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Effect of Different Innovative Nutrient Management Strategies on Productivity and Profitability of Transplanted Rice Under Organic Production System

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ABSTRACT

A field experiment was carried out at Agricultural Research Station, Gangavathi, UAS, Raichur, Karnataka, India during rabi/summer(2020-21), kharif (2021) and rabi/summer(2021-22) to study the effect of different innovative organic nutrient management practices on productivity and profitability of transplanted rice. While rice thrives in organic systems, challenges like nitrogen stress at critical growth stages, slow mineralization of organic manures, variety limitations, and weed competition hinder optimal yields. Hence, this experiment was designed to study the strategic use of integrating the slow releasing organic manures and fast mineralising liquid organic manures, split applications and alternate sources of organic sources of nutrients was tested in long term organic rice production system. The experiment was laid out in a randomized complete block design with three replications and ten treatments. Among all the treatments, the treatment receiving the combined application of organic manures (75% RDN) and liquid organic manures (Beejamrutha, jeevamrutha, 10 % cowurine and 10 %vermiwash)resulted in on par yields with that of FYM (100 % RDN), FYM+VC (100 % RDN). In addition, these treatments resulted in higher monetary returns than that of only organic manure applied treatment because of lower cost incurred for inputs.

Keywords: *Innovative practices, liquid organic manures, long term nutrient management, natural farming, nutrient management, organic rice, organic manures, split application and organic farming*

Introduction

Rice (*Oryza sativa* L.) is the major staple food crop in India as well as in the world. It is the most important food grain in the diets of millions of people living in the tropics and subtropics of Asia, Africa and Latin America. Rice continues to play a crucial role in sustaining food production in India, producing 20 to 25 percent of total production and ensuring food security for more than half of the population. It accounts for 55 percent of the country's total cereal production and major source of calories for 40 percent of the world population. In India, rice occupies an area of 45.76 million hectares with a production of 124.36 million tonnes with an average productivity of 2.71 tonnes per hectare[1].

Organic farming is often seen as a sustainable production system since it uses less inputs from outside the farm, has a greater input-output efficiency, and has positive effects on the environment. By improving natural processes and cycles in accordance with the environment, organic agriculture maintains soil fertility and productivity, helping to offset the issues related to input-intensive conventional agriculture.

Among the cereals, the performance of rice under organic farming has been found fairly impressive[2]. The comparatively higher yield of rice in organic farming than other cereal crops was evident in a multi-location study where organic to conventional yield (percent) manifested the following order rice (94 %) > corn (89 %) > oats (85 %) > wheat (73 %) and barley (69 %)[3]. This in turn indicates that the rice crop responds favorably to organic management and can be popularized under organic farming in rice growing areas. India has tremendous potential to become a major exporter of organic rice in the international market[4]. Currently, organic rice is in huge demand owing to its potential to fetch premium price in the global market[5].

Although rice performs well in organic production systems, a number of obstacles, such as nitrogen stress at crucial growth stages, a lack of quickly mineralizable organic manures, an inadequate selection of suitable varieties, and intense crop weed competition, make it difficult to reach the potential yield in

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a given eco-system. In general, the relative effectiveness of combined/integrated applications is superior over the application of only one organic source. Organic manures having C: N ratio of less than 15:1 like poultry manure, vermicompost mineralize rapidly in soil and manifest effects that are almost similar to mineral fertilizers[6]. Given the critical importance of N in organic management, split application of highly mineralizable N rich organic amendments like vermicompost, oil cake pellets and poultry manure can be performed at sensitive growth stages. Besides this, the application of liquid organic manures *viz.,* jeevamrutha, cow urine and vermiwash either through soil or foliage at different crop growth stages cause a striking effect on soil as well as on plant growth to boost the yield levels. For strategic nutrient management under organic rice, innovative organic management practices *i.e.* use of diverse organic nutrient sources including liquid organics and split application of fast mineralizable nutrient-rich manure (vermicompost, poultry manure) at different crop growth stages help to meet out the demand of nutrients by the crop. This in turn focuses on enhancing resource use efficiency (organic inputs) in rice production systems.

Material and Methods

The experiment was conducted on an existing 5 year-old long-term organic block with medium black soil located at Agricultural Research Station, Ganagavathi, UAS, Raichur, Karnataka. It was carried out during *rabi/*summer(2020-21), *kharif* (2021) and *rabi/*summer(2021-22). The experimental site is situated under the northern dry zone of Karnataka. The results obtained in two *rabi/*summer seasons (2020-21 and 2021-22) are pooled and pooled results of *rabi*/summer seasons are presented along with *kharif* season (2021) results. Further, the results over three seasons (*rabi/*summer pool and *Kharif* -2021) were pooled and presented as pooled results over seasons. In addition, prominence was given to presenting the results of the pooled data (*rabi/*summer pool + *kharif*) instead of individual season data as similar trend was observed in all the seasons. The experiment was laid out in a randomised complete block design with three replications and ten treatments. The treatment details are as follows.

Treatment Details

Sl. No.	Treatments
T_1	Soil application of jeevamrutha @ 500 l ha^{-1}
T_2	Soil application of jeevamrutha @ 1000 l ha^{-1}
T_3	FYM equivalent to 100 % RDN as basal dose
T_4	FYM (50 % N as basal dose) followed by vermicompost (50 % N as top dress) equivalent to 100 % RDN
T_5	FYM (50 % N as basal dose) followed by vermicompost (50 % N as top dress) equivalent to 75 % RDN
T_6	FYM (50 % N as basal dose) followed by vermicompost (50 % N as top dress) equivalent to 50 % RDN
T_7	T_5 + Soil application of jeevamrutha @ 500 l ha^{-1} + foliar spray of cow urine (10 %) alternated with vermiwash (10 %) at flowering and panicle initiation stage
T_8	T_5 + Soil application of jeevamrutha @ 1000 l ha^{-1} + foliar spray of cow urine (10 %) alternated with vermiwash (10 %) at flowering and panicle initiation stage
T_9	T_6 + Soil application of jeevamrutha @ 500 l ha^{-1} + foliar spray of cow urine (10 %) alternated with vermiwash (10 %) at flowering and panicle initiation stage
T_{10}	T_6 + Soil application of jeevamrutha @ 1000 l ha^{-1} + foliar spray of cow urine (10 %) alternated with vermiwash (10 %) at flowering and panicle initiation stage

Note: *Jeevamrutha application at planting, 25, 50 and 75 DAT (days after transplanting) in T_1, T_2, T_7, T_8, T_9 and T_{10} treatments along with seedling treatment with beejamrutha at the time of transplanting.*

Beejamrutha preparation

Beejamrutha is a treatment for seeds, seedlings or any planting material. It is effective in protecting young roots from fungus along with soil-borne and seed-borne illnesses that frequently affect crops after the monsoon period. It is composed of ingredients such as local cow dung, cow urine, lime, water and a handful of soil from the bund of the farm.

Beejamrutha was prepared by wrapping 5 kg of cow dung in a muslin cloth and hung in a bucket containing 20 liter of water and soaked overnight. 50 g of lime was added to 1 liter of water and then left overnight. Then the next morning, a bundle of cow dung was squeezed in that water continuously so that all the essence of cow dung would be accumulated in that water. A handful of soil, 5-liter desi cow urine and lime solution were added to that water[7]. Later, fresh beejamrutha was used for seedling treatment before planting as per treatments.

Jeevamrutha preparation

Jeevamrutha is a microbial consortium prepared by using locally available desi cow dung, cow urine, jaggery, pulse flour and garden soil. It will help in enriching the soil beneficial microbial population.

Jeevamrutha was prepared by mixing 10 kg desi cow dung with 10 liters of desi cow urine, add 2 kg jaggery, 2 kg pulse flour, and a handful of garden soil and the volume made upto 200 litres. The drum was kept in a shade covered with wet gunny bag and the mixture was stirred clockwise thrice a day and incubated for 7-8 days[7]. Then it was used for soil application as per the treatments.

FYM (Farm yard manure) and Vermicompost

FYM was applied at the time of planting as per the treatments and vermicompost (VC) was applied as topdressing. Foliar spray of cow urine or vermiwash was given at the flowering and panicle initiation stage. Soil application of liquid organic manure *i.e.*jeevamrutha was done as per the treatments at four split doses *i.e*. at the time of planting, 25 DAT, 50 DAT and 75 DAT. All other recommended practices for rice cultivation as per the organic production system in the nursery and main field were followed.

Results and Discussion

Productivity (Grain yield and Straw Yield)

In the present investigation which was carried out in organic fields, in pooled data (*rabi*/summer pool + *kharif*), among different innovative organic nutrient management practices, treatments supplemented with combination of FYM (50 % N basal) + VC (50 % N top dress) equivalent to 75 % RDN along with four times jeevamrutha at 500 and 1000 l ha^{-1} and followed by foliar sprays of cow urine and vermiwash at flowering and panicle initiation stages not only resulted in on par grain yields(T_7: 3774 kg $ha^{-1}$and T_8:3849 kg ha^{-1}) and straw yields (T_7: 5329 kg ha^{-1} and T_8:5360 kg ha^{-1}) (Table 1) with T_3: FYM (100 % RDN basal) (3854 and 5349kg $ha^{-1}$of grain yield and straw yield respectively) and T_4: FYM (50 % N basal) + VC (50 % N top dress) equivalent to 100 % RDN(3765 and 5208 kg ha^{-1} of grain yield and straw yield respectively) (Table 1) but also recorded significantly higher grain and straw yields over their corresponding treatments which received lower levels of organic manures in combined applications, FYM + VC equivalent to 50 % RDN with liquid organics (T_9 and T_{10})and without liquid organics (T_5 and T_6). In these treatments (T_7 and T_8), combined application of various sources of organics at different growth stages as basal, top dressing with vermicompost and foliar applications of liquid organics might have caused continuous and adequate availability of nutrients throughout the crop growth period on account of availability of higher concentration of available NPK nutrients in soil as a result of rapid mineralization of native and applied nutrients by higher beneficial effective microorganisms. Further, as a result, these treatments (T_7 and T_8) might have had higher uptake of NPK nutrients by the crop and thus resulted in on par grain yield with FYM (100 % RDN) and FYM + VC (100 % N) and also higher yields over their corresponding treatments where the combined application of various organics at lower levels (T_5, T_6, T_9 and T_{10}) was done. Further, the use of liquid organics in combination with other organic manures even with use of 25 % lesser recommended nitrogen in these treatments showed benefits by recording on-par yields of FYM and FYM + VC (100 % RDN). The beneficial microbes present in liquid organics - Jeevamrutha made the essential nutrients in soil to be available to the crop throughout the crop growth period. The foliar application of vermiwash and cow urine might have helped in easy absorption of nutrients which in turn resulted in better growth and yield. Similar results were reported by Gopakkali*et al.* (2011)[8], Yadav (2013)[9], Sreeja (2015)[10], Divya and Avinash (2015)[11] and RajanandHiremath (2018)[12] who reported increased yields with combined application of organic manures and liquid organic manures.Sweta*et al.* (2017)[13] also reported higher grain yield and straw yield with the application of 100 per cent N through FYM + seedling treatment with beejamruta + soil application of jeevamrutha @ 500 l ha^{-1} just after transplanting and at every 10 days interval up to 15 days before harvest.

Treatments supplemented with only jeevamrutha @ 500 l ha^{-1} and 1000 l ha^{-1} (T_1 and T_2) resulted in significantly lower and on par grain yields (2846 and 2904 kg ha^{-1}) and straw yields (4085 and 4193 kg ha^{-1})(Table 1) among themselves compared to rest of the treatments as a result of slow mineralisation of organic manures and non availability of adequate nutrients during the crop growth period, which might have reflected on growth set back. Similar results were also reported by Kiran (2014)[14].

Profitability (Cost of cultivation, Returns and Benefit cost ratio)

Economic analysis of net returns showed that in pooled data (*rabi*/summer pool + *kharif*), significantly higher net returns were recorded in T_6: FYM (50 % N basal) + VC (50 % N top dress) equivalent to 50 % RDN (₹ 61543 ha^{-1}) when compared to all other treatments except the treatments which received a combined application of organic manures such as FYM + VC + Jeevamrutha + cow urine + vermiwash in T_7, $T_9$and T_{10} (₹ 58270, 58780 and 58313 ha^{-1}). Other treatments were intermediary in their effect, while the treatment T_2: Jeevamrutha @ 1000 l ha^{-1} recorded the lowest net returns (₹ 51744 ha^{-1}). With respect to benefit-cost ratio, significantly higher benefit-cost ratio was recorded with T_1: Jeevamrutha @ 500 l ha^{-1} (3.92) followed by the treatment T_2: Jeevamrutha @ 1000 l ha^{-1} (3.49) and T_6: FYM (50 % N basal) + VC (50 % N top dress) equivalent to 50 % RDN (3.40) in pooled data (*rabi*/summer pool + *kharif*). FYM (100 % RDN) (T_3) resulted in significantly lowest benefit-cost ratio (2.22) compared to all the treatments(Table 2).

Higher gross returns recorded in treatments of FYM (100 % RDN) (T_3), FYM + VC with jeevamrutha at 500 and 1000 l ha^{-1} and foliar sprays of cow urine alternated with vermiwash (T_7 and T_8) were due to higher grain and straw yields in the respective treatments. While in net returns, treatments that received FYM + VC equivalent to 50 % RDN alone (T_6) and with jeevamrutha and cow urine and vermiwash sprays (T_9 and T_{10}) resulted in higher net returns on account of lower cost of cultivation as a result of use of lower quantity of organic manures (50 % RDN supplemented). However, these treatments were on par with FYM + VC equivalent to 75 % RDN along with jeevamrutha (500 l ha^{-1}) and cow urine and vermiwash sprays (T_7). This is due to the fact of fetching higher yields and gross returns. The treatment T_3 despite of achieving higher yields and gross returns, it showed lower net returns because of higher quantity and cost of FYM in the treatment. Benefit cost ratio was varied with treatments and was highest with application of jeevamrutha alone (500 l ha^{-1}) (3.92). The variation with lower B:C values in combined application of organic manurial treatments was mainly due to higher cost of cultivation.

From the point of yield, soil health, and economics in organic production system, it is evident that combined application of organic manures (FYM (50 % N) as basal + Vermicompost (50 % N) as Top dress) equivalent to 100 % RDN along with liquid organic manures (seedling treatment with beejamrutha + soil application of jeevamrutha @ 500 l ha^{-1} at the time of sowing, 25, 50 and 75 DAT and foliar spray of cow urine (10 %) and Vermiwash (10 %) at flowering and panicle initiation stage) with 75 % recommended nitrogen (T_7) helped in getting higher yields and monetary net returns than the sole application of organic manures alone or in combination without liquid organics. Similar results of higher economic yields and monetary benefits besides improving soil health and environment with combined application of various sources of organics were also noted by many scientists[15, 16, 17, 18].

Conclusion

Combined application of FYM (50 % N basal) + Vermicompost (50 % N top dress) equivalent to 75 % RDN along with seedling treatment of beejamrutha at planting and soil application of jeevamrutha @ 500 l ha^{-1} at the time of planting, 25, 50 and 75 DAT and foliar spray of 10 % cow urine alternated with 10 % vermiwash at flowering and panicle initiation stage resulted in higher and on par grain yields with that of FYM (100 % RDN) and FYM+VC(100 % RDN) despite of 25 % lower RDN through organics. This reduces the cost of cultivation and increases the monetary returns. Further, the reversible phenomenon of shifting from organic to an inorganic system due to non availability of organic inputs/manure can be avoided.

Future Scope of the study: Further exploration of low cost, readily available alternate sources organic nutrients for rice production. Research efforts can focus on optimizing the combination of organic sources, and assessing the long-term impacts on soil properties and environment.

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Table 1. Grain yield and straw yield of transplanted rice as influenced by different innovative organic nutrient management strategies

Treatments	Yield parameters					
	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
	R/S pool	K	Pooled data	R/S pool	K	Pooled data
T_1	2817	2875	2846	4051	4120	4085
T_2	2899	2908	2904	4245	4142	4193
T_3	3905	3804	3854	5296	5403	5349
T_4	3803	3727	3765	5172	5244	5208
T_5	3488	3563	3525	4873	5044	4958
T_6	3443	3550	3497	4948	5018	4983
T_7	3856	3691	3774	5322	5336	5329
T_8	3964	3734	3849	5329	5391	5360
T_9	3579	3532	3556	4973	5043	5008
T_{10}	3708	3577	3642	5001	5150	5075
S.Em ±	66	48	45	98	74	83
CD at 5 %	195	142	135	290	220	247

R/S pool - Pooled data of Rabi/Summer-2020-21 and Rabi/Summer-2021-22, K - Kharif-2021, Pooled data - pooled data of Rabi/Summer pool + Kharif

Table 2. Cost of cultivation, gross returns, net returns and benefit cost ratio of transplanted rice as influenced by different innovative organic nutrient management strategies

Treatments	Cost of cultivation (₹ha^{-1})			Gross returns (₹ha^{-1})			Net returns (₹ha^{-1})			B:C		
	R/S pool	K	Pooled data	R/S pool	K	Pooled data	R/S pool	K	Pooled data	R/S pool	K	Pooled data
T_1	18788	17550	18169	70337	71779	71058	51549	54229	52889	3.74	4.09	3.92
T_2	21388	20150	20769	72434	72592	72513	51046	52442	51744	3.39	3.60	3.49
T_3	45824	40950	43387	97348	94941	96144	51524	53991	52757	2.13	2.32	2.22
T_4	38645	35700	37173	94814	92994	93904	56169	57294	56731	2.45	2.60	2.53
T_5	32956	30450	31703	87011	88933	87972	54056	58483	56269	2.64	2.92	2.78
T_6	26791	24700	25746	85973	88605	87289	59182	63905	61543	3.21	3.59	3.40
T_7	37156	34650	35903	96163	92183	94173	59008	57533	58270	2.59	2.66	2.62
T_8	39756	37250	38503	98804	93235	96019	59048	55985	57517	2.49	2.50	2.49
T_9	30991	28900	29946	89286	88165	88725	58295	59265	58780	2.88	3.05	2.97
T_{10}	33591	31500	32546	92407	89309	90858	58816	57809	58313	2.75	2.84	2.79
S.Em ±	-	-	-	-	-	-	1609	1191	1127	0.05	0.04	0.04
CD at 5 %	-	-	-	-	-	-	4781	3538	3349	0.15	0.12	0.11

R/S pool - Pooled data of Rabi/Summer-2020-21 and Rabi/Summer-2021-22, K - Kharif-2021, Pooled data - pooled data of Rabi/Summer pool + Kharif

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