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Original Research Article

Performance of Organic Nutrition on Physiological Characters and Yield of Aerobic Rice

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Keywords

Aerobic rice, Organic manures, Foliar spray, LAI, CGR, Grain yield

A B S T R A C T

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural university, Madurai during *rabi'* 2014, *kharif'* 2015 and summer' 2016 to study the organic management options for aerobic rice. The two rice varieties ANNA 4 (V_1) and MDU 6 (V_2) were used in the main plot. Four different organic manures *viz.*, FYM (M_1), Vermicompost (M_2), Pressmud compost (M_3) and Seaweed compost (M_4) were used in the sub-plots and the three different foliar sprays PPFM (F_1), Seaweed extract (F_2) and Humic acid (F_3) were applied as sub-sub plot treatments. The result of the study revealed that the varieties ANNA 4 and MDU 6 have significant difference in physiological characters *viz.*, LAI, CGR, grain yield. ANNA 4 recorded higher physiological attributes *viz.*, LAI (2.44 and 4.81 at tillering and flowering stage), CGR (5.60 and 4.72 g m^{-2} day^{-1} at tillering to panicle initiation and panicle initiation to flowering stage) and grain yield (3334 kg ha^{-1}). Application of different organic manures significantly influenced the physiological characters *viz.*, LAI, CGR and grain yield. The application of pressmud compost (M_3) @ 6 t ha^{-1} influenced higher physiological characters *viz.*, LAI, CGR and grain yield by recording a LAI of 2.57 and 5.09 at tillering and flowering stage and CGR of 5.97 and 5.01 g m^{-2} day^{-1} at tillering to panicle initiation and panicle initiation to flowering stage respectively and also recorded higher grain yield. Like various foliar applications also significantly influenced the physiological characters *viz.*, LAI, CGR and grain yield. Among the foliar application, seaweed extract @ 500 ml ha^{-1} recorded the highest leaf area index of 2.31 and 4.61 at tillering and flowering stage and CGR 5.50 and 4.68 g m^{-2} day^{-1} at tillering to panicle initiation and panicle initiation to flowering stage, respectively. Based on the above experimental results it could be concluded that cultivation of rice ANNA 4 with application of pressmud compost @ 6.0 t ha^{-1} along with foliar application of seaweed extract @ 500 ml ha^{-1} was found to be a promising combination for higher physiological characters *viz.*, LAI, CGR and grain yield.

Introduction

Rice (*Oryza sativa* L.) is a staple food for more than 50 % of the world's population, including regions of high population density and rapid growth (Fageria, 2007). It is estimated that by the year 2025 it will be necessary to produce about 60 % more rice than what is currently produced to meet the food needs of a growing world population (Fageria *et al.,* 2003). However, the land available for crop production is decreasing steadily due to urban growth and land degradation. Hence, increases in rice production will have to come from the same or an even less area of land. Further, irrigated agriculture utilizes about 90 % of fresh water and of this 50 % is used in rice cultivation. Water scarcity is becoming more and more a global concern, and signs of serious water scarcity are already evident in several agricultural areas. Increasing water scarcity has necessitated the development of aerobic rice systems that require less water than traditional flooded rice.

Due of the lower water requirement and higher productivity, farmers are adopting aerobic rice in areas where water shortage is observed in northern China (Huaqi *et al.,* 2002). Nearly 50 per cent gain in food grain productivity seen in recent times has come through adoption of fertilization practices and water management in aerobic rice system (Bouman *et al.,* 2005). Achieving high yields under irrigated but aerobic soil conditions requires new varieties of aerobic rice that combine the drought-resistant characteristics of upland varieties with the high-yielding characteristics of lowland varieties (Lafitte *et al.,* 2002). As it is a new system of rice production, agro techniques for aerobic rice need to be standardized.

A change from chemically intensive agriculture to a more sustainable form of organic agriculture is desirable to overcome the constraints of modern agriculture. Further, it is not desirable to apply nutrients only through inorganic sources. Application of organic manures for increasing soil fertility has gained importance in recent years due to high cost and adverse impact of fertilizers. Incorporation of organic manures mainly farmyard manure, pressmud compost, vermicompost, seaweed compost *etc.* has given a hope to reduce the cost of cultivation and minimize adverse effects of chemical fertilizers. Pressmud compost is one such source of organic matter and nutrients (rich in potassium and phosphorus) which can be profitably utilized for crop production. Pressmud compost like other organic manures has great potential to supply nutrients in addition to its favourable effects on physico-chemical and biological properties of soil. It is a by-product of sugar industry and for every 100 tons of sugarcane crushed about 3 tons of pressmud cake is left behind as by-product. When this by-product is composted, it converted into very nutritive organic manure, enabling recycling and the final compost products could be used in agricultural field.

Supply of nutrients at critical growth periods in rice from non-soil sources can further enhance the plant growth and yield. One such source is foliar application which has a direct assimilation of nutrients through rice foliage. Seaweed extracts are bioactive substances extracted from marine algae and used in agricultural and horticultural crops (Russo and Beryln, 1990), especially in rain-fed crops as a means to avoid excessive fertilizer applications and to improve mineral absorption.

Seaweed extracts can improve crop growth through phytohormones (auxins, gibberellins, cytokinins and abscisic acid), macronutrients (N, P and K), micronutrients (Fe, Cu, Mo, Mn, Zn, Co, and Ni), and secondary metabolites such as amino acids and vitamins (Challen and Hemingway, 1965). In this context, a study was carried out to identify a rice variety suitable for aerobic rice production system and also to the effect of organic manures on LAI, CGR and grain yield of aerobic rice.

Materials and Methods

Study site

Field experiments were conducted at 'A' Block in field No. A8 at the Central Farm, Agricultural College and Research Institute, Tamil Nadu Agricultural university, Madurai during *rabi'* 2014, *kharif"* 2015 and summer' 2016 to study the organic management options for aerobic rice.

The experimental site is geographically located at 9°54' N latitude and 78°80'E longitude at an altitude of 147 m above mean sea level in the southern part of India.

The soil of the experimental field was sandy clay loam in texture and it belongs to Vylogam series the soil is classified taxonomically as Typic Udic Hapiustalf as per USDA classification.

The composite soil samples were collected initially from the experimental field was analyzed for physical and chemical properties. The soil of the experimental site was neutral in reaction with pH of 7.2. The fertility of the soil was found to be low in available nitrogen (215.4 kg ha^{-1}), medium in phosphorus (20.8 kg ha^{-1}) and medium in potassium (278.0 kg ha^{-1}). The organic carbon content present in the soil was 0.44%.

Experimental design

The experiment was laid out in strip split plot design with three replication. The two rice varieties V_1 (ANNA 4) and V_2 (MDU 6) were used in the main plot, four different organic sources M_1 (FYM @ 12.5 t ha^{-1}), M_2 (Vermicompost @ 5 t ha^{-1}), M_3 (Pressmud compost @ 6 t ha^{-1}) and M_4 (seaweed compost @ 2 t ha^{-1}) were used in the sub-plots treatments.

Leaf area index (LAI)

The leaf area index at all stage was worked out by the length and width measurement method as suggested by Palaniswamy and Gomez (1974).

$$LAI = \frac{L \times W \times K \times N}{S}$$

Where, L: Length of the 3rd leaf blade from the top (cm), W: Maximum width of the leaf blade

K: Constant factor of 0.75, N: Number of leaves $hill^{-1}$, S: Area occupied $hill^{-1}$ (cm^2)/spacing

The area occupied by single hill was arrived from the number of hills in a quadrat of 0.25 m^2 from where the leaf measurements were made.

Crop growth rate (CGR)

The CGR during the growth period *viz*., tillering to panicle initiation, panicle initiation to flowering stages were calculated as suggested by Watson (1958) and expressed in g m^{-2} day^{-1}.

$$CGR = \frac{(w_2 - w_1)}{P\,(t_2 - t_1)} \text{ g m}^{-2} \text{ day}^{-1}$$

Where, w_1 and w_2: Initial and final dry weight (g) of plant material per unit ground area, t_1 and t_2: Initial and final days of observation, P: Ground area occupied by each hill (cm^2).

Grain yield

Grain yield from each net plot was cleaned; sun dried and weighed at 14 per cent moisture content and the grain yield was expressed in kg ha^{-1}.

Statistical analysis

The recorded data were subjected to statistical analysis in the strip split plot design following the method of Gomez and Gomez (1984).

Results and Discussion

Physiological characters

Leaf area index

The photosynthetic surface area of plant is important for biological yield. The development of leaf area is a factor that could affect crop response to water availability. Leaf area index particularly at reproductive stage has a specific role in deciding dry matter production of rice. Morethan 80% of the total variance in grain yield among the treatment could be explained by LAI indicating that light interception and the availability of assimilate limits the yield (Hongbin Tao, 2004).

In the present investigation, the variety ANNA 4 recorded significantly higher LAI (2.25, 2.37, 2.44 and 4.59, 4.76, 4.81 at tillering and flowering stage) during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively with application of pressmud compost @ 6 t ha^{-1} (M_3) along with spraying of seaweed extract @ 500 ml ha^{-1} at tillering to panicle initiation stages (Table 1 and 2).

The variety ANNA 4 recorded higher LAI while MDU 6 exhibited the least value. This might be due to the genetic superiority of ANNA 4 aver MDU 6 under drought conditions as experiment in aerobic rice cultivation.

Among the organic manures, application of pressmud compost @ 6 t ha^{-1} recorded highest LAI of 2.45, 2.52, 2.57 and 4.92, 5.04, 5.09 at tillering and flowering stage during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. This might be due to the gradual mineralization from organic manures leading to supply of required N to the crop for increasing LAI. The nutrient supply to rice by organic source led to production of more leaves of larger size and thus higher leaf are index.

Among the foliar spray, application of seaweed extract @ 500 ml ha^{-1} recorded the highest LAI of 2.15, 2.27, 2.31 and 4.39, 4.54, 4.61 at tillering and flowering stage during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. The ameliorating role of seaweed extract might due to the high level of cytokinins, auxins, other growth hormones and other nutrients.

The role of seaweed extract is increasing the leaf area due to containing of macro and micronutrient by positive effect on cell division and cell elongation leading to enhanced leaf growth (Ramesh *et al.*, 2013).

Crop Growth Rate

The CGR are the extrapolations of observations made on the growth components *viz.*, leaf area and DMP. The crop growth rate was altered with age of the crop due to gradual changes in photosynthetic efficiency. The results of the study revealed that CGR was significantly higher with ANNA 4 as compared to MDU 6 in tillering to panicle initiation stage and panicle initiation to flowering stage during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively with application of pressmud compost at 6 @ t ha^{-1} (M_3) along with spraying of seaweed extract @ 500 ml ha^{-1} (Table 3 and 4).

Table.1 Effect of variety, organic manure and foliar spray on LAI at tillering stage of aerobic rice

	I Crop (*rabi'* 2014)				II Crop (*kharif'* 2015)				III Crop (summer' 2016)			
TREATMENT	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**
V1	2.15	2.37	2.24	**2.25**	2.26	2.49	2.35	**2.37**	2.35	2.55	2.42	**2.44**
V2	1.74	1.92	1.82	**1.83**	1.86	2.05	1.93	**1.94**	1.87	2.07	1.96	**1.97**
MEAN	**1.94**	**2.15**	**2.03**		**2.06**	**2.27**	**2.14**		**2.11**	**2.31**	**2.19**	
M1	1.50	1.63	1.56	**1.56**	1.64	1.80	1.71	**1.72**	1.70	1.87	1.77	**1.78**
M2	2.14	2.35	2.24	**2.24**	2.20	2.48	2.28	**2.32**	2.26	2.49	2.34	**2.36**
M3	2.33	2.58	2.43	**2.45**	2.42	2.64	2.50	**2.52**	2.45	2.71	2.55	**2.57**
M4	1.80	2.02	1.90	**1.90**	1.98	2.15	2.07	**2.07**	2.02	2.18	2.10	**2.10**
MEAN	**1.94**	**2.15**	**2.03**		**2.06**	**2.27**	**2.14**		**2.11**	**2.31**	**2.19**	
V1M1	1.71	1.83	1.75	**1.76**	1.82	2.00	1.90	**1.91**	1.95	2.15	2.02	**2.04**
V1M2	2.36	2.58	2.46	**2.47**	2.40	2.73	2.48	**2.54**	2.49	2.71	2.55	**2.58**
V1M3	2.53	2.83	2.64	**2.67**	2.63	2.87	2.75	**2.75**	2.69	2.94	2.79	**2.81**
V1M4	2.00	2.25	2.11	**2.12**	2.19	2.35	2.29	**2.28**	2.26	2.39	2.32	**2.33**
V2M1	1.30	1.42	1.37	**1.36**	1.46	1.59	1.52	**1.52**	1.46	1.60	1.52	**1.53**
V2M2	1.92	2.12	2.02	**2.02**	2.00	2.23	2.09	**2.11**	2.04	2.26	2.12	**2.14**
V2M3	2.13	2.33	2.21	**2.23**	2.20	2.42	2.26	**2.29**	2.21	2.47	2.30	**2.33**
V2M4	1.59	1.80	1.68	**1.69**	1.77	1.94	1.85	**1.85**	1.79	1.96	1.88	**1.88**
MEAN	**1.94**	**2.15**	**2.03**		**2.06**	**2.27**	**2.14**		**2.11**	**2.31**	**2.19**	
	SE_D		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**	
V	0.08		0.33		0.07		0.31		0.07		0.32	
M	0.08		0.20		0.07		0.18		0.08		0.19	
F	0.02		0.04		0.02		0.04		0.02		0.05	
V x M	0.13		0.33		0.12		0.30		0.13		0.32	
V x F	0.16		NS		0.15		NS		0.16		NS	
M x F	0.12		NS		0.11		NS		0.12		NS	
V x M x F	0.05		NS		0.05		NS		0.06		NS	

*V_1 - ANNA 4, V_2 - MDU 6, M_1 - FYM, M_2 - Vermicompost, M_3 - Pressmud Compost, M_4 - Seaweed Compost, F_1 - PPFM, F_2 - Seaweed Extract, F_3 -Humic acid

Table.2 Effect of variety, organic manure and foliar spray on LAI at flowering stage of aerobic rice

	I Crop (rabi' 2014)				II Crop (kharif' 2015)				III Crop (summer' 2016)			
TREATMENT	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**
V1	4.45	4.76	4.58	**4.59**	4.63	4.91	4.76	**4.76**	4.67	4.94	4.82	**4.81**
V2	3.77	4.03	3.88	**3.90**	3.96	4.18	4.07	**4.07**	3.99	4.27	4.12	**4.13**
MEAN	**4.11**	**4.39**	**4.23**		**4.29**	**4.54**	**4.41**		**4.33**	**4.61**	**4.47**	
M1	3.35	3.57	3.43	**3.45**	3.65	3.84	3.73	**3.74**	3.64	3.88	3.76	**3.76**
M2	4.38	4.71	4.51	**4.53**	4.52	4.83	4.65	**4.67**	4.60	4.90	4.75	**4.75**
M3	4.74	5.10	4.92	**4.92**	4.91	5.20	5.02	**5.04**	4.95	5.25	5.06	**5.09**
M4	3.98	4.20	4.06	**4.08**	4.09	4.31	4.24	**4.22**	4.13	4.39	4.30	**4.28**
MEAN	**4.11**	**4.39**	**4.23**		**4.29**	**4.54**	**4.41**		**4.33**	**4.61**	**4.47**	
V1M1	3.67	3.90	3.76	**3.78**	3.97	4.17	4.03	**4.06**	3.96	4.20	4.06	**4.07**
V1M2	4.72	5.06	4.85	**4.88**	4.87	5.19	5.00	**5.02**	4.92	5.24	5.08	**5.08**
V1M3	5.06	5.49	5.28	**5.28**	5.24	5.57	5.38	**5.40**	5.31	5.63	5.46	**5.47**
V1M4	4.34	4.57	4.40	**4.44**	4.45	4.69	4.61	**4.58**	4.48	4.71	4.67	**4.62**
V2M1	3.02	3.23	3.10	**3.12**	3.34	3.50	3.43	**3.43**	3.33	3.55	3.46	**3.45**
V2M2	4.03	4.35	4.16	**4.18**	4.17	4.47	4.30	**4.32**	4.28	4.57	4.43	**4.42**
V2M3	4.41	4.72	4.56	**4.56**	4.58	4.83	4.66	**4.69**	4.59	4.88	4.66	**4.71**
V2M4	3.63	3.82	3.71	**3.72**	3.74	3.93	3.88	**3.85**	3.78	4.07	3.94	**3.93**
MEAN	**4.11**	**4.39**	**4.23**		**4.29**	**4.54**	**4.41**		**4.33**	**4.61**	**4.47**	
	SE_D		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**	
V	0.11		0.47		0.14		0.61		0.14		0.62	
M	0.12		0.30		0.12		0.31		0.12		0.30	
F	0.02		0.05		0.03		0.05		0.02		0.05	
V x M	0.19		0.46		0.25		0.60		0.25		0.61	
V x F	0.22		NS		0.29		NS		0.29		NS	
M x F	0.18		NS		0.19		NS		0.18		NS	
V x M x F	0.06		NS		0.07		NS		0.07		NS	

*V_1 - ANNA 4, V_2 - MDU 6, M_1 - FYM, M_2 - Vermicompost, M_3 - Pressmud Compost, M_4 - Seaweed Compost, F_1 - PPFM, F_2 - Seaweed Extract, F_3 -Humic acid

Table.3 Effect of variety, organic manure and foliar spray on CGR (g m^{-2} day^{-1}) at tillering to panicle initiation stage of aerobic rice

	I Crop (*rabi*' 2014)				II Crop (*kharif*' 2015)				III Crop (summer' 2016)			
TREATMENT	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**
V1	5.07	5.26	5.10	**5.14**	5.29	5.52	5.40	**5.41**	5.48	5.73	5.60	**5.60**
V2	4.77	4.89	4.81	**4.82**	5.06	5.14	5.09	**5.10**	5.18	5.28	5.26	**5.24**
MEAN	**4.92**	**5.08**	**4.95**		**5.18**	**5.33**	**5.25**		**5.33**	**5.50**	**5.43**	
M1	4.13	4.27	4.21	**4.21**	4.35	4.56	4.42	**4.44**	4.52	4.73	4.56	**4.60**
M2	5.25	5.41	5.24	**5.30**	5.51	5.67	5.57	**5.58**	5.60	5.83	5.75	**5.73**
M3	5.43	5.61	5.51	**5.52**	5.73	5.86	5.79	**5.79**	5.88	6.03	6.02	**5.97**
M4	4.87	5.01	4.86	**4.91**	5.12	5.25	5.20	**5.19**	5.31	5.42	5.40	**5.38**
MEAN	**4.92**	**5.08**	**4.95**		**5.18**	**5.33**	**5.25**		**5.33**	**5.50**	**5.43**	
V1M1	4.28	4.30	4.33	**4.30**	4.46	4.68	4.47	**4.54**	4.67	4.90	4.59	**4.72**
V1M2	5.42	5.62	5.40	**5.48**	5.60	5.88	5.78	**5.75**	5.79	6.05	5.98	**5.94**
V1M3	5.58	5.89	5.71	**5.73**	5.88	6.09	5.97	**5.98**	6.03	6.27	6.20	**6.17**
V1M4	4.98	5.23	4.97	**5.06**	5.22	5.45	5.38	**5.35**	5.44	5.67	5.62	**5.58**
V2M1	3.98	4.24	4.10	**4.11**	4.23	4.44	4.37	**4.35**	4.38	4.55	4.52	**4.48**
V2M2	5.07	5.20	5.07	**5.11**	5.41	5.47	5.37	**5.41**	5.41	5.62	5.52	**5.51**
V2M3	5.28	5.34	5.32	**5.31**	5.58	5.62	5.62	**5.61**	5.74	5.78	5.83	**5.78**
V2M4	4.76	4.79	4.74	**4.76**	5.02	5.05	5.02	**5.03**	5.18	5.17	5.18	**5.18**
MEAN	**4.92**	**5.08**	**4.95**		**5.18**	**5.33**	**5.25**		**5.33**	**5.50**	**5.43**	
	SE_D		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**	
V	0.07		0.30		0.07		0.30		0.07		0.32	
M	0.09		0.21		0.07		0.17		0.09		0.21	
F	0.05		0.10		0.03		0.06		0.03		0.06	
V x M	0.13		0.31		0.13		0.32		0.13		0.32	
V x F	0.18		NS		0.16		NS		0.16		NS	
M x F	0.17		NS		0.12		NS		0.14		NS	
V x M x F	0.14		NS		0.09		NS		0.09		NS	

*V_1 - ANNA 4, V_2 - MDU 6, M_1 - FYM, M_2 - Vermicompost, M_3 - Pressmud Compost, M_4 - Seaweed Compost, F_1 - PPFM, F_2 - Seaweed Extract, F_3 -Humic acid

Table.4 Effect of variety, organic manure and foliar spray on CGR (g m^{-2} day^{-1}) at panicle initiation to flowering stage of aerobic rice

	I Crop (*rabi*' 2014)				II Crop (*kharif*' 2015)				III Crop (summer' 2016)			
TREATMENT	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**
V1	4.84	5.11	4.96	**4.97**	4.70	4.95	4.84	**4.83**	4.66	4.83	4.66	**4.72**
V2	4.46	4.72	4.52	**4.57**	4.29	4.58	4.38	**4.42**	4.25	4.52	4.34	**4.37**
MEAN	**4.65**	**4.91**	**4.74**		**4.50**	**4.77**	**4.61**		**4.46**	**4.68**	**4.50**	
M1	4.21	4.34	4.22	**4.26**	4.02	4.10	4.13	**4.08**	4.03	4.00	3.93	**3.99**
M2	4.74	5.10	4.86	**4.90**	4.55	4.94	4.71	**4.73**	4.55	4.87	4.65	**4.69**
M3	5.05	5.44	5.18	**5.22**	4.91	5.31	5.03	**5.08**	4.83	5.22	4.98	**5.01**
M4	4.59	4.78	4.71	**4.69**	4.51	4.71	4.57	**4.60**	4.41	4.61	4.44	**4.49**
MEAN	**4.65**	**4.91**	**4.74**		**4.50**	**4.77**	**4.61**		**4.46**	**4.68**	**4.50**	
V1M1	4.26	4.49	4.28	**4.35**	4.01	4.25	4.25	**4.17**	4.09	4.13	3.75	**3.99**
V1M2	4.95	5.30	5.16	**5.13**	4.87	5.12	4.98	**4.99**	4.80	5.03	4.93	**4.92**
V1M3	5.37	5.66	5.48	**5.50**	5.20	5.54	5.33	**5.36**	5.13	5.44	5.30	**5.29**
V1M4	4.78	4.99	4.94	**4.90**	4.72	4.88	4.79	**4.80**	4.61	4.73	4.66	**4.67**
V2M1	4.16	4.18	4.16	**4.17**	4.04	3.94	4.01	**4.00**	3.96	3.88	4.12	**3.99**
V2M2	4.54	4.90	4.56	**4.67**	4.23	4.77	4.43	**4.48**	4.31	4.71	4.37	**4.46**
V2M3	4.74	5.22	4.88	**4.95**	4.62	5.08	4.74	**4.81**	4.54	5.00	4.65	**4.73**
V2M4	4.41	4.57	4.49	**4.49**	4.30	4.55	4.35	**4.40**	4.20	4.49	4.22	**4.31**
MEAN	**4.65**	**4.91**	**4.74**		**4.50**	**4.77**	**4.61**		**4.46**	**4.68**	**4.50**	
	SE_D		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**	
V	0.08		0.35		0.08		0.37		0.08		0.33	
M	0.10		0.24		0.09		0.23		0.11		0.26	
F	0.04		0.08		0.06		0.12		0.06		0.13	
V x M	0.17		0.43		0.16		0.38		0.15		0.37	
V x F	0.18		NS		0.22		NS		0.21		NS	
M x F	0.17		NS		0.19		NS		0.21		NS	
V x M x F	0.11		NS		0.17		NS		0.18		NS	

*V_1 - ANNA 4, V_2 - MDU 6, M_1 - FYM, M_2 - Vermicompost, M_3 - Pressmud Compost, M_4 - Seaweed Compost, F_1 - PPFM, F_2 - Seaweed Extract, F_3 -Humic acid

Table.5 Effect of variety, organic manure and foliar spray on grain yield (kg ha^{-1}) of aerobic rice

	I Crop (*rabi*' 2014)				II Crop (*kharif*' 2015)				III Crop (summer' 2016)			
TREATMENT	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**	**F1**	**F2**	**F3**	**MEAN**
V1	3063	3376	3207	**3215**	3150	3439	3285	**3291**	3190	3487	3324	**3334**
V2	2584	2856	2711	**2717**	2628	2899	2751	**2759**	2680	2945	2800	**2808**
MEAN	**2823**	**3116**	**2959**		**2889**	**3169**	**3018**		**2935**	**3216**	**3062**	
M1	2141	2383	2265	**2263**	2190	2432	2308	**2310**	2266	2501	2381	**2382**
M2	3072	3396	3225	**3231**	3127	3447	3280	**3285**	3187	3487	3328	**3334**
M3	3377	3713	3522	**3537**	3429	3768	3566	**3587**	3489	3812	3618	**3640**
M4	2703	2971	2825	**2833**	2810	3027	2919	**2919**	2800	3064	2921	**2928**
MEAN	**2823**	**3116**	**2959**		**2889**	**3169**	**3018**		**2935**	**3216**	**3062**	
V1M1	2341	2601	2475	**2472**	2385	2659	2527	**2523**	2474	2730	2606	**2603**
V1M2	3319	3676	3490	**3495**	3391	3733	3557	**3561**	3453	3773	3602	**3609**
V1M3	3654	4002	3801	**3819**	3723	4064	3855	**3881**	3786	4110	3910	**3935**
V1M4	2937	3225	3064	**3075**	3100	3298	3203	**3201**	3048	3335	3178	**3187**
V2M1	1941	2165	2054	**2053**	1994	2206	2089	**2097**	2057	2271	2156	**2161**
V2M2	2825	3117	2961	**2967**	2863	3160	3003	**3009**	2920	3201	3054	**3058**
V2M3	3101	3423	3243	**3256**	3134	3472	3276	**3294**	3191	3515	3326	**3344**
V2M4	2469	2718	2585	**2591**	2519	2756	2635	**2637**	2552	2793	2664	**2670**
MEAN	**2823**	**3116**	**2959**		**2889**	**3169**	**3018**		**2935**	**3216**	**3062**	
	SE_D		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**		**SE_D**		**CD (P =0.05)**	
V	108		466		117		501		117		503	
M	119		291		113		277		116		285	
F	43		88		46		94		45		91	
V x M	190		465		208		508		206		505	
V x F	239		NS		256		NS		256		NS	
M x F	195		NS		192		NS		194		NS	
V x M x F	122		NS		130		NS		127		NS	

*V_1 - ANNA 4, V_2 - MDU 6, M_1 - FYM, M_2 - Vermicompost, M_3 - Pressmud Compost, M_4 - Seaweed Compost, F_1 - PPFM, F_2 - Seaweed Extract, F_3 -Humic acid

The variety ANNA 4 exhibited significantly higher CGR (5.14, 5.41 and 5.60 g m^{-2} day^{-1}) at tillering to panicle initiation stage and tended to decline from panicle initiation to flowering stage (4.97, 4.83 and 4.72 g m^{-2} day^{-1}) at compare to MDU 6. This might be due to the fact that, lowland rice is apparently very sensitive to reduced water availability under aerobic condition as evidenced by Fukai and Cooper (1995). Niranjana Murthy *et al.,* (1991) reported that rice genotypes maintained high yields due to higher tolerant habit coupled with test weight of grains and two attributes are highly related to CGR and LAI.

Among the organic manures, application of pressmud compost showed improvement in CGR. The pressmud compost 6 @ t ha^{-1} recorded highest CGR (5.52, 5.79 and 5.97) at tillering to panicle initiation stage and tended to decline from (5.22, 5.08 and 5.01) panicle initiation to flowering stage during *rabi'* 2014, *kharif'* 2015 and summer' 2016, respectively.

This might be due to higher uptake and utilizeation of nutrients leading to higher photosynthetic efficiency. The crop growth rate mainly depends upon the photosynthates accumulation and dry matter production.

Spraying of growth regulating substances also resulted in significantly increased CGR. Application of seaweed extract resulted in increased CGR (5.52, 5.79 and 5.97 g m^{-2} day^{-1}) at tillering to panicle initiation stage and tended to decline from panicle initiation to flowering stage (5.22, 5.08 and 5.01 g m^{-2} day^{-1}) during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. This might to be the diversion of adequate nutrients particularly iron to the photosynthesis parts. Similar such results were obtained by Patil and Dhomne (1998).

Grain yield

Grain yield is the ultimate manifestation of a plant's ability to survive, grow and produce more yield under water limited situation regardless of the tolerance mechanisms involved. In the present investigation, higher grain yield (Table 5) was obtained with ANNA 4 with 3215, 3291 and 3334 kg ha^{-1} during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. This might be due to enhancement in growth and yield parameters as well as uptake of nutrient by this variety. Obviously, the cumulative effects of these parameters contributed to increased yield. Moreover, LAI and DMP were positively correlated to grain yield. Hence, in aerobic rice cultivation drought tolerant genotypes could maintain sufficient leaf water potential at reproductive stage and this could maintain higher physiological efficiency, spikelet fertility and seed yield. In the present study ANNA 4 recorded higher yields compared to other entries. In support of this data, Saxena *et al.,*(1996) earlier reported that rice genotypes having greater tolerance to water stress recorded more number of grains test weight, grain yield and harvest index. Such genotypic variability among rice genotypes for yields under aerobic method of cultivation (Sridhara *et al.*, 2012).

The yield reduction in MDU 6 appeared to be due to incomplete grain filling and high floret sterility. Lower biomass, LAI and yield parameters of MDU 6 under aerobic condition might also be a sign of yield reduction. These observations were supported by earlier reports of Russo (2000). The main reason for reduced yield is due to reduction in sink capacity (Bouman *et al.*, 2006). The decline in yield is a natural trade-off when the rice crop is shifted from its natural habitat as an aquatic plant to an aerobic condition because of its physiological disruption of growth and yield parameters to produce higher grain yield (Castaneda *et al.*, 2006).

Among the organic manures, pressmud compost application @ 6 t ha^{-1} recorded the highest grain yield of 3537, 3587 and 3640 ka ha^{-1} during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. Higher grain yield obtained from the pressmud compost might be attributed to rapid mineralization of N and sustained supply of N from pressmud compost, which might have met the N requirement of crop over a long period and specifically at the critical stages of crop growth. Similar results were repeated earlier by Kalaivanan and Omar Hattab (2015).

The plants that received the foliar spray of seaweed extract @ 500 ml ha^{-1} registered higher grain yield of 3116, 3169 and 3216 kg ha^{-1} during *rabi'* 2014, *kharif'* 2015 and summer' 2016 respectively. The highest yield achieved under seaweed extract could be explained by the higher level of performance in growth as well as physiological attributes. The reason for its ability to enhance the productivity level of crops could be explained by its higher levels of phytohormones especially cytokinin and gibberellins as also a large amount of trace elements. Use of seaweed extracts in the improvement of yields in other crops such as pulses has also been reported (Nuray Ergun *et al.*, 2002). When the plants received additional source of nutrients from foliar spray of seaweed extract it compensated the reduction in the absorbed nutrients from the soil. Such increment might be due to the fact that seaweed extract is a biostimulant, which provide the rice plant with micro, macro nutrients and significant amounts of cytokinins, auxins and betaines (Biswajit Pramanick *et al.*, 2014) ultimately increasing the chlorophyll production by boosting the photosynthetic process, thereby stimulating vegetative growth. Thus, an overall plant performance would be enhanced accordingly and finally reflecting through an escalated productivity.

From the above results it can be influenced that rice variety ANNA 4 with application pressmud compost @ 6 t ha^{-1} as basal along with foliar spraying seaweed extract @ 500 ml ha^{-1} can be recommended for getting higher LAI, CGR and yield of aerobic rice.

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