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Study on integrated nutrient management on crop growth indices in unpuddled transplanted rice (*Oryza sativa* L.)

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Abstract

Study of integrated nutrient management on crop growth indices in unpuddled transplanted rice in inceptisol soil was studied by conducting an experiment at Agricultural Research Farm, Banaras Hindu University, Varanasi, India. An experiment was laid out with four summer green manuring treatments *viz.*, summer fallow, water hyacinth, *dhaincha* and sudan grass in main and three nitrogen management treatments *viz.*, 60% RDN, 80% RDN, and 100% RDN replicated thrice in split plot design. The recommended dose nutrients (N-P-K-Zn) of rice as 150-75-60-5 kg/ha with two splits of nitrogen and basal application P_2O_5, K_2O and Zn at planting was carried out for this experiment. Soil incorporation with *dhaincha* recorded higher crop growth indices *viz.*, crop growth rate, relative growth rate, lower number of days taken in 50% flowering, higher number of days taken in 50% maturity, and leaf area as compared to summer fallow and sudan grass, however, it was statistically at par with water hyacinth during both the years. Application of 100% RDN (50% nitrogen through FYM and 50% nitrogen through chemical) recorded significantly highest crop growth indices which was followed by 80% RDN (50% nitrogen through FYM and 50% nitrogen through chemical) and 60% RDN (50% nitrogen through FYM and 50% nitrogen through chemical). The net assimilation rate was not significantly influenced by summer green manuring and integrated nitrogen management during both the years.

Keywords: Green manuring, nitrogen, CGR, RGR, NAR

Introduction

Rice is a staple food for a majority of the world's population, feeding more than two billion people in Asia (IRRI, 2006) [5]. India is the second largest producer of rice after China. Hence, holds a great importance in Indian agriculture and the economy generated by it. India produces about 116.42 million tonnes of rice over an area of 43.79 m ha (Anonymous, 2019) [1] with a productivity as low as 2.65 tonnes/ha. This might have resulted due to poor management of soil by doing practices like monoculture, lack of crop rotation and intercropping, excessive tillage under hot and humid climate leading to higher rates of organic matter decomposition, excessive use of chemical fertilizers and pesticides and lastly lesser application of organic manures and green manuring. All these have led to poor balance of plant nutrients (Smalling, 1993) [15] with estimated negative nutrient balances approaching 20 – 60 kg N ha^{-1} and 5 – 15 kg P ha^{-1} annually for land under continuous cultivation. In order to alleviate this situation, soil fertility needs to be improved which cannot be done only by chemical fertilizers as these may result in problems like deterioration of soil structure, soil acidification, alterations in soil microbial population and its activities, etc. Hence, integrated nutrient management can be an effective solution for sustainable rice production.

In this regard, green manures can potentially enhance the soil fertility by subsequently adding a greater biomass into the soil. Green manures like *Sesbania*, being leguminous in nature can add substantial amount of N required for rice as well as adding organic matter to maintain soil fertility (Latt *et al.* 2009) [9]. Also, green manures extract nutrients from deeper layers thereby, letting the succeeding crop to extract nutrients from the surface layers (Noordwijk *et al.* 2015) [13] hence, reducing use of N- fertilizers and its risks related to NO_3^- leaching. All these may subsequently contribute to higher N uptake in rice cultivation and in succeeding crops. This may lead in increased growth attributes and biomass production in the crops as nitrogen is an important component of chlorophyll, proteins and nucleic acid (FAO 2000) [4] and hence, regulates the CGR, RGR, NAR, etc. Therefore, the present study was conducted to examine the effect of green manuring on growth attributes of unpuddled transplanted rice.

Materials and Methods

Site and soil conditions

The experiment was carried out at the Agricultural Research Farm of the Banaras Hindu University, Varanasi, Uttar Pradesh, India (82° 59′36″ E longitude; 25° 15′19″ N latitude and an altitude of 128.9 meters above sea level) for two consecutive years 2018 and 2019. The experimental land is high in topography and characterized by a sandy cay loam texture having pH 7.9, Electrical conductivity (dSm^{-2}) 0.33, Organic carbon 0.44%, available nitrogen 213.8 kg/ha, available phosphorous 23.5 kg/ha, available potassium 238.8 kg/ha, available zinc 1.17g/ha.

Experimental treatments and design

The treatments included in the study were four green manuring treatments (Summer fallow, water hyacinth, *dhaincha*, and sudan grass), and three integrated nitrogen management levels (60% RDN, 80% RDN, and 100% RDN). The experiment was laid out in a split-plot design assigning green manuring treatments in the main plot and integrated nitrogen management in the sub-plots with three replications. The unit size of the sub-plots was 4 m× 5 m and that of main plot was 60 m^2. The variety ARIZE-6444 (*Oryza sativa* L.) of *kharif* rice was grown.

Cultural practices

Cultural Practices Seeds of green manuring crops were sown on 13 May in the first year and on 17 May in the second year. They were not fertilized by any nutrients only two-two irrigation were applied during both the years. The seedlings of unpuddled transplanted rice were raised in an unpudddled nursery-bed in line then frequently irrigation was applied. Sprouted rice seeds were sown on 5 June during the first year and on 10 June during the second year in a well-prepared nursery-bed. Irrigation and insect pest management were performed as needed. The experimental plots were irrigated, ploughed, and created furrow with the help of ridge furrow maker and green manuring and FYM was placed into the furrow then furrow was covered by soil for anaerobic decomposition. After seven days of transplanting, the experimental plots were fertilized with half dose of chemical nitrogen and full dose of P, K, and Zn at a rate of 75, 60, and 5 kg ha^{-1}, respectively, in the form of urea, DAP, MOP, and zinc sulphate. Remaining doses of chemical nitrogen (15.9, 30, and 35 kg N ha^{-1}) were applied to the plots in the form of urea in second instalments as per treatment specifications at active tillering stage. Green manuring crops were incorporated at 45 days after sowing in furrow. 22-day-old healthy seedlings in first year and 25 days seedling in second year were uprooted carefully from the seed bed and were transplanted at the rate of two seedlings $hill^{-1}$ in the unit plots on 27 June in the first year and 2 July in the second year, respectively, with a spacing of 20 cm×15 cm.

Measurement of crop growth indices

Leaf area

Leaf area was calculated by leaf area meter at 30, 60, and 90 DAT. Leaf area is the area of photosynthetic surface produced by the per unit plant surface over a period of interval of time and expressed in cm^2/plant.

Crop growth rate ($g/m^2/day$)

Crop growth rate represents the dry matter productivity of per unit land covered area over a certain time spam. The crop growth rate has been calculated by using following formula given by Watson (1947) and expressed in $g/m^2/day$.

$$\text{CGR } (g/m^2/day) = \frac{W2-W1}{t2-t1} \times \frac{1}{L}$$

W_1 and W_2 are plant dry weight of biomass at times t_1 and t_2 L is land area.

Relative growth rate (g/g/day)

Relative growth rate was determined by measuring the plant dry weight 30 days interval of growth rate *viz.* at 30-60 and 60-90. It was computed by using the formula given by Red Ford, 1967 and expressed as g/g/day.

$$\text{RGR } (\frac{g}{g}/day) = \frac{\ln W2 - \ln W1}{(t2 - t1)}$$

W_1 and W_2 are the plant dry weight at time t_1 and t_2 respectively.

Net assimilation rate (NAR) ($g/m^2/day$)

Net assimilation rate was higher when all the leaves are exposed to sunlight. It was also found highest when plants were in initial stage and leaves were not many to get maximum sunlight without shading effect but when crop was older NAR decreased, because of shading of leaves and reduced photosynthetic efficiency of older leaves. It is the rate of dry weight increase per unit leaf area per unit time was calculated as suggested by Gregory (1926) and expressed in ($g/m^2/day$).

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \text{X} \ \frac{(\log eW_2 - \log eW_1)}{(L_2 - L_1)}$$

Where,

Log_e, W_1 = Leaf area (cm^2) and dry weight of the plant (g), respectively at time t_1

Log_e, W_2 = Leaf area (cm^2) and dry weight of the plant (g), respectively at time t_2

t_2 - t_1 = Time interval in days

Days taken to 50% flowering

Through visual observation, days taken to 50% flowering in each plot were recorded.

Days taken to 50% maturity

The days, when the plants having the panicle dried and turning into yellowish colour and seed were easily separated from panicle branches after thrashing in each net plot were considered for recording the maturity stage.

Result and Discussion

Leaf area

Data in table related to leaf area indicated that *dhaincha* recorded significantly higher leaf area as compared to other treatments, however, it was statistically at par with water hyacinth during both the years. Among nitrogen management, 100% RDN recorded higher leaf area which was statistically at with 80% RDN except first year at 60 DAT and both year of 90 DAT where 80% RDN was found second best treatment. Many factors involved in yield of crop but among the all leaf area is the most one which play the important role in supplied the energy for photosynthesis. Peng *et al.*, (2008) [14] ideotype of plant play an important role in enhancing the yield of rice. Donald (1968) [3] defined "crop ideotype" as an idealized plant type with a specific combination of characteristics favourable for photosynthesis, growth, and grain production based on knowledge of plant and crop physiology and morphology. Crop canopy is the spatial arrangement of the above ground portion of a plant community. Solar radiation provides free energy for plant growth through photosynthesis and yield of crops depend on the solar radiation received by the canopy. However, only the photosynthetically active part of the spectrum (400–700) known as photosynthetically active radiation (PAR) can directly drive photosynthesis. Maruyama *et al.*, (2007) [11] reported that interception of light by the rice canopy depends on the transmissivity and the reflectivity of the rice canopy and its leaf inclination. The canopy leaf area has a major role in the amount of light intercepted. The higher canopy leaf area results in greater interception of light and hence faster crop growth and if other resources are enough to a plant, the light is only factor that can have effective result on yield (Tohidi *et al.* 2012) [16]. These indicate that as light interception is high, the yield will be more. Increasing leaf area leads to more light interception which subsequently leads to more yield. It was observed that solar radiation is positively associated with dry matter production (Eloy *et al.* 2018), and interception of radiation by crops closely related to their leaf area index (Behling *et al*. 2015) [2]. Monteith (1972) [12] reported that interception of radiation by canopy is also related to nutritional status of the soil. Nitrogen causes vegetative growth though increases leaf area. Therefore, increased nitrogen available to plant can increase leaf area. Green manuring can deliver considerable amount of nitrogen and increase the leaf area and leaf area index of crops (Islam *et al.* 2015) [6]. Many researchers also reported that nitrogen fertilizer increase leaf numbers, LAI, light interception and led to higher yield of crops (Kibe *et al.* 2006; Liu *et al.* 2014) [8, 10]. Green manuring with *Sesbania aculeata* might increase nitrogen in soil and subsequently increase leaf area which led to higher rice yield.

Crop growth indices

Physiological characteristics such as CGR, RGR and NAR of hybrid rice increased with increasing other growth attributes. Data in table related to physiological characters indicated that, *Sesbania aculeata* incorporated at 45 DAS recorded significantly higher CGR and RGR as compared to sudan grass incorporated at 45 DAS and summer fallow, however, it was statistically at par with water hyacinth5 t/haduring both the years. This might be due to the fact that green manuring is the resulted of long-term fertility management in significant reduction in CN ratio and increase in mineral nitrogen. The total organic matter and carbon mass underwent a relatively rapid increase due to the incorporation of green manuring in the soil. This influenced the cell elongation and cell division that increased the size of leaves. Bigger size of leaf promotes the photosynthesis activity in the plant which directly proportion of higher number of leaves, chlorophyll content in leaves, and higher CGR, RGR and NAR. The similar finding was suggested by Islam *et al.*, (2015) [6] who revealed that *Sesbania aculeate* accelerated the CGR, RGR, and NARas compared to without green manure treatments. Physiological parameters including CGR, RGR, and NAR tended increased with increasing with leaf area and dry matter accumulation. CGR was significantly influenced by green manuring and gave significantly higher CGR as compared to without green manuring (Kar and Ram, 2014) [7].

Among nitrogen management treatment, the rate of CGR was highest in between 30-60 DAT in all the treatments when compared to 60-90 DAT. Thereafter, the plant growth was slow as the crop progressed towards maturity. The higher CGR and RGR was observed under 100% RDN (50% nitrogen through FYM and 50% nitrogen through chemical) as compared to 80% RDN (50% nitrogen through FYM and 50% nitrogen through chemical) and 60% RDN (50% nitrogen through FYM and 50% nitrogen through chemical) during both the years. It might be due to higher level of nitrogen management resulted in more dry matter accumulation and leaf area which enhanced crop growth indices like CGR, RGR, and NAR. Similar finding was reported by Harish *et al.*, (2017) who reported that integrated nutrient management (50% RDF through fertilizers + remaining 50% RDF through FYM and rock phosphate) recorded higher CGR and RGR as compared to inorganic nitrogen, organic manure and control in rice cultivation.

Phenological observation

Further data regarding days to 50% flowering, days to 50% physiological maturity was found significantly affected by summer green manuring. Data in table indicated that, *Sesbania aculeata* incorporated at 45 DAS counted significantly higher number of days to 50% flowering and higher number for 50% physiological maturity as compared to sudan grass incorporated at 45 DAS and summer fallow, however, it was statistically comparable with water hyacinth 5 t/ ha during both the years. The higher supply of nitrogen by green manure crops like *Sesbania aculeate* and water hyacinth enhanced the formation of organic compounds such as amino acids, proteins, coenzymes, nucleic acids, and chlorophyll which delay the maturity. However, data regarding days to 50% flowering, days to 50% physiological maturity was not affected by nitrogen management. This might be due to ageing of crop.

Table 1: Effect of summer green manuring and nitrogen management on crop growth rate and relative growth rate of rice

Treatment	Crop growth rate (g/m^2/day)				Relative growth rate (g/g/day)			
	30-60 DAT		60-90 DAT		30-60 DAT		60-90 DAT	
	2018	2019	2018	2019	2018	2019	2018	2019
Green manuring crops								
Summer fallow	8.91	9.82	15.94	15.36	0.046	0.049	0.026	0.026
Water hyacinth	10.10	12.38	18.69	20.25	0.058	0.061	0.030	0.028
Dhaincha	12.71	13.38	18.95	20.65	0.061	0.063	0.031	0.030
Sudan grass	8.63	9.29	13.63	15.97	0.050	0.051	0.028	0.027
SEm±	0.76	0.80	1.21	0.66	0.003	0.003	0.002	0.001
CD (P=0.05)	2.64	2.78	4.20	2.27	0.010	0.011	NS	0.002
CV (%)	22.66	21.45	21.67	10.90	15.76	16.23	20.72	7.34

Nitrogen management								
60% RDN	7.89	10.24	15.47	14.74	0.051	0.055	0.026	0.026
80% RDN	10.32	11.27	17.11	18.51	0.055	0.056	0.028	0.028
100% RDN	12.07	12.14	17.82	20.92	0.056	0.058	0.031	0.029
SEm±	0.35	0.26	0.53	0.55	0.001	0.001	0.001	0.001
CD (P=0.05)	1.05	0.79	1.58	1.65	0.004	NS	0.003	0.002
CV (%)	12.01	8.18	10.87	10.54	8.64	7.70	13.15	8.79

Table 2: Effect of green manuring crops and nitrogen management on net assimilation rate of hybrid rice

Treatment	Net assimilation rate (g/m^2/day)				Phenological stages			
	30-60 DAT		60-90 DAT		Days taken to 50% flowering		Days taken to 50% maturity	
	2018	2019	2018	2019	2018	2019	2018	2019
Summer green manuring								
Summer fallow	3.05	2.88	3.99	3.66	79	77	130	131
Water hyacinth	2.65	3.07	4.15	3.87	75	74	133	134
Dhaincha	2.96	3.09	3.73	3.84	76	74	133	134
Sudan grass	2.73	2.71	3.56	3.91	78	76	131	132
SEm±	0.29	0.24	0.25	0.21	0.30	0.18	0.41	0.37
CD (P=0.05)	NS	NS	NS	NS	1.05	0.64	1.42	1.28
CV (%)	21.05	14.73	19.48	16.88	1.18	0.73	0.93	0.83
Nitrogen management								
60% RDN	2.77	3.05	3.53	3.69	77	76	132	133
80% RDN	2.78	2.89	3.66	3.81	76	75	131	132
100% RDN	2.99	2.88	4.08	3.96	77	75	132	132
SEm±	0.12	0.06	0.28	0.17	0.35	0.27	0.38	0.27
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.30	7.95	7.44	5.94	1.56	1.24	1.00	0.71

Table 3: Effect of summer green manuring and nitrogen management on leaf area of rice

Treatment	Leaf area					
	30 DAT		60 DAT		90 DAT	
	2018	2019	2018	2019	2018	2019
Summer green manuring						
Summer fallow	600.0	696.7	1309.0	1467.7	1116.7	1089.7
Water hyacinth	776.7	821.3	1602.7	1744.0	1212.3	1393.6
Dhaincha	898.0	907.7	1764.0	1777.5	1290.7	1436.4
Sudan grass	694.3	722.7	1311.0	1428.0	1027.7	1110.6
SEm±	45.3	43.7	51.2	51.6	28.5	50.3
CD (P=0.05)	156.7	151.3	177.3	178.4	98.7	174.0
CV (%)	18.3	16.7	10.3	9.6	7.4	12.0
Nitrogen management						
60% RDN	627.8	712.3	1204.8	1384.1	921.0	1079.4
80% RDN	765.5	793.5	1581.0	1659.0	1225.0	1278.5
100% RDN	833.5	855.5	1704.3	1769.8	1339.5	1414.8
SEm±	33.9	26.4	41.5	43.4	22.2	28.7
CD (P=0.05)	101.7	79.0	124.4	130.2	66.5	86.0
CV (%)	15.8	11.6	9.6	9.4	6.6	7.9

Conclusion

The inclusion of summer green manuring in rice cultivation was found to achieve higher growth responsible parameters like, leaf area, crop growth rate, relative growth rate, and also effect the phenology of rice crop due to optimum supplying of nutrients throughout the cropping cycle. Based on two years of data, dhaincha incorporated at 45 DAS recorded significantly higher leaf area, CGR, RGR, less days taken to flowering and higher days taken to maturity as compared to sudan grass and summer fallow, however, it was found statistically at par with water hyacinth during both the years. Among nitrogen management treatments, the higher leaf area, CGR, RGR, was recorded in 100% RDN which was followed by 80% RDN and 60% RDN during both the years.

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