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Effect of organics, hydrogel and *Trichoderma* on the yield and economics of direct seeded rice under rainfed condition

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Abstract
Variability of monsoon is a major constraint for crop production. Uncertain and uneven precipitation under rainfed conditions affects the physiology of the crop resulting in poor productivity. Problems aggravate if dry conditions persist for a longer period. Increasing the productivity of water used in agriculture thus becomes essential to meet goals of food and nutritional security. Water and nutrient availability is of utmost importance which contributes to the growth and productivity of rice where nutrient uptake is often hindered due to the limitation of moisture. In view of the above, an experiment was conducted in the kharif seasons of 2016 and 2017 in the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University to find the effect of D-18 compost, farm yard manure, *Trichoderma* and hydrogel in different combinations on the performance of the crop. Two varieties *viz*., DRR 42 and IR 64- the isolines were chosen to conduct the comparative study of their performance under different treatment combinations. It was a factorial experiment with 14 treatment combinations laid out in a randomized complete block design with four replications. The results revealed that D-18 compost and *Trichoderma* were superior to other treatments with respect to grain yield, straw yield, panicles m^{-2}, filled spikelets $panicle^{-1}$. DRR 42, a drought tolerant variety, produced more grain yield (3.26 t ha^{-1}) and remained significantly superior to IR 64 (3.05 t ha^{-1}). DRR 42 registered higher input-output ratio (2.00) and was significantly superior to IR 64 (1.87). Among the soil/seed treatments, D-18 compost + *Trichoderma* sp. registered the highest yield although remained statistically at par with all other treatments except control. D-18 compost+ *Trichoderma* sp. also showed maximum input-output ratio. It was therefore clear that use of D-18 compost+ *Trichoderma* sp. could improve the productivity of DRR 42 by increasing its stress tolerance capacity under rainfed condition.

Keywords: Organics, hydrogel, *Trichoderma*, yield, economics

Introduction
Rice being the staple food of nearly half the population of the world is at a pivotal position to ensure food security of the world. Agriculture is now facing the era of water scarcity where availability of water is declining day by day. Under such situations, direct seeding of rice- an emerging popular technique (Kaur and Singh, 2017) [9] - offers advantages like faster and easier planting, less labour and drudgery, earlier crop maturity (by 7–10 days), higher profit, more efficient water use and higher tolerance to water deficit (Balasubramanian and Hill, 2002) [2]. With decreasing fresh water productivity, it is necessary to work out strategies for increasing the efficiency of rainfall and its optimal utilization - a major challenge to the sustainable rice production (Guerra *et al.*, 1998) [7].

Hydrogels are defined as polymeric materials which exhibit the abilities of swelling by absorbing moisture and retaining a significant fraction of water within their structure (Ahmed, 2015) [1]. Taking into account the water imbibing properties of hydrogels, the possibility of their application in agricultural field is increasingly being investigated to alleviate certain agricultural problems. Use of farm yard manure (FYM) and compost has been an age-old practice in the field of agriculture for improving soil health and supplying nutrients to the crops (Chandra, 2005). A mass of rotten organic matter made from waste is called compost. The wastes include available farm wastes like sugarcane trash, paddy straw, weeds, plant litter and other whole plants. On an average, the nutrient contents of farm compost are 1.0 per cent N, 0.5 per cent P_2O_5 and 1.1 per cent K_2O (Das, 2013) [5]. D-18 is a type of compost which is prepared by placing the above wastes layer by layer in iron cage of suitable sizes and each layer is well moisturized by sprinkling enough cowdung slurry or water. Application of farm yard manures and compost increases the porosity of the soil resulting in decreased bulk density, higher water holding capacity, infiltration rate and conductivity.

Trichoderma sp. is a genus of aerobic fungi, which colonize in the root epidermis and outer cortical layers. *Trichoderma spp. as* a cosmopolitan fungal organism has been utilized not only in biocontrol of plant pathogens but also in enhancing plant growth even under suboptimal plant-growth conditions (Saba *et al*., 2012) [14]. Studies clearly reveal that the use of *Trichoderma spp*. under drought stress can effectively augment plant growth (Chepsergon *et al*., 2014) [4].

Materials and Methods

A field experiment was conducted in the Agricultural Research Farm, Banaras Hindu University, Varanasi during the *kharif* seasons of 2016 and 2017. The factorial experiment was laid out in a randomized complete block design with 4 replications. The trial consisted of 2 varieties and 7 treatments making 14 treatment combinations of farm yard manure (FYM), D-18 compost, *Trichoderma* sp. and hydrogel as seed /soil treatment. The details of the treatment are as follows:

Table 1: Details of treatments

a) Varieties	Symbols used
DRR 42	V_1
IR 64	V_2
b) Seed/soil treatment	
D-18 Compost	T_1
D-18 Compost + *Trichoderma* sp. (seed treatment)	T_2
D-18 Compost+ Hydrogel (soil application)	T_3
FYM	T_4
FYM + *Trichoderma* sp. (seed treatment)	T_5
FYM + Hydrogel (soil application)	T_6
Control	T_7

Sowing was done on 2nd August and 28th June in the first and second year respectively. The recommended dose of fertilizer applied was 140,60,60,25 kg N, P_2O_5, K_2O, $ZnSO_4$ ha^{-1}. One -fourth of the recommended dose of nitrogen and full doses of P, K and Zn were applied as basal and half amount of nitrogen was top dressed at tillering stage of the crop and the rest one –fourth at panicle initiation stage at an optimum soil moisture condition.

Two varieties of paddy- DRR 42 and IR 64, were sown with a seed rate of 40 kg ha^{-1} at a row spacing of 20 cm. IR 64 (IET 9671) is a variety developed by the Directorate of Rice Research (DRR), Hyderabad. It is a semi dwarf variety of medium maturity (120-135 days) with an average yield of 4 -4.5 t ha^{-1}. It has been developed from a cross between IR 5657-35-2-1 and IR 2061465-1-5-5.DRR 42 {specifically IR 64 Drt 1 (IET 22836)} is a drought tolerant Near Isogenic Line (NIL) - developed under STRASA programme by introgressing QTLs (DRO 1) using Marker assisted selection (MAS) (Proceedings of the Variety Identification Committee Meeting, 2013). This variety is prominently cultivated in the rainfed areas of Tamil Nadu, Andhra Pradesh and Madhya Pradesh and matures a little earlier (120-125 days) than IR 64

FYM and D-18 compost were applied @ 12 t ha^{-1} each in the plots according to the treatments and mixed with the soil thoroughly 15-20 days before sowing. FYM was obtained from the dairy farm of the Institute of Agricultural Sciences, Banaras Hindu University. The process of composting of D-18 was in the following sequence:

1. Dry plant materials of 2.5-5 cm size were spread in the iron cage to ensure smooth aeration and drainage of excess water.
2. These dry materials were layered up to 10-12 cm thickness.
3. Water was sprayed.
4. A fine layer of fertile soil was applied
5. Green material of 6-8 cm was layered and water sprayed followed by application of a fine layer of soil again
6. 2-3 cm of wet cow dung was applied followed by a spray of water
7. Jaggery slurry was applied followed by handful of algae. The above mentioned procedure formed the first layer. The same step was followed 5-7 times and the content was prepared inside the iron cage/ wire mesh. At the end, the heap was covered with polythene in order to retain moisture and generate needed heat. In this process the pile generated high temperature within 24 to 48 hour.
8. The first turning was done on the 4th day after composting. After that, turning was done every alternate day. Compost became ready within 14-20 days.
9. Dry material, green material and cow dung were applied in the ratio of 3:2:1. The height of heap was 1.2 m with a diameter of 1.5 m. Good compost should have C/N ratio 30:1. Needed C (carbon) content was maintained by use of dry material and for N (nitrogen) - green material, cow dung and fresh garbage.
10. Jaggery solution was applied in each layer. It helped in producing more micro-organisms boosting decomposition process. Algae were used for enhancing nitrogen content and 50% moisture was ensured in the pile. The temperature inside the heap was maintained at 65-70 ^{0}C as higher temperature than this could destroy the essential micro-organisms. Turning of compost was done to maintain temperature and proper aeration. In case of over-heating, dry material like saw-dust or wheat-straw was added to reduce the temperature. Contrary to this under low temperature green material like green leaves, green weeds and cow dung were added to increase heat.

Pusa Hydrogel was applied to the plots according to the treatment @ 2.5 kg ha^{-1}. It was mixed with sand and incorporated in the soil. *Trichoderma asperellum*, T 42 (Gene bank accession no. JN128894) isolates were obtained from the Department of Mycology and Plant Pathology, B.H.U. and paddy seeds were treated with *Trichoderma* sp. and then sown in the particular plots allotted to the treatment. The spores of *Trichoderma* sp. were collected to make a suspension having an optical density of 1.14 and seeds were treated with the suspension containing effective spores. The seeds of paddy were treated with 50 ml of *Trichoderma* with 3 ml of gum acacia for 5 kg seeds for 6-8 hrs and dried before sowing. The crop was cultivated under rainfed condition and harvested on 21st November and 24th October in the first and second year respectively.

After harvesting the bundles were weighed and threshed on the threshing floor by a paddle thresher; winnowing was done and the clean seeds were weighed treatment-wise separately. The grain yield was then converted in t ha^{-1}.The straw yield was calculated by deducting the grain yield from the bundle weight and then converted into t ha^{-1}. No. of panicles m^{-2} was calculated in each plot by randomly placing quadrates in the plot and counting of the no. of panicles in it before harvest.

Cost of production for all the treatments was calculated on the basis of the price of inputs and market price of the output (current). The net returns ha^{-1} was calculated by deducting the cost of cultivation ha^{-1} from gross return ha^{-1}.Input-output ratio was calculated as per the following formula:

$$\text{Input-output ratio} = \frac{\text{Gross income (Rs ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs ha}^{-1}\text{)}}$$

The rainfall data during both the years has been represented in Table 2.

Table 2: Weekly rainfall data recorded during the experimental years.

Wk No.	Month & Date	Rainfall (mm)	Month & Date	Rainfall (mm)
22	May 27- 2	0.0	May 28-03	2.2
23	03-09	2.4	June 04-10	2.6
24	10-16	2.0	11-17	3.4
25	17-23	93.0	June 18-24	42.9
26	24-30	0.0	25-01*	0.0
27	July 01-07	176.2	July 02-08	136.5
28	08-14	46.6	09-15	74.2
29	15-21	158.4	16-22	48.8
30	22-28	49.2	23-29	139.8
31	July 29-04*	60.4	30- Aug 05	124.4
32	Aug 05-11	110	Aug 06-12	4.4
33	12-18	175.6	13-19	5.0
34	19-25	98.6	20-26	27.8
35	26-01	1.4	27-02	15.4
36	Sep 02-08	31.1	Sep 03-09	1.0
37	09-15	0.0	10-16	0.0
38	16-22	142.6	17-23	28.8
39	23-29	38.0	24-30	0.0
40	30-06	3.4	Oct 01-7	0.0
41	Oct 07-13	2.0	08-14	0.0
42	14-20	0.0	15-21	0.0
43	21-27	0.0	22-28*	0.0
44	28-03	0.0		
45	Nov 04-10	0.0		
46	11-17	0.0		
47	18-24*	0.0		

*Growing period of paddy

Results and Discussion

Yields and yield attributes: The data pertaining to number of panicles m^{-2}, grain yield, straw yield and number of filled spikelets $panicle^{-1}$ as influenced by different rice varieties and types of soil/ seed treatment have been presented in Table 4.3. The varieties showed significant differences in number of panicles m^{-2} between themselves and the higher values were observed in DRR 42 during both the years. DRR 42 (245.71 and 247.07 in 2016 and 2017 respectively) recorded 6.34% and 6.13% more-number of panicles m^{-2} than IR 64 in 2016 and 2017 respectively. Significant differences were observed in the soil/seed treatment also. The highest number of panicles m^{-2} (253.19, 256.25 in 2016 and 2017 respectively) was recorded by the application of D-18 compost + *Trichoderma* sp. In 2016, D-18 compost + *Trichoderma* sp. was at par with all the other soil/seed treatments and cumulatively recorded 22.74% more no. of panicles than control. In 2017, D-18 compost + *Trichoderma* sp. showed the same trend and cumulatively recorded 23.51% more no. of panicles in the second year than control, which produced the lowest number of panicles m^{-2} during both the years. The filled spikelets $panicle^{-1}$ was also found to be highest under D-18 compost+ *Trichoderma*.

Nitrogen is an important constituent of chlorophyll (Ohyama, 2010) [12] while phosphorus plays a crucial role in the constitution of nucleic acid, phytin and phospholipids (Lodish *et al.,* 2000) [11] and potassium helps in carbon assimilation and translocation of sugar and protein, and most importantly in entry of water in the plant roots (Wang *et al*., 2013) [17]. The escalated uptake of these nutrients resulted in better growth of plant, improving yield attributing characters and finally resulting in increased yield. With the application of organic manures or compost, nutrient assimilation may have been higher. The retention of moisture in the soil through application of *Trichoderma* sp. and hydrogel also played a vital role as under rainfed conditions solubility of nutrients is hindered (Li *et al*., 2019). Zia *et al*. (1992) [19] observed larger number of productive tillers and higher paddy yield under the application of *Sesbania* green manure and FYM.

Windham *et al.* (1986) [18] proposed that *Trichoderma* sp. produced growth promoters, plant growth stimulating factors and phytohormones like indole acetic acid (IAA) and their analogues and vitamins. Application of hydrogel on the other hand improves soil moisture content in all the sowing techniques in comparison to soil without hydrogel (Rehman *et al.* 2011) [13]. Hydrogels are super absorbent polymers that absorb and store water in their structure upto hundreds times of their own weight, i.e. 400-1500 g water per 1 gram dry weight of hydrogel (Johnson, 1984) [8]. It provides a medium to absorb water and eliminates water stress condition to certain extent. The effect of major nutrients particularly nitrogen on yield attributes is primarily a function of accumulation of assimilates facilitating higher N assimilation and adequate supply of photosynthates to grain (Daubresse *et al.*, 2010) [6].

DRR 42 performed better and produced 6.31% and 7.10% higher yield than IR 64 during the 1st and 2nd year respectively (Table 3). Cumulatively all the soil and seed treatments (although remaining at par among themselves) were found to produce significantly more yield than control which was to the extent of 50.93% and 55.76% in the first and second year respectively. However, among these seed and soil treatments D-18 compost + *Trichoderma* sp. produced the highest yield during both the years.

DRR 42 registered 8.58% and 9.66% higher straw yield than IR 64 during the 1st and 2nd year respectively. Highest straw yield was recorded by the application of D-18 compost + *Trichoderma* sp., but it remained at par with D-18 compost + Hydrogel, FYM, FYM + *Trichoderma* sp. and D-18 compost and these treatments cumulatively recorded 48.01% and 61.34% higher straw yield than control in the first year and second year respectively.

Table 3: Effect of treatments on yield and yield parameters.

Treatments	No. of panicles m^{-2}		Number of filled spikelets $panicle^{-1}$		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017
DRR 42 (V_1)	245.71	247.07	121.80	125.25	3.20	3.33	4.68	4.90
IR 64 (V_2)	231.05	232.79	114.70	120.55	3.01	3.10	4.31	4.45
Sem ±	3.95	3.12	2.10	1.08	0.07	0.07	0.13	0.12
CD (P = 0.05)	11.31	8.93	6.01	3.08	0.19	0.21	0.37	0.35
D-18 compost (T_1)	240.63	242.13	119.35	123.50	3.22	3.29	4.64	4.84
D-18 compost + *Trichoderma* sp. (T_2)	253.25	256.25	125.75	129.00	3.43	3.64	5.14	5.41
D-18compost + Hydrogel (T_3)	242.25	242.63	118.44	123.15	3.19	3.26	4.70	4.76
FYM (T_4)	247.50	250.38	119.91	124.55	3.28	3.42	4.69	4.90
FYM + *Trichoderma* sp. (T_5)	251.56	252.25	121.10	127.22	3.33	3.43	4.66	5.05
FYM + Hydrogel (T_6)	234.00	234.50	117.10	122.93	3.11	3.24	4.43	4.59
Control (T_7)	199.50	201.38	106.09	109.98	2.16	2.21	3.22	3.19
Sem ±	7.39	5.84	3.93	2.01	0.12	0.14	0.24	0.23
CD (P = 0.05)	21.15	16.71	11.25	5.75	0.11	0.40	0.68	0.65

Total rainfall received during the rice growing period was 620.1 mm and 605.6 mm in first and second year respectively (Table 2 and Figure 1). The rainfall was higher in the first year as compared to the second year. In the first year the rainfall receded after the month of September which coincided with the flowering period in rice and in the second year the rainfall ceased in the month of September with very little rainfall during the last fortnight of September. There was scarcity of moisture during the later stages of crop growth which coincided with the flowering stages during both the years. The scarcity in moisture created a stress condition and the genotype possessing drought tolerance trait (DRR 42) fared well than its isoline, IR 64 during both the years.

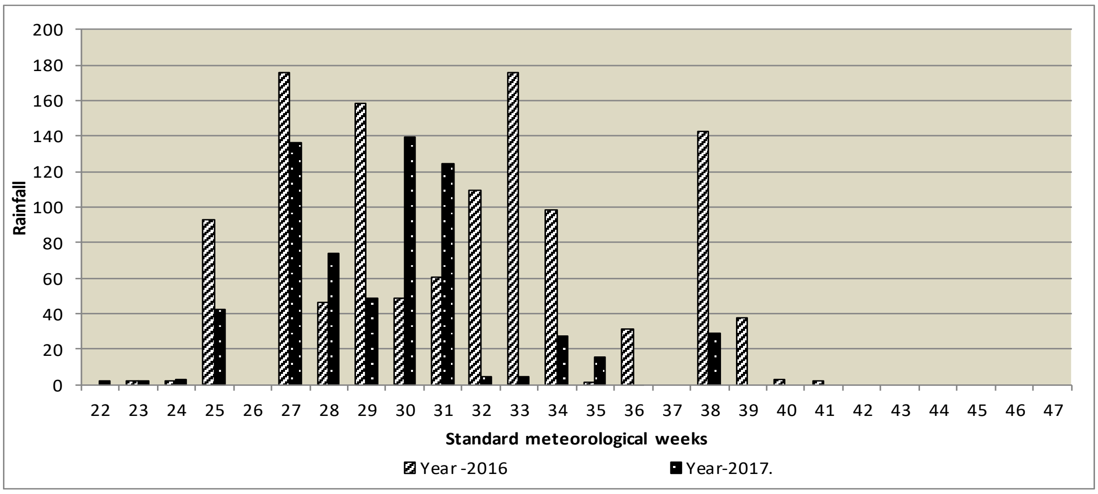

Fig 1: Comparison of rainfall (mm) between two experimental years

Economics: Data pertaining to economics of paddy cultivation have been presented in Table 4.4. It was clear from the data that irrespective of the varieties and soil/seed treatments, gross return, net return and input-output ratio were comparatively higher during second year than that of first year of experiment. The cost of cultivation was highest under D-18 compost + Hydrogel (₹ 38481.22 ha^{-1} and ₹ 38775.22 ha^{-1} in 2016 and 2017 respectively) followed by FYM + Hydrogel, D-18 compost+ *Trichoderma* sp., D-18 compost, FYM + *Trichoderma* sp., FYM and control.

The variety DRR 42 registered significantly higher gross return than IR 64. Perusal of the data further indicated that D-18 compost+ *Trichoderma* sp. recorded higher gross return but remained statistically at par with FYM + *Trichoderma* sp., FYM, D-18 compost, D-18 compost + Hydrogel during both the years. D-18 compost+ *Trichoderma* sp. recorded 58.86% and 65.82% higher gross returns than control in 2016 and 2017 respectively.

Table 4: Effect of treatments on cost of cultivation, gross and net returns and input-output ratio.

Treatments	Cost of cultivation (₹ ha^{-1})		Gross Returns (₹ ha^{-1})		Net Returns (₹ ha^{-1})		Input-output ratio	
	2016	2017	2016	2017	2016	2017	2016	2017
DRR 42 (V_1)	35354.79	35648.79	70028.21	72927.34	34673.42	37278.55	1.97	2.04
IR 64 (V_2)	35314.79	35608.79	65542.66	67535.97	30227.87	31927.18	1.86	1.89
Sem ±	-	-	1403.43	1614.85	1403.43	1614.85	0.04	0.04
CD (P = 0.05)	-	-	4014.53	4619.31	4014.53	4619.31	0.11	0.13
D-18 compost (T_1)	35981.22	36275.22	70212.75	72037.77	34231.53	35762.55	1.95	1.99
D-18 compost + *Trichoderma* sp. (T_2)	36018.72	36312.72	75406.00	79836.73	39387.28	43524.01	2.09	2.20
D-18compost + Hydrogel (T_3)	38481.22	38775.22	69862.13	71331.01	31380.91	32555.79	1.82	1.84
FYM (T_4)	35381.22	35675.22	71459.56	74560.02	36078.34	38884.80	2.02	2.09

FYM + *Trichoderma* sp. (T_5)	35418.72	35712.72	72340.13	75204.98	36921.41	39492.26	2.04	2.11
FYM + Hydrogel (T_6)	37881.22	38175.22	67752.00	70504.83	29870.78	32329.61	1.79	1.85
Control (T_7)	28181.22	28475.22	47465.50	48146.25	19284.28	19671.03	1.68	1.69
Sem ±	-	-	2625.57	3032.09	2625.57	3032.09	0.07	0.08
CD (P = 0.05)	-	-	7510.49	8673.33	7510.49	8673.33	0.21	0.24

An insight into the data clearly highlighted marked effect of both the variables on net returns of the crop. Between the varieties DRR 42 registered higher net return than IR 64 which was 14.71% and 16.76% more in 2016 and 2017 respectively. D-18 compost+ *Trichoderma* sp., FYM + *Trichoderma* sp., FYM and D-18 compost remained statistically at par among themselves during both the years. D-18 compost+ *Trichoderma* sp. recorded 104.25% and 121.26% higher net return than control in the first year and second year respectively.

DRR 42 (1.97 and 2.04 in 1st and 2nd year respectively) registered higher input-output ratio and was significantly superior to IR 64. Examination of the data revealed that input-output ratio was highest for the treatment D-18 compost+ *Trichoderma* sp. which registered 24.40% and 30.18% increase over control.

Economic feasibility of a system is very essential for its acceptance by the farmers. A practice or technology must be profitable enough to balance the cost of cultivation and the expenditure involved should be economically feasible. Between the varieties, DRR 42 (35354.79 ₹ ha^{-1}, 35648.79 ₹ ha^{-1} in 2016 and 2017 respectively) registered higher cost than IR 64 (35314.79 ₹ ha^{-1}, 35608.79 ₹ ha^{-1} in 2016 and 2017 respectively) but at the same time recorded higher gross and net return during both the years. As, the yield obtained from DRR 42 was economically higher, the input-output ratio was also higher, which indicated DRR 42 under rainfed condition is performed better than IR 64.

Among the soil/seed treatments, D-18 compost + hydrogel registered maximum input cost followed by FYM + hydrogel, D-18 compost + *Trichoderma* sp., D-18 compost, FYM + *Trichoderma* sp., FYM and control. The cost of hydrogel being higher (₹ 1000 kg^{-1}), the total cost of the treatments having hydrogel also increased. Among the soil/seed treatments, highest gross and net return was reported in D-18 compost + *Trichoderma* sp. The ratio of economic output to the cost of cultivation was higher in D-18 compost+ *Trichoderma* sp. The input cost was higher in compost (₹ 650 t^{-1}) in the soil but the output was also quite high when compared to the control. Srivastava *et al.* (2006) [16] also reported that the application of *Trichoderma* sp. was economical, non- hazardous and useful for improving the soil health. Field demonstration in Jaipur and Kota also confirmed similar results (Sharma *et al.* 2012) [15].

Conclusion

The grain yield was higher when farm yard manure /D-18 compost was added to the plots along with treatment of paddy seeds with *Trichoderma* sp. / soil application of hydrogel. However, the input-output ratio was highest for D-18 compost + *Trichoderma* sp. Thus, it can be concluded that DRR 42 with D-18 compost incorporated in soil and seeds treated with *Trichoderma* sp. could produce the highest returns and benefits.

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