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AMELIORATION OF THE CHEMICAL PROPERTIES OF SOIL THROUGH APPLICATION OF GREEN MANURE CROPS IN BAJOA SOIL SERIES

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Abstract: The experiment was conducted in the Soil Science Discipline, Khulna University, Bangladesh during July to December of 2009 to observe the influence of green manure on chemical properties (pH, CEC, EC, N, P, K, S, Ca, Mg, Zn, B, C:N ratio, organic matter) of Bajoa soil series. The experiment was laid out in a completely randomized design with three replications. The experiment comprised six treatments viz., control (no green manure) and five green manure crops varieties namely pigeon pea (*Cajanus cajen*), green gram (*Vigna radiate*) common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), yard long bean (*Vigna sesquipedalis*). EC (4.04 to 4.42 dS m^{-1}) and CEC (26.07 to 35.93 cmole/kg), organic matter (4.77 to 5.27 %) and the macro and micro nutrients such as N (0.115 to 0.124 %), P (7.2 to 12.6 µg g^{-1}), K (0.37 to 0.42 meq/100g), S (29.92 to 51.47 µg g^{-1}), Ca (14.0 to 19.0 meq/100g), Mg (5.24 to 5.73 meq/100g) and B (0.37 to 0.75 µg g^{-1}) and Zn (0.54 to 0.87 µg g^{-1}) were found due to the application of green manure crops. Organic matter and carbon are increased by green manure crop incorporation which eventually initiates CEC enhancement. Moreover, it was found that cowpea (*Vigna unguiculata*) green manure initiates more effective result than that of other treatments.

Keywords: *Bajoa* soil series, green manure, green manure crops, chemical properties of soil.

Introduction

Increasing population pressure, food demand of the people combined with reduction in productive agricultural land is forcing farmers to adopt more intensive farming systems. Farmers have responded to this pressure by growing more and more cereals in place of traditional fallow practices. Consequently, it has led to gradual deterioration of natural resource base and accelerated exhaustion of soil nutrient reserves. This rapid nutrient depletion has caused serious threats to agricultural productivity. So, we have to use soil as sustainable approach to improve the yield potential of crops per unit land under various soil stresses through organic manure such as green manure (Katkar *et al.,* 2002).

Soil productivity is an important concern for farmers. Green manuring with legumes is gaining popular to improve soil productivity (Arakari, 1962). Almost any crop can be used for green manuring but legumes are preferred because of their ability to fix nitrogen from the air and used as a soil building practice that adds organic residues, conserves and recycles plant nutrients (Werner, 1997). It can also be planted as a part of crop rotation during the growing season (Cheema *et al*., 1991).

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This study was designed to analyze the status of soil nutrients and EC, pH, CEC from incorporated five green manure corps (Bajoa soil series) and to know which one is suitable to use and its contribution to improve soil properties.

Materials and Methods

Pot experiment was conducted to observe the effects of green manures on the chemical properties of soil. The seived soil was well mixed with a shovel in 18 pots. Pots were filled with five kilogram soil up to 12 cm of the top and soil moisture was maintained at approximately field capacity (0.33 g water g $soil^{-1}$) by weighing individual pots and replacing lost water when necessary and room temperature was maintained uniform during the experiment.

Pot experiment and location of sampling: A long-term pot experiment was initiated at Soil Science Discipline, Khulna University, Khulna, Bangladesh during 2009. It was laid out with five treatments including control have three replication. Each pot was 12 cm by length and 8 cm by wide. The experimental soil from Bajoa soil series (Typic Endoaquepts) had pH 8.67, electrical conductivity 2.76 dS m^{-1}, total nitrogen 0.094%, phosphorus 6.5µg/g soil, potassium 0.27 meq/100g soil, sulfur 26.88µg/g soil, boron 0.36µg/g soil, calcium 10 me/100g, magnesium 5.03me/100g, zinc 0.47µg/g soil, cation exchange capacity or CEC 23.73 meq/100g .

Cultivation and application of Green manure crops: Five green manure crops were pigeon pea (*Cajanus cajen*), mung or green or golden gram (*Vigna radiate*), common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), yard long bean (*Vigna sesquipedalis*) were grown in five pots. One pot was used as control experiment where no green manure crop was grown. 10 gm seeds were broadcasted in each pot to a loosely tilled, fine seed bed for satisfactory germination during the last week of September 2009. Shallowly seeds were incorporated with garden rake and leaf rake to a depth of 0.25 to 0.75 inch deep. After 7 days of seedlings establishment plants were allowed to grow for 30 days. Before incorporation green manure crops were cut and same amount of green manure crops (300g) from each pot was measured by an electrical balance to ensure nutrient release from each experiment from same amount of green manure application at the flowering stage. The green manure crops were thoroughly mixed to the soil by a shovel; soil was watered daily for hastening decomposition and was kept for 3 weeks for proper decomposition.

Collection of soil samples: Green manure crops were well mixed to the soil for three weeks. After three weeks the color of the soil was changed and there was not a portion of fresh plants that means the plants were completely decomposed. Soil samples were then collected from each pot including control for laboratory analyses.

Preparation of Soil Samples: The collected soil samples were air dried by spreading on separate sheet of papers after it was transported to the laboratory. The larger aggregates of the samples were broken gently by crushing it with a wooden hammer. A portion of the crushed soils was sieved with a 2.0 mm sieve. The chemical analyses of these collected soil samples were carried out in the laboratories of the Soil Science Discipline, Khulna University. Khulna and SRDI, Dhaka.

Soil chemical Analysis: Soil pH was determined electrochemically with the help of a glass electrode pH meter as suggested by Jackson (1962). The electrical conductivity of the soil was measured at a soil: water ratio of 1: 5 by the help of EC meter (USDA, 2004). The CEC of the soils were determined by extracting the soil with 1N KCL (pH, 7.0) followed by the replacing the potassium in the exchange complex by 1 N NH_4OAc. The displaced potassium was determined by a flame analyzer at 589 nm wavelength (Jackson, 1962).

Organic carbon of soil sample was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1962). Organic matter was calculated by multiplying the percent value of organic carbon with the conventional van-Bemmelene's factor of 1.724 (Piper, 1950). Total nitrogen of the soil was determined by Micro-Kjeldahl's method following H_2SO_4 acid digestion as suggested by Jackson (1962).

Total content of Zn of the sample was determined by Atomic Absorption Spectrophotometer (Jackson, 1962), after digestion with HNO_3: $HClO_4$ (2: 1) acid mixture. The available K was determined from NH_4OAc. (pH, 7.0) extract as described by Jackson (1962). The extract was analyzed for available K by a flame analyzer at 589 nm wavelength (Jackson, 1962).

Available Phosphorus was extracted from the soil with 0.5 M $NaHCO_3$ (Olsen's Method) at pH 8.5 and Molybdophosphoric blue colour of analysis was employed for determination of phosphorus (Jackson, 1962). Available sulfur content was determined by turbidimetric method as described by (Jackson, 1962). It was measured by spectrophotometer at 420 nm wavelength.

The available Ca and Mg were determined from NH_4OAc. (pH 7.0) extract as described by Jackson (1962). The contents of Ca and Mg were measured by atomic absorption spectrophotometer. Available Boron was determined by hot water method using buffer solution and Azomethine Solution on Perkin-Elmer Lambada 11 (2.2) UV/VIS spectrometer at 420nm wavelength (Jackson, 1962).

Statistical analysis: This experiment was designed as completely randomized design with three replications. Data were subjected to a one factor (different green manure treatment) analysis of variance (ANOVA) to determine if the materials mineralized differently with several green manures with F test at 5% and 1% level of significance with the statistical package of MINITAB. Statistical mean values of different treatment were tested using independent Student t-tests at 5% and 1% level of significance and not to correlate the different soil properties (Table 2 and Table 3) (Ryan *et al*., 1985).

Results

Three soil samples from each pot including control treatment were analyzed to determine the chemical properties in the laboratory. After analysis the chemical properties of the soil samples the following results were found which is presented in Table 1. The total nitrogen content of the control treatment was 0.094%. The total nitrogen contents of pigeon pea (*Cajanus cajen*), mung or green or golden gram (*Vigna radiate*), common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*) and yard long bean (*Vigna sesquipedalis*) treated green manure crops in soil were 0.119 % , 0.116 %, 0.115 % , 0.124 % and 0.119 % respectively (Table 1).

The average 9.73 $\mu g\ g^{-1}$, 8 $\mu g\ g^{-1}$, 7.2 $\mu g\ g^{-1}$, 12.6 $\mu g\ g^{-1}$, 9.63 $\mu g\ g^{-1}$phosphorus in soil were observed in pigeon pea, green gram, common bean, cowpea, yard long bean incorporated respectively. Average 6.5 $\mu g\ g^{-1}$phosphorus value was obtained with controlled treatment.

In this experiment, 0.27 meq/100g available K was found in control experiment. On the other hand, K was found 0.40 meq/100g for pigeon pea, 0.41 meq/100g for green gram, 0.37 meq/100g for common bean, 0.42 meq/100g for cowpea and 0.40 meq/100g for yard long bean (Table 1).

Table 1. The following table shows different chemical properties of studied soil at approximately field capacity (0.33 g water g $soil^{-1}$) soil condition and when the experimental soil series was *Bajoa* ((Typic Endoaquepts)

The average S content of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control pot were found as 33.76 μg/g, 30.74 $\mu g\ g^{-1}$, 29.92 $\mu g\ g^{-1}$, 51.47 $\mu g\ g^{-1}$, 34.33 $\mu g\ g^{-1}$, 26.88 $\mu g\ g^{-1}$ in soil respectively (Table 1).

Table 1. Chemical properties of soils.

Treatment	Total N (%)	Available P (µgg^{-1})	K (meq/ 100g)	S (µg g^{-1})	Ca (meq/ 100g)	Mg (meq/ 100g)	B (µg g^{-1})	Zn (µg g^{-1})	CEC (meq/ 100g)	pH	EC (dS m^{-1})	Organic matter (%)	C:N
Pigeon pea (*Cajanus cajen*)	0.119	9.73	0.40	33.76	18	5.53	0.37	0.58	30.13	7.80	3.27	4.06	19.78
Green gram (*Vigna radiate*)	0.116	8	0.41	30.74	15	5.69	0.39	0.77	29.87	8.20	3.11	4.01	20.05
Common bean (*Phaseolus vulgaris*)	0.115	7.2	0.37	29.92	14	5.24	0.65	0.56	26.07	8.10	3.04	4.00	29.62
Cowpea (*Vigna unguiculata*)	0.124	12.6	0.42	51.47	19	5.73	0.75	0.87	35.93	8.13	3.42	4.17	19.50
Yard long bean (*Vigna sesquipedalis*)	0.119	9.63	0.40	34.33	18	5.37	0.61	0.54	28.27	8.23	3.34	4.08	19.88
Control	0.094	6.5	0.27	26.88	10	5.03	0.36	0.47	23.73	8.67	2.76	3.75	34.94

The average calcium content of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control experiment were observed 18.0 meq/100g, 15.0 meq/100g, 14.0 meq/100g, 19.0 meq/100g, 18.0 meq/100g, 10.0 meq/100g in soil respectively (Table 1). 2.76 dS m^{-1} EC was found in control treatment. And, EC was found 3.27 dS m^{-1} for pigeon pea, 3.11 dS m^{-1} for green gram, 3.04 dS m^{-1} for common bean, 3.42 dS m^{-1} for cowpea and 3.34 dS m^{-1} for yard long bean.

The average magnesium content of pigeon pea, green gram, common bean, cowpea, yard long bean) green manure crops and control experiment were 5.53 meq/100g, 5.69 meq/100g, 5.24 meq/100g, 5.73 meq/100g, 5.37 meq/100g, 5.03 meq/100g in soil respectively (Table 1). The Zn content (average) of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops were found 0.58 µg g^{-1}, 0.77 µg g^{-1}, 0.56 µg g^{-1}, 0.87 µg g^{-1}, 0.54 µg g^{-1} and 0.47µgg^{-1} respectively (Table 1).

The average boron content of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control experiment were observed 0.37 µg g^{-1}, 0.39 µg g^{-1}, 0.65 µg g^{-1}, 0.75 µg g^{-1}, 0.61 µg g^{-1}, 0.36 µg g^{-1} in soil respectively (Table 1).

An average value about 30.13 meq/100g.soil, 29.87meq/100g.soil, 26.07 meq/100g.soil, 35.93 meq/100g.soil, 28.27 meq/100g.soil, 23.73 meq/100g.soil CEC were found in pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control respectively (Table 1).

The average pH value of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control experiment were 7.80, 8.20, 8.10, 8.13, 8.23, 8.67 respectively (Table 1).

The percent organic matter content of pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control experiment were found 4.06, 4.01, 4.00, 4.17, 4.08, 3.75 respectively (Table 1).

The C:N ratio of Pigeon pea, green gram, common bean, cowpea, yard long bean green manure crops and control experiment were found 19.78, 20.05, 29.62, 19.50, 19.88, 34.94 in soil respectively (Table 1).

Discussion

The research work shows that cover crops are killed within 2-3 weeks prior to planting main crop, resulting adequate biomass and reduced risk of crop losses from soil moisture depletion and tie up of nutrients. The total N content after green manure application is increased (Table 1). Cowpea released highest percentage of nitrogen in soil than other treatment whereas common bean gives the lowest amount (Table 1) because the decomposition status of cowpea is highest. But, nitrogen content from green manure was not satisfactory, so decomposition needs more extra time for it's nutrients improvement than this study time of decomposition (3 weeks) because some organic compounds need more time for decomposition. The release of nitrogen from green manure depends on state of decomposition in soil and lignin percentage (Leuken *et al.,* 1962). Legumes are superior green manure crops as they fix atmospheric nitrogen by Rhizobia bacteria in root system (Carlson and Huss-Danell, 2003) and add it to the soil nitrogen pool (Mayer *et al.,* 2003).

Green manure application increases phosphorus content in soil because it increases soil phosphorus bioavailability in root zone by creating acidic environmental condition. Saskatoon (2004) reported that green manure plants (e.g. legumes) create acidic environments around the root zone and are thus able to extract phosphorus from the soil. Green manure application increased soil phosphorus bioavailability (Li *et al.*, 1990) More P was observed in cowpea but green gram gave the lowest value.

The application of green manure crops to the soil increases the availability of K to the soil (Table 1). Because this manure works like as mulch and contains higher CEC which finally do as a barrier and capturer of potassium losses in soil. K was lowest for common bean and highest for cowpea.

The availability of S was slightly increased by green manure application because it obtains more sulfur in soil as sulfate form (Table 1). The addition of organic matter by adding green manure improved sulfate form of sulfer content, depending on the composition and source of the organic matter (Cifuentes and Lindemann, 1993).

Green manure improves available calcium and magnesium content in soil. The calcium and magnesium value were found highest for using cowpea and it was lowest for using common bean (Table. 1). The solubility of calcium and magnesium was increased through the effect of the inorganic and organic acid produced as the result of the decomposing organic matter by incorporating green manure crops (Miller and Turk, 2004; Rosen *et al.,* 2005; Muslem *et al*, 2005).

Available zinc content was increased by adding green manure. For the soil <0.45 $\mu g\ g^{-1}$ of Zn indicated very low and 0.451-0.9 indicated low amount of Zn (Muslem *et al*., 2005). Different green manure treatments showed that application of green manure increased zinc 16% (Mosavi *et al.,* 2008). Green manure was used in those cases when increasing intensity of cropping is more progressive or a deficiency of zinc (Zn) is become more critical (Rosen *et al.,* 2005). Cowpea (*Vigna unguiculata*) enriches the highest amount of B in soil than others (Table 1). Micronutrient boron was managed in most situations through green manure but maintain B below critical level (Rosen *et al.,* 2005).

The organic matter and CEC were increased by green manure crops incorporation (Table 1). Leguminous green plant materials significantly increased soil organic matter and cation exchange capacity and finally improve soil. Cowpea green manure shows the high amount of CEC and organic matter (Table 1). Organic matter produced organic pools in soil which exchanged exchangeable cation from soil solution by sorption mechanism (Dogbe, 2010). There was no significant difference between green manure and control experiment. Pieters and McKee (1938) and Biswas and Mukherjee (1991) stated that improved organic matter in soil through reduced erosion and incorporation of organic material.

The pH of green manure incorporated soil ranged from 7.80 to 8.23 whereas control had 7.67 pH (Table 1). Green manure crop incorporated organic matter in the soil which produced organic acid. Therefore, pH became lower. Yard long bean showed high acidity in soil than others (Table 1). Green manure crop incorporated organic matter and it induced acidity *i.e.* pH become lower except when counterbalanced by high concentration of basic cations (FitzPatrick, 1986). Soil pH was decreased by only slightly by green manure (Hunter *et al.,* 1997).

This result showed that green manure decreased the C: N ratio in soil than other treatment (Table 1). Cowpea (*Vigna unguiculata*) shows lowest C: N ratio than others. In leguminous green manure plants C: N ratio closing to 25:1 was found (Brady, 1990).

Conclusion

The exchangeable bases N, P, K, S, Ca, Mg, B and Zn are increased by the incorporation of green manure because it increases available nutrients in soil by initiating a more acidic condition in root zone and root exudation. Therefore, pH is decreased because acidity reduces pH. Green manures soak up potentially-leachable nutrients thus tightening up the on-farm nutrient cycle and add organic matter and other nutrients by its decomposition. The nutrients are then held by the green manure until it is turned under. During decomposition, the nutrients will be released to the following crop (Biswas and Mukherjee, 1991). C:N ratio of green manure varied from 19.78 to 29.62 and average 34.94 value was observed in control experiment. Nitrogen was also fixed from *Rhizobia* bacteria as a process of nodulation in root system (Piper, 1950). Organic matter enhancement eventually initiates CEC enhancement. C: N ratio was less than 25:1 because more N is found by green manure application. It is more suggestive that extra time of decomposition are often more effective to release nutrients from complex organic compounds to labile form. Basically, more nutrients are usually released in the next cropping season (Hunter *et al.,* 1997). When green manure is choosing to grow, then the more functions the green manure can perform the better which are more ideal for cultivation. Research showed that cowpea (*Vigna unguiculata*) green manure initiates more effective result than other treatments.

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