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Changes in Soil Properties due to Long-term Nutrient Management

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Abstract

The changes in soil properties due to long-term manuring were studied at the Bangabandhu Sheikh Mujibur Rahman Agricultural University research farm, Gazipur, Bangladesh. Soil samples from long-term field experiment (after 16 years) were collected to determine the bulk density, particle density, porosity and soil pH. Application of organic manures (M) and nitrogen fertilizer (N) remarkably changed the bulk density, soil porosity and soil pH at different depths. Interactions of M × N, M × D, N × D and M × N × D had little effect on soil bulk density and porosity; however, these interactions were found to have significant (5%) positive effects on soil pH. The application of organic manures and nitrogen fertilizer decreased soil bulk density and the lowest bulk density was observed with compost treatment which received higher rates of nitrogen. The application of cowdung and compost increased soil pH but the application of nitrogen fertilizer decreased soil pH over the years. The particle density of soil was not affected significantly by the application of nitrogen fertilizer and any manure.

Keywords: Bulk density, particle density, porosity, pH

Introduction

Soil organic matter is of paramount importance with respect to availability of plant nutrients and improvement of physical, chemical and biological properties of soils [1]. The organic matter plays an important role in maintaining overall soil health by supplying nutrients and providing good physical condition to the plants. Organic matter, total nitrogen content, available water, infiltration rate are increased and soils become less compacted by the application of organic residues in terrace soils of Bangladesh [2]. The importanceoforganic matter in improving soil physical properties is already well known. Additions of organic manures into soil result in increased water holding capacity, porosity, infiltration capacity, hydraulic conductivity and water stable aggregation and decreased bulk density and surface crusting. Soil physical structure improvement caused by the manure application may bear esult of organic matter content increase, which had adilution effect on the soil, by bonding particles, increasing soil aggregation elasticity. Besides, most researchers reported that both long-term [3] and short-term [4]farm yard manure application had significant effects on soil physical properties. It was reported that

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soil bulk density and porosity were functions of soil organic matter, aggregate estability and size distribution, and soil particle density. A decrease in organic matter would cause an increase in bulk density and a decrease in porosity, thereby reducing soil infiltration, and water and air storage capacities.Soil bulk density is required to estimate, evaluate, and calculate many physical soil properties and processes and is essential to convert data from weight-based to volume- and area-related data.

Organic manure, such as farm yard manure, green manure, organic amendment and municipal solid waste, has been used as a source of plant nutrients and organic matter to improve fertility conditions of agricultural lands for a long time. Generally, the physical and chemical properties were improved when manures were incorporated into soils [5]. Several studies have shown the beneficial effects of animal manure on soil structural quality, by reducing bulk density, increasing porosity, water infiltration rate, saturated hydraulic conductivity and others [6]. Physical and chemical properties of soil can be improved by using compost, which may ultimately increase crop yields. So use of compost is the need of the time. Physical properties like bulk density, porosity, void ratio, water permeability and hydraulic conductivity were significantly improved when FYM (10 t ha^{-1}) was applied in combination with chemical amendments, resulting in enhanced rice and wheat yields in sodic soil [7].

In adequate quantities, soil organic matter reduces soil crusting and soil bulk density, and helps to maintain a stable soil pH. Application of manure pH from 4.8 to 5.2 and nitrogen application had tended to decrease soil pH [8]. The effect of green manure on chemical, physical and biological attributes of the soil and depending on the local conditions, green manure could promote increase in pH [9].

In Bangladesh most soils have less than 1.5%, some soils have less than 1.0% organic matter [10]. Because of the humid climate, organic matter decomposition in soils of Bangladesh is high. Moreover, farmers do not apply organic manure regularly. The organic matter content of our soils is declining with time due to poor attention to its improvement and maintenance [2]. It is now essential to increase organic matter content through periodic addition of organic manures along with application of inorganic fertilizers for maintaining soil productivity to achieve maximum and stabilized crop yield in the country. So long-term application of organic manures and plant residues perhaps is the best step to maintain soil organic matter in our climatic condition. Unfortunately, very little information on organic manures and nitrogen requirement for maintainingsoil physical and chemical parameters due to long-term nutrient management are available in Bangladesh. Keeping these facts in mind, the present investigation was aimed to assess the changes in the bulk density, particle density, porosity, soil pH and total N in soils.

Materials and Methods

A long-term experiment (LTE) was conducted at the experimental farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) at Salna, Gazipur since July 1988. The soil of the experimental field belongs to Salna series representing the Shallow Red-Brown Terrace in Bangladesh Soil. Classification System which falls under Inceptisols in Soil Taxonomy [11]. The test crops were rice (*Oryza sativa*) and wheat (*Triticum aestivum*). The high yielding rice variety "BR14" and wheat variety "Kanchan" were used as the test crops. Bangladesh Rice Research Institute (BRRI) and Wheat Research Center of BARI released these varieties. Seeds were collected from Bangladesh Agricultural Development Corporation farm of Kashimpur, Gazipur. The experiment: was laid out factorial randomized complete block design with two replications [12]. There were fifteen treatment combinations. Factor A (manuring): Mo = No application of organic manures, Cp = Compost at the rate of 25 t ha^{-1}. Compost was made of rice straw and cowdung that were kept in successive layers of 15 cm in a pit of 1.5 m deep and was allowed to rotten for 100-120 days, CD = Fresh cowdung at the rate of 25 t $ha^{-1,}$ Gm = Fresh ipilipil leaves as green manures at the rate of 7.5 t $ha^{-1,}$ Rs = Air-dry rice straw at the rate of 1.5 t $ha^{-1.}$ Factor B (Nitrogen): In rice: N_o = No nitrogen was applied, N_1= Nitrogen at the rate of 75 kg $ha^{-1,}$ N_2 = Nitrogen at the rate of 100 kg $ha^{-1,}$ In wheat:N_o = No nitrogen was applied, N_1 = Nitrogen at the rate of 80 kg $ha^{-1,}$ N_2 = Nitrogen at the rate of 120 kg ha^{-1}. Plot dimension was 12 m x 7 m and plot to plot distance was 1.5 m. Soil samples were collected at 5 different soil depths of 0-5, 5-10, 10-15, 15-30 and 30-45 cm of the soil profile from each of the experimental plots. The samples were air-dried, ground and passed through 2 and 0.25 mm sieves for analysis of physical and chemical properties of soil, respectively. The following analysis was determined on all soils. Bulk density was determined by obtaining undisturbed soil cores of known volume. The oven dry soil mass was divided by this field volume of the sample. To determine the bulk density of different layers, undisturbed soil cores of 5 cm long and 5 cm diameter were collected from the mid point of different layers 0-5, 5-10, 10-15, 15-30 and 30-45 cm with the help of the manually operated core sampler. Precautions were taken to avoid compaction of the soil mass. The collected soil cores were trimmed to the exact volume of the cylinder with the help of a sharp stainless knife and oven dried at 105^0C [13]. Particle density of soil was determined by Pycnometer Method [14]. The amount of pore space is determined largely by the arrangement of the solid particles. The porosity is calculated by using the following equation: Porosity= (1- Bulk density/Particle density) x 100. Soil pH was determined by using glass electrode pH meter in soil-water suspension. The suspension was made at the soil and water ratio of 1 : 2.5 as outlined by Jackson [15].

Statistical Analysis

All data were analyzed in the computer using MSTAT programs. Computation and preparation of graphs were done by the use of Microsoft EXCEL 2000 Program.

Results and Discussion

Bulk density

Individual effects of organic manures, nitrogen and soil depths were positively significant (5%) but the interaction of organic manures x soil depths, organic manures x nitrogen, nitrogen x soil depths and organic manures x nitrogen x soil depths were not significant at 5% level (Table 1). Soil bulk density increased progressively with the increase of soil depths. Application of organic manures and N fertilizers significantly reduced soil bulk density (Fig. 1a and 1b). Effect of organic manures on the reduction of soil bulk density was prominent up to 00-15 cm soil depth. Nitrogen fertilizer application at its lower dose decreased bulk density only at 00-05 cm depth, while higher dose of N extended bulk density, reducing up to 30 cm soil depth. There was a significant difference in bulk densities among the different soil depths (Fig 1c). The maximum bulk density (1.58 g cm^{-3}) was recorded in 30-45 cm soil depth and it was statistically similar with 15-30 cm soil depth. The minimum bulk density (1.42 g cm^{-3}) was recorded in 00-05 cm of soil depth and the value was statistically similar with 05-10 and 15-30 cm soil depths.

In control plot, receiving no nitrogen and no organic manures, bulk density at 00-05 cm depth was 1.55 g cm^{-3}, which was reduced to 1.42 g cm^{-3} whencompost was applied without nitrogen. Application of nitrogen at low (75 kg N in rice and 80 kg N ha^{-1} in wheat) and high doses (100 kg N in rice and 120 kg N ha^{-1} in wheat) reduced bulk density in compost applied soil to 1.36 and 1.32 g cm^{-3}, respectively (Table 2).

In sub surface layers (15-30 and 30-45cm) of the soil, bulk density did not differ significant among the treatments. The bulk density of soil in the control soils was slightly higher than the soils treated with organic manures. It was also observed that the bulk density values at the sub surface layers were higher than those in the upper layer. Similar results among the treatments in the sub surface soil and the lower values at the topsoil suggested that there was no noticeable impact of organic manures on bulk density at sub surface layer. It might be due to the least influence of organic manures towards the sub surface soil and un-disturbance of the sub surface soil due to tillage and other cultural practices. Organic manures were incorporated in the upper layer of soil and the tillage practices tilled the soil up to 15 cm from the surface. As a result its influence was prominent at that zone and the effect of organic matter was not notably migrated to the subsoil. The benefitsofcompost use in reducing soil bulk density was also observed foravarietyof compostsbyZebarth*etal.*[16].

Application of organic manures for 16 years period lowered the bulk density of soil and this change might have manifold beneficial effects on agricultural aspects through root proliferation and water transmission. In a study for 10 years Bellukki *et al.* [17] found similar trend of bulk density having the values of 1.46 g cm^{-3} in the control soils, and 1.36 and 1.31 g cm^{-3} in the soils where cowdung and rice straw were applied, respectively. Similarly the bulk density of a soil treated with organic manures decreased from 1.46 to 1.40 g cm^{-3} in nine years [18] which confirmed the present results. The results obtained in the present study also agreed with the findings of Panda et al. [19] and Santhy *et al.* [20]. Green manures also decreased the soil bulk density to a considerable extent. This result resembles with the finding of Bhattacharyya *et al.* [21] who stated that bulk density was minimum in NPK + FYM treated soil.

Particle density

The individual effects of organic manures, nitrogen, soil depths and interactions of organic manures x soil depths, organic manures x nitrogen, nitrogen x soil depths and organic manures x nitrogen x soil depths were not significant at 5% level (Table 1).

Effect of organic manures on the reduction of soil particle density was prominent up to 00-15 cm soil depth. The maximum particle density (2.59 g cm^{-3}) was recorded in the treatment where no organic matter was applied. The lowest particle density (2.45 g cm^{-3}) was observed in the soils receiving compost. This treatment was statistically similar with those in soils treated with rice straw. Relatively higher particle density was recorded where no nitrogen was applied (Fig. 2a). Nitrogen fertilizer application at its lower dose (75 kg N in rice and 80 kg N ha^{-1} in wheat) decreased particle density only at 00-10 cm depth, while higher dose (100 kg N in rice and 120 kg N ha^{-1} in wheat) of N increased particle density, reducing up to 30 cm soil depth (Fig. 2b). Soil particle density increased progressively with the increase of soil depths(Fig. 2c). Brady [22] and Donahue *et al.* [23] considered average particle density of mineral soils to be around 2.65 g cm^{-3}. The results obtained in the present study were in full agreement with their findings.

Porosity

Individual effects of organic manures, nitrogen and soil depths were significant but interactions of organic manures x soil depths, organic manures x nitrogen, nitrogen x soil depths and organic manures x nitrogen x soil depths were not significant at 5% level (Table 1). The maximum porosity (42.89%) being recorded in soil receiving green manures. The lowest porosity was recorded in control (Fig. 3a). Nitrogen fertilizer application extended porosity up to 30 cm soil depth and then reduced at No (no nitrogen) N_1 (75 kg N in rice and 80 kg N ha^{-1} in wheat) and N_2 (100 kg N in rice and 120 kg N ha^{-1} in wheat) respectively (Fig. 3b). Soil porosity increased progressively with the increase soil depths and was prominent up to 15 cm soil depth (Fig. 3c). The porosity values depended on bulk density and particle density of a soil. Application of organic matter for a period of 16 years remarkably changed the bulk density as well as particle density at different soil depths. As a result the porosity was changed accordingly. This observation corroborated with the findings of Bellukki *et al.* [17] who found a porosity of 44% in the control plots, 47.5 and 51.5% in the treatments with cowdung and paddy straw, respectively. The results of the present study also agreed with the results found by Alleoni *et al*. [9].

Soil pH

The individual effects of organic manures, nitrogen, soil depths and their interactions of organic manures x soil depths, organic manures x nitrogen, nitrogen x soil depths and organic manures x nitrogen x soil depths were found to have significant 5% positive effects (Table 1). Application of different organic manures and nitrogen for 16 years influenced soil pH at soil depths of 00-05, 05-10, 10-15, 15-30 and 30-45 cm, respectively. Results showed that there was a significant difference among the treatments receiving different organic manures (Fig. 4a). The highest soil pH (6.36) was recorded in the soil receiving compost. The second highest soil pH (5.83) was found by the treatment receiving green manures which was statistically similar with cowdung. The lowest soil pH was found in the treatment where no organic manures was applied. There was a significant difference in soil pH among the treatments receiving nitrogen (Fig. 4b). The highest pH value (6.16) was found in soils which did not receive any nitrogen since 16 years and the lowest pH value (5.39) was recorded where 100 kg N in rice and 120 kg N ha^{-1} in wheat were applied. Treatment receiving 75 kg N in rice and 80 kg N ha^{-1} in wheat gave the pH value in between N_0 (no nitrogen) and N_2 (100 kg N in rice and 120 kg N ha^{-1} in wheat). This effect might be due to the application of urea as source of N that had acidic effect on soil. It was observed from the result that the pH values at higher soil depths were higher than the corresponding values obtained at the upper soil depths (Fig. 4c). It might be due to the leaching of some base metals downward.

Interactions of organic manures, nitrogen and soil depths showed that the highest values of soil pH (6.40, 6.90, 7.00, 7.00 and 7.10) were found in the treatment where compost was used and no nitrogen was applied at soil depths of 00-05, 05-10, 10-15, 15-30 and 30-45 cm, respectively. Effect of organic manures on the increase of soil pH was prominent up to 45 cm soil depths (Table 3). The soil under study was acidic in nature and it might be caused by the hydrolysis of Al and Fe. Whenever organic manures were added to the soil pH might decrease due the formation of different organic acids. However, the organic acids are very weak acid, which have the lower dissociation constants. On the other hand, the organic radicals are formed during the decomposition process of organic manures. These radicals entrap Al and Fe to form some organic complexes and hinder to undergo hydrolysis reaction. As a result application of organic matter in acid soil may increase its pH to some extent. Patiram and Singh [8] found a change of pH value from 4.8 to 5.2 after three years with the application of manures. Iyamuremye *et al.* [24] found a pH value of 4.1 in control compared to 5.8 in manure treated soil, 5.8 in Alfalfa treated plot and 5.0 in wheat straw treated soil after 28 days incubation, which are in agreement with the results of present study. The result obtained in this study was also supported by Hue [25].

Conclusion

Among the organic manures compost performed best in respect of improving soil properties such as bulk density, particle density and soil pH.

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Table 1. *F-statistics of bulk density, particle density, porosity and soil pH of soil as influenced by the long-term application of organic manures and nitrogen at different soil depths.*

Treatment	Degrees of freedom	Bulk density($g\ cm^{-3}$)	Particle density ($g\ cm^{-3}$)	Porosity (%)	Soil pH
Manures (M)	4	12.20 *	1.07 ^{NS}	6.43*	2349.75*
Nitrogen (N)	2	8.50 *	2.88 ^{NS}	40.28*	4548.00*
Depths (D)	4	46.61*	1.96 ^{NS}	6.07*	2477.00*
M x N	8	0.16 ^{NS}	1.03 ^{NS}	0.71^{NS}	349.65*
M x D	16	0.84 ^{NS}	1.04 ^{NS}	0.58 ^{NS}	26.49 *
N x D	8	0.64 ^{NS}	1.52 ^{NS}	0.98 ^{NS}	34.74*
M x N x D	32	0.12 ^{NS}	0.50 ^{NS}	0.54 ^{NS}	16.99*
CV (%)		3.96	9.74	6.50	5.71

Table 2. *Bulk density as influenced by the long-term application of organic manures and nitrogen at different soil depths.*

Soil depths (cm)	**Control**	**Cowdung**	**Compost**	**Green Manures**	**Rice straw**
	$g\ cm^{-3}$				
			No		
00-05	1.55	1.47	1.42	1.44	1.45
05-10	1.56	1.48	1.42	1.45	1.47
10-15	1.57	1.47	1.42	1.44	1.49
15-30	1.61	1.58	1.56	1.56	1.56

Soil depths (cm)	Control	Cowdung	Compost	Green Manures	Rice straw
	g cm^{-3}				
30-45	1.57	1.60	1.58	1.59	1.59
			N_1		
00-05	1.48	1.45	1.36	1.39	1.40
05-10	1.54	1.45	1.38	1.40	1.41
10-15	1.54	1.42	1.40	1.41	1.44
15-30	1.58	1.56	1.52	1.59	1.55
30-45	1.63	1.58	1.56	1.57	1.58
			N_2		
00-05	1.44	1.42	1.32	1.35	1.36
05-10	1.49	1.43	1.36	1.38	1.41
10-15	1.51	1.46	1.37	1.39	1.44
15-30	1.56	1.56	1.51	1.53	1.54
30-45	1.60	1.58	1.56	1.56	1.57

LSD $_{0.05}$ Organic manures (OM): 0.04, Nitrogen (N): 0.05, Depths (D): 0.04, OM × D: NS, OM × N: NS, N × D: NS, OM × N × D: NS

Table 3. *Soil pH as influenced by the long-term application of organic manures and nitrogen at different soil depths.*

Soil depths (cm)	Control	Cowdung	Compost	Green manures	Rice straw
			No		
00-05	5.40	5.80	6.40	5.70	5.60
05-10	5.50	6.00	6.90	5.70	5.60
10-15	5.70	6.20	7.00	5.90	5.80
15-30	6.15	6.30	7.00	6.30	6.20
30-45	6.35	6.60	7.10	6.45	6.40
			N1		
00-05	5.10	5.50	5.90	5.30	5.50
05-10	5.20	5.80	6.50	5.50	5.50
10-15	5.50	6.00	6.80	5.70	5.60
15-30	5.20	6.20	6.80	6.20	6.10
30-45	5.90	6.45	7.00	6.30	6.25
			N2		
00-05	4.20	4.50	5.10	5.20	5.10
05-10	4.60	4.90	5.30	5.40	5.40

Soil depths (cm)	Control	Cowdung	Compost	Green manures	Rice straw
10-15	4.80	5.20	5.50	5.60	5.50
15-30	5.00	5.70	6.00	6.10	6.00
30-45	5.30	5.90	6.10	6.20	6.10

LSD $_{0.05}$

Organic manures (OM): 0.039, Nitrogen (N): 0.047, Depths (D): 0.039, OM x D: NS, OM x N: 0.056, N x D: 0.056, OM x N x D: 0.116

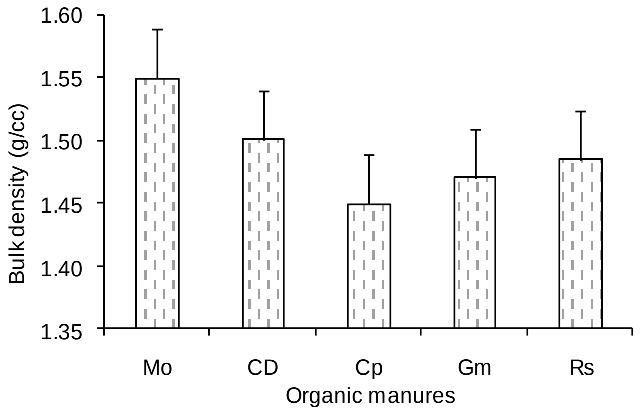

Fig. 1a: *Effect of long-term application of organic manures on bulk density of soil.*

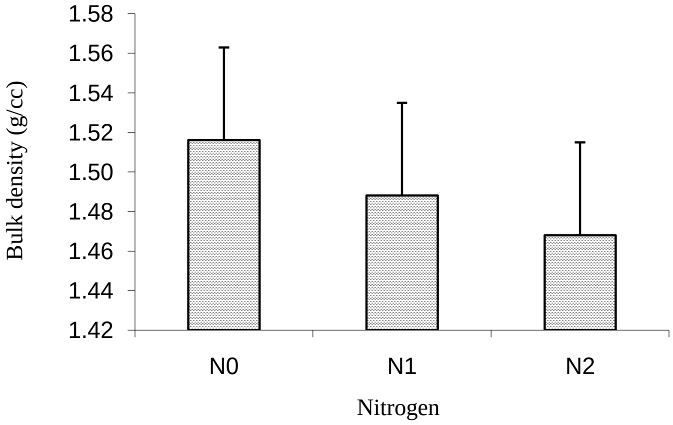

Fig. 1b: *Effect of long-term application of nitrogen on bulk density of soil.*

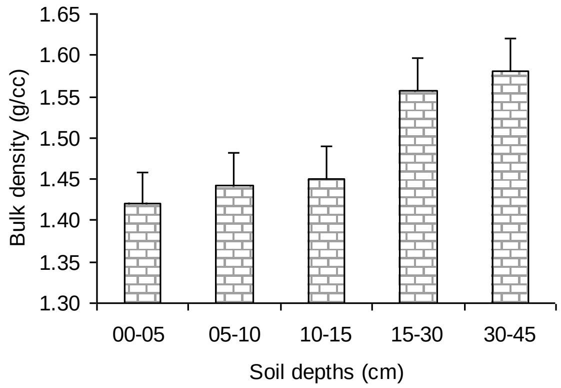

Fig. 1c: *Effect of long-term nutrient management on bulk density at different soil depths.*

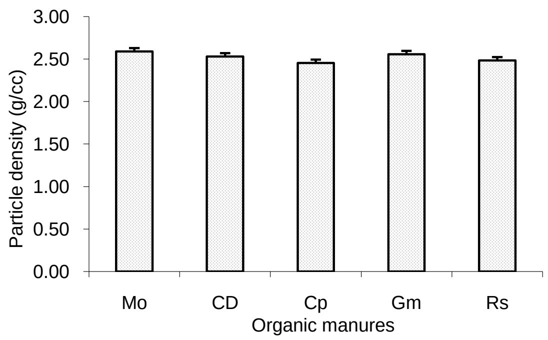

Fig. 2a: *Effect of long-term application of organic manures on particle density of soil.*

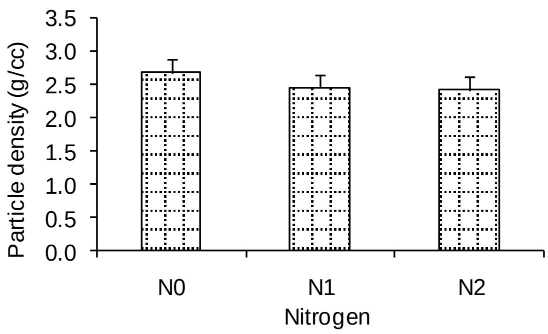

Fig. 2b: *Effect of long-term application of nitrogen on particle density of soil.*

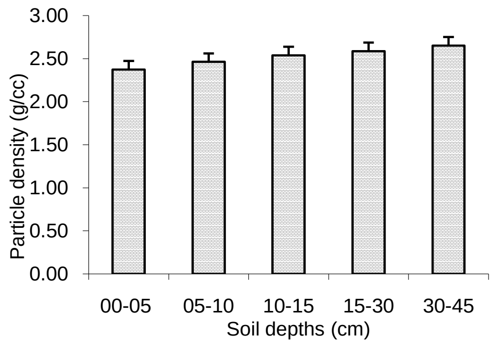

Fig. 2c: *Effect of long-term nutrient management on particle density at different soil depths.*

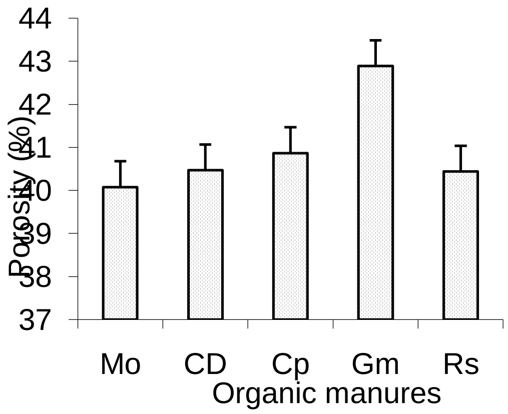

Fig. 3a: *Effect of long-term application of organic manures on porosity of soil.*

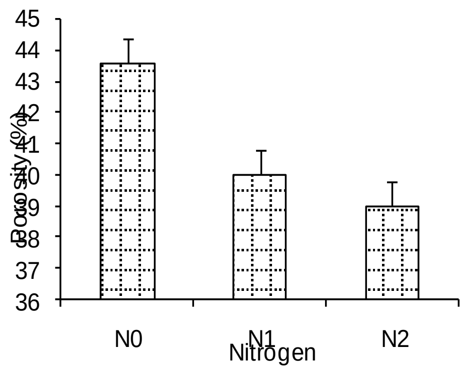

Fig. 3b: *Effect of long-term application of nitrogen on porosity of soil.*

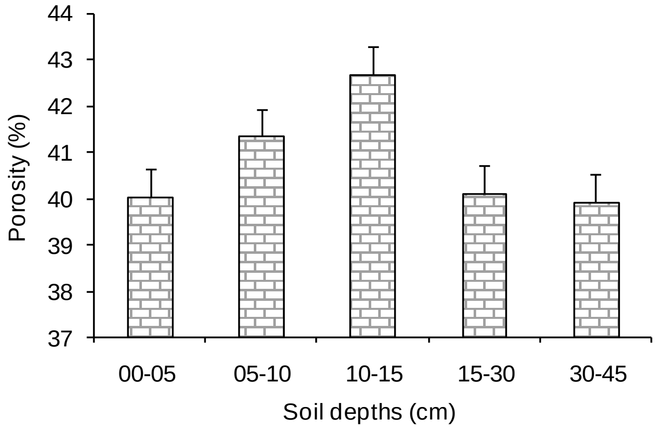

Fig. 3c: *Effect of long-term nutrient management on porosity at different soil depths.*

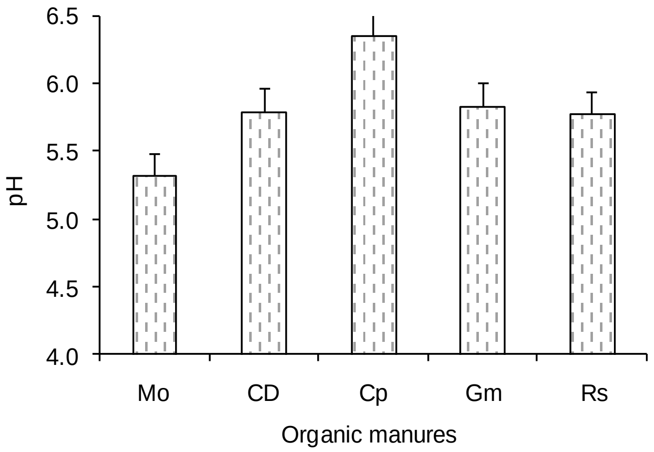

Fig. 4a: *Effect of long-term application of organic manures on soil pH.*

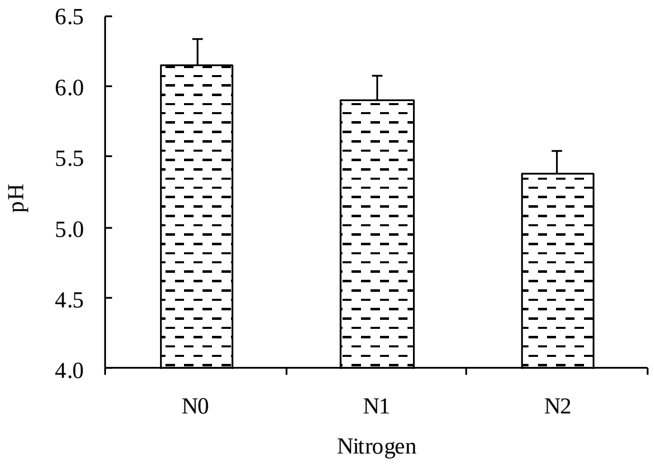

Fig. 4b: *Effect of long-term application of nitrogen on soil pH.*

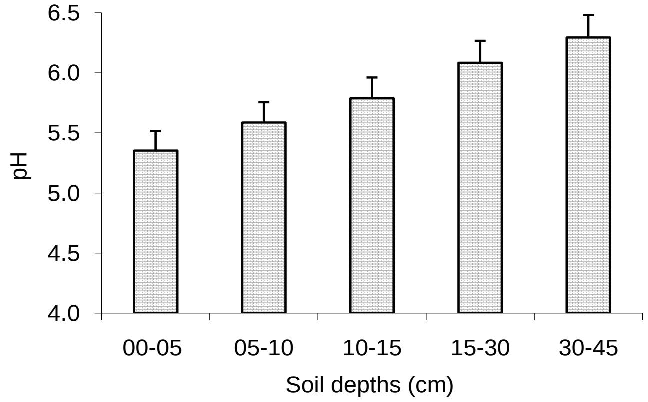

Fig. 4c: *Effect of long-term nutrient management on soil pH at different soil depths.*