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Effect of Different Tillage Systems on Some Physical and Chemical Properties of a Silt Loam Soil in Rice Field

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Abstract: A field experiment was carried out to study the effect of different tillage practices on some soil physical and chemical properties. The soil was calcareous grey belonging to Sonatala series of Old Brahmaputra flood plain soil. The treatments comprised of T_0, $T_1(CP_2)$, $T_2(CP_3)$, $T_3(CP_4)$, $T_4(PT_2)$, $T_5(PT_3)$ and $T_6(PT_4)$. The bulk density (1.20 g cm^{-3}) was h igher in T_0(no tillage) treatment than that of any other treatment. The lowest bulk density (0.86 g cm^{-3}) was found at T_6 (PT_4) treatment. Bulk density significantly varied within the depths. The highest bulk density was recorded in 20-30 cm soil depths and the lowest was 0-10 cm soil depth. Air filled porosity and soil moisture content increased remarkably by $T_6(PT_4)$ treatment compared to control. The highest organic matter was 1.60% and the lowest was 0.78% under T_o(control) and $T_6(PT_4)$ treatment respectively. The NH_4-N, available S, exchangeable K significantly influenced due to tillage operation whereas NO_3-N, available P and exchangeable Ca did not respond significantly. Available N, P, S, exchangeable K and Ca decreased with the increasing of depth.

Key words: Tillage systems, physical and chemical properties, silt loam, rice

Introduction

Soil tillage is to date an inevitable part of land preparation for wetland transplanted rice. Tillage is considered to be the oldest and the most fundamental farm activity of mankind for crop production. Tillage has some advantages in terms of weed control, ease of transplanting and minimization of loss of water and nutrients from the soil through percolation and leaching. Wang and Guang (1999) indicated full tillage could preserved the soil moisture better than that of no tillage and interval tillage. Mazid *et al.* (1999) revealed that tillage intensity decreased organic carbon and increased soil pH. Tillage intensity influence soil properties and thus the mineral nutrition thereby increase the yield of wetland rice. However, it is time, energy and capital intensive. The magnitude of tillage effects on depth varies with the use of tillage implements. Power tillage is used for deep ploughing, sub soiling and rotating the soil. No tillage is not a profitable for crop production, though it resists the soil from erosion and reduces energy but weed, insect and disease become a common phenomenon for a plant.

The objective of this study was to determine the effect of tillage in changing some physical and chemical properties of rice field.

Materials and Methods

An experiment was conducted at the Bangladesh Agricultural University Farm, Mymensingh, during the boro season of 2001 to study the effect of tillage practices on soil physical and chemical properties in the rice field. The soil belongs to the Sonatola series under the AEZ of old Bramaputra flood plain. The soil was silt loam in texture having pH 5.61, organic matter 1.60%. The experiment was conducted using two factors such as tillage and depth in a randomized complete block design (RCBD) comprising of seven treatments. The unit plot size was 6 X 5 m^2. The treatments were randomly allocated to the unit plot of a block. The treatment were T_o(control), $T_1(CP_2)$ (country plough with two passes), $T_2(CP_3)$ (country plough with three passes), T_3 (CP_4) (country plough with four passes), $T_4(PT_2)$ (power tiller with two passes), $T_5(PT_3)$ (power tiller with three passes) and $T_6(PT_4)$ (power tiller with four passes). Urea triple super phosphate (TSP) and muriate of potash (MP) were applied 124.20, 62.4 and 72 Kg ha^{-1} respectively. The whole amount of TSP and MP were applied during land preparation. Urea was applied in three splits.

Soil samples were collected from each plot at the depth of 0-10, 10-20 and 20-30 cm. Bulk density was determined by the help of a core sampler made of metal cylinders of known volume (Black, 1965) before panicle initiation stage and after harvest, air filled porosity (AFP) was calculated using the following formula at before the panicle initiation stage and after harvest.

$$\text{Air filled porosity (AFP)} = \frac{\text{Volume of air (cm}^3)}{\text{Total volume of soil (cm}^3)}$$

Where, volume of air (cm^3) = Total volume of soil (cm^3) – volume of water (cm^3) – volume of solid (cm^3)

Soil moisture (SM) was determined by the gravimetric method before panicle initiation stage and after harvest. Soil pH was measured with the help of a glass electrode pH meter described by Jackson (1958). Organic carbon percentage was determined by wet oxidation method as described by Black (1965) and the organic matter content was calculated by multiplying the % organic carbon with van Bemmelen factor 1.73 (Piper, 1950). NH_4-N and NO_3-N were determined by distillation method using successively MgO and Deverda alloy respectively (Page *et al.*, 1982). Available P was determined calorimetrically by $SnCl_2$ reduced phosphomolybdate blue colour method (Olsen *et al.*, 1954). Available S was determined by $CaCl_2$ solution (0.15%) as described by (Page *et al.*, 1982). Exchangeable K and Ca were determined by flame photometer.

The analysis of variance for soil properties was done following the ANOVA technique and the mean values were tested by the least significant difference (LSD) method. Correlation and regression, coefficient of variance among soil properties were also determined.

Results and Discussion

Effect on some soil physical properties

Bulk density (before panicle initiation stage): The highest soil bulk density of 1.20 g cm^{-3} was found in control treatment. The lowest bulk density of 0.86 g cm^{-3} was observed in $T_6(PT_4)$ treatment (Table 1) which was statistically identical with that of $T_5(PT_3)$ treatment but significantly different from all other treatments. Sharma *et al.* (1988) stated that the bulk density of surface layer decreased with the tillage intensity. Matin and Uddin (1994) found that soil bulk density was higher to tilling soil by country plough than power tiller. The high density indicates the existence of a hardpan in the subsoil for which the soil was compact. The compaction of soil decreased the porosity

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Table 1: Effect of different tillage practices on soil physical properties of rice field during winter season of 2001

Tillage treatments	Bulk density g cm^{-3}		Soil moisture (%)		Air filled porosity (%)	
	Before panicle initiation	After harvest	Before panicle initiation	After harvest	Before panicle initiation	After harvest
T_0(control)	1.20	1.30	37.12	35.24	1.43	0.83
$T_1(CP_2)$	1.10	1.16	39.43	36.28	1.63	1.06
$T_2(CP_3)$	1.07	1.14	39.91	36.36	1.65	1.07
$T_3(CP_4)$	1.03	0.98	40.72	37.38	1.66	1.63
$T_4(CT_2)$	1.02	0.97	40.73	37.76	1.67	1.64
$T_5(CT_3)$	0.88	0.90	41.85	40.20	2.08	2.38
$T_6(CT_4)$	0.86	0.87	42.55	40.70	2.10	2.73
$LSD_{(0.05)}$	0.067	0.05	3.290	3.51	0.14	0.20
Soil depth (cm)						
0-10	0.88	0.92	49.19	47.41	2.66	2.48
10-20	1.02	1.04	37.94	34.86	1.45	1.66
20-30	1.18	1.20	33.85	30.84	1.12	0.72
$LSD_{(0.05)}$	0.044	0.03	2.880	3.07	0.09	0.13

Table 2: Effect of different tillage practices on some soil chemical properties during winter season of 2002

Tillage treatment	Soil pH	Soil organic matter (%)	NH_4-N (ppm)	NO_3-N) (ppm)	Available S (ppm)	Available S (ppm)	Exchangeable K(me/100 g Soil)	Exchangeable Ca (me/100g soil)
T_0(control)	5.61	1.60	14.80	10.13	8.97	13.25	0.24	3.58
$T_1(CP_2)$	6.01	1.22	17.43	9.91	8.76	12.67	0.18	3.60
$T_2(CP_3)$	6.02	1.21	18.08	10.49	8.86	9.99	0.18	3.55
$T_3(CP_4)$	6.67	1.12	19.33	10.50	8.03	10.42	0.15	3.59
$T_4(PT_2)$	6.67	1.04	19.35	10.66	9.03	8.37	0.14	3.53
$T_5(PT_3)$	7.63	0.79	21.49	10.46	8.95	9.06	0.12	3.32
$T_6(PT_4)$	7.64	0.78	21.87	10.39	8.87	8.15	0.11	3.32
$LSD_{(0.05)}$	0.422	0.124	1.536	-	-	0.969	0.003	-
Soil depth (cm)								
0-10	6.52	1.66	22.60	12.58	12.63	13.46	0.24	4.18
10-20	6.57	0.98	19.49	11.45	10.39	10.93	0.17	3.70
20-30	6.73	0.69	14.63	7.07	3.72	6.43	0.07	2.60
LSD (%)	0.27	0.08	1.00	0.42	0.35	0.969	0.0006	0.275

Table 3: Regression between soil physical and chemical properties

Dependent variable	Independent variable	Regression equation	r-value
Air-filled porosity	Bulk density	AFP = -2.0246BD + 3.1866	-0.976
Soil moisture	Air-filled porosity	SM = 6.41AFP + 29.138	0.902
Soil pH	Soil organic matter	pH = -2.6854SO + 9.5841	-0.951
NH_4-N	Soil organic matter	NH_4-N = -8.5451SO + 28.380	-0.991

(Table 1) and did not allow to percolate the water from surface to downward as well as the nutrients. As a result the roots of the crop could not expand in the deeper layer and could not uptake more nutrient for their growth and development. In terms of soil depth, the highest soil bulk density of 1.18 g cm^{-3} and the lowest bulk density of 0.88 g cm^{-3} were noted at the depth of 20-30 cm and 0-10 cm respectively (Table 1). The 20-30 cm depth of soil showed significantly higher bulk density which indicated compactness of soil possibly due to formation of a hardpan. Higher bulk density refers to the poor physical condition of the soil. Molla *et al*. (2000) found that up to 65 cm depth soil was clay loam as well as the bulk density was 1.50 g/cc. Bulk density gradually increased with increasing of depth. A significant negative relationship (r = -0.976) was found between bulk density and air filled porosity (Table 3). The negative relation indicates that high density or in other words compact soil restricted the aeration in the soil.

Bulk density (after harvest): The different tillage treatments influenced soil bulk density significantly (Table 1). The highest value of bulk density (1.30 g cm^{-3}) was found in no tillage (T_0) treatment. On the other hand, the lowest bulk density (0.87 g cm^{-3}) was found in $T_6(PT_4)$ treatment, which was statistically similar to $T_5(PT_3)$ treatment but significantly different from the other treatments. With respect to soil depth, the bulk density was statistically significant (Table 1). The maximum and minimum soil bulk density was found 20–30 and 0–10 cm depths of soil respectively. The maximum value was observed 1.20 g cm^{-3} and the minimum value was 0.90 g cm^{-3}. The highest bulk density 1.20 g cm^{-3} was significantly different from two other bulk density among the depths.

Soil moisture (before panicle initiation stage): Tillage practices influenced soil moisture content significantly (Table 1). The highest value of soil moisture was 42.55% and the lowest value was 37.12%. The highest and the lowest value of soil moisture was observed in $T_6(PT_4)$ and T_0 (no tillage) respectively. The highest moisture (%) of $T_6(PT_4)$ treatment was significantly different from T_0(no tillage) treatment but statistically similar to the rest of the treatments. A significant positive relationship (r = 0.902) was found between soil moisture and air-filled porosity (Table 3). In terms of soil depth statistically significant result was found under different tillage practices (Table 1). The highest and the lowest moisture (%) were 49.19 and 33.85% at the depths of 0-10 and 20-30cm respectively. The highest moisture (%) was significantly different from two other moisture content of the soil. Soil moisture decreased with the increasing of soil depth. The lower soil moisture content was also observed in the 15-30 cm depth due to existence of hard plough pan (Sarder, 1990).

Soil moisture (SM) (after harvest): The soil moisture content showed statistically significant results under different tillage treatments (Table 1). The highest (40.70%) and the lowest (35.24%) soil moisture was found in $T_6(PT_4)$ and T_0(no tillage) treatments respectively. The $T_6(PT_4)$ and $T_5(PT_3)$ treatment gave statistically identical result which was also statistically similar to $T_4(PT_2)$ and $T_3(CP_4)$ treatments but significantly different from the rest of the treatments. Regarding soil depth the soil moisture significantly differed within the soil depths. The highest (47.41%)

and the lowest (30.84%) moisture content were found at 0-10 and 20-30 cm soil depth respectively. The highest value was statistically different from the rest. From the data it was noticed that the soil moisture decreased with the increasing of depth. It was possibly because of the absence of low fragipan layer. The soil moisture was lower in soil after harvesting stage than it was before panicle initiation.

Air-filled porosity (AFP) (before panicle initiation): Different tillage practices significantly changed the soil air-filled porosity. The highest air filled porosity of 2.10% and the lowest air filled porosity of 1.43% were found at $T_6(PT_4)$ and T_0(no tillage) treatments respectively. The highest value of air filled porosity of $T_6(PT_4)$ treatment did not statistically differ from $T_5(PT_3)$ treatment. But both of them were significantly different from the rest of the treatments. The treatments $T_1(CP_2)$, $T_2(CP_3)$, $T_3(CP_4)$ and $T_4(PT_2)$ gave statistically similar results. Air-filled porosity of soil decreased and soil organic carbon increased in the minimum tillage instead of intensive tillage (Chan *et al.*, 1999). Matin and Uddin (1994) observed that power tiller operation resulted the highest air-filled porosity (1.34%), whereas country plough operation showed the lowest air-filled porosity (0.92%). In terms of soil depth, statistically significant result was found under different soil depth. The highest value of air filled porosity (2.66%) and the lowest value (1.12%) were found at 0-10 and 20-30 cm soil depths respectively. Air filled porosity decreased with the increasing of depth. The results of this study are accorded with Schjqnning (1990). High percentage of air or in other wards adequate aeration in soil can encourage the activity of microorganism to present in soil that may accelerate the growth and development of a crop providing nutrient elements available to roots.

Air filled porosity (after harvest): The air filled porosity showed the statistically significant results under different tillage treatments and varied from 0.83 to 2.73% (Table 1). Maximum value of air filled porosity (2.73%) and minimum value of air filled porosity (0.83%) were found at $T_6(PT_4)$ and T_0(no tillage) treatment respectively. The highest value of air filled porosity was significantly different from all other treatments. The experimental results are accorded with the observation of Rahman (1997). From the above discussion it is conspicuous that soil air filled porosity is significantly influenced by different tillage practices. With respect to the soil depth, the soil air filled porosity significantly changed under different depth. The highest value of air filled porosity was 2.48% and the lowest was 0.72% at the depths of 0-10 and 20-30 cm respectively. From data it was found that the air filled porosity decreased with the increasing of soil depth due to different tillage practices. Similar result was observed by Rahman (1997).

Effect of tillage on soil chemical properties

Soil pH: Impact of different tillage operations did not significantly change soil pH (Table 2). The pH ranged from 5.61 to 7.64. The highest and the lowest pH values were recorded under $T_6(PT_4)$ and T_0 (no tillage) treatment respectively. Mazid *et al.* (1999) revealed that tillage intensity decreased organic matter and increased soil pH. In terms of depth, the significant result was found under different tillage treatments (Table 2). The highest value of soil pH (6.73) and the lowest value of soil pH (6.52) were found at the depth of 20-30 and 0-10 cm depth respectively. Soil pH of 10-20 cm depth did not differ statistically from soil pH of 20-30 cm depth.

Organic matter (SO): Soil organic matter (SO) content was influenced significantly by different tillage practices (Table 2). The highest (1.60%) and the lowest (0.78%) soil organic matter was found in the T_0(no tillage) and $T_6(PT_4)$ treatments respectively. The $T_5(PT_3)$ and $T_6(PT_4)$ treatment did not differ statistically. Both of them were significantly different from all other treatments. The organic matter showed highly negative significant relationship ($r=-0.951$) with the soil pH (Table 3). The highest value of organic matter was obtained under no tillage condition. Demaria *et al.* (1999) showed that higher amount of organic matter at the depth of 0-0.5 m depth under no tillage practices than chisel plough and conventional tillage. In terms of different depth, the highest organic matter (1.66%) and the lowest organic matter (0.69%) were found at the depths of 0-10 and 20-30 cm respectively under different tillage treatments (Table 2). The highest value of organic matter was significantly different from two other values of soil depths. Less soil disruption resulted in greater accumulation of surface residue. Any minor mixing of residue with soil would allow residue to remain wetter and therefore, provide more ideal conditions for microbial decomposition that leads to surface residue loss.

Available N: Different tillage practices influenced NH_4-N significantly (Table 2). The highest (21.87 ppm) was found in $T_6(PT_4)$ and the lowest NH_4 (14.80 ppm) was found in T_0(no tillage) treatment. The $T_6(PT_4)$ gave statistically similar result to $T_5(PT_3)$ but significantly different from the rest of treatments. The organic matter showed highly negative significant relationship ($r=-0.991$) with NH_4 (Table 3). Mazid *et al.* (1999) observed that tillage intensity increased available N. In terms of depth, NH_4-N (22.6 ppm) and the lowest NH_4-N (14.63 ppm) were found at the depth of 0-10 and 20-30 cm respectively (Table 2). Slower mineralization in zero tillage may have been responsible for the lower NH_4-N nitrogen concentration in the soil under T_0 (no tillage) and higher NH_4-N concentration in the T_6 (PT_4) tillage may be due to decomposition of organic matter. NO_3-N content did not differ significantly due to tillage operation (Table 2). The highest NO_3-N (10.66 ppm) and the lowest NO_3-N (10.13 ppm) were found at $T_6(PT_4)$ and T_0(control) treatment respectively. The result was accorded with Borison and Dinistrata (1996). Regarding the depth NO_3-N content decreased with the progressing of depth. The highest NO_3-N (12.58 ppm) and the lowest NO_3-N (7.07 ppm) were found at the depth of 0-10 and 20-30 cm respectively. The present finding is supported by Alvarez *et al.* (1998).

Available P: Different tillage practices did not influence available P significantly (Table 2.) The highest available P (9.03 ppm) and the lowest (8.03 ppm) were found $T_4(PT_2)$ and $T_3(CP_4)$ respectively. The present result was supported by Hussain *et al.* (1999) and Basunia (2000). In terms of depth, the highest available P(12.63 ppm) and the lowest (3.72 ppm) were found at the depth of 0-10 and 20-30 cm depth respectively (Table 2). The highest available P at the depth of 0-10 cm was significantly different from the P content of 10-20 and 20-30 cm depth.

Exchangeable K: Tillage affects exchangeable K significantly (Table 2). The highest K (0.24 me/100 g soil) and the lowest K (0.11me/100 g soil) were found under T_0 (no tilled soil) and T_6 (PT_4) treatment respectively. The highest exchangeable K was significantly different from the rest of the exchangeable K of the treatments. These results are satisfied with Demaria *et al.* (1999) and Mazid *et al.* (1999). In terms of depth the highest exchangeable K (0.24 me/100g soil) and the lowest exchangeable K (0.07 me/100 g soil) were found at the depth of 0-10 and 20-30 cm depth. The highest amount of exchangeable K was significantly larger than that of exchangeable K at the depth of 10-20 and 20-30cm.

Available S and exchangeable Ca: Available S influenced significantly by different tillage practices. The largest amount of available S (13.25 ppm) and the lowest amount of available S (8.15 ppm) were found at T_0(no tillage) and $T_6(PT_4)$ tillage respectively. The $T_6(PT_4)$ treatment was statistically similar to $T_5(PT_3)$ treatment but significantly different from other treatments. The subsurface compaction decreased the loss of available Sulfur. On the other hand the sub soiling increased the

loss of S in comparison to conventional tillage system (Majumder *et al.*, 1999). The loss of available S might happen due to decrease of subsurface compaction with the increase of tillage intensity. In terms of depth, the highest amount of S was (13.46 ppm) and the lowest amount of S (6.43 ppm) were found at the depth of 0-10 and 20-30 cm respectively. The amount of available S at the depth of 0-10 cm significantly differed from the amount of available S at the depth of 10-20 and 20-30 cm depth.

Exchangeable Ca did not change significantly by tillage effect. In terms of depth, exchangeable Ca decreased with the enhancing of depth. The highest exchangeable Ca (4.18 me/100 g soil) and the lowest exchangeable Ca (2.6 me/100 g soil) were found at the depth of 0-10 and 20-30 cm respectively. The exchangeable Ca of 0-10 cm depth was significantly different from the amount of 10-20 and 20-30 cm depth.

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