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CHANGES OF PHYSICAL AND CHEMICAL PROPERTIES OF POST HARVEST SOIL OF T. AMAN RICE AS INFLUENCED BY ORGANIC AND INORGANIC PHOSPHORUS

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ABSTRACT

Due to low organic matter content the agricultural soils of Bangladesh has poor physical and chemical condition. Moreover, the continuous use of phosphorus (P) fertilizers build-up of excessive P in many cultivated soils has created an interest in the combined use of organic and inorganic P fertilizer. Hence, a field experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University Farm, Gazipur, Bangladesh during the Aman season of July 2008 to January 2009 to investigate the effects of combined application of inorganic phosphorus (P_i) and organic phosphorus (P_o) on the changes of physical and chemical properties of soil after T. Aman cultivation. The eight treatments were T_0, Control/ no fertilizers; T_1, recommended dose of fertilizers; T_2, 50% P through TSP and 50% P through cowdung; T_3, 75% P through TSP and 25% P through cowdung; T_4, 50% P through TSP and 50% P through poultry manure; T_5, 75% P through TSP and 25% P through poultry manure; T_6, 50% P through TSP and 50% P through household wastes; T_7, 75% P through TSP and 25% P through household wastes. The experiment was laid out in randomized complete block design (RCBD) and replicated thrice. The physical and chemical properties of the soils were influenced directly by the above mentioned treatments. The physical properties of soil such as particle density and bulk density at different soil depth and plough pan decreased in response to addition of organic matters whereas no significant changes were found in response to inorganic P. The rate of improvement of chemical properties such as organic carbon (OC), cation exchange capacity (CEC), total nitrogen, available Phosphorus (P), exchangeable potassium (K), available sulphur(S), exchangeable calcium (Ca), exchangeable magnesium (Mg) and exchangeable sodium (Na) was higher with inorganic plus organic amendment than to inorganic alone. In addition, soil pH decreased in all treatments. Based on the above results it is suggested that the combined use of inorganic and organic P significantly improve physical and chemical properties of post harvest T. Aman soil.

Keywords: phosphorus, organic amendment, inorganic fertilizers, physical and chemical properties

INTRODUCTION

The fertility along with the productivity of soil is decreasing gradually due to intensive use of agricultural land and anthropogenic activities. It is now becoming a very alarming issue for the scientists as well as policy makers of the world in order to meet the demand of excess food for increased population. In addition, Bangladesh is an over populated country and losing arable land due to increasing rate of population thus create a pressure to meet the demand of total crop food requirement as developing countries in the world. The crop growth and development is modulated with different nutrients, including nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) those are easily absorbed by plants as cations and anions from the soil. Previous many authors showed that P functions in cell division, flowering, fruiting, seed formation and maturation of crops and is an important constituent of nucleic acid, phospholipids, Adenosine Di-phosphate (ADP) and Adenosine Tri-phosphate (ATP) (Sanker *et al.,* 1984; Holford, 1989) and suggesting that P deficiency is a common crop growth and yield-limiting factor.Mineral fertilization provides readily available nutrients for plant growth which may not to improve

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soil physical condition. It was also reported that the application of imbalanced and/or excessive nutrients led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere (Aulakh and Adhya, 2005) and groundwater quality (Aulakh *et al.*, 2009) causing health hazards and climate change. The continuous use of inorganic phosphorus (P) fertilizers has resulted in the build-up of excessive P in many cultivated soils (Correll, 1998). Separately, the organic matter content is a significant component and a key indicator for improving physical soil properties namely, bulk density, porosity, water infiltration and water holding capacity etc. Numerous experiments have indicated that soil application of organic manure will improve its physical properties (Oades, 1984; Mbagwu, 1989; Tisdale and Oades, 1992; Andraski *et al.*, 2003; Soda *et al.*, 2006; Adeli *et al.*, 2007), chemical characteristics (Warren and Fonteno, 1993; Kingery *et al.*, 1994; Maftoun *et al.*, 2004; Soda *et al.*, 2006; Adeli *et al.*, 2007) and fertility status (Pratt *et al.*, 1976; Cabral *et al.*, 1998; Lithourgidis *et al.*, 2007). Chavan *et al.* (2007) reported that the physicochemical properties of the soil improved significantly by the addition of organic manures and that there was very little change due to inorganic fertilizers. These results indicated that integration of inorganic and organic P believe to improve both soil physical and chemical properties rather than inorganic alone. Thus, our previous experimental results suggest that combined application of P fertilizer and different sources of organic matter improve rice growth, grain yield, energy component and P efficiency parameters. However, to our knowledge little is known regarding the changes of soil physical and chemical properties after T. Aman cultivation with the combined use of inorganic and organic P.

MATERIALS AND METHODS

A field experiment was conducted during the Aman season of July 2008 to January 2009 on rice cv. BRRI Dhan 33 at Bangabandhu Sheikh Mujibur Rahman Agricultural University Research Farm, Gazipur. To study the influence of phosphorus (P) applied through triple super phosphate (TSP) and different organic manures, eight treatments consisting of TSP, cowdung, poultry manure and household wastes including one absolute control were applied. The eight treatments were T_0, Control/ no fertilizers; T_1, recommended dose of fertilizers; T_2, 50 % P through TSP and 50 % P through cowdung; T_3, 75 % P through TSP and 25 % P through cowdung; T_4, 50 % P through TSP and 50 % P through poultry manure; T_5, 75 % P through TSP and 25 % P through poultry manure; T_6, 50 % P through TSP and 50 % P through household wastes; T_7, 75 % P through TSP and 25 % P through household wastes. The experiment was laid out in randomized complete block design (RCBD) with three replicates. The morphological characteristics of the soil are shown in Table: 1 and the physical and chemical characteristics of the soil are shown in Table: 2. All the treatments received recommended dose of P either from TSP or both from TSP and organic manures. Nutrient contents of cowdung (CD), poultry manure (PM), and household wastes (HW) were adjusted with urea, TSP, MP and gypsum, at the time of calculating the fertilizer.

Table 1. Morphological characteristics of the experimental field

Morphological features		Characteristics
Locality	:	Bangabandhu Sheikh Mujibur Rahaman Agricultural University Farm, Gazipur.
Topography	:	Fairly levelled
Flood level	:	Above flood level
Drainage	:	Moderate
Firmness (Consistency)	:	Friable moist
Cropping pattern	:	Rice-Rice

Table 2. Physical and chemical properties of the initial soils sample

Physical properties	Value
Bulk density (g/cc)	1.37
Particle density (g/cc)	2.68
Chemical properties	**Value**
Soil pH	5.95
Organic Carbon (%)	0.93
Total N (%)	0.079
Available P (ppm)	5.8
Exchangeable K (meq/100 g soil)	0.14
Available S (ppm)	7.12
Exchangeable Ca (meq/100 g soil)	6.55
Exchangeable Mg (meq/100 g soil)	1.88
Exchangeable Na (meq/100 g soil)	0.32
Cation exchange capacity (CEC meq/100 g soil)	10.65

Soil collection and analysis

The initial soil sample was collected from the experimental field before manuring and fertilization. Ten samples of 0-15 cm depth were collected, mixed, air-dried, ground and sieved through a 2 mm (10 mesh) sieve. The composite sample was stored in clean plastic bag for physical and chemical analyses. Post-harvest soil samples of 0-15 cm depth were also collected from each plot. The samples were air-dried, ground, sieved through a 2 mm sieve and kept for analyses. At the same time soil sample from 0-5, 5-10, 10-15 and 15-20 cm depth were separately collected for determination of soil bulk and particle densities. The initial and post harvest soils was analyzed for particle density, bulk density, plough pan, pH, organic carbon, total nitrogen, available P, exchangeable K, available S, available Zn, exchangeable Ca, Mg, Na and cation exchange capacity.

Particle density: Particle density of soil (0-5, 5-10, 10-15, 15-20 cm depth) was determined by volumetric flask method (Black, 1965) following the formula:

$$\text{Particle density (Ps)} = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil (solid)}}\ \text{g/cc}$$

Bulk density: Bulk density of soil (0-5, 5-10, 10-15, 15-20 cm depth) was determined by paraffin clod method following the formula:

$$\text{Bulk density (Pb)} = \frac{\text{Weight of oven dry soil}}{\text{Total volume of soil}}\ \text{g/cc}$$

Plough pan: Plough pan was measured with the help of plane augur.

Soil pH: Soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5 as described by Jackson (1962).

Organic carbon: Organic carbon was determined following the wet oxidation method as described by Page *et al.* (1982).

Cation exchange capacity (CEC): Cation exchange capacity (CEC) was determined by saturating the soil samples with sodium acetate. Sodium in the solution was then determined by flame-photometer.

Total nitrogen: Total nitrogen of soil was estimated following the micro-kjeldahl method. The soil was digested with H_2O_2 and conc. H_2SO_4 in presence of the catalyst mixture (K_2SO_4:$CuSO_4$ 5 H_2O: Se in the ratio 10:1:0.1) and nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of distillate trapped in H_2B0_3 with 0.1 N H_2SO_4 (Page, *et al.* 1982).

Available phosphorus: Available phosphorus was extracted from the soil with 0.5 M $NaHC0_3$ at pH 8.5. The phosphorus in the extract was then determined by developing the blue colour by $SnCl_2$

reduction of phosho-molybadate complex and measuring the colour calorimetrically at 660 nm (Olsen *et al.* 1954).

Exchangeable potassium Exchangeable calcium Exchangeable magnesium, Exchangeable sodium of soil was determined from 1 N ammonium acetate (pH 7.0) extract of the soil by using flame-photometer.

Available sulphur: Available sulphur in soil was determined by extracting the soil samples with $CaCl_2$ (0.15%) solution (Page *et al.*, 1982). The S content in the extract was determined by spectrophotometer at 420 nm wave length.

All data were subjected to analysis of variance and mean comparisons were made by Duncan's Multiple Range Test (DMRT)

RESULTS AND DISCUSSION

Properties of the post harvest soils

Physical and chemical properties of the post harvest soil of T. Aman rice as influenced by P through TSP, cowdung, poultry manure and household wastes are presented and discussed. Investigated physical and chemical properties of soil in this experiment were: bulk density of soil, particle density of soil, plough pan, soil pH, soil organic matter content, cation exchange capacity, total nitrogen, available phosphorus, exchangeable potassium, available sulphur, exchangeable calcium, exchangeable magnesium , exchangeable sodium contents in soil.

Soil bulk density

Soil bulk density increased progressively with the increase of soil depth. Application of organic manures and P fertilizers significantly reduced soil bulk density (Table 3).

Table 3. Effects of phosphorus applied through triple super phosphate (TSP), cowdung, poultry manure and household wastes on bulk density in post harvest soil of T. Aman rice

Treatment	Bulk density (g/cc) at different soil depth			
	0-5 cm	5-10 cm	10-15 cm	15-20 cm
T_0 = Control	1.177a	1.307a	1.417a	1.577a
T_1 = Recommended dose	1.177a	1.293b	1.407b	1.567b
T_2 = TSP_{50}+CD_{50}	1.030f	1.097g	1.187h	1.397g
T_3 = TSP_{75}+CD_{25}	1.110b	1.190c	1.277e	1.527c
T_4 = TSP_{50}+ PM_{50}	1.003g	1.130e	1.287d	1.347h
T_5 = TSP_{75}+ PM_{25}	1.103c	1.190c	1.290c	1.487e
T_6 = TSP_{50}+ HW_{50}	1.050e	1.117f	1.267f	1.427f
T_7 = TSP_{75}+ HW_{25}	1.083d	1.167d	1.257g	1.507d
CV (%)	4.62	5.62	4.63	6.35

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT
Figures shown as subscript represent percent phosphorus either from triple super phosphate (TSP), cowdung (CD), poultry manure (PM) or household wastes (HW)

The effect of organic matter on the reduction of soil bulk density was prominent up to 20 cm soil depth. The highest bulk densities of 1.177, 1.307, 1.417 and 1.577 g/cc at 0-5, 5-10, 10-15 and 15-20 cm soil depth, respectively were recorded in treatment control (T_0) where no organic matter or chemical fertilizer was applied. The lowest bulk densities of 1.03, 1.097 and 1.187g/cc at 0-5, 5-10 and 10-15 cm soil depth, were recorded in treatment T_2 receiving 50% P through TSP and 50% P through cowdung and 1.347 g/cc at 15-20 cm soil depth was recorded in treatment T_4 receiving 50% P through TSP and 50% P through poultry manure. At 0-5 cm soil depth the highest bulk density (1.177 g/cc) was recorded in control (T_0) which was statistically identical to T_1 treatment but superior to the rest of the treatments. Application of organic manures for appreciably longer period lowered bulk density of soil and this change might have the manifold beneficial effects on agricultural aspects through root proliferation and water transmission. In a study for 10 years, Bellukki *et al.* (1998) found similar trend of bulk density having the values of 1.46 g/cc in the control, and 1.36 and 1.31g/cc in the treatments where cowdung and rice straw were applied, respectively. This result resembles with the finding of Bhattacharyya *et al.* (2004) who stated that bulk density was minimum in NPK + FYM treated soil at all depths.

Soil particle density

Effects of cowdung, poultry manure and household wastes on particle density were significant. Effect of application of different levels of cowdung, poultry manure and household wastes on soil particle density at different soil depths of 0-5, 5-10, 10-15, and 15-20 cm, are shown in Table 4. Soil particle density of 0-5 cm depth was significantly influenced by the addition of triple super phosphate along with cowdung, poultry manure and household wastes. The mean maximum particle density of 2.37 g/cc was recorded in treatment control where no organic matter or chemical fertilizer was applied. The lowest mean particle density of 2.017g/cc was observed in the soils of the treatment receiving 50% P from triple super phosphate and 50% P from poultry manure. A significant difference in particle densities of 5-10 cm depth of soil was observed due to addition of P through TSP along with cowdung, poultry manure and household wastes. The mean highest particle density of 2.630 g/cc was found in the treatment where no fertilizer was applied. The lowest mean particle density of 2.210 g/cc was recorded in the soils of the treatment T_2 containing 50% P through TSP along with 50% cowdung in rice.

Particle density of 10-15 cm depth of soil was significantly influenced by the application of P through TSP along with cowdung, poultry manure and household wastes (Table 4). The mean maximum particle density of 2.70 g/cc was recorded in control and the minimum particle density of 2.26g/cc was noted in T_2 treatment but in case of 15-20 cm soil depth the highest value of particle density was observed in control (T_0) and the lowest value was recorded in the treatment T_4 receiving 50% P through TSP and 50% P through poultry manure. Results also showed that there was a significant difference among the particle densities of all the layers. The maximum particle density was recorded in the subsurface soil due to the absence of organic matter. Control treatment receiving no organic or inorganic fertilizer showed the highest particle density and the second highest particle density was noted in the treatment receiving recommended fertilizer. Treatment receiving cowdung, poultry manure and household wastes created lower particle density of post harvest soil of T. Aman rice compared to recommended (T_1) and control (T_0) treatments. Mathew and Nair (1997) recorded comparatively maximum volume expansion but smaller values for bulk density and particle density with the application of cattle manure.

Table 4. Effects of phosphorus applied through triple super phosphate (TSP), cowdung, poultry manure and household wastes on particle density and plough pan in post harvest soil of T. Aman rice

Treatment	Particle density (g/cc) at different soil depth				Plough pan (cm)
	0-5 cm	5-10 cm	10-15 cm	15-20 cm	
T_0 = Control	2.370a	2.630a	2.700a	2.833a	33.67a
T_1 = Recommended dose	2.363a	2.603b	2.680b	2.813b	31.00b
$T_2 = TSP_{50}+CD_{50}$	2.070e	2.210g	2.263h	2.513g	27.33ef
$T_3 = TSP_{75}+CD_{25}$	2.230b	2.397c	2.433e	2.743c	29.33bcd
$T_4 = TSP_{50}+ PM_{50}$	2.017f	2.277e	2.453d	2.423h	27.00f
$T_5 = TSP_{75}+ PM_{25}$	2.217b	2.397c	2.460c	2.673e	29.00cde
$T_6 = TSP_{50}+ HW_{50}$	2.110d	2.250f	2.413f	2.563f	28.00def
$T_7 = TSP_{75}+ HW_{25}$	2.177c	2.350d	2.393g	2.707d	30.33bc
CV (%)	5.41	4.28	5.16	6.00	4.49

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT
Figures shown as subscript represent percent phosphorus either from triple super phosphate (TSP), cowdung (CD), poultry manure (PM) or household wastes (HW)

Soil plough pan

Results in Table 4 show that in all the treatments receiving with organic residues and without organic residues, plough pan of soil was decreased from its initial value of 35 cm. This decrease was significantly lower in organic matter treatments compared to no organic matter treatments. The lowest plough pan of 26 cm was observed in T_4 treatment receiving 50% P through TSP and 50% P through poultry manure. Similar decreasing trend of plough pan was observed by the treatments T_2 receiving 50% P from cowdung along with 50% P from TSP and T_6 receiving 50% P from household wastes along with 50% P from TSP. The highest plough pan of 33.67 cm was recorded in control (T_0) treatment and the recommended chemical fertilizer (T_1) treatment noted in second position. Organic manures, viz. cowdung, poultry manure and household wastes used to substitute either 50% or 25% of recommended NPKS dose in T. Aman crop were effective in decreasing the plough pan of post harvest soil. The quantity of biomass added to the soil through different organic sources and the quality of end product of decomposition of the organic matter capable of imparting binding effect on soil particles might have been responsible to reduce soil plough pan which in turn might have induced favorable effect on physical properties of soil.

Soil pH

Soil pH was significantly influenced by the application of P through TSP along with cowdung, poultry manure and household wastes (Table 5). The highest pH of 5.93 was observed in T_0 treatment receiving neither organic matter nor chemical fertilizer and the lowest value of 5.45 was observed in T_2 treatment receiving 50% P from triple super phosphate and 50% P from cowdung. Data indicated that use of inorganic fertilizer and organic manures decreased soil pH from its initial value (5.95) by 0.02, 0.11, 0.50, 0.48, 0.40, 0.47, 0.44 and 0.49 units in T_0, T_1, T_2, T_3, T_4, T_5, T_6 and T_7 treatments, respectively. The decrease in pH of soil might be due to the production of different organic acids in organic matter treated soils. At pH below 7.0 R-OH might have dissociated as R^+ and OH^-, the H^- decreased soil pH eventually. The pH of most soils tends to change towards neutrality after submergence and an equilibrium pH in the range of 6.5 to 7.5 is usually attained (Ponnamperuma, 1978).

Table 5. Effects of phosphorus applied through triple super phosphate (TSP), cowdung, poultry manure and household wastes on pH, organic carbon and CEC in post harvest soil of T. Aman rice

Treatment	pH	%OC content	CEC (mq/100 g soil)
T_0 = Control	5.93a	0.95h	10.91f
T_1 = Recommended dose	5.84a	0.99g	12.09e
T_2 = TSP_{50}+CD_{50}	5.45b	1.29a	12.76b
T_3 = TSP_{75}+CD_{25}	5.47b	1.20d	12.36d
T_4 = TSP_{50}+ PM_{50}	5.55b	1.23c	12.97a
T_5 = TSP_{75}+ PM_{25}	5.48b	1.16f	12.61c
T_6 = TSP_{50}+ HW_{50}	5.51b	1.27b	12.71b
T_7 = TSP_{75}+ HW_{25}	5.46b	1.18e	12.40c
CV (%)	6.15	5.18	10.25

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT
Figures shown as subscript represent percent phosphorus either from triple super phosphate (TSP), cowdung (CD), poultry manure (PM) or household wastes (HW)

Organic carbon content

Results presented in Table 5 showed that organic carbon content was significantly influenced with the application of P applied through TSP along with cowdung, poultry manure and household wastes. Treatments receiving organic matter increased organic carbon content of the soil significantly than that of no organic matter treated soil. The highest organic carbon content of 1.29% was observed in T_2 treatment which was 0.36% higher than its initial value (0.93%) and the lowest 0.95% organic carbon content was observed in control (T_0) treatment which was almost similar to its initial value. Organic carbon content of soil was also increased from 0.16 to 0.3% in the treatments that received organic matter but no inorganic fertilizers. Sing *et al.* (2006) reported that the value of organic carbon content of the soil increased from initial status with the combined use of organic and inorganic fertilizers.

Cation exchange capacity (CEC)

Cation exchange capacity of soil was influenced by the application of P applied through TSP along with cowdung, poultry manure and household wastes (Table 5). The highest CEC (12.97 meq/100 g soil) was observed in T_4 treatment and the lowest (10.91 meq/100 g soil) in control treatment. This increase in CEC of soil due to organic matter application may be attributed to the effect of exchangeable cations which are observed in data presented in Table 5. The increase of exchangeable Ca, Mg, K and Na ultimately increased CEC of soil. Swarup (1979) showed a significant increase in CEC of soil with the application of farmyard manure.

Total nitrogen content

It is seen that in all the treatments receiving organic matter and chemical fertilizers, N content of post harvest soil was increased from its initial value of 0.069% (Table 6). This increase was significantly higher in organic matter containing treatments compared to no organic matter treatments. Results clearly show that addition of different levels of P applied through TSP along with cowdung, poultry manure and household wastes increased total N content of soil appreciably and it was due to higher N (data not shown) content of organic matter added to the soil. Maximum nitrogen content in soil (0.108%) was found in T_4 treatment receiving 50% P applied through TSP and 50% P through poultry manure. Inorganic phosphorus along with cowdung, poultry manure and household wastes increased nitrogen content in soil of all the treatments except control. Control treatment contained the minimum nitrogen in soil (0.069%). Nitrogen content data of initial and post harvest soil of T. Aman rice revealed that, after harvesting of T. Aman rice there was a significant changes in total soil N. Total soil N decreased in control treatment and increased little in T_1 (recommended dose) treatment and all the organic matter sources increased the levels of total N in post harvest soil of T.aman rice. Incorporation of an easily decomposable biomass with relatively high N content can lead to an increased mineralization of the organic soil fraction in rice soils (Broadbent, 1979). Several workers showed that the addition of organic materials could improve total N content of soil (IRRI, 1979; Singh *et al.*, 1985; Nahar *et al.*, 1996; Katyal *et al.*, 2002).

Table 6. Effects of phosphorus applied through triple super phosphate (TSP), cowdung, poultry manure and household wastes on nitrogen, phosphorus, potassium and sulphur contents in post harvest soil of T. Aman rice

Treatment	Total N (%)	Available P (ppm)	Exchangeable K (me/100g soil)	Available S(ppm)
T_0 = Control	0.069h	5.6e	0.131h	6.247d
T_1 = Recommended dose	0.088g	8.5d	0.143g	7.638c
T_2 = TSP_{50}+CD_{50}	0.097c	9.65a	0.221a	10.98b
T_3 = TSP_{75}+CD_{25}	0.092f	8.79cd	0.201d	8.309c
T_4 = TSP_{50}+ PM_{50}	0.108a	9.97a	0.212c	11.28b
T_5 = TSP_{75}+ PM_{25}	0.096d	8.85cd	0.190f	8.085c
T_6 = TSP_{50}+ HW_{50}	0.105b	9.53ab	0.219b	12.76a
T_7 = TSP_{75}+ HW_{25}	0.095e	9.12bc	0.197e	8.642c
CV (%)	4.00	4.32	5.73	6.66

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT
Figures shown as subscript represent percent phosphorus either from triple super phosphate (TSP), cowdung (CD), poultry manure (PM) or household wastes (HW)

Available phosphorus content

A good response in phosphorus content in post harvest soil of T. Aman rice was observed due the application of P applied through TSP in combination with cowdung, poultry manure and household wastes (Table 6). The highest phosphorus content in soil (9.97 ppm) was recorded in treatment T_4 receiving 50% P applied through TSP and 50% P from poultry manure which was statistically similar with T_2 and T_6 treatments but superior to the rest of the treatments. This might be due to the application of triple super phosphate in combination with poultry manure, cowdung and household wastes resulting comparatively better condition for exploiting more phosphorus fromin soil of T. Aman rice. The lowest phosphorus content in soil (5.6 ppm) was found in T_0 (control) treatment. Mathew and Nair (1997) reported that cattle manure applied alone or in combination with chemical fertilizer of NPK increased the organic carbon content, total N, available P and K in rice soils.

Exchangeable potassium content

The effects of P applied through TSP in combination with cowdung, poultry manure and household wastes on exchangeable potassium content in the post-harvest soil of T. Aman rice are presented in Table 6. Treatments that received organic manure showed significantly higher exchangeable K status in soil. This may be due to release of non-exchangeable K on account of addition of organic manures for utilization by rice. It clearly indicates that inclusion of organic manures helps maintaining exchangeable K in soil. Exchangeable potassium content in the post-harvest soil of T. Aman rice ranged from 0.131 to 0.221 meq/100 g soil. The highest value of exchangeable potassium content in soil was observed in T_2 (0.221 meq/100 g soil) which was 57% higher than initial value (0.14 meq/100 g soil) and the lowest value (0.131 meq/100 g soil) was noted in T_0 (control). Such increase in soil exchangeable K content due to the application organic matter was also reported by Bhoite (2005).

Available sulphur content

Available S content in post harvest soils of T. Aman rice was positively influenced by the application of P applied through TSP, cowdung, poultry manure and household wastes (Table 6). An appreciable amount of available S was increased due to the application of organic manures with chemical fertilizers compared to its initial value (7.12 ppm). All the organic manure treatments significantly increased available S content than no organic manure treatments. Sulphur content of the post harvest soils ranged from 6.247 to 12.76 ppm. The highest available sulphur content (12.76 ppm) in soil was noted in treatment T_6 receiving 50% P from TSP along with 50% P from household wastes which was statistically superior to the rest of the treatments. The lowest sulphur content (6.247 ppm) was recorded in control (T_0) treatment. The effect of application of organic manures increased available S by 0.45 to 5.16 ppm compared to no organic manure treatment. These results indicated that application of P applied through TSP along with cowdung, poultry manure and household wastes exerted positive effect on the sulphur content of the post harvest soils of rice. Sanchez (1976) reported that organic matter supplied most of the sulphur to plants. These results are also in agreement with the findings of Rashid (2009).

Exchangeable calcium content

Data in Table 7 illustrated that different kinds of organic matter improved exchangeable Ca content markedly from its initial value of 6.55 meq/100 g soil to a maximum of 1.11 meq/100 gm soil in the treatment T_6 where 50% P from TSP was applied with 50% P from household wastes. All the organic fertilizer significantly increased exchangeable Ca than no organic fertilizer treatment. The highest value of exchangeable Ca (7.66 meq/100 g soil) was observed in T_6 treatment which was statistically similar to T_4 treatment. The lowest Ca (6.26 meq/100g soil) was recorded in control treatment. Swarup (1991) showed a marked improvement of Ca in the soil due to the long term application of green manure in the soil.

Exchangeable magnesium content

Exchangeable Mg content in post harvest soils was influenced significantly due to the application of P applied through TSP along with cowdung, poultry manure and household wastes (Table 7). Exchangeable magnesium content of the post harvest soils ranged from 1.34 to 2.22 ppm against the exchangeable

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