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Study of Growth Indices and Chlorophyll content in *kharif* Rice as Influenced by Irrigation Scheduling and Bio-inoculants Enriched Municipal Solid Waste Compost

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ABSTRACT: Irrigation as well as nutrient management plays an important role in rice growth and photosynthetic activity leading to increased crop yield. Therefore, making it essential to study the growth indices throughout the growing season. Also, long-term intensive rice cultivation using traditional methods has been linked with severe problems especially groundwater depletion and multiple nutrient deficiencies raising concerns with respect to sustainable rice growth and production. To address this issue, a two-year experiment was conducted to investigate the effect of irrigation schedule and bio-inoculants enriched municipal solid waste compost on *kharif* rice in Varanasi, U.P., India. The experiment was laid out in split plot design with four irrigation scheduling treatment in main plot *viz*. Alternate wetting and drying, Saturation (at field capacity), 2.5 cm irrigation at 7 days, 5 cm irrigation at 7 days and five treatments in sub plot *viz*. NPK (RDF), NPK (RDF)+MSW@10 t ha^{-1}, NPK (RDF)+MSW(N-fixers)@10 t ha^{-1}, NPK (RDF)+MSW(PSB)@10 t ha^{-1}, NPK (RDF)+MSW (Zn solubilizers) @10 t ha^{-1} with three replications. The results reported that the higher growth indices *viz.* LAI, CGR and chlorophyll content were recorded under Saturation (at field capacity) as compared to other two irrigation schedule, however, it was statistically at par with 5 cm irrigation at 7 days during both the years of experimentation. Among nutrient levels, NPK (RDF)+MSW (Zn solubilizers) @10 t ha^{-1} recorded higher growth indices which was followed by NPK (RDF)+MSW(PSB)@10 t ha^{-1} during both the years. In case of chlorophyll content, NPK (RDF)+MSW(N-fixers) @10 t ha^{-1} recorded highest values. However, NPK(RDF) recorded significantly lower values in all the parameters during both the years of study. Also, there was no significant difference recorded in case of NAR during both the years of study. These results also imply that use of chemical fertilizers only might adversely affect the crop growth indices leading to low yield. Use of E-MSW along with proper irrigation scheduling can help us in achieving our goals in a judicious manner.

Keywords: Irrigation scheduling, E-MSW (Enriched Municipal solid Waste compost), LAI, CGR, Chlorophyll content and NAR.

INTRODUCTION

Rice (*Oryza sativa* L.) is a primary source of food consumed by more than 3 billion people across the world and hence, deserves a special status among the cereals. In terms of production, India holds the second rank after China and hence, rice has a great importance in Indian agriculture as well as the economy generated by it. In India, rice is cultivated in 44.72 m ha, with a total production of around 117.47 million tonnes (Anonymous, 2020-21) but productivity as low as 2.65 t/ha (Agricultural Statistics at a Glance, 2019). According to the projections made by the Population Foundation of India, the country's population will be 1824 million by the end of 2050. To feed these population, demand of rice will be 137.3 million tonnes by the year 2050 (Vision 2050). Therefore, exploring ways to produce more with less is essential for food security and sustaining environmental health.

Traditional method of transplanting under continuous submergence has been prevailing as the most common method of crop establishment for low land rice cultivation especially in Asia. Hence, in Asia, rice alone uses up to 50% of the water set aside for irrigation (Tuong and Bouman, 2003). India is placed at the top in terms of freshwater consumption which is 91% for food production usages (http://www.fao.org/nr/water/aquastat/). Also, Xu (2001) suggested that use of chemical fertilization exclusively along with continuous submergence of soil in rice cultivation increased the soil bulk density and decreased paddy soil organic matter (SOM). Hence, this practice is not only threatening the sustainability of the rice-based production system but also leads to low water productivity and decline in overall soil fertility (Bouman and Tuong, 2001; Timsina and Connor, 2001; Solaimalai *et al.,* 2000; Abrol, 1999; Choudhary *et al.* 2021). In order to address this issue, many water saving technologies have been developed *viz.* (i) reducing the depth of ponded water/shallow irrigation, (ii) keeping the soil just saturated or (iii) alternate wetting/drying or intermittent irrigation, i.e. allowing the soil to dry out to a certain extent before re-applying irrigation water. Thus, to improve the SOM, municipal solid waste compost can come into rescue as there has been a dramatical increase in municipal solid waste in recent past. This is due to the result of increasing population, urbanization and consumption habits. However, it is also a potential nutrient source if well decomposed. Municipal solid waste compost although being a good source of organic matter produced by mechanical composting is usually low in nutrients which make it less acceptable by the farmers. Hence, Enriched Municipal Solid Waste compost (EMSW) can be used to overcome this problem. It is well documented that addition of organic matter improves overall soil properties as well as its fertility level which helps in its better growth and increased growth indices resulting in higher dry matter accumulation and finally higher yield. Hence, the aim of this study is to focus on the relative effectiveness of inorganic fertilizers along with enriched municipal solid waste compost (E-MSW) treatments on the growth habit and growth indices of rice under different irrigation scheduling.

MATERIALS AND METHODS

A. 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. Climatologically Varanasi district has a subtropical climate and is subjected to extremes of weather conditions *i.e.*, extremely hot summer and cold winter. This region falls in semi-arid to the sub-humid type of climate. The average annual rain fall is about 1100 mm of which more than 80 % is received during the monsoon season (July to September) and a light share of rainfall is observed during winter (December to February). Rice–wheat cropping system is dominant in the region. The experimental land is high in topography and characterized by a sandy cay loam texture having pH 7.39, Electrical conductivity (dSm^{-2}) 0.22, Organic carbon 0.41%, available nitrogen 180.5 kg/ha, available phosphorous 22.2 kg/ha, available potassium 218.5 kg/ha, available zinc 1.17 kg/ha.

B. Experimental design and irrigation scheduling and soil nutrient treatment details

The experiment was laid out in a split-plot design using three replications. The unit size of the sub-plots was 4 m× 4 m and that of main plot was 80 m^2. This experiment was carried out in permanent irrigation blocks. These plots are made up of concrete structures with a horizontal water meter installed in each plot for precise irrigation and a drainage hole along with channel for removal of excess water. This particular structure is useful to prevent side-seepage from one plot to another. The plots were irrigated with groundwater each at one time via pipe line with a separate outlet to each plot. The volume of water applied to each plot was hence measured by these horizontal water meter fixed on the outlet. During both the years, transplanting was done after commencement of monsoon which was necessary for proper crop establishment. The variety Swarna sub-1 (*Oryza sativa* L.) of *kharif* rice was grown.

The main plot treatments included in the study were four irrigation scheduling: (i) Alternate Wetting and drying (AWD), of which plots were allowed to dry and then irrigated with 5cm of irrigation water when there was visual symptoms of hair line cracks on the soil surface, (ii) Saturation- Field capacity, of which 5 cm of irrigation was applied and soil moisture was tried to maintain at saturation throughout the growing season, (iii) 2.5 cm irrigation at 7 days interval, here 2.5 cm of irrigation water was applied at 7 days interval unless there was rainfall and (iv) 5 cm irrigation at 7 days interval, here 5 cm of irrigation water was applied at 7 days interval unless there was rainfall.

The sub plot treatments in the study included five different nutrient levels with a combination of recommended doses of fertilizers (RDF) along with MSW (Municipal Solid Waste Compost) and biofertilizers (N-fixer, PSB, Zn-solubilizers). Full doses of NPK fertilizers were applied viz. urea, DAP and MOP in combination with different biofertilizers inoculated in MSW (Municipal Solid Waste Compost). The combinations were, (i) NPK (RDF), it consisted of 100 % recommended doses of NPK, (ii) NPK (RDF)+ MSW @ 10 t ha^{-1}, (iii) NPK(RDF)+E-MSW Compost (N-fixers)@10t ha^{-1}, (iv) NPK(RDF)+E-MSW Compost

(PSB)@10t ha^{-1} and (v) NPK(RDF)+E-MSW Compost(Zn- solubilizers)@10 t ha^{-1}. P and K fertilizers were applied as DAP and MOP as basal after transplanting. Nitrogen was applied in four equal split applications: 1st part *i.e.* one-fourth of total N fertilizers (urea) after transplanting and the other three parts at tillering, booting and grain filling stages respectively. MSW (both enriched and not enriched) was incorporated into paddy soil two weeks before transplanting each year. Rice was transplanted in 3rd week of July in 2018 and 2nd week of July in 2019 with spacing of 20 cm × 10 cm and harvested in November.

Leaf area index. The leaf area of per hill was measured at 30, 60, and 90 days stages for calculating the leaf area index. The 5 hills which were selected for dry matter used for calculating LAI. Green leaves were separated out from tillers to record their surface area by automatic leaf area meter. The LAI was computed by the following formula:

$$\mathrm{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Ground area (cm}^2\text{)}}$$

Chlorophyll content. The SPAD-502 meter is a hand-held chlorophyll meter which was used for rapid non-destructive estimation of extractable chlorophyll in green leaves (Earl and Tollenaar, 1997). Randomly ten 3rd and 1st leaves selected from various rice plants in net plot area was measured chlorophyll content with the help of SPAD at 30, 60 and 90 DAS.

Crop growth rate (g $plant^{-1}$ day^{-1}). The crop growth rate has been calculated by using following formula given by Watson (1952) and expressed in g $plant^{-1}$ day^{-1}.

$$\mathrm{CGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

W_1 and W_2 are plant dry weight m^2 at times t_1 and t_2 and L is land area.

Relative growth rate (g g^{-1} day^{-1}). 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 Hoffmann and Poorter (2002) and expressed as (g g^{-1} day^{-1}).

$$RGR = \frac{ln\, W2 - ln\, W1}{(t2 - t1)}$$

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^{-1}). It is the rate of dry weight increase per unit leaf area per unit time and it was calculated as suggested by Gregory (1926) and expressed in (g m^{-2} day^{-1}).

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{(log\, e\, W_2 - log\, e\, W_1)}{(L_2 - L_1)}$$

Where,

Loge, W_1 = Leaf area (cm^2) and dry weight of the plant (g), respectively at time t_1 Loge, W_2 = Leaf area (cm^2) and dry weight of the plant (g), respectively at timet$_2$ - t_1 = Time interval in days

Data statistics and analysis. All analyses were carried out on the four replicates. Data were analyzed statistically by analysis of variance (ANOVA) procedure. The effects of nutrient and water regimes were declared as significant at 5% probability level.

RESULT AND DISCUSSION

Data in table related to physiological characters indicated that significant difference was observed in LAI, CGR and chlorophyll content. Saturation (at field capacity) (I_2) recorded significantly higher LAI, CGR and chlorophyll content at all stages of crop growth except at 30 DAT over Alternate wetting and drying (I_1) and I_3 (2.5 cm irrigation at 7 days interval) during both the experimental season (Table 1-3). However, it was at par with 5 cm irrigation at 7 days interval (I_4) during both the years. This might be due to the availability of more quantity as well as in frequency of irrigation water in saturation (at field capacity) (I_2) which was conducive for the cell division, elongation resulting in bigger size of leaves. Hence, this might have resulted in increased leaf area as well as photosynthetic activity in the plant which is directly proportion to the higher number of leaves, chlorophyll content in leaves, LAI and higher CGR. It was observed that there was no significant difference marked under different irrigation scheduling in case of RGR (Table 4) and NAR (Fig. 1). The result found are in accordance with Shekara and Krishnamurthy (2010); Sandhu *et al.* (2012); Nayak *et al*. (2015); Choudhary *et al.* (2021).

Among the nutrient management treatments, significant differences were recorded in LAI, CGR and RGR of the crop. The growth indices were recorded highest values in the treatment NPK (RDF)+MSW (Zn- solubilizers) @ 10 t ha^{-1} which was at par with NPK (RDF)+MSW (PSB)@ 10 t ha^{-1} during all stages of crop growth during both the years except for RGR at 0-30 DAT in 1st growing season (Table 1, 2 and 4). However, the treatment NPK (RDF) recorded lowest LAI, CGR and RGR throughout the growing season during both the years (Table 1, 2 and 4). This might be due to increased availability of soluble nutrients in soil environment due to application of enriched-MSW leading to more dry matter accumulation and also production of a greater number of leaves leading to increased CGR, RGR and LAI. Similar results were recorded by Kavitha and Subramanian (2007); Oroka (2012). In case of chlorophyll content, it increased significantly up to higher vegetative stage and decreased as the plant started to move towards senescence (Table 3). However, among the nutrient levels, highest values were recorded in case of NPK (RDF) + MSW (N-fixers) @10 t ha^{-1} which was at par with the treatment NPK (RDF) + MSW (Zn- solubilizers) @ 10 t ha^{-1} at all stages of crop growth during both the years (Table 3). This might be due to increased availability of nitrogen in soil environment which plays a key role in development of the photosynthetic apparatus i.e. chlorophyll molecule in plants Bassi *et al.* (2018).

Similar results were confirmed by Yilmaz and Temizgul (2012); Sortino *et al.* (2014); Kumar *et al.* (2021). There was no marked difference found in NAR for different nutrient levels during both the years of study throughout the growing season (Fig. 1).

Table 1: Effect of irrigation scheduling and bio-inoculants enriched municipal solid waste compost on leaf area index of *kharif* rice.

Treatments	LAI (30 DAT)		LAI (60 DAT)		LAI (90 DAT)	
	2018	2019	2018	2019	2018	2019
Irrigation Scheduling						
I_1-Alternate wetting and drying	2.41	2.54	4.34	4.77	3.67	3.84
I_2-- Saturation at field capacity	2.62	2.73	5.56	5.84	4.32	4.51
I_3- 2.5 cm irrigation at 7 days interval	2.43	2.59	4.47	4.88	3.68	3.71
I_4- 5cm irrigation at 7 days interval	2.50	2.65	5.27	5.45	4.03	4.33
Sem ±	0.04	0.05	0.17	0.19	0.13	0.11
LSD (P = 0.05)	NS	NS	0.59	0.65	0.46	0.38
Nutrient management						
N_1- NPK (RDF)	2.20	2.32	4.36	4.60	3.48	3.62
N_2- NPK (RDF)+MSW	2.36	2.50	4.51	4.77	3.73	3.91
N_3- NPK (RDF)+ E-MSW (N-Fixers)	2.44	2.59	4.83	5.14	3.86	4.04
N_4- NPK (RDF)+ E-MSW (PSB)	2.68	2.78	5.23	5.60	4.16	4.34
N_5-NPK (RDF)+E-MSW (Zn solubilizers)	2.78	2.94	5.62	6.06	4.38	4.56
Sem ±	0.06	0.07	0.16	0.18	0.13	0.11
LSD (P = 0.05)	0.19	0.21	0.47	0.53	0.38	0.31

MSW: Municipal Solid Waste compost; N-fixers: Nitrogen fixing bacteria (Halo-Azo); PSB: phosphorus solubilizing bacteria (Halo-PSB); Zn solubilizers: zinc solubilizing bacteria (Halo-Zinc)

Table 2: Effect of irrigation scheduling and bio-inoculant enriched municipal solid waste compost on crop growth rate of *kharif* rice.

Treatments	CGR (0-30 DAT) (g^{-1} $plant^{-1}$ day)		CGR (30-60 DAT) (g^{-1} $plant^{-1}$ day)		CGR (60-90 DAT) (g^{-1} $plant^{-1}$ day)		CGR (90 to at harvest) (g^{-1} $plant^{-1}$ day)	
	2018	2019	2018	2019	2018	2019	2018	2019
Irrigation Scheduling								
I_1-Alternate wetting and drying	0.139	0.169	1.08	1.22	0.725	0.760	0.169	0.220
I_2-- Saturation at field capacity	0.148	0.198	1.21	1.38	0.880	0.906	0.188	0.253
I_3- 2.5 cm irrigation at 7 days interval	0.144	0.173	1.13	1.24	0.758	0.784	0.173	0.230
I_4- 5cm irrigation at 7 days interval	0.149	0.178	1.18	1.30	0.852	0.892	0.178	0.246
Sem ±	0.003	0.006	0.019	0.029	0.024	0.023	0.004	0.004
LSD (P = 0.05)	NS	NS	0.065	0.101	0.081	0.085	0.013	0.013
Nutrient management								
N_1- NPK (RDF)	0.142	0.154	0.98	1.16	0.709	0.739	0.152	0.219
N_2- NPK (RDF)+MSW	0.144	0.171	1.10	1.22	0.754	0.793	0.169	0.236
N_3- NPK (RDF)+ E-MSW (N-Fixers)	0.152	0.180	1.16	1.29	0.808	0.831	0.177	0.238
N_4- NPK (RDF)+ E- MSW (PSB)	0.142	0.193	1.20	1.36	0.848	0.900	0.190	0.243
N_5-NPK (RDF)+ E-MSW (Zn solubilizers)	0.146	0.199	1.26	1.40	0.901	0.914	0.196	0.250
Sem ±	0.003	0.005	0.027	0.026	0.024	0.027	0.005	0.005
LSD (P = 0.05)	NS	0.014	0.078	0.073	0.070	0.072	0.014	0.014

MSW: Municipal Solid Waste compost; N-fixers: Nitrogen fixing bacteria (Halo-Azo); PSB: phosphorus solubilizing bacteria (Halo-PSB); Zn solubilizers: zinc solubilizing bacteria (Halo-Zinc)

Table 3: Effect of irrigation scheduling and bio-inoculant enriched municipal solid waste compost on chlorophyll content of *kharif* rice

Treatments	Chlorophyll content (30 DAT)		Chlorophyll content (60 DAT)		Chlorophyll content(90 DAT)	
	2018	2019	2018	2019	2018	2019
Irrigation Scheduling						
I_1-Alternate wetting and drying	39.9	40.8	39.4	39.87	38.35	39.15
I_2-- Saturation at field capacity	41.4	42.5	42.9	43.35	42.10	42.37
I_3- 2.5 cm irrigation at 7 days interval	40.0	41.1	41.0	41.46	39.49	40.12
I_4- 5cm irrigation at 7 days interval	40.7	41.6	42.0	42.50	41.26	41.09
Sem ±	0.54	0.55	0.59	0.59	0.45	0.46
LSD (P = 0.05)	NS	NS	2.03	2.04	1.57	1.61
Nutrient level						
N_1- NPK (RDF)	39.6	39.2	38.6	39.2	38.0	38.0
N_2- NPK (RDF)+MSW	40.1	40.6	40.7	40.9	39.6	40.1
N_3- NPK (RDF)+ E-MSW (N-Fixers)	41.6	42.7	43.1	44.2	42.1	42.6
N_4- NPK (RDF)+ E-MSW (PSB)	40.5	41.5	41.4	41.9	40.3	40.8
N_5-NPK (RDF)+ E-MSW (Zn solubilizers)	40.8	42.6	42.7	42.9	41.5	41.9
Sem ±	0.31	0.39	0.55	0.63	0.44	0.31
LSD (P = 0.05)	0.90	1.12	1.59	1.82	1.28	0.88

MSW: Municipal Solid Waste compost; N-fixers: Nitrogen fixing bacteria (Halo-Azo); PSB: phosphorus solubilizing bacteria (Halo-PSB); Zn solubilizers: zinc solubilizing bacteria (Halo-Zinc)

Table 4: Effect of irrigation scheduling and bio-inoculant enriched municipal solid waste compost on relative growth rate of *kharif* rice.

Treatments	RGR (0-30 DAT) (g^{-1}g^{-1}day)		RGR (30-60 DAT) (g^{-1}g^{-1}day)		RGR (60-90 DAT) (g^{-1}g^{-1}day)	
	2018	2019	2018	2019	2018	2019
Irrigation Scheduling						
I_1-Alternate wetting and drying	0.040	0.046	0.030	0.031	0.020	0.021
I_2-- Saturation at field capacity	0.043	0.048	0.033	0.034	0.022	0.024
I_3- 2.5 cm irrigation at 7 days interval	0.042	0.047	0.031	0.033	0.021	0.022
I_4- 5cm irrigation at 7 days interval	0.041	0.044	0.032	0.036	0.020	0.022
Sem ±	0.0008	0.001	0.0007	0.0007	0.0005	0.0007
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS
Nutrient level						
N_1- NPK (RDF)	0.039	0.043	0.029	0.028	0.019	0.020
N_2- NPK (RDF)+MSW	0.040	0.044	0.031	0.032	0.020	0.021
N_3- NPK (RDF)+ E-MSW (N-Fixers)	0.042	0.047	0.032	0.034	0.021	0.022
N_4- NPK (RDF)+ E-MSW (PSB)	0.043	0.048	0.032	0.036	0.021	0.023
N_5-NPK (RDF)+ E-MSW (Zn solubilizers)	0.044	0.049	0.033	0.037	0.022	0.024
Sem ±	0.0007	0.0009	0.0005	0.0005	0.0005	0.0007
LSD (P = 0.05)	0.002	0.0026	0.0015	0.0016	0.0014	0.002

MSW: Municipal Solid Waste compost; N-fixers: Nitrogen fixing bacteria (Halo-Azo); PSB: phosphorus solubilizing bacteria (Halo-PSB); Zn solubilizers: zinc solubilizing bacteria (Halo-Zinc)

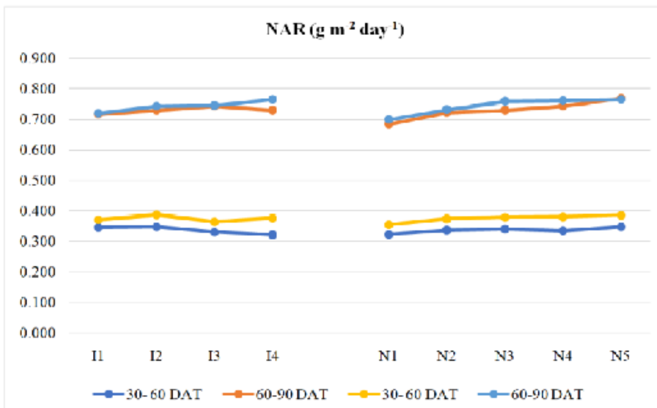

Fig. 1. Effect of irrigation scheduling and bio-inoculants enriched municipal solid waste compost on net assimilation rate in *kharif* rice at different time interval.

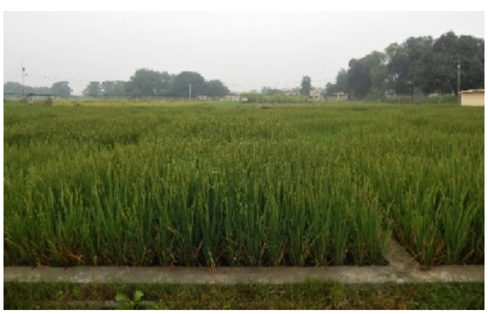

Plate 1. General view of experimental field.

Plate 2. Preparation of E-MSW (Enriched Municipal Solid Waste).

Plate 3

Plate 4

CONCLUSION

Incorporation of E-MSW (Enriched Municipal Solid Waste compost) along with inorganic fertilizers into rice field could improve the growth indices *viz.*, LAI, CGR, RGR as well as the chlorophyll content of the crop. When comes to different irrigation scheduling, however, it is evident that beneficial effects of the combined application of chemical fertilizers and enriched municipal solid waste are significantly different. Saturation (at field capacity) significantly increased the LAI, CGR as well as the chlorophyll content of rice crop as compared to other irrigation scheduling treatments. However, the alternate wetting and drying showed significantly lower growth indices by the rice plants.

FUTURE SCOPE

Decrease in global fresh water resources and increase in urban areas in the last few decades are evident. Hence, this creates a tremendous scope in this particular area of research to be done in recent future. This can be a sustainable way to feed our ever-growing population keeping in view our current availability and future needs.

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