Middle-East Journal of Scientific Research 24 (2): 437-444, 2016
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2016.24.02.22973

Effect of Vermicompost and Chemical Fertilizer on the Nutrient Content in Rice Grain, Straw and Post Harvest Soil

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Abstract: In order to study the combined effect of vermicompost and chemical fertilizers on the nutrient content in grain, straw and post harvest soil of boro rice cv. BRRI dhan29, a field experiment was conducted in December, 2013 to June, 2014 at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Sixteen combinations of 4 vermicompost level @ 0, 1, 2, 4 t ha^{-1} and 4 NPKS levels i.e. 0-0-0-0, 50-8-33-6, 100-16-66-12, 150-24-99-18 kg ha^{-1}, respectively were applied in a Randomized Complete Block Design (RCBD) with three replications. Results showed that the highest dose of vermicompost and chemical fertilizer increased the concentration of P, K and S by rice grain and straw significantly at the harvesting stage. Combined application of vermicompost and chemical fertilizer failed to increase the total N content of post-harvest soil. Combination of vermicompost and chemical fertilizers also increased the organic matter, P, K and S status of post harvest soil significantly.

Key words: Chemical fertilizer · Organic matter · Post harvest soil · Rice · Vermicompost

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and extensively cultivated food crop, which provides half the daily food for one of every three persons on the earth. To feed these large numbers of people high yielding varieties, intensive cultivation, inorganic fertilizers lead from the front. Due to the extensive and improper use of chemical fertilizers in the soil, our soil is degrading to an alarming level, causing an imbalance in the ecosystem and environmental pollution as well [1-3] which leads to deterioration in soil physical and chemical properties, biological activity and generally in soil health [2].

More recently, attention is being focused on the global environmental problems. Organic materials are the safer sources of plant nutrient without any detrimental effect to crops and soil [4]. Many research findings have shown that neither inorganic fertilizers nor organic sources alone can result in sustainable productivity [1, 5]. The best remedy for soil fertility management is, therefore, a combination of both inorganic and organic fertilizers, where the inorganic fertilizer provides nutrients and the organic fertilizer mainly increases soil organic matter and improves soil structure and buffering capacity of the soil [5].

Vermicomposting with earthworms has been recognized as a composting technique that transforms complex organic substances into stabilized, humus like product [6]. The application of vermicompost to soil is considered a good management practice in any agricultural production system because of the stimulation of soil microbial growth and activity, subsequent mineralization of plant nutrients and increased soil fertility and quality [7, 8].

Based on the evaluation of soil quality indicators, Dutta *et al*. [9] reported that the use of organic fertilizers together with chemical fertilizers, compared to the addition of organic fertilizers alone, had a higher positive effect on microbial biomass and hence soil health. Application of organic manure in combination with chemical fertilizer has

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been reported to increase absorption of N, P and K in sugarcane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone [10]. Uptake of N, P and K in rice grain and straw showed that application of manure fertilizer with the recommended doses of N, P and K would maximize the uptake of nutrients than the application of recommended levels of fertilizers alone without any manure [11]. After harvesting the straw and grains are used for fuel purpose or feed the cattle in Bangladesh. If these residues are returned back to the field as compost, the crop fertilizer requirement will be gradually decreasing day by day. It will reduce the cost of farming and environmental pollution. But research on this line is very scarce in Bangladesh. Therefore, the study was undertaken to investigate the effect of organic and inorganic fertilizers on nutrient content of harvested rice plants (straw, grain) and post harvest soil in boro season.

MATERIALS AND METHODS

Experimental Location, Soil and Climate: The study was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh situated at 23°46´ N latitude and 90°23´ E longitude at an altitude of 8.45 m above the sea level during the growing period from December 2013 to June 2014. The soil of the experimental site was silty clay loam in texture with 17.60% sand, 47.40% silt, 35.00% clay, 44.5 porosity, 1.48 g/cc bulk density, 2.52 g/cc particle density, 5.70 soil pH, 0.89% organic carbon, 0.063% total N, 14.90 mg kg^{-1}soil available P, 0.12 meq/100g soil exchangeable K and 11.00 mg kg^{-1}available S. The experimental area was situated in the subtropical humid climatic zone and the detailed mean maximum, minimum temperature and rainfall is presented in Fig. 1.

Planting Material: A rice variety called BRRI dhan29 was used as a test crop. This variety was developed at the Bangladesh Rice Research Institute (BRRI) from the cross between BG 90-2 and BR51-46-5 in 1994. It is recommended for boro season.

Experimental Design, Treatment and Plot Size: Sixteen combinations of fertilizers from four different levels of vermicompost *viz.,* V_0=0 t ha^{-1} (control), V_1=1 t ha^{-1}, V_2=2 t ha^{-1}, V_3=4 t ha^{-1} and four levels of chemical fertilizers *viz.,* F_0= control (0-0-0-0 kg N, P, K, S ha^{-1}, respectively), F_1= 50-8-33-6 kg N, P, K, S ha^{-1}, respectively, F_2= 100-16-66-12 kg N, P, K, S ha^{-1}, respectively, F_3= 150-24-99-18 kg N, P, K, S ha^{-1}, respectively were applied in a Randomized Complete Block Design (RCBD) with three replications each. The size of the plot was 2 × 2 m (4 m^2). The distance maintained between two plots was 0.5 m and between blocks was 1 m. Vermicompost contained 11.06% organic matter, 0.630% total N, 0.022% available P, 0.078% available K and 0.031% available S.

Collection and Preparation of Grain and Straw samples: Grain and straw samples were collected after threshing for N, P, K and S analyses. The plant samples were dried in an oven at 65°C for 72 hours and then grind by a grinding machine. The samples were stored in plastic vial for analyses of N, P, K and S concentrations.

Digestion of Grain and Straw samples with Sulphuric Acid for N Analysis: For the determination of nitrogen an amount of 0.5g oven dried, grinded samples were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se in the ratio of 100:10:1) and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160°C and

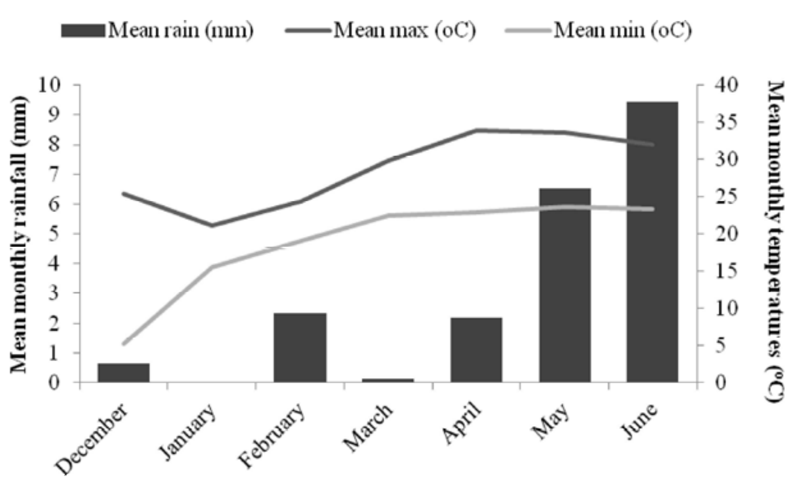

Fig. 1: Mean maximum, minimum temperature and rainfall during the experimental period.

added 2 ml 30% H_2O_2 then heating was continued at 360°C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

Digestion of Grain and Straw Samples with Nitric-perchloric Acid for P, K and S Analysis: A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. 10 ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200°C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water.

Determination of P, K and S from Grain and Straw Samples

Phosphorus: Grain and straw samples were digested by di-acid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development [12]. Phosphorus in the digest was determined by using 1 ml for grain samples and 2 ml for straw samples from 100 ml digest by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve [13].

Potassium: About 10 ml of digest sample for the grains and 5 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

Sulphur: Sulphur content was determined from the digest of the plant samples (grains and straw) as described by Page *et al*. [13]. The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths [14].

Post-harvest Soil Sample Analysis

Organic Matter: Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black [15]. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in the presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage [13].

Total Nitrogen: Total N content of soil were determined followed by the Micro Kjeldahl method. About 1.0 g of oven dry grind soil sample was taken into micro kjeldahl flask to which 1.1g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1) and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160°C and added 2 ml H_2O_2 and then heating at 360°C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination [13]. Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10N NaOH solutions was added in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100 / S$$

where:

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

Available Phosphorus: Available P was extracted from the soil with 0.5 M $NaHCO_3$ at pH 8.5. The phosphorus in the extract was then determined by developing the blue color by ascorbic acid reduction of phosho-molybdate complex and measuring the color calorimetrically at 660 nm [12].

Exchangeable Potassium: Exchangeable K of soil was determined from 1 N ammonium acetate (pH 7.0) extract of the soil by using flame-photometer.

Available Sulphur: Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by [13]. The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

Statistical Analysis: The data were statistically analyzed by using MSTAT-C [16] programme. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Table 1: Effect of vermicompost and NPKS fertilizer on N, P, K, S concentration in rice grain.

Vermicompost × NPKS fertilizer	Concentration (%) in grain			
	N	P	K	S
V_0F_0	0.334 g	0.149 h	0.295 f	0.104 f
V_0F_1	0.441 f	0.163 gh	0.336 ef	0.128 d-f
V_0F_2	0.529 ef	0.171 f-h	0.344 ef	0.135 c-f
V_0F_3	0.724 c	0.181 e-h	0.345 ef	0.158 b-e
V_1F_0	0.565 de	0.207 d-g	0.364 de	0.121 ef
V_1F_1	0.872 b	0.215 c-g	0.375 de	0.154 b-f
V_1F_2	0.705 c	0.223 b-f	0.399 cd	0.188 ab
V_1F_3	1.104 a	0.230 b-e	0.409 b-d	0.192 ab
V_2F_0	0.657 cd	0.214 d-g	0.332 ef	0.134 c-f
V_2F_1	0.704 c	0.240 a-d	0.453 ab	0.163 b-e
V_2F_2	0.851 b	0.247 a-d	0.445 a-c	0.179 a-d
V_2F_3	1.153 a	0.258 a-d	0.474 a	0.204 ab
V_3F_0	0.840 b	0.253 a-d	0.340 ef	0.181 a-c
V_3F_1	0.884 b	0.268 a-c	0.327 ef	0.196 ab
V_3F_2	0.945 b	0.272 ab	0.329 ef	0.205 ab
V_3F_3	1.192 a	0.287 a	0.345 ef	0.217 a
$LSD_{(0.05)}$	0.106	0.053	0.053	0.053
CV (%)	8.32	6.60	8.39	5.77

Means with different letters in the same row indicate significant differences according to the LSD test ($p \leq 0.05$). V_0=control, V_1=1 t ha^{-1}, V_2=2 t ha^{-1}, V_3=4 t ha^{-1}; F_0 = control, F_1= (50-8-33-6 kg ha^{-1} N, P, K, S, respectively), F_2 = (100-16-66-12 kg ha^{-1} N, P, K, S, respectively), F_3 = (150-24-99-18 kg ha^{-1} N, P, K, S, respectively).

RESULTS AND DISCUSSION

Nutrient Concentrations in Rice Grain

Nitrogen Content: Effect of different doses of vermicompost and NPKS fertilizer showed significant variation on nitrogen content in rice grain (Table 1). The maximum nitrogen content in grain (1.192%) was obtained from V_3F_3 which was statistically similar with V_2F_3 and V_1F_3 whereas, the minimum (0.334%) was observed from control treatment. Sengar *et al*. [17] reported that the N uptake by rice grain increased significantly with the combined application of organic manure and chemical fertilizers. Rahman [18] and Duhan and Singh [19] also reported similar results.

Phosphorus Content: Variation was observed for phosphorus content in rice grain due to the combined effect of vermicompost and NPKS fertilizer (Table 1). The maximum phosphorus content in grain (0.287%)was observed from V_3F_3 which was statistically similar with V_3F_2, V_2F_3, V_2F_3, V_3F_0, V_2F_2 and V_2F_1 whereas, the minimum (0.149%) was found from control treatment which was statistically at par with V_0F_1, V_0F_2 and V_0F_3. Sengar *et al*. [16] recorded that the highest P uptake by rice grain was recorded with the combined application of organic manure and phosphatic fertilizers.

Potassium Content: It is evident from Table 1 that combined effect of different doses of vermicompost and NPKS fertilizer exerted significant effect on potassium content in rice grain. The maximum potassium content in grain (0.474%)was found from V_2F_3 which was statistically similar with V_2F_1 and V_2F_2 whereas, the minimum (0.295%) was observed from V_0F_0 which was statistically similar with V_3F_1, V_3F_2, V_2F_0, V_0F_1, V_3F_0, V_0F_2, V_0F_3 and V_3F_3. Singh *et al*. [19] revealed that potassium content in grains was increased due to combined application of organic manure and chemical fertilizers. Similar results were also found by Verma *et al*. [21].

Sulphur Content: Significant variation was recorded in sulphur content of rice grain due to the combined effect of vermicompost and NPKS fertilizers as shown in Table 1. The maximum sulphur content in grain (0.217%) was obtained from V_3F_3 which was statistically similar with V_3F_2, V_2F_3, V_3F_1, V_1F_3, V_1F_2, V_3F_0 and V_2F_2 whereas, the minimum (0.104%) was observed from control treatment which was statistically similar with V_1F_0, V_0F_1, V_2F_0, V_0F_2 and V_1F_1 treatments. Sengar *et al*. [16] recorded the higher uptake of S with the application of manure and fertilizers either alone or in combinations. Similar results were also reported by Rahman [17].

Table 2: Effect of vermicompost and NPKS fertilizer on N, P, K, S concentration in rice straw.

Vermicompost × NPKS fertilizer	Concentration (%) in straw			
	N	P	K	S
V_0F_0	0.14 h	0.10 c	1.26 h	0.070 c
V_0F_1	0.24 g	0.13 bc	1.39 g	0.08 bc
V_0F_2	0.33 fg	0.14 a-c	1.58 f	0.09 a-c
V_0F_3	0.52 e	0.17 ab	1.76 b-d	0.13 ab
V_1F_0	0.37 f	0.13 a-c	1.30 h	0.09 a-c
V_1F_1	0.51 e	0.14 a-c	1.47 g	0.10 a-c
V_1F_2	0.67 cd	0.16 ab	1.71 de	0.12 ab
V_1F_3	0.87 b	0.17 ab	1.84 ab	0.13 ab
V_2F_0	0.46 e	0.14 a-c	1.47 g	0.10 a-c
V_2F_1	0.50 e	0.15 a-c	1.63 ef	0.10 a-c
V_2F_2	0.65 d	0.17 ab	1.68 de	0.13 ab
V_2F_3	0.95 ab	0.18 ab	1.74 cd	0.13 ab
V_3F_0	0.64 d	0.14 a-c	1.25 h	0.10 a-c
V_3F_1	0.67 cd	0.16 ab	1.68 de	0.12 ab
V_3F_2	0.76 c	0.18 ab	1.81 a-c	0.13 ab
V_3F_3	0.98 a	0.19 a	1.88 a	0.14 a
$LSD_{(0.05)}$	0.091	0.055	0.091	0.051
CV (%)	9.35	8.24	3.58	8.36

Means with different letters in the same row indicate significant differences according to the LSD test ($p \leq 0.05$). V_0=control, V_1=1 t ha^{-1}, V_2=2 t ha^{-1}, V_3=4 t ha^{-1}; F_0 = control, F_1= (50-8-33-6 kg ha^{-1} N, P, K, S, respectively), F_2 = (100-16-66-12 kg ha^{-1} N, P, K, S, respectively), F_3 = (150-24-99-18 kg ha^{-1} N, P, K, S, respectively).

Nutrient Concentrations in Rice straw

Nitrogen Content: Nitrogen content in rice straw varied significantly due to different doses of vermicompost and NPKS fertilizer (Table 2). The maximum nitrogen content in straw (0.9%) was obtained from V_3F_3 which was statistically similar with V_2F_3 and the minimum (0.14%) was observed from control treatment. Baron *et al*. [22] found that the addition of organic manure has a positive influence on the N uptake by wheat plants. Jeong *et al*. [23] found that 5 t ha^{-1} fermented chicken manure increased nitrogen concentration in rice plant.

Phosphorus Content: Different doses of vermicompost and NPKS fertilizer showed significant variation on phosphorus content in rice straw (Table 2). The maximum phosphorus content in straw (0.19%)was observed from V_3F_3 which was statistically similar with V_3F_2, V_2F_3, V_2F_2, V_1F_3, V_0F_3, V_3F_1, V_1F_2, V_2F_1, V_3F_0, V_2F_0, V_1F_1, V_0F_2 and V_1F_0 whereas, the minimum (0.10%) was observed from V_0F_0 (control) treatment which was statistically similar with V_0F_1, V_1F_0, V_0F_2, V_1F_1, V_2F_0, V_3F_0, V_2F_1. A significant increase in P content in rice straw is due to the application of organic manure and fertilizers have been reported by investigators [24, 25].

Potassium Content: Results in Table 2 revealed that the combined effect of different doses of vermicompost and NPKS fertilizer had significant effect on potassium content in rice straw. The maximum potassium content in straw (1.88%) was found from V_3F_3 which was statistically similar with V_3F_2 and V_1F_3 whereas, the minimum (1.26%) was observed from control treatment.

Sulphur Content: Concerning the combined effect of different doses of vermicompost and NPKS fertilizer on sulphur content in rice straw, data in Table 2 showed that the maximum sulphur content in straw (0.14%) was obtained from V_3F_3 which was statistically similar with V_3F_2, V_2F_3, V_2F_2, V_1F_3, V_0F_3, V_3F_1, V_1F_2, V_2F_1, V_3F_0, V_2F_0, V_1F_1, V_0F_2 and V_1F_0. The minimum sulphur content in straw (0.05%) was observed from V_0F_0 (control) treatment which was statistically similar with V_0F_1, V_1F_0, V_0F_2, V_1F_1, V_2F_0, V_3F_0, V_2F_1.

Nutrient status in Post Harvest Soil

Organic Matter (%): Combined effect of different doses of vermicompost and NPKS fertilizer showed significant effect on organic matter content in postharvest soil of research field (Table 3). The maximum organic matter content in postharvest soil (1.77%) was obtained from V_3F_1 which was statistically similar with V_3F_2 and the minimum (1.07%) was observed from control treatment. Vermicompost added organic matter in the soil as consequence the amount of organic matter in post harvest soil showed higher values compared to control plot. Xu *et al*. [26] reported that application of chemical fertilizer with organic manure increase soil organic matter.

Total N (%): Effect of different doses of vermicompost and NPKS fertilizer had non-significant effect on total nitrogen content in postharvest soil of research farm (Table 3). Numerically the maximum total nitrogen content in postharvest soil (0.087%) was found from V_3F_3 and the minimum (0.052%) was observed in control treatment. This was due to the fact that vermicompost added N in soil and reduced the loss of nitrogen in soil. Bangar *et al*. [27] found that compost enriched the N content of soil. Tolanur and Badanur [28] reported that soil available nutrients like N, P and K increased significantly with the application of various organic sources of nutrients in combination with chemical fertilizer.

Available P (mg kg^{-1}): Significant differences were observed in available phosphorus content in postharvest soil due to combined effect of different doses of

Table 3: Effect of vermicompost and NPKS fertilizer on organic matter and N, P, K, S content in post harvest soil

Vermicompost × NPKS fertilizer	Organic matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (mg kg^{-1})	Available S (mg kg^{-1})
V_0F_0	1.07 j	0.052	12.85 i	11.60 i	10.39 l
V_0F_1	1.20 i	0.059	13.09 hi	12.65 h	10.60 kl
V_0F_2	1.32 gh	0.063	13.85 g	13.60 g	10.80 k
V_0F_3	1.38 ef	0.069	14.53 ef	14.55 f	11.50 j
V_1F_0	1.27 h	0.060	12.52 i	12.35 h	11.63 ij
V_1F_1	1.30 gh	0.064	13.56 gh	13.68 g	12.28 e-h
V_1F_2	1.39 ef	0.069	13.95 fg	15.85 e	12.05 gh
V_1F_3	1.52 cd	0.078	15.17 de	16.72 d	12.67 de
V_2F_0	1.35 fg	0.065	14.65 e	13.48 g	11.98 hi
V_2F_1	1.43 e	0.070	15.12 de	15.40 e	12.23 f-h
V_2F_2	1.50 cd	0.076	15.77 cd	16.96 d	12.47 d-f
V_2F_3	1.55 bc	0.080	16.35 bc	19.34 b	13.13 bc
V_3F_0	1.49 d	0.071	14.95 e	15.64 e	12.43 d-g
V_3F_1	1.77 a	0.077	15.94 c	17.86 c	12.82 cd
V_3F_2	1.76 a	0.082	16.67 ab	18.47 c	13.45 b
V_3F_3	1.603 b	0.087	17.14 a	20.21 a	14.08 a
$LSD_{(0.05)}$	0.053	ns	0.657	0.702	0.409
CV (%)	1.67	10.73	2.67	2.71	2.02

Means with different letters in the same row indicate significant differences according to the LSD test ($p \leq 0.05$). ns = non-significant, V_0=control, V_1=1 t ha^{-1}, V_2=2 t ha^{-1}, V_3=4 t ha^{-1}; F_0 = control, F_1= (50-8-33-6 kg ha^{-1} N, P, K, S, respectively), F_2 = (100-16-66-12 kg ha^{-1} N, P, K, S, respectively), F_3 = (150-24-99-18 kg ha^{-1} N, P, K, S, respectively).

vermicompost and NPKS fertilizer (Table 3). The maximum available phosphorus content in postharvest soil (17.14 mg kg^{-1}) was obtained from V_3F_3 which was statistically similar with V_3F_2 and the minimum (12.52 mg kg^{-1}) was observed from V_1F_0 which was statistically similar with V_0F_0 and V_0F_1.

Exchangeable K (mg kg^{-1}): Combined effect of different doses of vermicompost and NPKS fertilizer had significant effect on exchangeable potassium in postharvest soil of research farm (Table 3). The maximum exchangeable potassium in postharvest soil (20.21 mg kg^{-1}) was observed from V_3F_3 and the minimum (11.60 mg kg^{-1}) was observed from V_0F_0. Increase in exchangeable K due to the application of organic manure might be attributed to the release of K to the available pool of the soil besides the reduction of K fixation. These results are similar with the findings of some earlier workers [29, 30].

Available S (mg kg^{-1}): Data in Table 3 showed that available sulphur content in postharvest soil of research field influenced by combined effect of different doses of vermicompost and NPKS fertilizer. The maximum available sulphur content in postharvest soil (14.08 mg kg^{-1}) was obtained from V_3F_3 and the minimum (10.39 mg kg^{-1}) was observed from V_0F_0 which was statistically similar with V_0F_1.

CONCLUSIONS

The combined application of vermicompost and chemical fertilizer significantly influenced the N, P, K and S contents in grain and straw. The post-harvest soil properties such as organic matter, total nitrogen, available phosphorous, exchangeable potassium and available sulphur contents were increased due to the combined application of vermicompost and NPKS fertilizer. For sustainable crop production and net improvement of land productivity, a recommendation was proposed that the crop residues should back to the soils instead of burning or wasting otherwise.

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