Journal Crop and Weed, 11(2):28-33(2015)

Effect of organic nutrient management on growth rate and crop productivity in sustainable rice-rice system

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Received : 22.06.2015, Revised : 11.08.2015, Accepted : 25.08.2015

ABSTRACT

A field experiment was carried out at Bhubaneswar during 2013-14. The soil of the experimental site was sandy loam in texture with 6.35 pH. Rice-rice sequence was taken for six consecutive years with seven organic nutrient management treatments in Randomized Block Design. Organic nutrient management expressed significant effect on DM (dry matter accumulation), CGR (Crop growth rate), RGR (Relative Growth Rate) crop yield and productivity. DM, CGR, RGR were highest in treatment T_5 receiving Dhanicha+ FYM+Vermicompost in kharif and FYM+Vermicompost in summer (75.99 and 75.80 g hill^{-1} DM). Maximum average grain yield of 4.47 and 4.26 t ha^{-1} were also witnessed in T_5 during kharif and summer seasons respectively.

Key words: CGR, crop productivity, DM production, RGR

Rice not only meets most of the needs on earth but also symbolizes revolution, industrialization, calorie and earth. It is the cause of revolution on earth in nutrition as well as on food security front. Rice-rice sequence is a predominant system in coastal agro-ecosystems of Odisha. In the present situation of diminishing factor productivity and escalated environmental degradation, preference is focussed on organic farming to bolster sustainable agricultural growth. The productivity of this system has to be sustainable to stabilize the economic condition of bulk of the farming community in this zone. Moreover, the organic farming system is in concordance with soil health, clean environment, promotion and enrichment of agro-ecosystem services, biodiversity, biological cycles and soil biological properties (Kalra *et al*., 2012). In this perspective, organic farming is the most ideal and appropriate agricultural system. An ideal organic system is sustainable, benefits producers and consumers economically, protects the environment and produces enough food for an increasing world population (Higa, 1991). Organic residues including green manure, farmyard manure (FYM) and vermicompost are traditionally applied to rice soils in order to maintain the soil organic matter and plant nutrients status and improve the physical, chemical and biological soil properties that directly or indirectly affect soil fertility and productivity. It has been reported that due to green manure decomposition, high concentration of organic acids, phenolic substances and other organic compounds are released which could influence the growth and establishment of rice seedlings (Diekmann and De Dutta, 1992). Green manuring had positive correlation with dry biomass, CGR, RGR as reported by Virdi *et al.* (2006). Organic farming not only increased the grain yield but also increased the micronutrient concentrations and ultimately their uptake in grain. Increase in uptake of micronutrients may be due to the availability of these nutrients in organic source of nutrients and increased grain yield due to these nutrients (Bhattacharya and Chakraborty, 2005). It was evident that due to application of FYM and vermicompost, wheat yield increased (Singh *et al.,* 2007) whereas Kumar *et al.,* (2007) recorded higher yield of rice and wheat with the use of organic manures. Keeping this in view, the present investigation was conducted to estimate growth and crop productivity of organically grown rice in a rice-rice sequence.

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MATERIALS AND METHODS

A field experiment was conducted during 2013-2014 at the Organic Block of Central Research Station of Orissa University of Agriculture and Technology, Bhubaneswar located at 20^0 15' N latitude and 85^0 52' E longitude and at an altitude of 25.9 m above mean sea level. The station comes under the East and South Eastern Coastal Plain Agro-climatic Zone of Orissa. The region is characterized by a sub-tropical climate with a hot and humid summer (March-June), hot and wet monsoon (late June-mid October) and a mild and dry winter (November-February). The soil of the experiment was sandy loam in texture with pH 6.35. *Kharif* rice followed by summer rice was cultivated for six consecutive years in a fixed site and layout with seven treatment combinations (Table 1).

Table 1: Treatment details

Kharif	Summer
T_1: *Dhanicha* @ 25 kg seed ha^{-1}	T_1:Control
T_2: T_1 + FYM 5t ha^{-1} (basal)	T_2:FYM 5t ha^{-1} (basal)
T_3: T_1 + vermicompost 2t ha^{-1} (basal)	T_3:Vermicompost 2t ha^{-1} (basal)
T_4: T_1 + vermicompost 2t ha^{-1} (20 and 40 DAT)	T_4:Vermicompost 2t ha^{-1} (20 and 40 DAT)
T_5: T_1 + FYM + vermicompost 2t ha^{-1} (split)	T_5:FYM + vermicompost 2t ha^{-1} (split)
T_6: T_1 + FYM + vermicompost 2t ha^{-1} (basal)	T_6:FYM + vermicompost 2t ha^{-1} (basal)
T_7: T_1 + FYM + *Panchagavya*	T_7:FYM + *Panchagavya*

The experiment was laid out in a randomized block design with three replications. Rice cv. 'Lalat' was cultivated in both the seasons in all six years. 10 days old seedlings were transplanted one seedling per hill with spacing of 25 × 25 cm in individual plot of size 12 × 6m. Organic management options were adopted as per the treatments along with biodynamic formulation '*Panchagavya'* which provides availability of macro (N, P, K and Ca) and micro (Zn, Fe, Cu and Mn) nutrients besides total reducing sugars (glucose). The plots were kept moist all along. Vermicompost was applied in splits at 20 and 40 DAT. Cono weeder was used thrice at 15 days interval starting from 10 DAT in order to manage the weeds (Pradhan *et al.,*2015). No major incidence of diseases and insect pests were noticed. However, as a prophylactic measure, pot manure (5 kg cow dung + 5 litre urine + 250 g gur + 1.0 kg each of *Azadirachta indica*, *Pongamia pinnata* and *Calotropis gigantia* leaves, fermented for 15 days) was sprayed four times at 15 days interval starting from 15 DAT in both the seasons (Bastia *et al*., 2013; Kar *et al*., 2013).

Studies on dry matter accumulation were carried out following the destructive sampling technique. One hill from each plot was uprooted and its roots were clearly washed in water. The root and shoot portions were separated. The samples were air dried and subsequently oven dried at 70°C to a constant weight and the dry weights were converted to g m^{-2}. Dry matter accumulation study was carried out at 15 days interval up to maturity of the crop and the following growth studies were made using the prescribed formulae:

(i) Crop Growth Rate (CGR)

It represents the increase of plant dry matter per unit area per unit time and it was calculated according to the formula given by Gregory (1962).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} g\ g^{-1} day^{-1}$$

W_1: Initial dry matter weight per unit area g m^{-2}

W_2:Final dry matter weight per unit area g m^{-2}

t_2-t_1: Time interval (days)

(ii) Relative Growth Rate (RGR)

It is defined as the increase in dry weight of the plant per unit of original weight per unit of time. It was calculated by the formula (Hoffman *et al.,* 2002).

$$RGR = \frac{\ln W_2 - \ln W_1}{t_2 - t_1} g\ g^{-1} day^{-1}$$

W_1: Total dry weight of plant at time t_1

W_2: Total dry weight of plant at time t_2

t_2-t_1: Time interval (days)

RESULTS AND DISCUSSION

Dry matter production

It was observed that the dry matter production due to organic nutrient management increased linearly up to maturity during both the seasons. The average dry matter production were (5.70 and 5.44, 11.80 and 11.20, 30.31 and 29.48, 40.79 and 39.86, 52.84 and 51.51,61.06 and 59.54, 63.07 and 62.27 g $hill^{-1}$ in *kharif* and summer seasons, respectively) recorded at 15, 30, 45, 60, 75, 90 DAT and at harvest. Dry matter production was found more in the treatment T_5 (75.99 and 75.80 g $hill^{-1}$ in *kharif* and summer seasons, respectively) at harvest (Table 2,3). Application of FYM improves physical properties of soil, availability of plant nutrients and encourages enzymatic activities that encourage root development and growth of crop (Rao *et al*., 2004; Kumari *et al*., 2010; Shekara *et al*., 2010). *Sesbania* green manure slowly but continuously maintains nitrogen supply during most of the rice growing season thereby enhancing dry matter production, LAI, NAR, CGR and LAD (Vennila *et al.,* 2007; Surekha *et al*., 2008). Rao *et al*. (2004) also reported that increase in plant height and dry matter production due to FYM application might be due to the fact that application of FYM increases the soil organic carbon, which holds more moisture in soil and creates suitable condition for better root growth and proliferation which enables extraction of nutrients from larger profile area. Beneficial effects of FYM with increased plant height, LAI and higher DMP over other organics were observed by Ramasamy (1998).

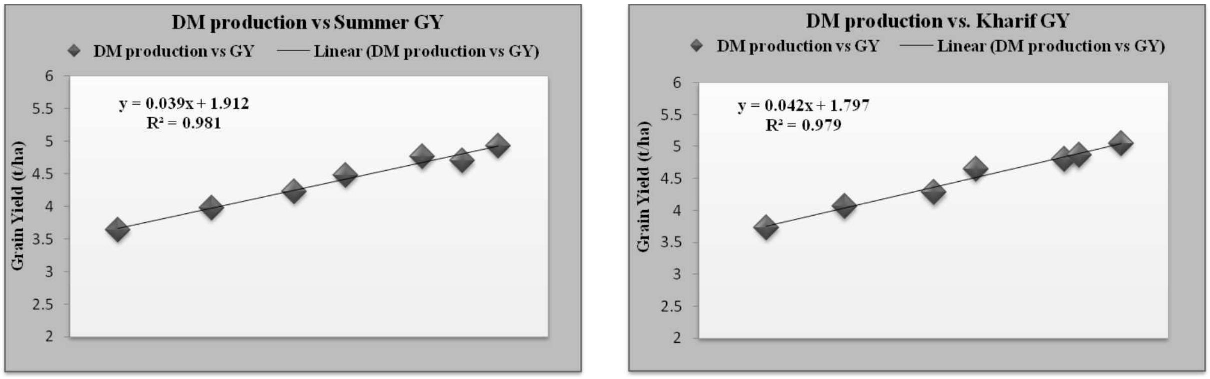

Fig. 1: Correlation between DMP and grain yield

Table 2: Effect of organic nutrient management on dry matter accumulation (g hill^{-1}) of *kharif* rice

	Days after transplanting						
Treatment	**15**	**30**	**45**	**60**	**75**	**90**	**At harvest**
T_1	4.11	8.62	20.48	25.75	36.10	43.37	45.80
T_2	4.97	9.98	25.84	31.66	42.98	49.78	52.43
T_3	5.14	10.69	30.26	34.45	49.44	57.43	60.09
T_4	5.98	13.27	33.30	47.13	58.29	68.76	71.17
T_5	7.49	14.83	36.62	53.93	65.22	74.36	75.99
T_6	6.01	12.77	35.03	50.55	62.25	71.17	72.42
T_7	6.21	12.46	30.66	42.06	55.63	62.61	63.61
SEm(±)	**0.40**	**0.79**	**1.08**	**1.68**	**1.87**	**2.22**	**2.21**
LSD(0.05)	**1.23**	**2.42**	**3.32**	**5.16**	**5.77**	**6.82**	**6.80**

Table 3: Effect of organic nutrient management on dry matter accumulation (g hill^{-1}) of summer rice

	Days after transplanting						
Treatment	**15**	**30**	**45**	**60**	**75**	**90**	**At harvest**
T_1	3.89	7.87	19.84	24.88	35.57	42.19	44.04
T_2	4.68	9.18	25.14	30.83	41.44	48.28	51.86
T_3	4.75	10.23	29.38	33.86	48.37	56.13	58.80
T_4	5.75	12.60	32.33	45.96	57.54	66.81	69.50
T_5	7.11	13.93	35.97	51.65	62.96	73.29	75.80
T_6	6.20	12.46	33.85	50.21	60.98	69.84	72.84
T_7	5.72	12.15	29.89	41.66	53.77	60.28	63.08
Sem(±)	**0.39**	**0.83**	**1.33**	**2.25**	**2.21**	**2.77**	**1.91**
LSD(0.05)	**1.19**	**2.54**	**4.09**	**6.91**	**6.81**	**8.52**	**5.89**

Vennila *et al*. (2007) reported significant increase in growth factors due to application of FYM. Matiwade and Sheelavantar (1994) reported that green manuring enhanced the values of dry matter production, LAI, CGR, LAD and thereby increased rice growth. A highly positive linear relationship (R^2 = 0.979 and 0.981 in *kharif* and summer seasons, respectively) was observed between DMP and grain yield (Fig.1).

CGR and RGR

Crop growth rate due to simultaneous application of organic sources were found maximum in all growth stages than the organic sources applied alone. Highest crop growth rate (g m^{-2} d^{-1}) was found during 15-30, 30-45, 45-60 DAT was found in treatment T_5 (7.82 and 7.27, 23.24 and 23.50, 18.54 and 16.72) (Table 4,5). The average RGR at 15-30, 30-45, 45-60, 60-75, 75DAT-harvest were 0.021 and 0.020, 0.027 and 0.027, 0.007 and 0.008, 0.007 and 0.007, 0.004 and 0.001 g g^{-1}day^{-1} in *kharif* and summer seasons, respectively (Table 6,7). Growth of a plant is the permanent and irreversible increase in its size and form. It is affected by its environment like availability of plant nutrients, water, energy, space, etc. Therefore, the growth of a plant in a community differs in many ways from the individual plant because of inter plant

Table 4: Effect of organic nutrient management on crop growth rate (g m^{-2} day^{-1}) of *kharif* rice

	Days after transplanting				
Treatment	15-30	30-45	45-60	60-75	75- Harvest
T_1	4.81	12.65	5.62	11.04	3.44
T_2	5.34	16.91	6.20	12.07	3.36
T_3	5.92	20.87	4.46	15.98	3.78
T_4	7.77	21.36	14.75	11.90	4.57
T_5	7.82	23.24	18.46	12.04	3.82
T_6	7.21	23.14	16.55	12.48	3.61
T_7	6.66	19.41	12.16	14.47	2.83
Sem(±)	**0.38**	**1.13**	**0.51**	**0.93**	**0.36**
LSD(0.05)	**1.14**	**3.37**	**1.53**	**2.80**	**1.06**

Table 5: Effect of organic nutrient management on crop growth rate (g m^{-2} day^{-1}) of summer rice

	Days after transplanting				
Treatment	15-30	30-45	45-60	60-75	75- Harvest
T_1	4.24	12.76	5.37	11.40	2.77
T_2	4.80	17.02	6.06	11.31	3.47
T_3	5.84	20.42	4.77	15.47	3.70
T_4	7.30	21.04	14.53	12.35	3.65
T_5	7.27	23.50	16.72	12.06	4.09
T_6	6.67	22.81	11.48	9.45	3.86
T_7	6.85	18.92	12.55	12.91	2.95
SEm(±)	**0.38**	**1.21**	**0.87**	**0.75**	**0.33**
LSD(0.05)	**1.14**	**3.63**	**2.60**	**2.26**	**0.98**

Table 6: Effect of organic nutrient management on relative growth rate (g $g^{-1}$$day^{-1}$) of *kharif* rice

	Days after transplanting				
Treatment	15-30	30-45	45-60	60-75	75- Harvest
T_1	0.021	0.025	0.006	0.009	0.002
T_2	0.020	0.028	0.006	0.008	0.017
T_3	0.020	0.030	0.003	0.010	0.005
T_4	0.023	0.026	0.010	0.006	0.002
T_5	0.020	0.026	0.011	0.005	0.001
T_6	0.022	0.029	0.010	0.006	0.001
T_7	0.020	0.026	0.009	0.008	0.001
SEm(±)	**0.001**	**0.002**	**0.0002**	**0.0005**	**0.0003**
LSD(0.05)	**0.004**	**0.006**	**0.001**	**0.001**	**0.001**

Table 7: Effect of organic nutrient management on relative growth rate (g $g^{-1}$$day^{-1}$) of summer rice

	Days after transplanting				
Treatment	15-30	30-45	45-60	60-75	75- Harvest
T_1	0.020	0.026	0.006	0.010	0.001
T_2	0.019	0.029	0.005	0.009	0.001
T_3	0.022	0.030	0.004	0.010	0.001
T_4	0.023	0.026	0.010	0.006	0.001
T_5	0.019	0.027	0.010	0.005	0.002
T_6	0.020	0.028	0.012	0.005	0.001
T_7	0.022	0.026	0.009	0.008	0.001
Sem(±)	**0.0013**	**0.0019**	**0.0001**	**0.0005**	**0.0002**
LSD(0.05)	**0.004**	**0.005**	**0.001**	**0.001**	**0.001**

interaction in the field. Full production potential of individual plants can only be realized when the growth and development conditions during the early phases are optimal. The dry matter accumulation showed a typical sigmoidal curve. The pattern indicates that early vegetative growth in rice tends to be exponential but because of mutual interactions within the individuals that impose limitation on growth, the actual growth curve falls away in sigmoidal manner which is more characteristic of its entire life span. Since growth is not exponential, CGR is not a constant value and it always declines and ascends later in the life curve (Evans, 1972).

Grain yield

The grain yield of different seasons and years were different due to application of organic nutrients (Table 8). The average grain yield was highest in *kharif* and summer seasons in T_5 (4.47 and 4.26 t ha^{-1}). Simultaneous application of organic nutrients (T_5, T_6 and T_7) resulted in higher yield than sole application treatments (T_1, T_2, T_3 and T_4).

Integrated use of two or three sources of organic nutrients with biofertilizers resulted in higher grain yield of rice (Yadav *et al*., 2009; Davari and Sharma, 2010; Singh *et al*., 2011). Organic manures when applied in sufficient quantities supplied all the essential nutrients in adequate amounts for plant growth and development and ultimately resulted in yield. Manure application encourages the activity of microbes which, in turn, release enzymes and hormones that promote plant growth. Mankotia (2007) reported higher yield of rice due to *in situ* green manure of *Dhanicha* along with application of FYM. Vennila *et al*. (2007) confirmed that *Sesbania* green manure slowly but continuously maintain nitrogen supply during most of the rice growing season.

Table 8: Effect of organic nutrient management on grain yield (t ha^{-1})

Treatment	*Kharif* grain yield						Mean	Summer grain yield (t ha^{-1})						Mean
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14		2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	
T_1	2.40	2.53	3.06	3.09	3.30	3.73	3.01	2.42	2.45	2.93	2.98	3.26	3.64	2.95
T_2	2.73	3.14	3.18	3.27	3.72	4.06	3.35	2.72	3.12	3.12	3.12	3.67	3.98	3.28
T_3	2.87	3.06	3.41	3.52	4.08	4.28	3.53	2.63	2.96	3.37	3.39	3.72	4.23	3.38
T_4	3.34	3.40	4.03	4.12	4.40	4.80	4.01	3.06	3.31	4.01	3.90	4.39	4.76	3.90
T_5	3.70	4.03	4.54	4.58	4.92	5.05	4.47	3.54	4.01	4.24	4.34	4.53	4.93	4.26
T_6	3.25	3.84	3.97	4.26	4.47	4.86	4.10	3.14	3.75	3.92	4.12	4.43	4.70	4.01
T_7	3.01	3.72	3.80	4.07	4.31	4.65	3.92	3.02	3.68	3.73	3.76	4.07	4.48	3.80
Sem(±)	**0.15**	**0.17**	**0.21**	**0.20**	**0.21**	**0.22**		**0.17**	**0.18**	**0.16**	**0.20**	**0.21**	**0.22**	
LSD(0.05)	**0.46**	**0.55**	**0.66**	**0.65**	**0.64**	**0.68**		**0.54**	**0.57**	**0.50**	**0.66**	**0.63**	**0.68**	

The rate of decomposition and N mineralization of green manures added to soil depend on a large extent on the chemical composition or quality of the manures. Quality of manures is determined largely by the organic constituents and nutrient contents of the material and the ease of mineralization by decomposer organisms. As regards to these aspects *Sesbania* is a very good green manuring crop. Shekara *et al*. (2010) suggested that increase in the growth, yield attributes and yield of rice due to addition of various organic manures could be attributed to adequate supply of nutrients, higher uptake and recovery of applied nutrients, which in turn, must have improved synthesis and translocation of metabolites to various reproductive structures of the plant.

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