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Research Article

Effectiveness of Integrated Nutrient Management Practices on Yield and Soil Fertility in Basmati Rice Cultivation

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Abstract

To maintain the nutritional quality and productivity of aromatic basmati rice, integrated nutrient management (INM) is essential to provide fertilizers enriched manures to the desirable quantity and hasten the nutrient biofortification in basmati rice. Hence, to assess the response of biofortification through organically enriched manures with and without chemical fertilizers on basmati rice (Pusa 1121), a field experiment was conducted consisting of ten treatments viz. treatments (Control; Recommended Dose of Fertilizer (RDF) (100% N Urea); 100% Nitrogen through Vermicompost (VC); 100% Nitrogen through Farmyard Manure (FYM); 100% Nitrogen through Poultry Manure (PM); 100% Nitrogen through Press Mud (PrM); 50% Nitrogen through VC + 50% RDF (50% N Urea+50% N VC); 50% Nitrogen through FYM + 50% RDF (50% N Urea+50% N FYM); 50% Nitrogen through PM + 50% RDF (50% N Urea+50% N PM); 50% Nitrogen through PrM + 50% RDF (50% N Urea+50% N PrM). The results revealed that biofortification of macro and micronutrients in grains and yield of basmati rice improved significantly with integrated use fertilizers enriched manures with chemical fertilizers. Available NPK and extractable micro-nutrients (Zn, Cu, Fe and Mn) in soil improved statistically in treatment having integrated use of organic manures with 50% recommended fertilizers as compared to application of manures alone. In overall, it is concluded that fortification of soil with 50% RDF + 50% nitrogen through PrM or VC is most effective for improving the productivity and nutrient enrichment of aromatic basmati rice and sustaining the soil fertility.

Keywords: Integrated Nutrient Management; Biofortification; Nutrient Uptake

Introduction

Over the past few decades, intensive cultivation involving high-yielding varieties of rice with inadequate agricultural practices has depleted the nutrient pool of Indian soil. Further, the imbalanced use of chemical fertilisers and declines in the soil organic carbon has threatened the yield sustainability due to deterioration in soil health [9,24,31]. Among cereals, rice-wheat are world's most important staple food crops and are generally grown in sequence on an area of about 13.5 million ha in South Asia. In India, Indo-Gangetic plains occupy about 10.0 million ha under rice-wheat cropping system [14]. The imbalanced and skewed application of NPK fertilizers accompanied by restricted use of organic manures resulted in deficiency of soil macro and micro nutrients [4]. The emerging nutrient deficiencies have forced the system to adopt conventional bio fortification techniques *via* INM practices for improving soil health and to keep the production system more sustainable for providing qualitative nutrient enriched food. Integrated nutrient management is an important strategy for increasing system productivity by improving soil physical, chemical and biological properties [20]. The use of organically enriched fertilizers is one of the practices to make the production system more sustainable without affecting natural resources and environment [8,22,25]. The rice-wheat cropping system has shown sign of fatigue and evidences about the degradation of natural resources and reduction in system productivity. The issues of resource degradation and sustainability can be maintained by using the INM systems under rice-wheat cropping system. The cultivation of higher quality basmati rice is also one of the best options due to its lower nutritional requirement [2,20]. and quality of basmati rice can be maintained under INM approach. The application of organically enriched manures along with chemical fertilizers tailored the soil properties in addition to improvement in quality of basmati rice. Integrated nutrient management provides desirable quantity of nutrients in a timely manner and hastens the nutrient uptake and thus growth as well as yield of rice [6,18]. The adoption of plant bio supplementation from top to bottom with different approaches like INM is mandatory to produce crops in line with global standards of quantity and quality. In consideration of these facts, INM has played significant role in tailoring the soil properties with improved crop productivity. Apart from their role as a source of macro and micro nutrients, the organic fertilizers also improve the soil-physical behaviour as well as increase the utilization potential of applied nutrients resulting in increased crop yield and soil health [22]. Keeping all these points in view, the present study was conducted to find out the effect of different organic manures on yield, yield attributes, nutrient uptake and soil health under basmati rice cultivation trail.

Materials and Methods

Experimental site and soil

The present study was conducted on a field experiment started in 2016 at Research Farm, Khalsa College, Amritsar (Punjab), located at 31.6331°N latitude and 74.8301°E longitude at altitude of 234 m above the mean sea level from central alluvial plains of agro-climate zone of Punjab. The average annual rainfall is 681mm. The experimental soil is sandy loam (sand 73.2%, silt 18.7% and clay 8.1%) in texture, slightly alkaline in reaction with soil pH 8.24, electrical conductivity 0.54 $dSm^{-1}$and soil organic carbon content 2.6 g kg^{-1}, respectively. The available N, P and K content of soil was 182.8,18.6 and 296.5 $kgha^{-1}$, respectively. The content of DTPA extractable micronutrient cations *viz.,* Zn, Cu, Fe and Mn were 1.24, 0.61, 13.26 and 8.29 mg kg^{-1}, respectively.

Experimental design

The field experiment comprised of ten treatments (T_1: Control; T_2: recommended dose of fertilizer (100% N Urea); T_3: 100% nitrogen through vermicompost (100% N VC); T_4: 100% nitrogen through farmyard manure (100% N FYM); T_5: 100% nitrogen through poultry manure (100% N PM); T_6: 100% nitrogen through press mud (100% N PrM); T_7: 50% nitrogen through VC + 50% recommended dose of fertilizer (50% N Urea+50% N VC); T_8: 50% nitrogen through FYM + 50% recommended dose of fertilizer (50% N Urea+50% N FYM_2); T_9: 50%nitrogen through PM+50% recommended dose of fertilizer (50% N Urea+50% N PM); T_{10}: 50% nitrogen through PrM+50% recommended dose of fertilizer (50% N Urea+50% N PrM) and laid out in randomized block design (RBD) with 10 treatments replicated thrice. The test crop was basmati rice (var. PUSA Basmati 1121) with recommended NPK doses of fertilizers i.e., 89 kg urea and 185.25 kg single super phosphate (SSP) per hectare.

Application of organic manures and nutrient composition

Laboratory samples of four value-added organically enriched manures, namely VC, FYM, PM and PrM collected and after air drying passed through 2mm sieve and were analyzed for macro and micro nutrients by following standard procedures. The nutrient content of four organically enriched manures is represented in Table 1. After nutrient analysis, manures were used for purpose of biofortification in the present field experiment and were applied into appropriate measured plots, 15 days before transplanting by considering N as basal dose. The seeds were sown on nursery beds to raise seedlings for transplanting in the field. The experimental field was prepared by crosswise ploughing followed by puddling. The organically enriched manures and inorganic fertilizers were applied in the form of PM, VC, PrM and FYM, urea and diammonium phosphate (DAP) as per treatments. Transplanting was performed at 20 cm × 15 cm spacing with two seedling $hill^{-1}$ of 25 days old seedling.

Observations recorded

Among yield attributes, tiller number, grains per panicle, 1000 grain weight were recorded on five randomly selected plants in net plot area of each treatment. At maturity all the plants from net plot area were harvested and data on grain yield and straw yield were calculated. After harvesting of the crop, soil samples (0-15 cm) from each plot were collected. All soil samples were processed and analyzed for pH in 1:2.5 soil: water suspension with the help of pH meter [11], electrical conductivity (EC) [11], soil organic carbon (OC) by Walkley and Black method (1934) [37], available N by alkaline potassium permanganate method [29], available P by Olsen's method (Olsen, 1954) [19]., available K by ammonium acetate extraction method (Jackson 1973) [11] and DTPA micronutrients (Zn, Cu, Fe and Mn) by DTPA-extractable method through Micro Plasma

Atomic Emission Spectrometer (MP-AES 4200, Agilent Technologies) [16].

The plant samples of both grain and straw of basmati rice collected at harvest from each plot was oven dried, finely ground and estimated in laboratory. The NPK and micronutrients (Zn, Cu, Fe, Mn) in grain and straw were estimated by following techniques, micro-Kjeldahl, colorimeter, flame photometer and micro plasma atomic emission spectrophotometer (MP-AES) methods, respectively [11]. Uptake of various nutrients was calculated by using following formula:

Statistical analysis

The data obtained from the field experiment were subjected to analysis of variance (ANOVA) using RBD with the help of SAS software. Critical difference (CD) at p = 0.05 followed by Duncan's multiple range test to analyze the difference between the means of individual treatments.

Results

Nutrient content in manures

The analysis of nutrient status among four organically enriched manures revealed that poultry manure had highest macro and micronutrients content followed by vermicompost, FYM and minimum in press mud (Table 1). The nitrogen and potassium content were highest in poultry manure (2.16% and 1.94%) and minimum in the press mud (0.67% and 0.81%), however the phosphorus content was highest in poultry manure (2.38%) and least in the FYM (0.44%).

	Macronutrient content (%)			**Micronutrients content (mgkg^{-1})**			
Manure	N	**P**	**K**	**Zn**	**Cu**	**Fe**	**Mn**
Poultry manure (PM)	2.16	2.38	1.94	228	83	1438	459
Vermicompost (VC)	1.84	0.91	1.43	197	64	1275	427
Press mud (PrM)	0.67	2.11	0.81	173	46	982	358
Farmyard manure (FYM)	0.87	0.44	0.96	147	38	858	376

Table 1: Laboratory estimation of nutrient composition of different manures.

Yield and yield attributes

The yield and yield attributes increased significantly with the application of organically enriched manures with and without chemical fertilizers over the control treatment (Table 2). The effective tillers per hill increased from 13.9 to 21.5 with maximum tillers in treatment T9 which was statistically at pat with treatment T7. Similarly, panicle length, grain per panicle and 100 grain weight was highest in the treatment T9 which was statistically at par with treatment T7. The grain yield of basmati rice increased from 2.25-3.68 t ha^{-1} with the integrated application of different manures and fertilizers. The maximum grain yield (3.68 t ha^{-1}) was recorded with the treatment T9 which was statistically at par with treatment T7 (3.62 t ha^{-1}), similarly the straw yield was maximum in the treatment T9 and significantly higher over other treatments.

Plant nutrient content

Among macronutrients, the NPK content in grain and straw were significantly influenced with the levels of fertilizers enriched manures application (Table 3). The highest content of macro nutrients in grains and straw of basmati rice was observed in INM as N content (%): 0.91-1.04 (grain), 0.66-0.73 (straw); P content (%): 0.26-0.29 (grain), 0.18-0.19 (straw) K content (%): 0.35-0.38 (grain), 0.19-1.21 (straw), respectively. In treatments having N only through organically enriched manures, the N, P, K content was 0.69-0.70%, 0.23-0.25% and0.32-0.34% in grain and 0.58-0.64 (%), 0.16-0.17% and 1.12-1.16% in straw, respectively. It was observed that biofortification through 50% N replaced by organically enriched fertilizers showed highest improvement in nutrient status of grain and straw of basmati rice over that of 0% and 100% replacement of N by organically enriched fertilizers [8,18].

Treatment	Effective tiller per hill	Panicle length (cm)	Grains per panicle	1000 grain weight (g)	Yield (t ha^{-1})	
					Grain	Straw
T1-Control	13.9d	16.2e	90.4f	14.2f	2.25e	3.31h
T2-100% N Urea	20.4ab	23.5a	125.3ab	24.4ab	3.03b	5.34b
T3-100% N VC	16.2c	20.5cd	111.7d	19.5d	2.74c	4.04f
T4-100% N FYM	15.2c	19.7d	105.3d	17.2e	2.36d	3.48g
T5-100% N PM	16.6c	21.0bcd	113.4d	19.7d	2.82c	4.15d
T6-100% N PrM	15.2c	19.3d	102.7e	16.9e	2.41d	3.56g
T7-50% N Urea+50% N VC	20.9ab	23.2ab	127.6a	24.7ab	3.62a	5.34b
T8-50% N Urea+50% N FYM	19.6b	23.0ab	121.4bc	22.6bc	3.16b	4.65c
T9-50% N Urea+50% N PM	21.5a	24.8a	129.4a	25.2a	3.68a	5.43a
T10-50% N Urea+50% N PrM	19.4b	22.5abc	119.3c	21.6c	3.08b	4.54d
CD (p = 0.05)	1.5	2.4	5.2	2.3	0.09	0.08

Table 2: Effect of different nutrient management practices on yield and yield contributing attributes of basmati rice.

VC: Vermicompost; FYM: Farmyard Manure; PM: Poultry Manure; PrM: Press Mud

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
T1-Control	0.57d	0.40d	0.19e	0.10c	0.27c	0.96e
T2-100% N Urea	0.89b	0.65abc	0.23d	0.17ab	0.32b	1.12d
T3-100% N VC	0.77c	0.63bc	0.24cd	0.17ab	0.34ab	1.15bc
T4-100% N FYM	0.69c	0.59c	0.23d	0.17ab	0.32b	1.13cd
T5-100% N PM	0.78c	0.64abc	0.25bcd	0.17ab	0.34ab	1.16b
T6-100% N PrM	0.70c	0.58c	0.24cd	0.16b	0.32b	1.12d
T7-50% N Urea+50% N VC	1.03a	0.72ab	0.28ab	0.18ab	0.37a	1.20a
T8-50% N Urea+50% N FYM	0.91b	0.66abc	0.26abcd	0.18ab	0.35ab	1.19a
T9-50% N Urea+50% N PM	1.04a	0.73a	0.29a	0.19a	0.38a	1.21a
T10-50% N Urea+50% N PrM	0.91b	0.66abc	0.26abcd	0.18ab	0.35ab	1.19a
CD (p = 0.05)	0.10	0.09	0.03	0.02	0.04	0.02

Table 3: Effect of different nutrient management practices on nitrogen, phosphorus and potassium content in grain and straw of basmati rice.

VC: Vermicompost; FYM: Farmyard Manure; PM: Poultry Manure; PrM: Press Mud

Biofortification of micro-nutrient in grain and straw of basmati rice showed statistically significant difference among different treatments of organically enriched manures and inorganic fertilizer application over the control treatment (Table 4). Treatments under integrated use of organically enriched manures and inorganic fertilizers recorded maximum biofortification of micronutrient content in grains and straw as compared to treatments under organic manures alone and recommended inorganic fertilizers treatments, respectively. The content (mg kg^{-1}) of micronutrient was found enriched in grain as Zn: 28.20 > Cu: 4.83 > Fe: 4.81>Mn: 53.03 mg kg^{-1}, whereas in straw the content (mg kg^{-1}) of micronutrient is Zn: 18.17> Cu: 2.91> Fe: 67.88>Mn: 110.82 mg kg^{-1} in treatments T9 (50% recommended fertilizer + 50% N as poultry manure) which was at par with T7 (50% recommended fertilizer + 50% N as vermicompost) and significantly superior over all other treatments.

Treatment	Micronutrient content (mg kg^{-1})							
	Zn		Cu		Fe		Mn	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T1-Control	18.3e	8.4e	4.06f	2.18e	24e	46.9d	38.3e	80e
T2-100% N Urea	21.3d	11.1d	4.21e	2.29d	26.1d	51.0cd	41.5d	86.8d
T3-100% N VC	23.4bc	13.2c	4.49bc	2.57b	29.4b	57.4bc	45.1c	94.3bc
T4-100% N FYM	21.9cd	11.7d	4.35cde	2.43c	27.5c	53.6bcd	42.4d	88.7cd
T5-100% N PM	23.8b	13.6c	4.55b	2.63b	29.9b	58.4bc	45.7bc	95.5b
T6-100% N PrM	21.9cd	11.8d	4.32d	2.40c	27.3c	53.3bcd	42.6	89.1cd
T7-50% N Urea+50% N VC	27.9a	17.7a	4.81a	2.90a	34.4a	67.0a	52.4a	109.4a
T8-50% N Urea+50% N FYM	24.9b	14.7b	4.76a	2.84a	30.4b	59.3b	47.7b	99.8b
T9-50% N Urea+50% N PM	28.2a	18.2a	4.83a	2.91a	34.8a	67.9a	53.0a	110.8a
T10-50% N Urea+50% N PrM	24.6b	14.4b	4.77a	2.85a	30.2b	58.8bc	47.6b	99.5b
CD (p = 0.05)	1.5	0.7	0.15	0.07	1.6	7.8	2.3	6.2

Table 4: Effect of different nutrient management practices on micronutrient content by grain and straw of basmati rice.
VC: Vermicompost; FYM: Farmyard Manure; PM: Poultry Manure; PrM: Press Mud

Plant nutrient uptake

Among macronutrients, the NPK uptake in grain and straw were significantly influenced with the levels of different fertilizers enriched manures application (Figure 1). The uptake of nitrogen, phosphorus and potassium of basmati rice with INM varied from 29.1-37.5, 8.43-10.38 and 11.3-11.4 kg ha^{-1} in grain, 29.9-39.5, 8.0-10.1 and 53.4-65.6 kg ha^{-1} in straw, respectively.

Micro-nutrient uptake in grain and straw of basmati rice increased significantly among organically enriched manures and inorganic fertilizer application over the control treatment. (Figure 2). Treatments under integrated use of organically enriched manures and inorganic fertilizers recorded maximum micronutrient fortification in grains and straw as compared to treatments under organically enriched manures alone and recommended fertilizers treatment, respectively. The uptake of micronutrient was found highest in grain Zn: 101.67> Cu: 17.43> Fe: 125.45>Mn: 194.14 g ha^{-1}, whereas in straw Zn: 98.61> Cu: 15.81> Fe: 368.16>Mn: 601.23 g ha^{-1} in treatments T9 (50% recommended fertilizer + 50% N as poultry manure) in grain and straw which was at par with treatment T7(50% recommended fertilizer + 50% N as vermicompost) and significantly superior over all other treatments.

Soil fertility status

The soil pH has shown significant difference due to different nutrient management practices during the time of experimentation. The pH of the organic treated plots was significantly lower in 100% N VC (7.9), 100% N FYM (7.5), 100% N PM (8.0), 100% N PrM (7.4) than the control (8.3), RDF (8.4) and the plots receiving recommended fertilizer in combination with FYM (8.2), press mud (8.3), vermicompost (8.4) and poultry manure (8.3). The EC values had a narrow range of 0.34 to 0.37 dSm^{-1} under different treatments. In surface soil layer, the lowest EC (0.34 dSm^{-1}) was recorded in treatment T_4 (100% FYM) followed by value 0.35 dSm^{-1} in T_6 (100% PrM) which were significantly lower than control (0.37 dSm^{-1}), recommended fertilizer (0.376 dSm^{-1}). The OC content (%) of soil increased significantly with the application of organically enriched manuresalone in order: 100% N FYM in T_4 (0.54) >100% N PrM in T_6 (0.54) >100% N VC in T3 (0.53)>100% N PM in T_5 (0.53). The soil organic carbonin treatment plots with organically enriched manures was significantly higher than control, RDF and INM plots.

The organically enriched manures application was able to significantly influence the biofortification of NPK in soil (Table 5). It is cleared that available NPK were significantly higher in INM treat-

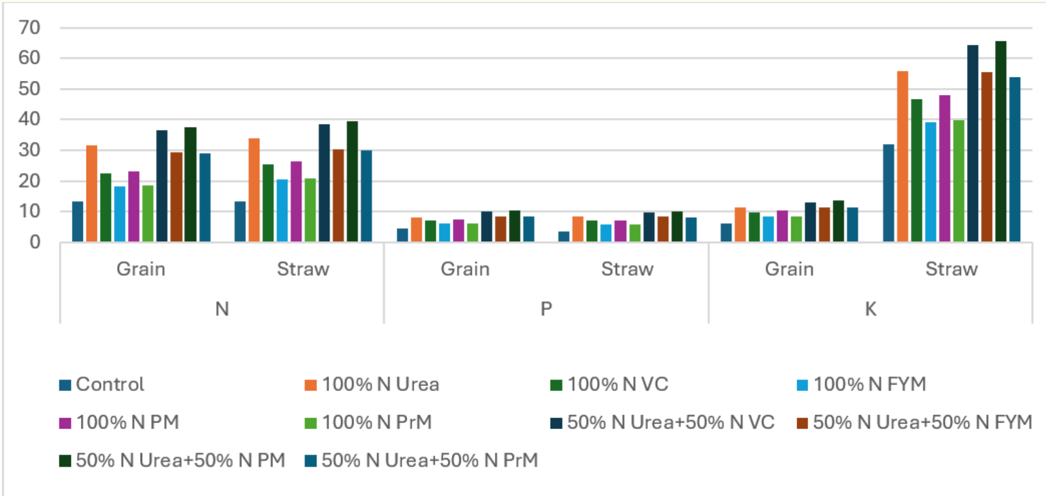

Figure 1: Influence of different nutrient management practices on macro-nutrient uptake by grain and straw of basmati rice.

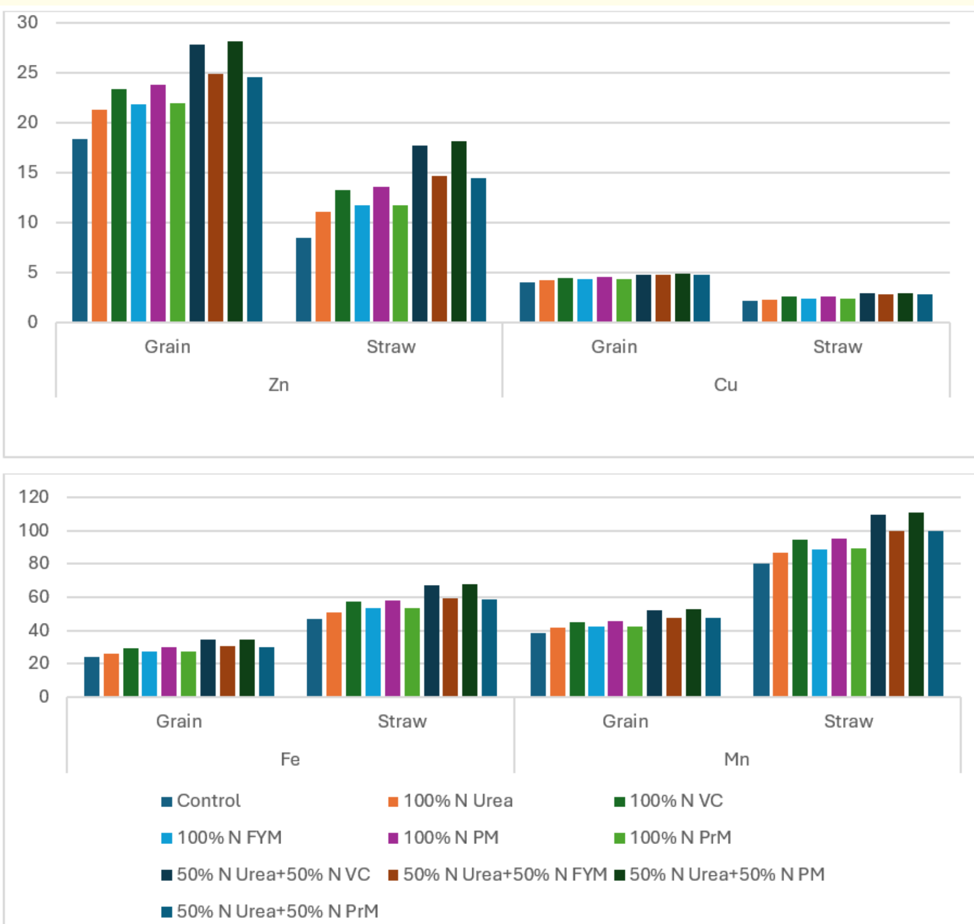

Figure 2: Influence of different nutrient management practices on micro-nutrient uptake by grain and straw of basmati rice.

Treatment	pH	EC (dSm-1)	OC (%)	Available macronutrients (kg ha-1)			Available micronutrients (mg kg-1)			
				N	P	K	Zn	Cu	Fe	Mn
T1-Control	8.3a	0.37b	2.2c	168d	12.9d	291e	0.88e	0.57f	12.9f	7.02e
T2-100% N Urea	8.4a	0.38a	2.5c	223b	19.9b	318cd	1.61d	0.67e	13.5e	9.08d
T3-100% N VC	7.9c	0.35d	5.3a	188c	16.4c	321cd	1.92c	0.77c	18.2c	11.8c
T4-100% N FYM	7.5d	0.34e	5.4a	178d	16.2c	318cd	1.68d	0.71de	15.0d	9.82d
T5-100% N PM	8.0b	0.35d	5.3a	195c	17.2c	324c	1.99c	0.81c	18.7c	12.4c
T6-100% N PrM	7.4d	0.35d	5.4a	179d	16.2c	317d	1.67d	0.72d	14.5d	9.61
T7-50% N Urea+50% N VC	8.4a	0.36c	3.7b	237a	24.2a	342a	2.70a	0.94a	24.1a	17.9a
T8-50% N Urea+50% N FYM	8.2ab	0.37b	3.7b	228b	21.1b	335b	2.47b	0.84b	21.6b	16.0b
T9-50% N Urea+50% N PM	8.3a	0.37b	3.6b	242a	24.9a	346a	2.78a	0.97a	24.7a	18.5a
T10-50% N Urea+50% N PrM	8.3a	0.37b	3.7b	226b	20.2b	333b	2.45b	0.82b	21.3b	15.8b
CD (p = 0.05)	0.2	0.01	0.5	7	1.6	6	0.08	0.04	0.8	0.7

Table 5: Effect of different nutrient management practices on various soil properties under basmati rice.
VC: Vermicompost; FYM: Farmyard Manure: PM: Poultry Manure; PrM: Press Mud

ments as compared to organic treatments and control. Although organic manures treatments were also showed significantly higher values **(**kgha^{-1}) of N: 194.78 (T5) > 188.19 (T3) >178.55 (T6) >178.15 (T4); P: 17.18 (T5) > 16.43 (T3) >16.18 (T6) >16.16 (T4); K: 324.23 (T5) > 321.12 (T3) >316.71 (T6) > 317.83(T4) from 100% N through PM, 100% N through VC, 100% N through PrM and 100% N through FYM, respectively as compared to control. Incorporation of manures along with inorganic P might have increased its availability in order: T9 (24.91) >T_7 (24.17)>T_8 (21.13)> T10 (20.24) to crop and mineralization rate due to microbial action enhanced mobility of available P [34].

The status of biofortification of available micronutrient viz., Zn, Cu, Fe and Mn ranged between 0.88 to 2.78 mgkg^{-1}, 0.57 to 0.97 mg kg^{-1}, 12.93 to 24.74 mg kg^{-1} and 7.02 to 18.47 mg kg^{-1}, respectively (Table 5) in soil. The INM treatments showed statistically superior results as compared to treatment having application of organically enriched manuresalone (T3, T4, T5 and T6), recommended fertilizers (T_2) and control (T1). It was found that application of 50% nitrogen from poultry manure along with the recommended dose of fertilizers gives higher value (mg kg^{-1}) as 2.78 (Zn), 0.97 (Cu), 24.7 (Fe) and 18.5 (Mn) as compared to other organically enriched manures combinations.

Discussion

Yield and yield attributes

The higher yield attributes due to incorporation of inorganic fertilizers with manures might be attributed to increased activity of photosynthesis and enzymes and responsible for transformation of energy, carbohydrates, fat metabolism and respiration of plant [13,17].

Plant nutrient content

As observed from the results, the highest NPK content under poultry manure treated plots might be associated with the increased availability of this nutrient in soil due torapid mineralization of N from PM as compared to VC, FYM and PrM [32]. The biofortification of phosphorus content under INM might be attributed to the solubilisation of fixed-P due to the action of organic acids produced from decomposition of different manures and also due to balanced application of P [12]. Highest K fortification was observed under INM which might be due to better proliferation of root architect, resulting in better K absorption under integrated nutrient treated plots as compared to organically enriched manures, inorganically treated and control plots. The biofortification of K content under recommended fertilizers was not much higher, which might be due to the absence of application of inorganic potassium fertilizer into basmati rice, as K was not part of recommended dose of nutrients of basmati rice. As we consider about organically enriched manures, best biofortification results were shown by the treatments under poultry manures which might be due its high concentration and high capacity of providing nutrients to plant as compared to other manures [3,6,28,29].

The observed trend of micro-nutrient supplementation in grain and straw of basmati rice might be due to the fact that use of chemical fertilizers provides better root structure and penetration which, in turn resulted in forages larger volume of soil mass. Addition of organically enriched manures may probably due to the fact that after their decomposition, the release of micro nutrient cations will further increases its bioavailability and is easily taken up by plants [5,21]. Among graded doses of recommended nutrients, integrated application of chemical fertilizers and poultry manure registered maximum content due to higher supply of nutrients, high mineralization efficiency and increasing Cu availability under reduced conditions [7,10,21,33]. Increased in Fe content with recommended fertilizer and poultry manure may be ascribed to increase availability of Fe because of their favourable impact on oxidation-reduction regime and higher chelation [5,10,21,33]. As comparing different manures, maximum biofortification of Zn, Cu, Fe and Mn was recorded under poultry manure both under combined use with chemical fertilizers and alone, which might be due to narrow C: N ratio, higher availability from unavailable forms through higher chelating capacity in comparison to vermicompost, FYM and press mud [1,9].

Plant nutrient uptake

The biofortification of N,P,K in grain and straw was affected with different manure application [18,28,32]. Bio-fortification of micro-nutrients by grain and straw of basmati rice had shown almost similar results. The findings are in good agreements with the results of [5,21,33].

Soil fertility status

The decrease in the pH in organically treated plots might be ascribed to the production of organic acids and CO_2 released during the decomposition of organic matter by microbes [6,28]. The declined in EC might be attributed to the higher leaching losses and reduced salt accumulation in the root zone under rice crop [28]. The percent increase in soil OC content in T3, T4, T5,T6 with the application of four organically enriched manures like vermicompost, farmyard manure, poultry manure, press mud might be attributed to the direct incorporation of these organic materials in the soil and the subsequent decomposition of these materials resulting in enhanced organic carbon content of the soil [27].

For macronutrients, different researchers also found significant improvement in available NPK status of soil in chemical fertilized treatments over control [30]. The increase in soil available N status due to organically enriched manures application with fertilizers would also be due to multiplication of soil microbes leads to enhanced conversion of organically bound N into inorganic forms and rapid mineralization. The favourable soil conditions under organic manure application might be improved mineralization of soil N leading to build up of higher available nitrogen [36]. These results are in line with the findings of [26]. who also observed that available N content increased in soil with the use of recommended fertilizers with manures.

The higher availability of P with organics along with fertilizers could be attributed to their solubilising effect on the native insoluble P fractions through release of various organic acids thus resulting into a significant improvement in available P status of soil [35]. In addition, the organic matter may inhibit the fixation of organic P by providing protective cover on sesquioxides and thus increase the available P in soil solution. The increase in available K under integrated treatments might be due to addition of organic matter that reduced K fixation due to interaction between organic matter and clay, besides the direct K addition to the pool of soil [30,35]. The addition of poultry manure may cause decomposition of organic matter and release considerable amount of CO_2. The released CO_2 when dissolved in water forms carbonic acid and decomposes primary minerals to release nutrients [4].

For micronutrients, organic manures together with recommended fertilizers increasing contents of organic matter in soil, availability of Zn in soil increased because this element forms labile organic-mineral complexes [3,8,9]. The results of present study were in accordance with the previous studies reported by [15,21,36]. They had concluded that integrated nutrient application significantly enhanced the Zn concentration in rice over the control, recommended fertilizer and organic manure treated plots. The highest Cu and Fe content in soil under poultry manure treatments might be due to addition of low organic matter in soil through poultry manure (on weight basis) because with increasing content of organic matter in soil, mobility of Cu in soil solution decreased as a result of stable bonds formation [23] and decreased their availability. The improved Fe content in all treatments except control was due to submerge conditions during growing season, thus increasing the concentration of the soluble Fe^{2+} ions in soil. The improved status of DTPA-extractable Mn might be probably due to the chelating action of organically enriched manures and reduction of Mn^{4+} to Mn^{2+} which resulted in its higher solubility under submerged conditions [6,10].

Conclusions

From present study, it was observed that soil bio-fortification of minerals through integrated use of organic manures like PM, VC, FYM and PrM along with chemical fertilizers significantly improved the basmati yield, nutrient content and uptake, soil nutrient status than sole application of organic manures. The application of 50% RDF + 50% nitrogen through poultry manure is most effective for improving the productivity of basmati rice and `maintaining soil fertility which was statistically par with 50% RDF + 50% nitrogen through vermicompost.

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