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The Use of Municipal Solid Waste Compost in Combination with Proper Irrigation Scheduling Influences the Productivity, Microbial Activity and Water Use Efficiency of Direct Seeded Rice

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Abstract: Appropriate irrigation scheduling, along with proper nutrient management practice for direct seeded rice (DSR), are very much essential to attain higher water use efficiency. Huge amounts of municipal waste are been produced every year and these wastes are left untreated and have caused many environmental hazards. However, these wastes can be converted into potential manures for crop production when enhanced with microbial consortia. Concerning these, the current research was carried out to know the effect of compost of enriched municipal soil waste (E-MSWC) with suitable irrigation scheduling on growth, yield, microbial activity, and water use efficiency of the DSR grown under Indo-Gangetic plains during two consecutive rice seasons of 2017–2018 and 2018–2019 at Varanasi, India. From the experiment, it was found that E-MSWC applied at 10 Mg·ha^{-1} along with 75% recommended dose of fertilizer (RDF) was capable to improve growth, yield, soil microbes, and water use efficiency (WUE) of rice. Amongst different enriched MSWC, the consortia (blend of N-fixing, P and Zn-solubilizing bacteria and *Trichoderma*) enriched MSWC was found to be the most effective. Concerning, different irrigation scheduling, it was observed that 50 mm cumulative pan evaporation (CPE) based irrigation was the most suitable as compared to providing irrigation at 75 mm CPE. Comparing rice varieties used in the research, the rice variety Swarna has appeared as a better choice in terms of yield and WUE than the variety, Sahbhagi. Thus, it can be recommended that irrigation at 50 mm of CPE in conjunction with 75% RDF + E-MSWC (consortia) at 10 Mg·ha^{-1} could improve the water use efficiency of rice grown in Indo-Gangetic plains.

Keywords: municipal solid waste compost; irrigation scheduling; yield; water use efficiency; microbial population; direct seeded rice

1. Introduction

Amongst the cereals, rice (*Oryza sativa* L.) is one of the furthermost staple crops across the globe. About 90% of global production and consumption is occurred in Asia [1]. Concerning rice-producing countries, India occupied 43 Mha of rice area, with the second greatest amount in the globe after China. The area production and productivity of rice in the world are about 158 Mha, 700 Mt, and 4.4 Mg·ha^{-1}, respectively, while the area, production, and productivity of rice in India is about 43 Mha, 105 Mt, and 2.3 Mg·ha^{-1}, respectively [2]. The world's population is approaching to reach 9.3 billion by the year 2050 from 6 billion of today [3]. However, the area under crops is shrinking day by day, due to the demand of urbanization and industrialization [4,5]. Crop production is also declining rapidly due to the negative impact of numerous stresses. Water scarcity, due to the sudden occurrence of drought, caused by climatic change phenomenon, is one of the most burning issues of agriculture currently. The eastern states of India account for 27.26 Mha of rice area, out of which nearly 4.28 Mha of the area is prone to regular drought [6]. On the other hand, the water use efficiency of rice is much lower as compared to other field crops. Thus, proper scheduling of irrigation should be aimed at increasing the efficiency of water used by any crop. Direct seeded rice (DSR) is a potential technology to grow rice using a lower amount of water [7]. However, the variety of rice which would be suitable under this technology is yet to explore properly. Thus, in this study, along with different irrigation scheduling practices, diverse varieties of rice were also tested.

A high amount of municipal soil waste (MSW), accounting for 127,486 Mg·d^{-1}, is created in India; in which 13% of MSW is processed or preserved [8]. These wastes qualitatively and quantitatively contaminate the environment and cause a potential health risk for humans and domestic animals. However, municipal solid wastes can be successfully converted to potential compost as they contain a high amount of organic matter and other minerals [9]. Hence, proper management of solid waste minimizes the adverse effects on the environment and subsequently improves resource efficiency [9]. In recent years, there has been a focus on growing global anxiety for nourishment and ecological excellence on the use of microbes for reducing chemical inputs and increase in food quality in agriculture and which are also linked with growth and development. Amongst them, rhizobacteria (PGPRs) is the most important one [10]. PGPRs have been applied to various crops to enhance growth, seed emergence, tolerance to drought, nutrient uptake, and, ultimately, crop yield [11,12]. Thus, the enrichment of any compost with these PGPRs improve the efficacy of the compost [13]. However, limited research findings are available concerning the effect PGPRs enriched municipal solid waste compost on the crop, as well as water productivity.

Of most concern, the research gap on the effect of enriched municipal solid waste compost (E-MSWC) on the water use efficiency of rice is quite wide. Thus, the study was planned to evaluate the hypothesis that E-MSWC can improve the productivity and water utilization efficiency of rice when this is applied with suitable irrigation scheduling. Henceforth, the main objectives of this research were to assess the efficacy of E-MSWC on the productivity of rice varieties; to estimate the microbial population dynamics under different treatments; and also to find out the water use efficiency under various irrigation schedulings in different E-MSWC.

2. Materials and Methods

2.1. Experimental Details

The present investigation was established at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India (25°18′ N, 83°30′ E and 128.9 m above MSL) during the rainy seasons of two consecutive years, 2017–2018 and 2018–2019. The study area possesses sub-humid climatic conditions and is categorized in the sub-tropical climatic zone, with some disproportion in the temperatures of the seasons (extreme hot and cold). The temperature varied from 15 °C to 35 °C, and 12 °C to 36 °C during 2017–2018, and 2018–2019, respectively. Relative humidity in the 1st year and 2nd year of the study were 76–93%, and 78–94%, respectively. Total rainfall received during 2017–2018 and 2018–2019 were 789 mm and 1004 mm, respectively.

The initial soil properties of the experimental field were sandy clay in texture, having a low level of nitrogen (N) (96 mg·kg^{-1}) and organic carbon (3.8 g·kg^{-1}), and a medium level of available phosphorus (P) (8.0 mg·kg^{-1}) and potassium (K) (88 mg·kg^{-1}) with pH and electrical conductivity (EC) of 7.31 and 0.21 dS·m^{-1}, respectively. Bulk density and particle density at 0–15 cm soil-depth of the study site were 1.32 g·cm^{-3} and 2.62 g·cm^{-3}, respectively. Field capacity (FC) and permanent wilting point (PWP) of the initial soil were about 20–22% and gravimetric water contents were 10–11%, respectively.

This experiment was designed statistically with a split-plot design (SPD) replicated thrice. Different irrigation schedulings and varieties of rice were taken in the main plot and varied nutrient management practices along with microbes were put in the sub-plot. Each sub-plot was of 20 m^2 area (5 m × 4 m). Irrigation was scheduled at 50 mm and 75 mm cumulative pan evaporation (CPE). Two popular rice varieties, Swarna and Sahbhagi were chosen for this study, as these are the most commonly adopted varieties by the farmers of the study areas. Concerning the nutrient management practices along with microbes, there were eight different practices as follows: 100% recommended dose of fertilizer (RDF); 75% RDF; 75% RDF + municipal solid waste compost (MSWC) at 10 Mg·ha^{-1}; 75% RDF + enriched MSWC (nitrogen-fixing bacteria) at 10 Mg·ha^{-1}; 75% RDF + enriched MSWC (phosphorus solubilizing bacteria) at 10 Mg·ha^{-1}; 75% RDF + enriched MSWC (zinc solubilizing bacteria) at 10 Mg·ha^{-1}; 75% RDF + enriched MSWC (*Trichoderma*) at 10 Mg·ha^{-1} and 75% RDF + enriched MSWC (Consortia) at 10 Mg·ha^{-1}. The layout of the present study is shown in Figure 1.

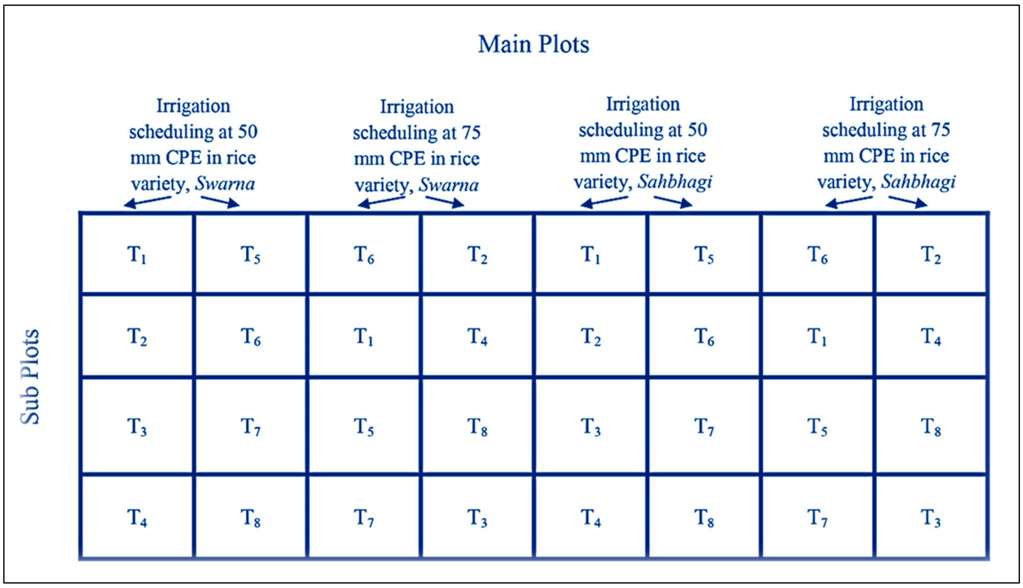

Figure 1. Field arrangement of main plots and sub-plots treatments in a replication and repeated same in other two replications. CPE, cumulative pan evaporation; T_1, 100% recommended dose of fertilizer (RDF); T_2, 75% RDF; T_3, 75% RDF + municipal solid waste compost (MSWC) at 10 Mg·ha^{-1}; T_4, 75% RDF + enriched MSWC (nitrogen fixing bacteria) at 10 Mg·ha^{-1}; T_5, 75% RDF + enriched MSWC (phosphorus solubilizing bacteria) at 10 Mg·ha^{-1}; T_6, 75% RDF + enriched MSWC (zinc solubilizing bacteria) at 10 Mg·ha^{-1}; T_7, 75% RDF + enriched MSWC (*Trichoderma*) at 10 Mg·ha^{-1}, and T_8, 75% RDF + enriched MSWC (Consortia) at 10 Mg·ha^{-1}.

2.2. Crop Management

Rice crops of two different varieties were grown as a direct seeding method. Seeds of rice at 30 kg·ha^{-1} were sown on the last week of June for Year 1 and Year 2 with the help of drum seeder by maintaining 20 cm row to row and 10 cm plant to plant spacing. RDF applied for rice was 120 kg·ha^{-1} N, 60 kg·ha^{-1} P_2O_5, 60 kg·ha^{-1} K_2O, and 20 kg·ha^{-1} $ZnSO_4$. The whole amounts of P_2O_5, K_2O, and $ZnSO_4$ along with half of the N were applied as basal through di-ammonium phosphate (DAP), urea, and muriate of potash (MOP). The remaining half of N was top-dressed in two equal instalments at tillering and panicle initiation stages as the form of urea fertilizer. Broad-spectrum herbicide bispyribac sodium, at 20 g·ha^{-1}, was sprayed at 15 days after sowing on all the plots as a common treatment to reduce the weed population below the threshold level during both years of study. No occurrences of insect, pest, and diseases were observed during the two crop cycles. Details of the calendar of agronomic practices are presented in Table 1.

Table 1. Details of the calendar of agronomic practices during experimentation.

Particulars of Agronomic Practices	Time Schedule	
	2017	**2018**
Land preparation	24 June 2017	24 June 2018
Seed sowing	25 June 2017	25 June 2018
Basal fertilizer application	25 June 2017	25 June 2018
1st top dressing of urea	2 August 2017	3 August 2018
2nd top dressing of urea	2 September 2017	1 September 2018
Application of herbicide	9 July 2017	9 July 2018
Harvesting	11 October 2017 (for var. Sahbhagi) 15 November 2018 (for var. Swarna)	12 October 2017 (for var. Sahbhagi) 14 November 2018 (for var. Swarna)

2.3. Irrigation Scheduling

The climatological approach of irrigation scheduling, i.e., irrigation was done in this study based on cumulative pan evaporation (CPE). In this method, a recognized amount of irrigation (IW) is used when CPE reaches a predetermined level [14]; while CPE is the loss of water due to evaporation from a USWB Class-A open pan evaporimeter. CPE will be less when there will be higher rainfall. Thus, this approach is very much related to the rainfall condition of the study area. In this study, there was higher rainfall during the second year than the rainfall received in the first year of the study. So, the frequency of irrigation in the second year was less than that of the first year of study. The known amount of IW for each irrigation was 50 mm during both years. A Parshall flume was used to measure the amount of applied irrigation water. For irrigation scheduling, two different CPE (50 mm and 75 mm) were considered. The total number of irrigations given to the rice variety Swarna during 2017 and 2018 were 6 and 4, respectively, under irrigation scheduling at 50 mm CPE, while, the number of irrigations were 3 and 2 during 2017 and 2018, respectively, under irrigation at 75 mm CPE. In the case of variety Sahbhagi, the numbers of required irrigations were 4 and 2 during 2017 and 2018, respectively, under irrigation at 50 mm CPE, while; single irrigation was given to this variety during both the years at 75 mm CPE.

2.4. Municipal Solid Waste Compost

The segregated municipal solid waste (MSW) containing degraded materials, including paper or cardboard, organic matter, garbage, and woods or twigs, etc., was analyzed in the laboratory to examine its chemical composition. The municipal city wastes were collected from Lucknow city, India. Afterwards, the collected municipal wastes were carefully differentiated into organic and inorganic wastes. At the time of segregation of MSW, the organic wastes were considered and the possible toxic materials, such as heavy metals, were separated using an organic liquefying press. The chemical composition of MSW is depicted in Table 2.

Table 2. Chemical characteristics of municipal solid waste.

Attributes	Amounts	
	2017	2018
pH	6.97	6.93
Nitrogen ($g \cdot kg^{-1}$)	5.2	5.1
Phosphorus ($g \cdot kg^{-1}$)	0.53	0.54
Potassium ($g \cdot kg^{-1}$)	2.8	2.7
Calcium ($g \cdot kg^{-1}$)	3.6	3.6
Magnesium ($g \cdot kg^{-1}$)	1.0	0.9
Sulphate ($g \cdot kg^{-1}$)	1.06	1.06
Total Carbon ($g \cdot kg^{-1}$)	283.5	282.1

The municipal solid waste compost was applied at 10 $Mg \cdot ha^{-1}$. The nitrogen-fixing bacteria (NFB) was *Azospirillum*, phosphorus solubilizing bacteria (PSB) was *Pseudomonas*, Zn solubilizing bacteria was *Acinetobacter*. NFB, PSB, and Zn solubilizing bacteria were isolated from experimental plots of similar Gangetic plain zone soils of Lucknow and all the microbes are available for farmers' use from ICAR-Central Soil Salinity Research Institute, India. They are available with the name of Halo-NFB, Halo-PSB, and Halo-Zn. They are commercially available and the application rate is 250 $mL \cdot ha^{-1}$. *Trichoderma* applied for enriching the MSWC is commercially available as Halo-*Trichodema*. *Trichoderma* was also isolated from experimental plots of similar Gangetic plain zone soils of Lucknow, India. Its application rate is 250 $mL \cdot ha^{-1}$. The nitrogen-fixing bacteria (*Azospirillum*), phosphorus solubilizing bacteria (*Pseudomonas*), zinc solubilizing bacteria (*Acinetobacter*), and *Trichoderma* were applied to compost at 250 mL for 10 Mg of MSW. After thorough mixing of these microbes with MSW, the enriched compost was made and left for seven days in the shade for proper colonization of the microbes. Similarly, consortia (a mixture of *Azospirillum*, *Pseudomonas*, *Acinetobacter*, and *Trichoderma*) was prepared by adding all microbes' solution to the compost and it was also left for colonization for the period of seven days. After that, it was applied to the field as per the treatments.

2.5. Crop Growth and Yield Study

The plant height of the five marked plants was estimated in cm from the plant base of the plant to the tip of the longest leaf in each plant. Subsequently, the mean height of 5 plants was considered as the final height/plant for every treatment. The destructive sampling was done on a 1 m^2 area to assess the dry matter. For minimizing high sample moisture, initially, all samples were sun-dried, after that they were kept in an oven at 70 °C ± 1 °C for 48 h. Then, dry weight was taken with a digital electronic balance and expressed in $g \cdot m^{-2}$. Leaf area index (LAI) was measured using LI-COR leaf area meter (Model No. LI-3100C, LI-COR Bioscience, Lincoln, NE, USA). Net assimilation rate (NAR) was determined using the following formula [15]:

$$\text{NAR} = \frac{(\text{W2} - \text{W1})(\text{Log eL2} - \text{Log eL1})}{(\text{t2} - \text{t1})(\text{L2} - \text{L1})} \quad (1)$$

where, L1 and W1 are leaf area and dry weight of plants at time t1, and L2 and W2 are leaf area and dry weight of plants at time t2.

The numbers of tillers that bear panicles were counted at the time of harvesting. Five panicles were harvested separately from tagged plants. A numbers of fertile $grains \cdot panicle^{-1}$ were calculated by counting the total number of fertile grains of five panicles from tagged plants. The $grains \cdot panicle^{-1}$ was the average account of randomly selected five panicles at one day before harvesting the crop. Grain and straw yields were determined from the net plot area (4.2 m × 3.6 m) and expressed into $Mg \cdot ha^{-1}$. Grain yield was reported at 14% moisture level.

2.6. Water Use Efficiency

Water use efficiency (WUE) was estimated from the following formula [14]:

$$\text{WUE} = \frac{\text{Yield of the crop}}{\text{Water used by the crop}} \quad (2)$$

Water used by the crop or ET = Effective rainfall received (R) + Capillary rise (C) + Water applied through irrigation (I) + Water contribution from the soil profile (ΔSW).

The water table during the growing season of the crop was below 4 m depth. Hence, capillary rise (C) was considered as negligible or zero. Effective rainfall (R) is the amount of rain water received by the crop excluding runoff, evaporation, and deep percolation, as well as drainage loss of rain water. FAO suggested two simple formulas to calculate the effective rainfall from the total rainfall received [16]. Table 3 represents the total amount of water consumed by the crop during 2017–2018 and 2018–2019.

Table 3. The number of irrigations and total water consumed by the plants under different irrigation levels along with various rice varieties.

Irrigation Scheduling with Rice Variety	Irrigation (no.)		Total Applied Irrigation (mm) [A]		Total Rainfall (mm) [B]		Effective Rainfall (mm) [C]		Soil Water Contribution (mm) [D]		Water Cuptakeby Plant (mm) [A + C + D]	
	2017	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
50 mm CPE in Swarna	6	4	300	200	789	1004	606	777	5.8	5.2	912	982
50 mm CPE in Sahbhagi	4	2	200	100	789	1004	606	777	5.8	5.2	812	882
75 mm CPE in Swarna	3	2	150	100	789	1004	606	777	8.0	7.0	764	884
75 mm CPE in Sahbhagi	1	1	50	50	789	1004	606	777	8.0	7.0	664	834

Swarna and Sahbhagi are the varieties of rice, CPE denotes cumulative pan evaporation.

Effective rainfall (R) = 0.8P (total rainfall) − 25, when P (total rainfall) is more than 75 mm;

R = 0.6P − 10, when P is less than 75 mm.

R is always equal to or larger than zero, never negative.

Soil water content was calculated using the following equation [17]:

$$\text{Soil water content (depth basis)} = \text{Pd} \times \text{BD} \times \text{depth of soil} \quad (3)$$

where Pd is moisture content on a weight basis, BD is the bulk density ($g \cdot cm^{-3}$).

2.7. Soil Microbial Population Study

One gram (g) moist soil sample was reserved in 10 mL distilled water in a test tube. This was called mother or stock culture. Then, 1 mL sample was taken from this mother or stock solution and poured into 9 mL distilled water in another test tube to make 10^{-1} dilution. For counting bacteria, it was further diluted to 10^{-5}, while, for counting fungus, it was diluted to 10^{-3}. The 'Jensen's media' was used to account for the number of nitrogen-fixing colonies forming units (CFU). For Zn fixing bacterial, 0.1 mL soil solution was taken and grown on 'Jensen's media + 0.5% Zn oxide' and CFU were counted [18]. A similar procedure was followed for phosphorus solubilizing bacteria using 'Pikovskaya's Agar' as media instead of 'Jensen's media'. For counting fungus colony-forming units, serial dilution was done and, thereafter, it was grown on 'Rose Bengal Chloramphenicol agar'; and for confirming the phosphorus solubilizing activity, its colony were raised on 'Pikovskaya's Agar' [19].

2.8. Statistical Analysis

The recorded data were analyzed statistically to know the analysis of variance (ANOVA) by using statistical software namely 'SAS version 9.4'. For pair-wise evaluation of mean values of all observed data, the least significant difference (LSD) test was carried out as per

Gomez and Gomez [20]. All the figures presented in this manuscript were drawn with the help of the SigmaPlot v14.0 software (Systat Software Inc., Chicago, IL, USA).

3. Results

The analysis of variance (ANOVA) (Supplementary Table S1) shows that the main effects of irrigation schedulings, rice varieties, and different nutrient management practices along with microbes (from municipal compost) were significantly varied for almost all the parameters like growth, yield attributes, yield, microbial population, water use efficiency, etc., during both the years of experiment. The interaction effects between irrigation levels and varieties (irrigation × variety); irrigation levels and nutrient management practices along with microbes (irrigation × nutrient management); varieties and nutrient management practices along with microbes (variety × nutrient management); and irrigations and varieties and nutrient management practices along with microbes (irrigation × variety × nutrient management) were non-significant for all the parameters tested in this study (Table S1).

3.1. Growth of Rice Is Influenced by Irrigation Scheduling, Varieties, and Nutrient Management

Various growth parameters, such as plant height, dry matter, leaf area index (LAI), net assimilation rate (NAR), were significantly influenced by different irrigation levels, varieties and nutrient management practices along with microbes during both years (Table 4).

Table 4. The growth of rice is influenced by various irrigation scheduling, varieties and nutrient management practices along with microbes.

Treatments	Plant Height at Harvest (cm)		DMA at Harvest ($g{\cdot}m^{-2}$)		LAI at 90 DAS		NAR during 60–90 DAS ($g{\cdot}m^{-2}{\cdot}d^{-1}$)	
	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation scheduling								
50 mm CPE	107 ± 7.5 ^{a}	109 ± 5.9 ^{a}	699 ± 33.9 ^{a}	725 ± 71.2 ^{a}	5.99 ± 2.3 ^{a}	6.12 ± 3.3 ^{a}	3.65 ± 1.1 ^{a}	3.63 ± 0.9 ^{a}
75 mm CPE	100 ± 5.1 ^{b}	101 ± 5.8 ^{b}	660 ± 41.7 ^{b}	686 ± 53.3 ^{b}	5.59 ± 2.9 ^{b}	5.51 ± 1.5 ^{b}	3.57 ± 1.9 ^{a}	3.61 ± 1.0 ^{a}
LSD ($p \leq 0.05$)	3	3	23	14	0.21	0.37	ns	ns
Varieties								
Swarna	90 ± 4.9 ^{b}	92 ± 6.7 ^{b}	709 ± 99.3 ^{a}	735 ± 104.3 ^{a}	6.15 ± 1.0 ^{a}	6.17 ± 1.1 ^{a}	4.11 ± 0.9 ^{a}	4.12 ± 0.9 ^{a}
Sahbhagi	117 ± 9.1 ^{a}	118 ± 11.1 ^{a}	650 ± 72.1 ^{b}	676 ± 70.1 ^{b}	5.44 ± 0.9 ^{b}	5.46 ± 1.2 ^{b}	3.11 ± 0.8 ^{b}	3.13 ± 0.7 ^{b}
LSD ($p \leq 0.05$)	3	3	23	14	0.21	0.37	0.14	0.46
Nutrient management								
T1	106 ± 3.9 ^{a}	103 ± 12.3 ^{bc}	644 ± 63.0 ^{cd}	672 ± 45.5 ^{cd}	5.20 ± 0.3 ^{e}	5.23 ± 0.5 ^{de}	3.85 ± 0.6 ^{bc}	3.62 ± 0.9 ^{bc}
T2	100 ± 2.5 ^{b}	99 ± 8.9 ^{c}	611 ± 78.9 ^{d}	627 ± 57.9 ^{e}	4.75 ± 0.9 ^{f}	4.77 ± 0.6 ^{e}	3.07 ± 0.4 ^{f}	3.00 ± 0.8 ^{c}
T3	101 ± 11.2 ^{b}	101 ± 7.2 ^{c}	627 ± 40.7 ^{d}	652 ± 88.2 ^{d}	5.22 ± 0.5 ^{de}	5.25 ± 1.1 ^{d}	3.19 ± 0.5 ^{f}	3.13 ± 1.1 ^{c}
T4	107 ± 10.2 ^{a}	108 ± 7.9 ^{ab}	714 ± 39.9 ^{b}	744 ± 67.7 ^{b}	6.17 ± 0.4 ^{c}	6.20 ± 1.3 ^{c}	3.61 ± 0.9 ^{de}	3.62 ± 1.0 ^{bc}
T5	98 ± 5.5 ^{bc}	103 ± 9.9 ^{bc}	696 ± 33.3 ^{b}	724 ± 103.1 ^{b}	5.51 ± 0.7 ^{d}	5.53 ± 1.1 ^{d}	3.44 ± 1.0 ^{e}	3.43 ± 1.2 ^{c}
T6	95 ± 5.1 ^{c}	102 ± 4.7 ^{c}	665 ± 55.1 ^{c}	692 ± 100.1 ^{c}	5.43 ± 1.0 ^{de}	5.45 ± 0.9 ^{d}	3.66 ± 0.8 ^{cd}	3.59 ± 0.7 ^{b}
T7	108 ± 6.0 ^{a}	109 ± 5.0 ^{a}	724 ± 90.0 ^{ab}	760 ± 57.3 ^{a}	6.85 ± 0.3 ^{b}	6.86 ± 0.8 ^{a}	3.95 ± 0.5 ^{ab}	4.14 ± 0.9 ^{ab}
T8	110 ± 6.1 ^{a}	112 ± 7.1 ^{a}	754 ± 77.9 ^{a}	775 ± 33.9 ^{a}	7.22 ± 1.1 ^{a}	7.25 ± 0.8 ^{a}	4.10 ± 1.1 ^{a}	4.44±1.2 ^{a}
LSD ($p \leq 0.05$)	4	5	33	20	0.29	0.53	0.20	0.65

DMA, dry matter accumulation; LAI, leaf area index, NAR, net assimilation rate; CPE (cumulative pan evaporation), CPE, cumulative pan evaporation; T_1, 100% recommended dose of fertilizer (RDF); T_2, 75% RDF; T_3, 75% RDF + municipal solid waste compost (MSWC) at 10 $Mg{\cdot}ha^{-1}$; T_4, 75% RDF + enriched MSWC (nitrogen fixing bacteria (NFB)) at 10 $Mg{\cdot}ha^{-1}$; T_5, 75% RDF + enriched MSWC (phosphorus solubilizing bacteria (PSB)) at 10 $Mg{\cdot}ha^{-1}$; T_6, 75% RDF + enriched MSWC (zinc solubilizing bacteria (ZSB)) at 10 $Mg{\cdot}ha^{-1}$; T_7, 75% RDF + enriched MSWC (*Trichoderma*) at 10 $Mg{\cdot}ha^{-1}$, and T_8, 75% RDF + enriched MSWC (Consortia) at 10 $Mg{\cdot}ha^{-1}$; NFB (nitrogen-fixing bacteria), PSB (phosphorus solubilizing bacteria), and ZSB (zinc solubilizing bacteria). Numbers followed by different letters indicate significant differences at $p \leq 0.05$ (otherwise statistically at par); ns denotes non-significant; values are followed by the standard deviation (±) (n = 3).

Plant height, dry matter accumulation (DMA) and LAI were recorded significantly higher under irrigation scheduling at 50 mm CPE than those at 75 mm CPE during 2017 and 2018. Irrigation scheduling at 50 mm CPE instead of 75 mm CPE resulted in about

6–11% higher plant growth (Table 4). However, NAR was not significantly influenced by the different irrigation levels during both years. Considering the varied varieties of rice, it was observed that the plant height was higher in Sahbhagi than the plant height of the variety, Swarna; however, the other growth parameters viz. DMA, LAI, and NAR were found significantly higher in variety Swarna during 2017 and 2018 (Table 4).

Concerning the effect of various nutrient management practices along with microbes on the growth of rice, it was recorded that application of 75% RDF + 10 Mg·ha^{-1} enriched municipal waste compost (consortia) (MSWC (consortia) resulted in the maximum plant height, DMA, LAI and NAR, while the least growth parameters of rice were recorded under 75% RDF during both the years. Comparing the effect of different enriched MSWC on the growth of rice, it was observed that MSWC enriched with *Trichoderma* depicted at par growth with MSWC enriched with microbial consortia. However, zinc solubilizing bacteria (ZSB) enriched MSWC resulted in the minimum growth of rice compared to other enriched MSWC viz. NFB enriched MSWC, PSB enriched MSWC, etc. (Table 4). Use of 75% RDF + 10 Mg·ha^{-1} E-MSWC (consortia) was found to augment the DMA, LAI and NAR of rice to the tune of 15–17%, 38–39% and 6–23%, respectively, during 2017 and 2018 over 100% RDF. Comparing the growth of rice with the application of various enriched MSWC between two years of study, it was observed that all the growth parameters were increased during the second year than that of in the first year of study.

3.2. Yield Attributes and Yield

Application of various irrigation levels, use of different varieties of rice and nutrient management practices along with microbes influenced the number of panicles·m^{-2}, filled grains·panicle^{-1}, grain and straw yield of rice significantly during both the years of study (Table 5).

Table 5. Yield attributes and yields of rice as influenced by various irrigation scheduling, varieties and nutrient management practices along with microbes.

Treatments	Panicles·m^{-2}		Filled Grains·Panicle^{-1}		Test Weight (g)		Grain Yield (Mg·ha^{-1})		Straw Yield (Mg·ha^{-1})	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation scheduling										
50 mm CPE	238 ± 29.9 ^{a}	255 ± 21.3 ^{a}	94.4 ± 3.8 ^{a}	99.1 ± 3.2 ^{a}	20.7 ± 0.9 ^{a}	20.9 ± 0.6 ^{a}	4.10 ± 1.1 ^{a}	4.22 ± 1.0 ^{a}	5.57 ± 0.7 ^{a}	5.42 ± 1.2 ^{a}
75 mm CPE	227 ± 31.5 ^{b}	234 ± 11.2 ^{b}	91.0 ± 9.9 ^{b}	96.3 ± 2.3 ^{b}	20.7 ± 0.8 ^{a}	20.8 ± 0.7 ^{a}	3.66 ± 0.8 ^{b}	3.84 ± 0.9 ^{b}	5.33 ± 0.6 ^{a}	5.06 ± 1.0 ^{b}
LSD ($p \leq 0.05$)	8	7	3.2	1.2	ns	ns	0.14	0.16	ns	0.19
Varieties										
Swarna	255 ± 33.5 ^{a}	267 ± 22.4 ^{a}	100.4 ± 19.9 ^{a}	106.2 ± 12.3 ^{a}	20.3 ± 0.9 ^{b}	20.4 ± 1.0 ^{b}	4.23 ± 0.9 ^{a}	4.37 ± 1.1 ^{a}	5.90 ± 1.2 ^{a}	5.72 ± 0.7 ^{a}
Sahbhagi	210 ± 31.2 ^{b}	222 ± 21.3 ^{b}	85.9 ± 17.8 ^{b}	89.2 ± 15.7 ^{b}	21.1 ± 1.2 ^{a}	21.4 ± 1.1 ^{a}	3.52 ± 1.2 ^{b}	3.68 ± 1.1 ^{b}	5.00 ± 1.3 ^{b}	4.75 ± 0.9 ^{b}
LSD ($p \leq 0.05$)	8	7	3.2	1.2	0.7	0.9	0.14	0.16	0.36	0.19
Nutrient management										
T1	226 ± 21.2 ^{d}	240 ± 19.3 ^{d}	92.4 ± 3.9 ^{cd}	96.7 ± 3.5 ^{c}	20.5 ± 0.4 ^{a}	20.8 ± 0.6 ^{a}	3.82 ± 0.9 ^{cd}	3.96 ± 0.4 ^{de}	5.28 ± 1.1 ^{bc}	5.22 ± 0.7 ^{bc}
T2	204 ± 22.4 ^{e}	210 ± 18.0 ^{f}	77.8 ± 7.7 ^{e}	80.5 ± 4.5 ^{e}	20.4 ± 0.7 ^{a}	20.5 ± 0.5 ^{a}	3.15 ± 1.0 ^{e}	3.23 ± 1.2 ^{f}	5.15 ± 1.4 ^{bc}	5.02 ± 0.8 ^{c}
T3	210 ± 38.8 ^{e}	226 ± 23.2 ^{e}	89.9 ± 7.9 ^{d}	93.0 ± 4.9 ^{d}	20.3 ± 0.3 ^{a}	20.6 ± 0.4 ^{a}	3.69 ± 0.7 ^{d}	3.84 ± 0.8 ^{e}	5.07 ± 2.3 ^{c}	5.08 ± 0.9 ^{c}
T4	241 ± 25.1 ^{bc}	253 ± 10.8 ^{bc}	96.4 ± 11.1 ^{bc}	101.5 ± 5.0 ^{b}	20.7 ± 0.5 ^{a}	20.8 ± 0.3 ^{a}	4.01 ± 2.2 ^{bc}	4.22 ± 1.1 ^{bc}	5.49 ± 1.1 ^{b}	5.27 ± 0.3 ^{bc}
T5	236 ± 12.9 ^{cd}	249 ± 22.2 ^{cd}	94.7 ± 5.5 ^{bc}	101.2 ± 11.2 ^{b}	20.8 ± 0.8 ^{a}	20.9 ± 0.4 ^{a}	3.99 ± 1.2 ^{bc}	4.14 ± 1.9 ^{bcd}	5.37 ± 0.9 ^{bc}	5.21 ± 1.1 ^{bc}
T6	234 ± 33.3 ^{cd}	244 ± 29.5 ^{cd}	95.1 ± 3.4 ^{bc}	100.5 ± 9.2 ^{b}	20.8 ± 0.7 ^{a}	20.9 ± 0.3 ^{a}	3.92 ± 1.0 ^{c}	4.02 ± 1.3 ^{cd}	5.03 ± 0.3 ^{c}	5.16 ± 0.4 ^{bc}
T7	250 ± 35.1 ^{ab}	262 ± 22.9 ^{ab}	97.9 ± 8.9 ^{ab}	103.5 ± 8.9 ^{a}	21.0 ± 0.5 ^{a}	21.0 ± 0.2 ^{a}	4.17 ± 0.8 ^{ab}	4.35 ± 0.7 ^{ab}	5.97 ± 1.2 ^{a}	5.38 ± 0.3 ^{ab}
T8	259 ± 21.2 ^{a}	271 ± 28.1 ^{a}	101.2 ± 10.0 ^{a}	104.7 ± 9.5 ^{a}	21.1 ± 0.4 ^{a}	21.1 ± 0.5 ^{a}	4.27 ± 0.9 ^{a}	4.47 ± 0.6 ^{a}	6.24 ± 0.5 ^{a}	5.56 ± 0.7 ^{a}
LSD ($p \leq 0.05$)	12	10	4.6	1.7	ns	ns	0.19	0.23	0.41	0.26

Treatments detail in Table 4; Numbers followed by different letters indicate significant differences at $p \leq 0.05$ (otherwise statistically at par); ns denotes non-significant; values are followed by the standard deviation (±) (n = 3).

The test weight of rice was significantly influenced only due to different varieties of rice, otherwise, the results on test weight were found to be non-significant. Panicle number·m^{-2}, filled grains·panicle^{-1}, grain and straw yield were increased to the tune of 5–9%, 3–4%, 10–12%, and 5–7%, respectively, during 2017 and 2018 at 50 mm CPE over 75 mm CPE. Concerning the different varieties of rice, significantly higher yield attributing characters and yield were recorded with Swarna variety over Sahbhagi. Comparing the impact of different nutrient management practices along with microbes, it was observed that the values of yield and yield attributing parameters were the maximum with 75% RDF + 10 Mg·ha^{-1} E-MSWC (consortia) and this treatment was at par with 75% RDF +

10 Mg·ha^{-1} E-MSWC (*Trichoderma*). These two enriched MSWC resulted in about 9–15%, 6–10%, 9–13%, and 3–18% more panicles·m^{-2}, grains·panicle^{-1}, grain and straw yield, respectively, over 100% RDF (Table 5).

3.3. Different Metabolic Group of Soil Microbes

The population of nitrogen-fixing bacteria (NFB), phosphorus solubilizing bacteria (PSB), zinc solubilizing bacteria (ZSB), and *Trichoderma* were significantly influenced by the different irrigation levels and nutrient management practices along with microbes during both years of experimentation. However, the effect of different rice varieties on NFB, ZSB was found to be non-significant during both years. The PSB population was significantly influenced due to different varieties only in 2018; while, the *Trichoderma* population was significantly influenced in 2017 (Table 6).

Table 6. Soil microbial population as influenced by varied irrigation levels, varieties and nutrient management practices along with microbes.

Treatments	NFB × 10^5 (Cfu·g^{-1} of Soil)		PSB × 10^5 (Cfu·g^{-1} of Soil)		ZSB × 10^5 (Cfu·g^{-1} of Soil)		Trichoderma × 10^3 (Cfu·g^{-1} of Soil)	
	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation scheduling								
50 mm CPE	13.8 ± 1.1 ^{a}	15.6 ± 1.3 ^{a}	13.3 ± 0.9 ^{a}	16.5 ± 1.0 ^{a}	3.38 ± 1.0 ^{a}	4.71 ± 1.1 ^{a}	7.69 ± 1.2 ^{a}	9.34 ± 0.7 ^{a}
75 mm CPE	10.4 ± 1.2 ^{b}	12.4 ± 1.0 ^{b}	10.4 ± 1.0 ^{b}	12.5 ± 1.2 ^{b}	2.28 ± 1.3 ^{b}	3.55 ± 0.9 ^{b}	6.75 ± 1.3 ^{b}	8.04 ± 0.8 ^{b}
LSD ($p \leq 0.05$)	1.0	1.0	0.9	1.4	0.73	0.57	0.81	0.95
Varieties								
Swarna	12.4 ± 0.3 ^{a}	14.4 ± 0.4 ^{a}	12.2 ± 0.3 ^{a}	15.2 ± 1.0 ^{a}	3.18 ± 1.1 ^{a}	4.53 ± 0.2 ^{a}	7.62 ± 1.7 ^{a}	9.09 ± 0.3 ^{a}
Sahbhagi	11.8 ± 0.2 ^{a}	13.5 ± 0.1 ^{a}	11.5 ± 0.3 ^{a}	13.7 ± 0.9 ^{b}	2.48 ± 0.2 ^{a}	3.74 ± 0.3 ^{a}	6.80 ± 1.5 ^{b}	8.29 ± 0.9 ^{a}
LSD ($p \leq 0.05$)	ns	ns	ns	1.4	ns	ns	0.81	ns
Nutrient management								
T1	8.1 ± 1.1 ^{d}	10.0 ± 1.2 ^{d}	3.3 ± 1.0 ^{d}	5.1 ± 0.5 ^{d}	0.94 ± 0.3 ^{de}	1.48 ± 0.9 ^{d}	2.25 ± 0.5 ^{d}	3.50 ± 0.6 ^{d}
T2	7.4 ± 0.9 ^{d}	9.3 ± 1.4 ^{d}	2.1 ± 0.4 ^{d}	3.4 ± 0.3 ^{d}	0.80 ± 0.1 ^{e}	0.91 ± 0.3 ^{d}	0.98 ± 0.2 ^{e}	2.02 ± 0.7 ^{e}
T3	11.1 ± 1.0 ^{c}	13.0 ± 1.1 ^{c}	10.6 ± 1.1 ^{c}	13.1 ± 0.9 ^{c}	1.51 ± 0.2 ^{d}	3.11 ± 0.4 ^{c}	5.25 ± 1.1 ^{c}	7.25 ± 2.2 ^{c}
T4	16.4 ± 0.8 ^{a}	18.8 ± 0.9 ^{a}	13.8 ± 1.3 ^{b}	16.6 ± 1.8 ^{b}	1.92 ± 0.3 ^{cd}	3.11 ± 0.9 ^{c}	7.00 ± 1.2 ^{b}	9.50 ± 1.1 ^{b}
T5	13.4 ± 0.7 ^{b}	15.3 ± 0.3 ^{b}	18.8 ± 1.2 ^{a}	22.0 ± 2.3 ^{a}	3.17 ± 1.0 ^{b}	4.61 ± 0.2 ^{b}	8.00 ± 0.7 ^{b}	9.50 ± 2.9 ^{b}
T6	12.1 ± 1.1 ^{bc}	14.0 ± 2.1 ^{bc}	13.6 ± 0.9 ^{b}	16.9 ± 1.0 ^{b}	5.86 ± 0.7 ^{a}	7.97 ± 0.8 ^{a}	7.50 ± 0.8 ^{b}	10.0 ± 1.2 ^{b}
T7	12.1 ± 1.2 ^{bc}	14.0 ± 0.9 ^{bc}	14.8 ± 0.8 ^{b}	18.4 ± 1.4 ^{b}	2.67 ± 0.7 ^{bc}	4.43 ± 1.0 ^{b}	14.0 ± 0.3 ^{a}	14.3 ± 0.5 ^{a}
T8	15.9 ± 0.8 ^{a}	17.5 ± 0.6 ^{a}	17.8 ± 0.9 ^{a}	20.6 ± 1.8 ^{a}	5.77 ± 0.8 ^{a}	7.47 ± 0.8 ^{a}	12.8 ± 0.6 ^{a}	13.5 ± 0.8 ^{a}
LSD ($p \leq 0.05$)	1.4	1.4	1.3	2.0	1.03	0.81	1.16	1.34

Treatments detail in Table 4; Numbers followed by different letters indicate significant differences at $p \leq 0.05$ (otherwise statistically at par); ns denotes non-significant; values are followed by the standard deviation (±) (n = 3).

Application of frequent irrigation at 50 mm CPE was found to increase the soil microbial population to a great extent than less irrigation under 75 mm CPE. It was also attainted that the relative increase in the population of soil bacteria was much higher under frequent irrigation than the population increase in soil fungus, *Trichoderma*. Populations of NFB, PSB, and ZSB were increased to the tune of about 26–48% at 50 mm CPE over 75 mm CPE. Concerning the different effects of nutrient management practices along with microbes on soil microbial population, it was observed that the application of 75% RDF + 10 Mg·ha^{-1} E-MSWC (NFB), 75% RDF + 10 Mg·ha^{-1} E-MSWC (PSB), 75% RDF + 10 Mg·ha^{-1} E-MSWC (ZSB), and 75% RDF + 10 Mg·ha^{-1} E-MSWC (*Trichoderma*) resulted in the maximum population of NFB, PSB, ZSB, and *Trichoderma* in the soil, respectively, during 2017 and 2018. These treatments were at par with the application of 75% RDF + 10 Mg·ha^{-1} enriched municipal waste compost (consortia) (E-MSWC (consortia)) during both years. It was also observed that the use of microbial consortia with MSWC augmented the soil ZSB and *Trichoderma* population at a higher rate than that of the rate of increase in the population of soil NFB and PSB.

Figure 2 represents the relationship between the total microbial population and the yield of rice. A strong positive relationship (R^2 = +0.74) between soil microbial population and yield was observed from this study as well.

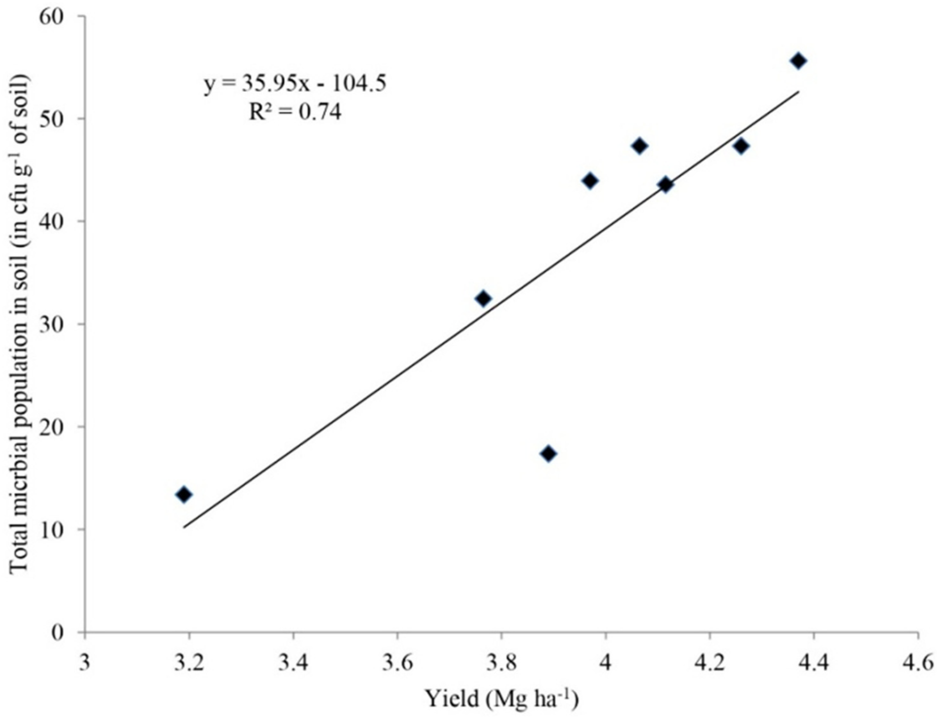

Figure 2. Relationship between yield and total soil microbial population.

3.4. Water Use Efficiency

Water use efficiency (WUE) was also significantly influenced by the use of different irrigation levels, varieties of rice and nutrient management practices along with microbes during both years (Table 7). Application of irrigation at 75 mm CPE resulted in significantly higher WUE than the application of irrigation at 50 mm CPE during 2017–2018; however, just the reverse was recorded during 2018–2019. Frequent irrigation at 50 mm CPE was found to decrease the WUE to the tune of about 7% over 75 mm CPE in 1st year. Concerning, different varieties, Swarna exhibited significantly higher (about 7–10%) WUE than that of recorded with the variety, Sahbhagi. Regarding different nutrient management practices along with microbes, it was observed that the application of 75% RDF + 10 Mg·ha^{-1} E-MSWC (consortia) resulted in the maximum amount of WUE and this treatment was statistically superior to all other nutrient management practices, along with microbes during both years. The 75% RDF + 10 Mg·ha^{-1} E-MSWC (consortia) increased WUE about 13–16% over 100% RDF during both the years. Comparing 75% RDF + 10 Mg·ha^{-1} E-MSWC (consortia) with 75% RDF + 10 Mg·ha^{-1} MSWC (non-enriched), it was observed that the microbial consortia-enriched MSWC resulted in the augmentation of the value of WUE to the tune of 16% over non-enriched one (Table 7).

Table 7. Water use efficiency (WUE) is influenced by varied irrigation levels, varieties, and nutrient management practices along with microbes.

Treatments	WUE (kg·ha^{-1}·mm^{-1})	
	2017	2018
	Irrigation scheduling	
50 mm CPE	4.78 ± 1.0^{b}	4.54 ± 0.9^{a}
75 mm CPE	5.12 ± 1.2^{a}	4.49 ± 1.1^{b}
LSD ($p \leq 0.05$)	0.02	0.02
	Varieties	
Swarna	5.11 ± 1.1^{a}	4.72 ± 1.0^{a}
Sahbhagi	4.79 ± 1.2^{b}	4.31 ± 1.1^{b}
LSD ($p \leq 0.05$)	0.02	0.02
	Nutrient management	
T1	4.74 ± 0.9^{e}	4.44 ± 0.8^{f}
T2	4.01 ± 0.7^{f}	3.61 ± 0.7^{h}
T3	4.72 ± 0.8^{e}	4.31 ± 0.6^{g}
T4	5.15 ± 0.9^{c}	4.74 ± 0.9^{c}
T5	5.13 ± 1.1^{c}	4.65 ± 0.3^{d}
T6	5.03 ± 1.0^{d}	4.51 ± 0.7^{e}
T7	5.35 ± 1.1^{b}	4.87 ± 1.8^{b}
T8	5.48 ± 0.6^{a}	5.01 ± 0.6^{a}
LSD ($p \leq 0.05$)	0.06	0.06

Treatments detail in Table 4; Numbers followed by different letters indicate significant differences at $p \leq 0.05$ (otherwise statistically at par); ns denotes non-significant; values are followed by the standard deviation (±) (n = 3).

4. Discussion

4.1. Growth

Higher growth attributes of rice were recorded with irrigation at 50 mm CPE. The scientific reason behind such higher growth of the crop might be attributed to the availability of the optimum amount of moisture during the growth period under irrigation at 50 mm CPE. Moisture being a solvent helped the essential nutrients to be present in the soil solution and this phenomenon made the plant nutrients more available to the crop [21]. These nutrients were absorbed by the plant through transpiration pull and helped in the development of tissue, leading to more photosynthesis which ultimately reflected through the higher growth of the crop [22]. Concerning the different varieties of rice, Swarna being a dwarf variety depicted lower plant height than the height of Sahbhagi. However, the duration of the variety, Swarna was more than that of Sahbhagi. Hence, higher DMA and LAI were recorded with this variety. The reason behind significantly higher growth of the plant using enriched municipal soil waste compost (E-MSWC) over-application of chemical fertilizers only might be attributed that MSWC compost contained a good amount of carbon, as well as almost all primary and secondary nutrients necessary for the growth and development of the plant (Table 2). Thus, the application of MSWC along with RDF provided all the essential nutrients to the plant resulting in more cell division, cell elongation, tissue formation and cell differentiation. Henceforth, more growth of the crop was observed. When this MSWC was enriched with different nutrient fixing and solubilizing microbes, it helped in more microbial activities in the soil rhizosphere. This would facilitate the nutrient availability of the plant [17]. A similar trend of results was previously recorded by Jat et al. [23].

4.2. Yield Attributes and Yield

Significantly higher growth was recorded with the irrigation at 50 mm CPE and such higher growth ultimately reproduced better yield attributing characters and yield of rice. Frequent irrigation at 50 mm CPE increased efficient uptake of water and nutrients (macro and micronutrients) throughout the growing period, leading to an increase in the number of tillers and filled grains·panicle^{-1}. Improved yield attributes resulted in significantly higher grain, as well as straw yield of rice. The experimental finding was in harmony with Narolia et al. [24]. The higher yield of the variety Swarna might be attributed to its genetic characteristics. Amongst nutrient management treatments, the application of 75% RDF + E-MSWC (Consortia) at 10 Mg·ha^{-1} showed the best result. This might be due to the fact that consortia-enriched MSWC helped in the higher availability of all essential nutrients to the plant as it consisted of nitrogen-fixing bacteria, phosphorus solubilizing bacteria, zinc solubilizing bacteria, and *Trichoderma*. These microbes positively influenced axillary meristems which led to the formation of more tiller buds, resulting in an increase in the number of tillers, filled grains, etc. [25]. Microorganisms also enhanced the process of nutrients released into the soil, making them available for plant uptake [26]. Figure 2 also depicts the strong relationship between the yield of rice and the total microbial population in the soil. The experimental finding is in close accordance with Wang et al. [27] and Show et al. [28].

4.3. Microbial Population

A higher microbial population was observed with frequent irrigation at 50 mm CPE than the application of irrigation at 75 mm CPE. Many previous studies showed that the application of irrigation may significantly increase [29,30] or not significantly affect [31] soil microbial population. Time of irrigation, quality and quantity of irrigation water, water deficit, etc., strongly influence the soil microbial populations [32]. Application of irrigation at 50 mm CPE might help in providing energy, balanced nutrient, and favorable environmental conditions to the soil microbes. Thus, it is not surprising to observe a higher microbial population under irrigation at 50 mm CPE. Soil microbial population was not varied with different varieties of rice. The significantly higher population of nitrogen-fixing bacteria, phosphorus solubilizing bacteria, zinc fixing bacteria and *Trichoderma* were recorded with 75% RDF + E-MSWC (NFB) at 10 Mg·ha^{-1}, 75% RDF + E-MSWC (PSB) at 10 Mg·ha^{-1}, 75% RDF + E-MSWC (ZSB) at 10 Mg·ha^{-1}, and 75% RDF + E-MSWC (*Trichoderma*) at 10 Mg·ha^{-1}, respectively. It is obvious to get the higher population of particular microbes in soil when the MSWC was enriched with those respective micro-organisms and applied to the soil. Gill et al. [33] also reported that the application of 50% inorganic fertilizer + 10 Mg·ha^{-1} compost significantly improved bacterial, fungal and phosphorus solubilizing bacteria. Wang et al. [34] and Sannathimmappa et al. [35] reported that the application of organic manure increased the microbial population.

4.4. Water Use Efficiency

Water use efficiency (WUE) was much higher under irrigation scheduling at 75 mm CPE than that of 50 mm CPE in 1st year of study. However, the value of WUE was only 1% higher at 50 mm CPE than 75 mm CPE in 2nd year of study. Many previous studies, suggested that frequent irrigation generally reduced the WUE of many crops [14]. Rice is a crop that requires more amount of water to produce an optimum yield. In the second year of study, frequent irrigation at 50 mm CPE and higher effective rainfall resulted in higher biomass production per unit use of water. Thus, a bit of higher WUE was recorded at 50 mm CPE than that of 75 mm CPE during 2nd year of study. WUE was lower in the 2nd year of experimentation than the WUE in the 1st year. This might be due to the fact that the total water consumed by the crop in the 2nd year was much higher (70–120 mm more) than that of the 1st year (Table 3). However, the yield of the crop was not so higher in 2nd year. Thus, the WUE was lower during 2018–2019. Concerning the varied variety of rice, Swarna showed higher WUE than the variety, Sahbhagi. Being a long duration rice variety, the yield potentiality of Swarna was higher than that of Sahbhagi. Although, the variety Swarna consumed about 50–100 mm more water than Sahbhagi, the yield of Swarna was about 600 kg more, compared to the yield of Sahbhagi in the one ha area. Application of 75% RDF + E-MSWC (Consortia) at 10 Mg·ha^{-1} resulted in higher WUE during both years. This might be due to the presence of all microorganisms in the consortia which improved the availability of nutrients to the plant to produce higher biomass. Shafei et al. [36] also reported a similar kind of observation from their study previously.

5. Conclusions

Municipal solid waste compost (MSWC) enriched with consortia (blend of NFB, PSB, ZSB, and *Trichoderma*) has boosted the growth parameters, such as plant height, crop growth rate, leaf area index, etc.; yield attributes, such as the number of tillers, numbers of filled grain, and yield of rice. Furthermore, this enriched MSWC augmented the water use efficiency and soil microbial populations. From this study, it can be stated that the application of microbial consortia-enriched MSWC at 10 Mg·ha^{-1} can successfully substitute 25% of recommended chemical fertilizer dose in rice grown under direct-seeded conditions. Concerning scheduling irrigation, it can be opined that irrigation at 50 mm of CPE is better than scheduling irrigation at 75 mm CPE. Finding suitable variety, Swarna emerged as a better choice in terms of yield and water use efficiency than the variety, Sahbhagi. Based on two years of data, it may be concluded that irrigation at 50 mm of CPE in conjunction with 75% RDF + enriched MSWC (consortia) at 10 Mg·ha^{-1} could improve the water use efficiency of rice grown in Indo-Gangetic plains.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/agriculture11100941/s1, Table S1: Analysis of variance (ANOVA) (F values) for plant height, dry matter accumulation, leaf area index, net assimilation rate, panicles·m^{-2}, filled grain·panicle^{-1}, test weight, grain and straw yield, as well as water use efficiency (WUE) in 2017 and 2018.

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