very much susceptible to losses by nitrate nitrogen (NO_3-N) leaching, denitrification, surface runoff and ammonia (NH_3-N) volatilization. The N *use efficiency* of low land *rice* rarely exceeds 30-40% due to high losses of N from the system in various forms (Panda *et al.,* 2007). The unutilized N is lost to atmosphere and groundwater creating environmental pollution through eutrophication, nitrate leaching, acid deposition and stratospheric ozone depletion (Pathak *et al.* 2009). Biologically fixed nitrogen is less subjected to such losses and is also eco-friendly in nature, which can substitute a part of the chemical nitrogen for better crop performance, improvement in soil health and for healthy environment. There is a need to ascertain the extent to which, chemical nitrogen will be substituted by biologically fixed nitrogen without sacrificing crop productivity. Many workers have reported advantages of green manuring of *dhaincha* in rice. In the past, several rice varieties have been developed with great variability in phenology, canopy architecture, resistance/tolerance to abiotic and biotic stresses and growth and development rhythms. Accordingly, these are expected to exhibit variable degree of response to agro-inputs,

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adaptability to crop growing environment and stability of production. Long duration rice varieties give higher yield than early varieties (Lal *et al.*, 2017), but these limit number of crops in the cropping system. There is need to assess performance of rice varieties of varying duration under green manure based integrated nutrient management in a cropping system.

MATERIALS AND METHODS

Field experiments were conducted at Agronomy Main Research Farm, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha during *kharif* seasons of 2018 and 2019. Geographically, the experimental site is located at $20^0$15'N latitude and $85^0$52'E longitude with an elevation of 25.9 m above mean sea level and about 64 km away from the Bay of Bengal. The climate of Bhubaneswar is characterized by hot, moist and sub-humid with hot summer and mild winter. The rainfall is monsoonal and unimodal. Soil of the experimental site was sandy loam in texture. Six treatment combinations comprising of three nutrient management (N_1: 100% Soil Test Based Nitrogen Recommendation (STBNR), N_2: 75% STBNR + *in situ* green manuring (*dhaincha*) and N_3: 50% STBNR+ *in situ* green manuring of *dhaincha*) and two rice varieties (V_1: Manaswinee of 125d duration and V_2: Hasanta of 145d duration) were tried in randomized complete block design (RCBD) with four replications. Sowing of *dhaincha was* undertaken on 12 June of both 2018 and 2019. Nursery raising was done on 28 and 29 June and transplanting on 25 July and 3 August of respective seasons. Rice cv. 'Manaswinee' was harvested on 15 and 16 November and cv. 'Hasanta' on 28 and 29 November, respectively, during 2018 and 2019. The growth indices of crop were computed during 30-60 and 60-90 days after transplanting (DAT) by using the following formulae (Radford, 1967).

Crop growth rate (CGR): $CGR = \frac{W_2 - W_1}{t_2 - t_1}$

Relative growth rate (RGR): $RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$

Net assimilation rate (NAR): $NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$

Where, W_1 and W_2 are total dry weight per unit area and A_1 and A_2 are LAI at time t_1 and t_2, respectively.

The crop was harvested plot wise leaving border and sampling areas. Threshing was done after sun drying for 3-4 days by a pedal thresher and grain yield was recorded in kg $plot^{-1}$ and converted to t ha^{-1}. Correlation coefficients between grain yield and physiological indices were computed and the significance was tested at 5 and 1% level of significance.

RESULTS AND DISCUSSION

Crop Growth Rate (CGR)

The mean CGR values of rice were 10.43 and 18.96 g/m^2/day during 30-60 and 60-90 DAT, respectively (Table 1). For the rice varieties maturing in 125 to 145d, the period between 60-90 DAT coincides with stem elongation and panicle exertion resulting in the highest CGR. Similar variations between crop growth stages for CGR was reported by Ghosal *et al.* (2016) in six basmati rice cultivars, viz., 'Pusa Basmati 1401', 'Pusa Basmati 1460', 'Pusa Rice Hybrid 10', 'Pusa Basmati 1509', 'Pusa Sugandh 5' and 'Pusa Basmati 1121'. Under present investigation, the crop was sown in the nursery on 12 June during both the years. The 60-90 DAT period coincided with mid September to mid October and the bright sunshine hours was more during this period as compared to 30-60 DAT coinciding with mid August to mid September in the rainy season. In modern rice varieties like 'Manaswinee' and 'Hasanta', leaves stay green even at maturity. Nutrient management exerted significant influence on CGR during 30-60 DAT in 2018 and 60-90 DAT in 2019 for CGR, but in both the stages, when data were pooled over the years, application of 75% STBNR + green manuring of *dhaincha* (GM) recorded the maximum CGR of 11.33 and 20.80 g/m^2/day at 30-60 and 60-90 DAT, respectively and which were superior to 100% STBNR and 50% STBNR + GM. The combination of chemical nitrogen and green manuring ensured steady supply of nitrogen throughout the crop growth period and contributed to higher dry matter accumulation than supply of only chemical nitrogen. Slow release of the nutrients from the organic source i.e., GM and blending effect of that on inorganic

Table 1: Effect of nutrient management and variety on crop growth rate (g/m^2/day) of rice at different growth stages

Treatment	30-60 DAT			60-90 DAT		
	2018	2019	Pooled	2018	2019	Pooled
Nutrient management						
100% STBNR	10.77	10.53	10.65	17.68	17.70	17.69
75% STBNR+GM	11.68	10.98	11.33	19.57	22.04	20.80
50% STBNR+GM	9.14	9.49	9.32	18.25	18.50	18.37
SE(m)±	0.42	0.45	0.31	0.90	1.00	0.67
CD (0.05)	1.27	NS	0.89	NS	3.02	1.94
Rice variety						
Manaswinee	9.74	10.03	9.88	17.18	17.80	17.49
Hasanta	11.32	10.64	10.98	19.82	21.02	20.42
SE(m)±	0.34	0.37	0.25	0.73	0.82	0.55
CD (0.05)	1.03	NS	0.72	2.22	2.46	1.59
Mean	10.53	10.33	10.43	18.50	19.41	18.96

source under integrated use of nutrients helped in reducing nutrient loss, prolonging the availability of nutrients to match with the absorption pattern of rice plant resulting in improvement of growth parameters (Panigrahi *et al.*, 2015). Islam *et al.* (2015 and 2019) reported positive effects of judicious combination of nitrogen fertilizer and green manuring on morpho-physiological parameters like CGR. The nutrient management practices exhibited the trend 75% STBNR + GM > 100% STBNR > 50% STBNR + GM for pooled CGR during 30-60 DAT. A different trend was noticed for pooled CGR during 60-90 DAT i.e., 75% STBNR + GM > 50% STBNR + GM > 100% STBNR. The difference in trend may be due to readily available plant nutrients from inorganic source during initial growth stages. However, the plants under integrated application of organic and inorganic sources were more vigorous at later stages. The two cultivars differed significantly during 60-90 DAT in both the years but 30-60 DAT in 2018 only. Pooled over the years, rice cv. 'Hasanta' recorded the maximum CGR of 10.98 and 20.42 g/m^2/day during 30-60 and 60-90 DAT, respectively, and was superior to cv. 'Manaswinee'. Growth parameters are mainly controlled by the genetic makeup of the variety, resulting in differential growth behaviour among different rice varieties. Higher CGR in rice cv. 'Hasanta' was due to tall statured plants with more spreading canopy than cv. 'Manaswinee'.

Table 2: Effect of nutrient management and variety on relative growth rate (mg/g/day) of rice at different growth stages

Treatment	30-60 DAT			60-90 DAT		
	2018	2019	Pooled	2018	2019	Pooled
Nutrient management						
100% STBNR	27.39	25.36	26.37	21.61	21.36	21.49
75% STBNR+GM	27.81	24.97	26.39	22.18	23.86	23.02
50% STBNR+GM	25.32	25.04	25.18	24.08	23.45	23.77
SE(m)±	0.44	0.73	0.43	0.56	0.61	0.41
CD (0.05)	1.34	NS	NS	1.68	1.85	1.20
Rice variety						
Manaswinee	26.25	25.83	26.04	22.49	22.30	22.40
Hasanta	27.44	24.41	25.93	22.76	23.48	23.12
SE(m)±	0.36	0.60	0.35	0.46	0.50	0.34
CD (0.05)	1.09	NS	NS	NS	NS	NS
Mean	26.84	25.12	25.98	22.63	22.89	22.76

Relative Growth Rate (RGR)

The mean RGR values during 30-60 and 60-90 DAT were 25.98 and 22.76 mg/m^2/day, respectively (Table 2). It was observed an inverse relationship between RGR and plant age. The RGR value at 60-90 DAT was less than that 30-60 DAT, because of the gradual development of plant directed towards the reproductive events for generation of new sinks, ultimately the relative growth was reduced. The decrease in RGR with advancement of crop growth stage is in agreement with findings of Chandrika *et al.* (2015), who reported decrease in RGR of 11 cultivars of rice at Hyderabad with advancement of crop growth stage. The nutrient management practices differed significantly during 60-90 DAT in both the years. The maximum value of 23.77 mg/g/day was registered with 50% STBNR + GM, being at par with 75% STBNR + GM, when data were pooled over the years. However, during 30-60 DAT, significant variation among the nutrient management practices was noticed in 2018 only. The highest RGR was recorded in 75% STBNR + GM, followed by 100% STBNR, while the lowest RGR was recorded with 50% STBNR + GM. The cultivars failed to cause significant difference in RGR except during 30-60 DAT in 2018. Pooled over the seasons, numerically higher value was recorded with rice cv. 'Manaswinee' at 30-60 DAT, but the value was higher for rice cv. 'Hasanta' during 60-90 DAT. Rice cv. 'Hasanta' recorded RGR of 25.93 mg/g/day as against 26.04 mg/g/day in cv. 'Manaswinee' during 30-60 DAT. The corresponding values during 60-90 DAT were 23.12 and 22.40 mg/g/day. The RGR values were similar to those reported by Ghosal *et al.* (2016).

Table 3: Effect of nutrient management and variety on net assimilation rate (g/m^2/day) of rice at different growth stages

Treatment	30-60 DAT			60-90 DAT		
	2018	2019	Pooled	2018	2019	Pooled
Nutrient management						
100% STBNR	3.40	3.21	3.31	3.82	3.80	3.81
75% STBNR+GM	3.59	3.23	3.41	4.08	4.44	4.26
50% STBNR+GM	2.97	3.04	3.01	4.12	4.09	4.11
SE(m)±	0.08	0.12	0.07	0.15	0.15	0.10
CD (0.05)	0.23	NS	0.20	NS	0.44	0.30
Rice variety						
Manaswinee	3.21	3.14	3.18	3.96	3.99	3.98
Hasanta	3.44	3.18	3.31	4.06	4.23	4.14
SE(m)±	0.06	0.09	0.06	0.12	0.12	0.08
CD (0.05)	0.19	NS	NS	NS	NS	NS
Mean	3.32	3.16	3.24	4.01	4.11	4.06

Net Assimilation Rate (NAR)

The mean NAR values of two rice varieties under three nutrient management practices were 3.24 and 4.06 g/m^2 leaf area/day at 30-60 and 60-90 DAT, respectively (Table 3). Nutrient management caused significant variation on NAR values during 30-60 DAT in 2018 and 60-90 DAT in 2019. Pooled over the years, application of 75% STBNR + GM recorded the maximum NAR of 3.41 g/m^2 leaf area/day at 30-60 DAT, but was at par with 100% STBNR. However, the maximum NAR value of 4.26 g/m^2 leaf area/day was registered with 75% STBNR + GM, being at par with 50% STBNR + GM and superior to 100% STBNR. Islam *et al.* (2015 and 2019) reported positive effects of judicious combination of nitrogen fertilizer and green manuring on NAR. Irrespective of seasons, both 'Hasanta' and 'Manaswinee' rice proved equally efficient for NAR during both the stages, except during 30-60 DAT in 2018, in which rice cv. 'Hasanta' recorded significantly higher value over rice cv. 'Manaswinee'. The variation was not notable among cultivars in later stage might be due to their stay green and erectophylic leaves. This is in contradiction to findings of Panigrahi *et al.* (2015), who reported varietal difference in NAR of two basmati rice varieties.

Grain yield of rice

Among nutrient management practices, application of 75% STBNR + GM recorded the maximum grain yield of 5.909 and 6.447 t ha^{-1} during 2018 and 2019, respectively (Fig 1). During 2018, application of 100% STBNR recorded statistically similar grain yield and 50% STBNR + GM recorded significantly less yield. During 2019, both 100 % STBNR and 50%

STBNR + GM recorded significantly less grain yield than 75% STBNR + GM. Higher grain yield under 75% STBNR + GM was due to availability of optimum nitrogen matching to crop need at different stages of growth and development. Qaswar *et al.* (2019) reported substitution of nitrogen requirement to the extent of 20% by *dhaincha* green manuring in rice. During both the years, rice cv. 'Hasanta' recorded significantly higher grain yield than cv. 'Manaswinee'. The higher grain yield under cv. 'Hasanta' is attributed to longer duration than cv. 'Manaswinee' that helped in higher accumulation of photosynthates.

Table 4: Simple correlation coefficients between physiological parameters and grain yield of rice

Sl. No	Dependent variable	Independent variable	Correlation coefficient (r)
1	Grain yield (t ha^{-1})	CGR during 30-60 DAT	0.73**
2		CGR during 60-90 DAT	0.71**
3		RGR during 30-60 DAT	0.01
4		RGR during 60-90 DAT	0.17
5		NAR during 30-60 DAT	0.39**
6		NAR during 60-90 DAT	0.36*

Correlation studies

The correlation coefficients between grain yield and CGR were significant at 1% level of significance both during 30-60 and 60-90 DAT (Table 4). The correlation coefficients between grain yield and RGR were positive, but non-significant. Grain yield and NAR values exhibited significant positive correlation, but the relationship was significant at 1% level during 30-60 DAT and 5% during 60-90 DAT. Kumar *et al.* (2016) reported positive correlation between grain yield with all the three physiological indices. Chozin *et al.* (2015) reported positive correlation between grain yield and RGR, but negative correlation between grain yield and NAR.

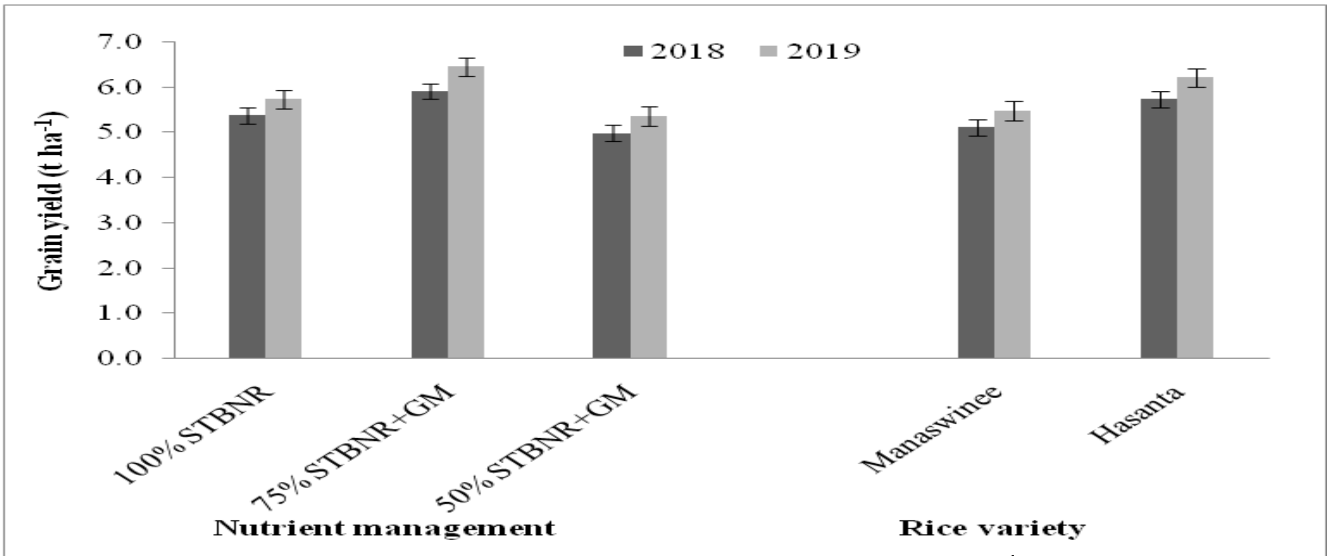

Figure 1: Effect of integrated nutrient management and variety on grain yield (t ha^{-1}) of rice during 2018 and 2019

The green manuring based nutrient management exerted significant influence on CGR, RGR and NAR during both 30-60 and 60-90 DAT, whereas the differences caused by cultivars on these physiological indices were not conspicuous except for CGR. However, the effect of cultivars on RGR and NAR was significant only during 30-60 DAT in 2018. Application of 75% STBNR + GM and 'Hasanta' variety recorded higher CGR than other treatments. The maximum values for RGR and NAR were registered with application of 75% STBNR + GM, being at par with 100% STBNR and 50% STBNR + GM during 30-60 DAT and

60-90 DAT, respectively. Higher grain yields were recorded under 75% STBNR + GM among nutrient management practices and cv. 'Hasanta' between rice varieties. Grain yield and the three physiological indices were positively correlated, but the correlation coefficient values were significant for CGR and NAR.

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