INFLUENCE OF AZOLLA, GRASS, WATER HYACINTH AND PEANUT RESIDUES IN AMENDING SOIL PROPERTIES

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Abstract

An incubation experiment was undertaken to evaluate the effects of azolla, grass, water hyacinth, and peanut residues for amending some soil properties. The experiment was laid out in pots comprising 7 treatments, *viz.* T_1: Control, T_2: Azolla (*Azolla pinnata*) @ 100 g/pot, T_3: Grass (*Phleum pretense*) @ 100 g/pot, T_4: Water hyacinth (*Pontederia crassipes*) @100 g/pot, T_5: Peanut (*Arachis hypogaea*) @ 100 g/pot, T_6: Azolla @ 50 g/pot + Water hyacinth @ 50 g/pot, and T_7: Peanut@ 50 g/pot + Grass @ 50 g/pot. The results revealed that peanut treated soils (T_5) played an important role in enhancing soil properties significantly ($p < 0.05$) and the values of soil organic carbon (SOC), pH, nitrogen, moisture content and cation exchange capacity (CEC) reached at an optimum level to support microbial growth over a year.

Keys words: Green residues; Amending soil properties; Azolla; Peanut.

INTRODUCTION

Intensive agricultural systems with monoculture crops and reliance on external inputs of chemical fertilizers are criticized for their severe environmental impacts due to soil organic matter deterioration and biodiversity loss (Malézieux *et al.* 2009). Furthermore, Yang *et al.* (2020) stated that mono-cropping has resulted in a variety of soil-related problems, hastening yield decline. To combat the continuous soil degradation and nutrient mining, the application of green residues in the agricultural systems should be given high priority. It is reported that organic matter released from the organic residues played a significant role in the regeneration and stabilization of soil structure (Cambardella *et al.* 2003). The low contents of organic matter in soil is a global concern and of course in Bangladesh which poses a severe challenges to achieving food security and maintaining soil health. According to BARC (2018), more than 50% of agricultural soils in Bangladesh have less than 0.86% organic carbon. Uddin *et al.* (2022) demonstrated that SOC is declining in the agricultural soils of Bangladesh as a result of land use intensification which could be attributed to low residual input with no fallow periods.

According to FAO (2011), crop residues can be used as valuable agricultural resources in developing countries and are used in boosting agricultural production due to their high nutrient content, ability to reduce soil erosion and runoff, and capacity to retain more water, all of which are essential for the growth of microorganisms and plants (Erenstein, 2002). Deshmukh *et al.* (2002) reported that incorporation and incubation of crop residues into the soil has the potential to provide a balanced supply of plant nutrients. Bauder (2002) concluded that crop residue incorporation in the soil enhances the release of nutrients through their continuous breakdown processes. The goal of this study was to amend soil properties by incorporating and incubating green residues into the soil where that peanut residues amended soil properties faster than other green residues.

MATERIAL AND METHODS

The experimental soil samples were collected from a maize field at a depth of 30 cm following composite sampling located in Atrai Upazila under Naogaon district of Bangladesh. Samples were collected in polythene bags and were sealed properly precluding moisture loss from the samples. Prior to analysis, the soil samples were spread on a polythene sheet and big lumps were broken and air dried under shade. The soil samples were grounded with a wooden hammer, passed through a 2 mm sieve, and mixed thoroughly. The samples were then preserved in plastic containers for laboratory analysis. It may be noted that the experimental green residues like azolla, grass, water hyacinth, and peanut were also collected from the agricultural fields of Atrai upazila. The experiment was laid out in pots comprising 7 treatments, *viz*. T_1: Control, T_2: Azolla (*Azolla pinnata*) @100 g/pot, T_3: Grass (*Phleum pretense*) @100 g/pot, T_4: Water hyacinth (*Pontederia crassipes*) @100 g/pot, T_5: Peanut (*Arachis hypogaea*) @100 g/pot, T_6: Azolla (*Azolla pinnata*) @50 g/pot + Water hyacinth (*Pontederia crassipes*) @50 g/pot, and T_7: Peanut (*Arachis hypogaea*) @50 g/pot + Grass (*Phleum pretense*) @50 g/pot. All the treatments were laid out in triplicate. It may be noted that fresh green residues were sorted and washed with tap water, and then cut into small pieces and mixed thoroughly. Green residues were mixed with 500g soil uniformly. Then 10ml of water were added in order to accelerate the decomposition rate and then kept in large jars freely exposed to the air and sunshine for 12 months in a well-ventilated room.

Water was added regularly to maintain the optimum soil moisture level which helps to keep favorable condition for decomposition. The initial soil properties, *viz.* pH, organic carbon, total nitrogen, moisture contents, carbon and nitrogen ratio, and cation exchange capacity (CEC) were analyzed following standard methods. These parameters were also analyzed sequentially for three times (4, 8 and 12 months) in the experimental soils over a year to observe the changes. The carbon nitrogen ratio of the fresh green residues was also calculated. The microbial colony growth was also observed in the experimental soils at the final stage.

Table 1. Some physico-chemical properties of the experimental soil.

Soil properties	Values	Methodology followed
Soil pH	4.53	Page *et al.* (1982)
Organic carbon	0.30 %	Nelson and Sommers (1982)
Total nitrogen	0.083 %	Bremner and Mulvaney (1982)
Cation Exchange Capacity	23 meq/100 g	Black (1965)
Moisture contents	3.51 %	Dane and Topp (2002)
Bulk density	1.38 %	Blake and Hartge (1986)
Textural class	Silty clay loam (sand= 8.0%, silt= 63%, and clay 29%)	Gee and Bauder (1986)

The results of initial soil properties like soil pH, organic carbon, total nitrogen, cation exchange capacity (CEC), soil moisture content, bulk density, particle size and textural class *etc*. are presented in Table 1. The experimental soil is extremely acidic with low organic carbon contents. The textural class of the soil is silty clay loam. Moreover, carbon and nitrogen contents of green residues used in the experiments are also presented in Table 2. The carbon and nitrogen contents in the green residues varied from 39 to 70% and 1.59 to 2.41%, respectively. Thus, the C: N ratio in the green residues ranged from

16.18 to 34.87 whereas the lowest C: N ratio was reported in peanut residues. Watson *et al.* (2002) stated that the lower C: N ratio enhances more nitrogen release into the soil for the immediate crop use.

Table 2. Carbon and nitrogen contents of azolla, water hyacinth, peanut and silase grass used in the experiment.

Green manures	Carbon content (%)	Total nitrogen (%)	C: N ratio
Azolla	51	1.59	32.08
Water hyacinth	70	1.83	38.25
Peanut	39	2.41	16.18
Silase grass	68	1.95	34.87

Soil bacterial colony count

Sample preparation and sterilization

For microbial analysis, the samples were hydrated to 3/4 of the field capacity and incubated for 5 days as suggested by Vieira and Nahas (2005). All the glass wares were cleaned with distilled water, dried and sterilized at 121°C for 30 minutes using an autoclave.

Culture media preparation

The various ingredients of the media were prepared accurately and were dissolved in water with constant heating. The mouth of a conical flask was plugged with absorbent cotton and wrapped with a Kraft paper. The flask with the contents was sterilized within an autoclave for 15-20 minutes at a pressure of 15 PSI and at a temperature of 121° C. After sterilization, the media was cooled and stored at 4°C. The media were then distributed to culture plates and allowed to solidify.

Serial dilution technique

The bacterial colony count was carried out by using the serial dilution pour plate method as stated by Wollum (1982). The population of microbes was expressed as colony forming unit (CFU) per ml.

Statistical analysis

Data were analyzed by ANOVA technique using IBM SPSS Statistics 24.0 program for proper interpretation. The means were separated using the Fisher's Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Soil pH under various treatments with green residues indicated that pH changes from 4.53 to 6.14 with the treatment peanut residues (Table 3). It also showed that soil pH became more suitable for crop growth under the peanut treated residues compared to other residues. Soil organic carbon (SOC) under various treatments with green residues indicated that SOC rises quickly from 0.30 to 0.77% over one year with the peanut treated residues (Table 3). It also indicated that soil became regenerative under the peanut treated residues. Witcombe and Tiemann (2022) reported that groundnut residues have the potential abilities to sustain SOC and total nitrogen (TN) stocks if retained in the field.

In the present experiment, soil total nitrogen (STN) changes rapidly from 0.082 to 0.21% over one year with the peanut treated residues (Table 4) which indicates that soil became more fertilized with nitrogenous spore forming bacteria. It may be noted that legume rhizodeposition acts as a possible source of N for the subsequent crop (Zhang *et al.* 2018). Zhou *et al.* (2020) stated that peanut residue incorporation increased soil nutrient availability with nitrogen accumulation. Tang *et al.* (2020) reported that intercropping with peanuts and cassava significantly increased available nitrogen and pH compared with that of mono cropping. CEC in the experimental soils also changes sharply from 23.0 to 36.0 over one year with the peanut treated residues than the other treatments (Table 4).

Table 3. Soil pH and organic carbon (%) contents under various treatments with different green amendments over a year.

Treatments	Before incorporation of green amendments		4 months after incorporation of green amendments		8 months after incorporation of green amendments		12 months after incorporation of green amendments	
	pH	SOC (%)	pH	SOC (%)	pH	SOC (%)	pH	SOC (%)
T_1	4.53	0.30	4.53	0.36	4.59	0.35	4.99	0.37
T_2	-	-	4.69	0.54	4.72	0.56	5.89	0.56
T_3	-	-	5.13	0.40	5.68	0.45	5.24	0.48
T_4	-	-	4.99	0.41	6.21	0.43	6.00	0.49
T_5	-	-	4.83	0.70	6.03	0.75	6.14	0.77
T_6	-	-	4.80	0.39	5.54	0.38	5.73	0.40
T_7	-	-	5.02	0.26	5.96	0.29	5.99	0.53
Range	**-**	**-**	**4.53-5.13**	**0.26-0.70**	**4.59-6.21**	**0.29-0.75**	**4.99-6.14**	**0.37-0.77**
Mean	**-**	**-**	**4.85**	**0.44**	**5.53**	**0.46**	**5.71**	**0.51**

Soil moisture content was reported 4.25 % with azolla, 4.82 % with grass, 2.89 % with water hyacinth, 5.04 % with peanut, 3.66 % in combination with azolla and water hyacinth, and 5.26 % in combination with peanut and grass. So, it was found that peanut and grass mixed residues showed higher contents of soil moisture. It may be noted that the peanut treated soils becomes enriched with carbon, nitrogen, moisture over a year and as a result, CEC is going up to support physicochemical properties of the soils under favorable pH condition. Thus, CEC is a vital parameter to uphold the soil quality. Similar finding was reported by Win *et al.* (2019) regarding soil amendment with peanut shell.

Table 4. Soil nitrogen (%) and cation exchange capacity (CEC) under various treatments with different green amendments over a year.

Treatments	Before incorporation of green amendments		4 months after incorporation of green amendments		8 months after incorporation of green amendments		12 months after incorporation of green amendments	
	N (%)	CEC (meq/100g)	N (%)	CEC (meq/100g)	N (%)	CEC (meq/100g)	N (%)	CEC (meq/100g)
T_1	0.082	23	0.09	24.0	0.09	25.0	0.09	24.9
T_2	-	-	0.13	26.3	0.14	26.1	0.16	26.5
T_3	-	-	0.15	27.0	0.15	27.5	0.17	27.6
T_4	-	-	0.14	28.5	0.16	28.0	0.16	29.9
T_5	-	-	0.18	32.5	0.20	36.0	0.21	36.0
T_6	-	-	0.13	27.3	0.13	29.75	0.15	28.1
T_7	-	-	0.16	31.0	0.17	32.92	0.17	31.7
Range	**-**	**-**	**0.09-0.18**	**24.0-32.5**	**0.09-0.20**	**25.0-36.0**	**0.09-0.21**	**24.9-36.0**
Mean	**-**	**-**	**0.14**	**28.08**	**0.15**	**29.32**	**0.16**	**29.24**

Peanut mixed soil showed a significant ($p < 0.05$) number of spore-forming bacteria more than that of the control (T_1) soil after 48 hours of incubation. It was found that bacterial population in the control soil was 2.11±0.15 whereas the spore-forming bacterial colony in the peanut mixed soil was

793.17±3.89 (total count 793.17, 79.3%). Similar statement was given by Ramsay and Dunbrack (1986) that peanut treated soils enhanced the bacterial colony multiplication.

According to the ANOVA analysis, soil pH, nitrogen, organic carbon, soil moisture contents and cation exchange capacity under peanut treated soils varied significantly ($p < 0.05$) over a year at 95% confidence level.

The present study revealed that SOC increased by 0.3% in a year and CEC increased substantially in the peanut treated soils more than the other treatments. In the peanut treated soils, the soil properties reached at an optimum level over a year to support microbial growth. The peanut treated soils showed the highest level of microbial colony growth indicating more nitrogen fixation abilities. From the Paris climate Agreement, this has been formally recognized through the '*soil carbon 4 per mille' initiative*, the aim of which is to increase global soil organic stocks by 4 per 1000 (0.4%) per year as compensation for the global emission of greenhouse gases (Minasny *et al*. 2017). The aim of increasing SOC by 0.4% per year is encouraging for the restoration of soil quality, attaining food security and offsetting global CO_2 emissions. It aims to boost carbon storage in agricultural soils by 0.4% each year to help mitigate climate change and in increasing food security. Similarly, it may be said that SOC storage can be increased at 0.3 % level annually in the agricultural soils with peanut cultivation under crop diversification program. As such situation, the crop diversification with leguminous cropping pattern may be an important option in achieving the sustainable development goals (SDGs). It could be mentioned that yield increases caused by peanut residue incorporation were detected only from the perspective of multiple cropping systems rather than single crop seasons (Zhang *et al.* 2022). The adoption and extension of green residues specifically peanut in the agricultural systems would be an important option of amending soil properties and enhancing soil fertility.

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