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Effect of poultry manure and inorganic fertilizer on the productivity of cotton

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Abstract The effect of poultry manure combined with inorganic NPKS fertilizers at the rate of deficient to recommended to excessive on cotton yield and yield contributing characters was conducted at three cotton research farms located in Jagadishpur, Jessore; Sadarpur, Dinajpur and Sreepur, Gazipur in 2012-13 growing period. The performance of six treatments viz. T_1 (without fertilizer), T_2 (recommended doses of inorganic fertilizer, i.e. 104-45-138-22 kg NPKS ha^{-1} respectively), T_3 (75% of recommended doses of inorganic fertilizer), T_4 (75% of T_2 + 2 t ha^{-1} poultry manure), T_5 (75% of T_2 + 4 t ha^{-1} poultry manure) and T_6 (75% of T_2 + 6 t ha^{-1} poultry manure) were investigated in RCB design with 3 replications. The main effect of treatment was found significant for vegetative branch, fruiting branch and plant height at harvest, boll number and seed cotton yield. While, the location effect was found significant on vegetative branch, fruiting branch and plant height at harvest, boll number, individual boll weight and seed cotton yield. The interaction effect of treatment × location was found significant for boll number and seed cotton yield. Application of poultry manure significantly increased the cotton yield and yield contributing characters. The highest seed cotton yield at Sreepur and Sadarpur farms were obtained from 2 t ha^{-1} poultry manure and at Jagadishpur farm from 4 t ha^{-1} poultry manure together with 75% recommended dose of NPKS fertilizers. With the increase of poultry manure rate the seed cotton yield decreases. Besides, the NPKS use efficiencies and benefit cost ratio varied from location to location for different treatments.

Key words: Poultry manure, inorganic fertilizers, productivity, cotton.

Introduction

Cotton is an important cash crop in Bangladesh as well as the main raw materials of textile industry. The present yield of cotton per hectare is lower in comparison to other cotton growing countries. Bangladesh has low average yields (450 kg lint ha^{-1}) compared to the world average (761 kg lint ha^{-1}). Soil fertility stress is an important factor for the lower cotton yield in Bangladesh. Supplying optimal quantities of mineral nutrients of macro and micronutrients to growing crops is one way to improve crop yields (Zubillage *et al.,* 2002). Over the past four decades only the uses of inorganic fertilizers have been incorporated into production practices. The availability of mineral nutrients in the soil solution depends on many factors such as pH, soil organic matter and fertilizer application. Depleted soil nutrient status under intensive cultivation, will not sustain the productivity in the long run, unless they are replenished timely with both organic and inorganic sources. Organic materials hold great promise due to their local availability as a source of multiple nutrients and ability to improve soil characteristics. According to several authors the improvement of fertility and quality of soil requires the input of organic materials (Stamatiadis *et al*., 1999; Palm *et al*., 2001; Soumare *et al*., 2003).

The poultry industry is growing rapidly in Bangladesh. It is reported that at an average rate 1.2-1.7 tons of poultry litter is generated per thousands of broilers (Grimes *et al.,* 2006). Poultry litter, composed of manure and bedding materials, is generated as a byproduct of the chicken production industry. There is a growing concern that the indiscriminate disposal of poultry litter could cause non-point water contamination through NO_3 -N leaching and ground water eutrophication with runoff P (Liebhardt *et al.,* 1979; Pratt, 1979; Sharpley *et al.,* 1991; Sallade and Sims, 1992). It contains many of the plant nutrients and is widely used as a fertilizer, a sustainable way of poultry waste management. Poultry litter has proven to be an effective fertilizer for agronomic and horticultural crops (Sistani *et al*., 2008; Tewolde *et al*., 2008; Demir *et al*., 2010). However, the yield performance of cotton fertilized with poultry litter in Bangladesh is not yet investigated. Thus, the determination of cotton fertilized with poultry manure vs. conventional inorganic fertilizer with rates that range between deficient to sufficient to excess is vital.

Materials and Methods

The experiment was conducted in the three research farms of Cotton Development Board located at Sreepur, Gazipur; Sadarpur, Dinajpur and Jagadishpur, Jessore in 2012-2013. The soil properties of experiment sites are described in Table 1.

The performance of two doses of inorganic fertilizers and 3 doses of combined inorganic and organic fertilizers were evaluated against control (without fertilizer) in randomized complete block design (RCBD) with three replications. The treatment combination were T_1 (control i.e. without fertilizer), T_2 (recommended doses of inorganic fertilizer, i.e. 104-45-138-22 kg NPKS ha^{-1} respectively), T_3 (75% of recommended doses of inorganic fertilizer), T_4 (75% of T_2 + 2 t ha^{-1} poultry manure), T_5 (75% of T_2 + 4 t ha^{-1} poultry manure) and T_6 (75% of T_2 + 6 t ha^{-1} poultry manure) NPKS were applied in 5 splitting at 0 days after sowing (DAS) as basal and 25, 45, 60 and 80 DAS as side dressing in line adjacent to cotton line. Before seed sowing, 10% of recommended dose of N (104 kg ha^{-1}), 40% of recommended dose of P (45 kg ha^{-1}), 10% of recommended dose of K (138 kg ha^{-1}) and 30% of recommended dose of S (22 kg ha^{-1}) were applied. At 25 DAS, 10% of N and 15% of K were applied. 30% of N, 30% of P, 25% of K and 40% of S were applied at 45 DAS followed by 30% of N, 30% of P, 30% of K and 30% S were applied at 60 DAS. Remaining NPKS, 20% of N, 20% of K were applied at 80 DAS. Similarly, 75% of recommended doses of NPKS were applied in different plots according to the treatments. Poultry manure was applied at the rate of 2, 4 and 6 t ha^{-1} according to the treatments. The chemical properties of the poultry manure used in the experiment are given in Table 2.

The unit plot size was 4.5m × 4.5m and the plant spacing was 90cm × 45cm. Two or three seeds were sowing per hill. Though, after final thinning one seedling per hill was allowed to grow. Intercultural operations such as weeding, thinning, gap-filling, earthling-up, irrigations, insects and pest management were done in all plots uniformly. Cotton yield contributing characters such as plant height, number of vegetative and fruiting branches per plant, number of effective boll per plant, single boll weight were recorded from 10 randomly selected plants and seed cotton yield was recorded from each plot. Statistical analysis was done by Cropstat (2007).

Table 1. Soil properties of experiment sites

Location	Soil Texture	Organic matter (%)	pH	N (%)	P (μg g^{-1})	K(meq (100g^{-1})	S (μg g^{-1})
Sreepur	Clay loam	0.81	5.37	0.06	38.6	0.16	3.81
Sadarpur	Sandy loam	1.03	5.8	0,08	6.90	0.21	3.56
Jagadishpur	Sandy loam	1.03	7.43	0,05	5.90	0.17	12.69

Table 2. Properties of poultry manure used in the experiment

Color	Odour	Organic carbon (%)	pH	N (%)	P (%)	K (%)	S (%)
Grey	Absence of foul odour	19.7	8.5	2.52	1.9	1.14	0.33

The agronomic efficiency of nutrient use was calculated as follows:

$$\text{Nutrient use efficiency (g/g)} = \frac{\text{Yield (T)} - \text{Yield (C)}}{\text{Quantity of applied nutrient}}$$

Where, T and C denote treatment and control plots respectively.

Benefit cost ratio was computed for each treatment considering the cost of fertilizer and gross return from seed cotton yield using the following equations:

$$\text{Benefit Cost Ratio} = \frac{\text{Gross return (Ti)} - \text{Gross return (T1)}}{\text{FC (Ti)} - \text{FC (T1)}}$$

Where, Ti= T2, T3… T6 Treatments, T1= Control treatment, FC= Fertilizer cost

Results

The output of Analysis of Variance (ANOVA) is presented in Table 3. The main effect of treatment was found significant for vegetative branch, fruiting branch and plant height at harvest, boll number and seed cotton yield. While, the location effect was found significant on vegetative branch, fruiting branch and plant height at harvest, boll number, individual boll weight and seed cotton yield. The interaction effect of treatment × location was found significant for boll number and seed cotton yield.

Table 3. ANOVA (P-values) of cotton yield and yield contributing characters

SOV	df	Vegetative branch plant^{-1}	Fruiting branch plant^{-1}	Plant height at harvest (cm)	Boll number plant^{-1}	Individual boll wt. (g)	Seed cotton yield (tha^{-1})
Treatment (T)	5	0.000	0.002	0.055	0.000	0.890	0.000
Replication (R)	2	0.283	0.983	0.462	0.098	0.507	0.472
Location (L)	2	0.000	0.000	0.009	0.000	0.001	0.000
T×R	10	0.213	0.639	0.662	0.285	0.084	0.342
R×L	4	0.171	0.962	0.555	0.283	0.600	0.704
T×L	10	0.056	0.467	0.707	0.000	0.054	0.003

Vegetative Branches per plant: Significant variations were observed for number of vegetative branches per plant as a consequence of fertilizer effect (Fig. 1). The lowest number of vegetative branch was obtained from unfertilized treatment that significantly increased with fertilizer application. However, the number of vegetative branch did not differ significantly from 75% of recommended doses to 100% recommended dose of inorganic NPKS fertilizers. The highest number of vegetative branch per plant was obtained from the treatment containing poultry manure although the increasing rate of poultry manure from 2 t ha^{-1} to 6 t ha^{-1} did not significantly increase the number of vegetative branch per plant. The location had significant effect on vegetative branch per plant (Fig. 2). The significantly highest vegetative branch was observed at Sadarpur Farm (3.03 plant^{-1}).

Fruiting Branches per plant: The effect of treatment on number of fruiting branch per plant is given in Fig. 3. The significantly lowest number of fruiting branch was found in treatment of without fertilizer. However, the different rates of inorganic fertilizer and poultry manure did not significantly affected the fruiting branch number.

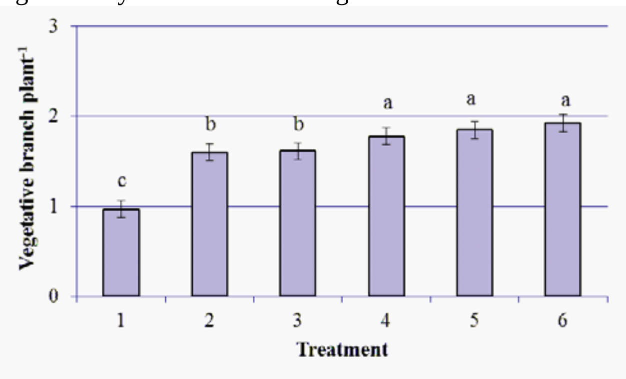

Fig. 1. Effect of poultry manure and inorganic fertilizer on vegetative branch plant^{-1} (T_1 (control i.e. without fertilizer), T_2 (recommended doses of inorganic fertilizer, i.e. 104-45-138-22 kg NPKS ha^{-1} respectively), T_3 (75% of recommended doses of inorganic fertilizer), T_4 (75% of T_2 + 2 t ha^{-1} poultry manure), T_5 (75% of T_2 + 4 t ha^{-1} poultry manure) and T_6 (75% of T_2 + 6 t ha^{-1} poultry manure); dissimilar letters indicate significant differences (p<0.05), error bar represents the standard error.)

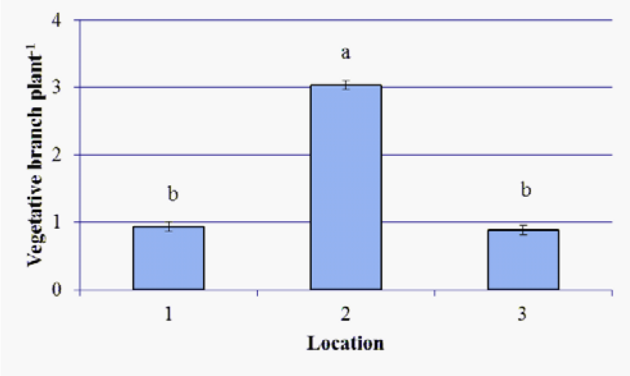

Fig. 2. Effect of location on Vegetative branch plant^{-1} (1- Sreepur Farm, 2- Sadarpur Farm, 3- Jagadishpur farm Dissimilar letters indicate significant differences ($p<0.05$), values are means (n=18), Error bars are ± standard error).

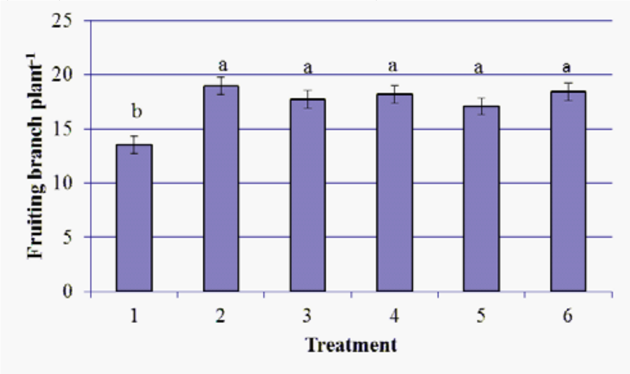

Fig. 3. Effect of poultry manure and inorganic fertilizer on fruiting branch plant^{-1} at Sadarpur Farm (T_1 (control i.e. without fertilizer), T_2 (recommended doses of inorganic fertilizer, i.e. 104-45-138-22 kg NPKS ha^{-1} respectively), T_3 (75% of recommended doses of inorganic fertilizer), T_4 (75% of T_2 + 2 t ha^{-1} poultry manure), T_5 (75% of T_2 + 4 t ha^{-1} poultry manure) and T_6 (75% of T_2 + 6 t ha^{-1} poultry manure); dissimilar letters indicate significant differences ($p<0.05$), error bar represents the standard error).

Bolls per plant: The interaction effect of treatment × location on boll per plant is given in Table 4 and Fig. 4. In three locations, the lowest number of boll per plant was obtained from control treatment. With the increasing rate of inorganic NPKS the boll number per plant increased. Application of 2 t ha^{-1} poultry manure together with 75% recommended dose of inorganic NPKS fertilizer gave the highest number of boll in both Sreepur and Sadarpur farm and further increasing rate of poultry manure decreased the boll number per plant. While at Jagadishpur Farm, the highest number of boll per plant was obtained from applying 4 t ha^{-1} poultry manure together with 75% of recommended NPKS rate and further increase of poultry manure rate decreased the number of boll per plant.

Single boll weight: Likewise other parameter, single boll weight was not varied significantly among the treatments though the addition of fertilizer increases its weight. The effect of location was found significant for individual boll weight (Fig. 5). The highest individual boll weight (5.12g) was obtained from Sadarpur Farm. The individual boll weight at Sreepur and Jagadishpur farms were 4.52 and 4.12 respectively.

Plant height: The significantly lowest mean plant height (81.8 cm) was obtained from control treatment (Fig. 6). However the different combination of inorganic fertilizer and poultry did not significantly affect plant height although the highest plant height (108.1 cm) was obtained from the highest does of poultry manure 9 6 t ha^{-1}) together with 75% of recommended dose of inorganic NPKS fertilizer. The effect of location on plant height is presented in Fig. 7. The lowest mean plant height (88.5 cm) was obtained at Sreepur farm that increased to 99.3 cm at Jagadishpur farm. The highest plant height was recorded in Jagadishpur farm (109.2 cm).

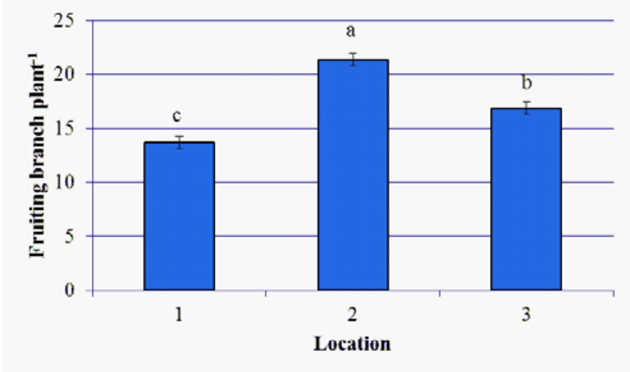

Fig. 4. Effect of poultry manure and inorganic fertilizer on fruiting branch plant^{-1} at Sreepur Farm (1- Sreepur Farm, 2- Sadarpur Farm, 3- Jagadishpur farm; dissimilar letters indicate significant differences ($p<0.05$), Error bars are ± standard error).

Table 4. Treatment × Location interaction effect on number of boll plant^{-1}

Treatment	Sreepur	Sadarpur	Jagadishpur
1	19.0g	22.0efg	12.3h
2	24.1defg	30.8bc	26.2cde
3	23.1efg	23.8defg	25.1def
4	24.3defg	41.5a	23.7defg
5	22.0efg	41.3a	28.9bcd
6	19.6fg	33.5b	29.2bcd

Dissimilar letters indicate significant differences ($p<0.05$).

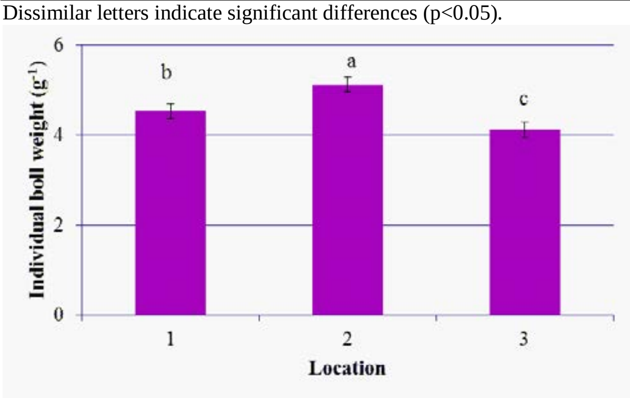

Fig. 5. Effect of location on individual boll weight (1- Sreepur Farm, 2- Sadarpur Farm, 3- Jagadishpur farm; dissimilar letters indicate significant differences ($p<0.05$), Error bars are ± standard error).

Seed cotton yield: The interaction effect of treatment × location on seed cotton yield (kg ha^{-1}) is given in Table 5. In Sreepur, Sadarpur and Jagadishpur farms; the lowest seed cotton yields were obtained from control treatment and with the increasing rate of inorganic NPKS fertilizers, the seed cotton yield increased significantly. Application of 2 t ha^{-1} poultry manure together with 75% recommended dose of inorganic NPKS fertilizers gave the highest seed cotton yield both the Sreepur and Sadarpur farms and further increasing rate of poultry manure decreased the seed cotton yield. While at Jagadishpur Farm, the highest seed cotton yield was obtained from 4 t ha^{-1} poultry manure together with 75% recommended dose of inorganic NPKS fertilizers and further increase of poultry manure quantity the seed cotton yield decreased.

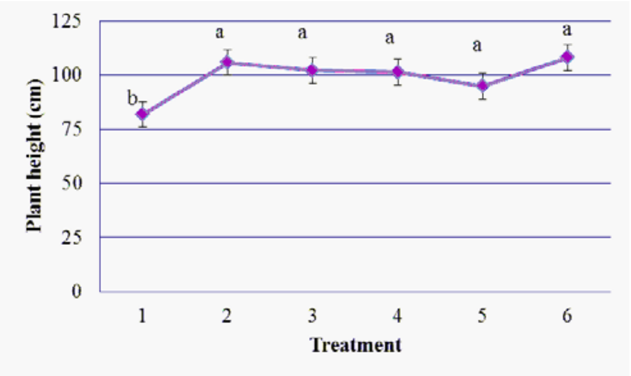

Fig. 6. Effect of treatment on plant height (T_1 (control i.e. without fertilizer), T_2 (recommended doses of inorganic fertilizer, i.e. 104-45-138-22 kg NPKS ha^{-1} respectively), T_3 (75% of recommended doses of inorganic fertilizer), T_4 (75% of T_2 + 2 t ha^{-1} poultry manure), T_5 (75% of T_2 + 4 t ha^{-1} poultry manure) and T_6 (75% of T_2 + 6 t ha^{-1} poultry manure); dissimilar letters indicate significant differences (p<0.05), error bar represents the standard error).

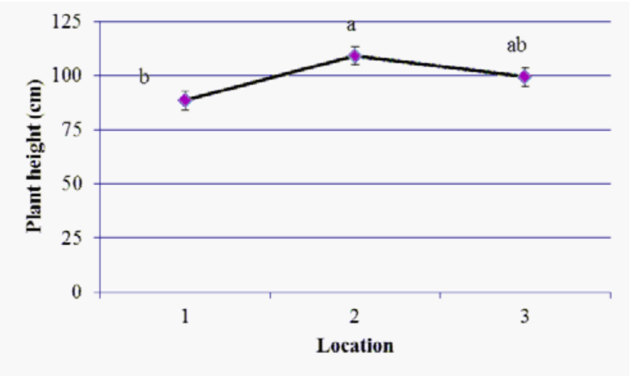

Fig. 7. Effect of location on plant height (1- Sreepur Farm, 2- Sadarpur Farm, 3- Jagadishpur farm; dissimilar letters indicate significant differences (p<0.05), Error bars are ± standard error).

Table 5. Interaction effect of treatment × location on seed cotton yield (kg ha^{-1})

Treatment	Sreepur	Sadarpur	Jagadishpur
1	1975h	2979def	1097i
2	2644efg	4222ab	2400fg
3	2536efg	3605bc	2167gh
4	2665efg	4460a	2373fgh
5	2323gh	4024ab	3401cd
6	2149gh	4049ab	3113cde

Dissimilar letters indicate significant differences (p<0.05).

Nutrient use efficiency: The agronomic efficiency of NPKS use by cotton is given in Figures 8, 9, 10 and 11 respectively that differed from location to location and treatment to treatment. In Sreepur and Jagadishpur farm, the highest N use efficiencies (7.2 and 13.7 respectively) were obtained from 75% of recommended dose of N fertilizer that decreased with the increasing rate of N. In Sadarpur farm, the highest N use efficiency was obtained from 100% of recommended dose of N and further increase of N dose decreased the nutrient use efficiency.

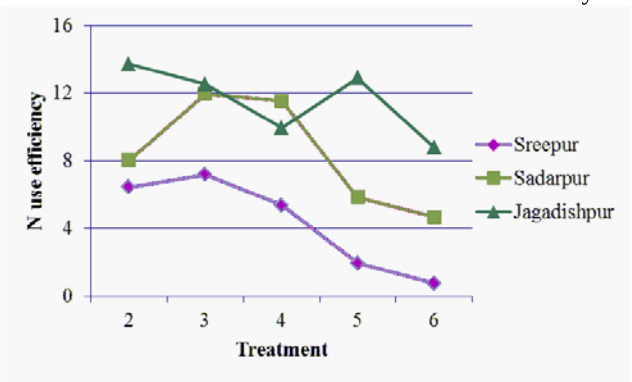

Fig. 8. Effect of poultry manure and inorganic fertilizer on cotton N use efficiency

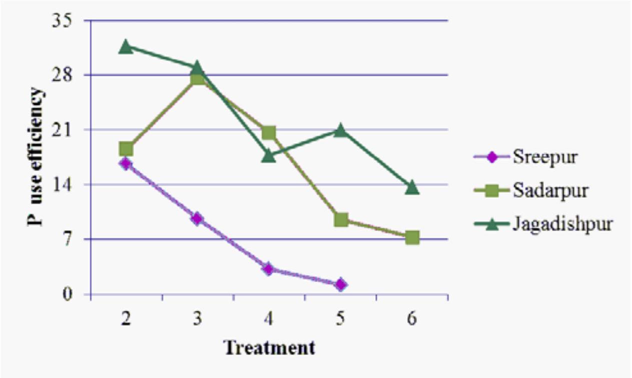

Fig. 9. Effect of poultry manure and inorganic fertilizer on cotton P use efficiency

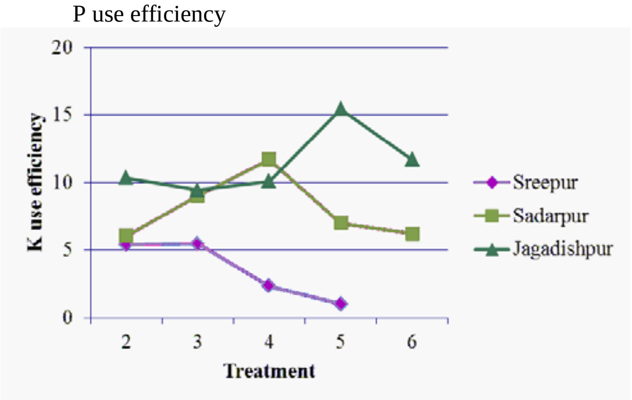

Fig. 10. Effect of poultry manure and inorganic fertilizer on cotton K use efficiency

The lowest N use efficiencies viz. 0.8, 4.7 and 8.8 were obtained at Sreepur, Sadarpur and Jagadishpur farm respectively from treatment 6 that contained the highest quantity of N. Similarly, the highest values of P use efficiency were 16.6 and 31.7 that obtained from treatment 3 and the lowest values were 1.2 and 13.6 that obtained from treatment 6 at Sreepur and Jagadishpur farm respectively. The highest values of K use efficiency were 5.5 and 11.7 that obtained from treatment 4 at Sreepur and Sadarpur farm respectively. The highest K use efficiency was obtained 15.5 at Jagadishpur farm from treatment 5. The highest efficiency of S use was obtained from 75% of recommended dose at Sreepur that decreased with the increasing rate of S with the lowest 4.8 in treatment 6. In Sadarpur Farm, S use efficiency obtained from 75% of recommended dose of fertilizer was 37.9 that increased to 64.1 at treatment 4 and decreased again with the increasing rate of S to 29.5 in treatment 6. The highest S use efficiency at Jagadishpur farm was obtained 77.6 from treatment 5 and the lowest 55.2 from treatment 4.

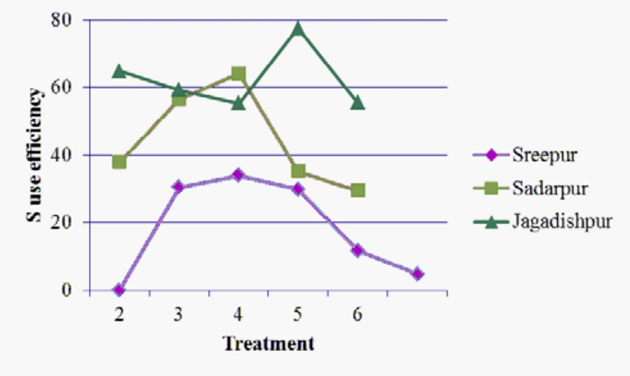

Fig. 11. Effect of poultry manure and inorganic fertilizer on cotton S use efficiency.

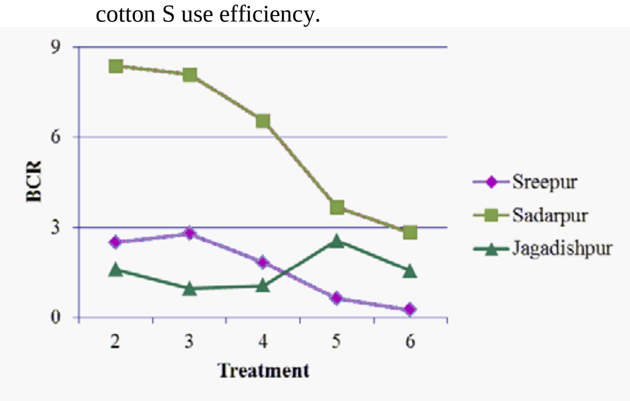

Fig. 12. Benefit cost ratio of treatments used in this experiment

Benefit cost ratio: The benefit cost ratio of various treatments used in the experiment is given in Fig. 12. In Sreepur farm, the highest BCR (2.8) obtained from 75% of recommended dose of fertilizer that decreased with the increasing rate of NPKS. In Sadarpur farm, the highest BCR (8.4) was obtained from the 100% of recommendation dose of NPKS that decrease with the increasing rate of NPKS. In Jagadishpur farm, the highest BCR (2.6) was obtained from treatment 5 that decreased with decreasing or increasing rate of NPKS.

Discussion

Efficient agronomic management of poultry manure requires information on its contribution to the nutrient budget of the soil-crop system. In this regard, the timing of nutrient mineralization from the organic fraction of the manure is important.

The primary source of N in poultry manure is NH_4^+. Under field conditions, the nitrification process converts NH_4^+ to NO_3^- (Reddy *et. al*., 2007). Nitrification inhibitors are capable of delaying the conversion of NH_4^+ to NO_3^- (Rao, 1996), which enhances the availability of nitrate N to the plants for a longer period (Touchton and Bosewell, 1980; Burmester, 1993; Crawford and Chalk, 1993).

The importance of environmental conditions such as temperature, water, and aeration on microbial activities and consequently N turnover is well documented (Paul and Clark, 1989; Griffin and Honeycutt, 2000). Soil water content has great impact on the decomposition and transformation of nutrients (Doel *et al.*, 1990).

In a wide range of soils, maximum aerobic microbial activities occur when 60% of the soil pore spaces are filled with water (Linn and Doran, 1984). The transformation processes of N from a specific animal manure are controlled largely by three factors: soil water status, soil type, and soil temperature (Hadas *et al.*, 1983; Griffin *et al.*, 2002, Sistani *et al*., 2008).

The three farms of CDB located in three different agro-ecological zone of Bangladesh. Besides, the physiographic and chemical properties of experiment soil differed from one to another that induced variable mineralization rates of available nutrient in the applied poultry manure.

The nutrition requirements for cotton growth are mostly from soil supply during growing stages and nitrogen, phosphorus and potassium are very important nutrient elements for cotton growth and development (El-Zahi *et al.*, 2012).

Besides, the increase in cotton yield due to application of gypsum as source of sulphur has been obtained in several cotton growing areas of the world (Mathews, 1972; Mascagni *et al.*, 1991; Tandon, 1995, Makhdum *et al.*, 2001).

Mullins and Burmester (1990) and Unruh and Silvertooth (1996) reported that the cotton crop contains about 22.7-25.0 kg N bale^{-1}. Deficiency of N in cotton can reduce both vegetative and reproductive growth and induce premature senescence leading to potential yield loss (Gerik *et al*., 1994). Alternatively, excess N promotes vegetative development often at the expense of reproductive development, especially at bloom or at early boll fill (Mullins and Burmester, 1990; Tewolde and Fernandez, 1997; Howard *et al.*, 2001; Grima *et al*., 2007).

In our experiment, the beneficial effect of applied inorganic fertilizer and poultry manure observed in the inorganic fertilizer and poultry manure applied plots in respect of control plot due to the availability of adequate nutrient elements while as the reduction of seed cotton yield and yield contributing characters were associated with the excessive nutrients.

Fertilizer nutrients applied, but not taken up by the crop, are vulnerable to losses through leaching, erosion or they could be temporarily immobilized in soil organic matter, all of which impact nutrient use efficiency (Roberts, 2008).

Fertilizer use efficiency/ NUE depend upon the right rate, right time, and right method of application and sources (Bangroo *et al*., 2011). The low nutrient use efficiency may be attributed to fertilizer overuse and high nutrient loss (Fan, 2012). Similarly, in our experiment, the lower nutrient efficiency can be explained by the deficient or higher rates of applied nutrient (NPKS) elements.

In Bangladesh, cotton cultivation requires high quantity of NPKS fertilizers and the requirements are only me by inorganic fertilizer. On the other hand, indiscriminate disposal of poultry litter is growing concern although it contains valuable plant nutrients. Our study suggested that inorganic fertilizer use can be replace with the use of poultry manure in cotton cultivation that simultaneously reduce the risk of environment pollution due to the indiscriminate disposal of poultry litter.

References

Bangroo, S.A., Nazir, S. and Wani, M. A. 2011.Nutrient Water Plant Interactions vis-à-vis Input Use Efficiencies. Research Journal of Agricultural Sciences, 2(1): 185-190.

Burmester, C. H. 1993. Cotton production guide. Alabama cotton notes. Alabama Cooperative Extension Service, Auburn University, Alabama.

Crawford, D.M. and Chalk, P. M. 1993. Sources of N uptake by wheat (*Triticum aestivum* L.) and N transformation in soil treated with nitrification inhibitor. Plant Soil, 149:59-72.

Demir, K., Sahin, O., Kadioglu, Y.K., Pilbeam, D.J. and Gunes, A. 2010. Essential and non-essential element composition of tomato plants fertilized with poultry manure. Sci. Hortic. (Amsterdam) 127:16–22.

Doel, D.S., Honeycutt, C.W. and Halteman, W.A. 1990. Soil water effects on the use of heat units to predict crop residue carbon and nitrogen mineralization. Biol. Fert. Soils 10:102–106.

El-Zahi, E.S., Arif, S.A., Jehan, B.A., El-Naggar and Madeha, E.H. 2012. Inorganic Fertilization of Cotton Field-Plants In Relation To Sucking Insects and Yield Production Components of Cotton Plants. Journal of American Science. 8(2): 509-517.

Fan, M., Shen, J., Yuan, L., Jiang, R, Chen, X., Davies, W.J. and Zhang, F. 2012. Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China. Journal of Experimental Botany, 63(1): 13-24.

Gerik, T.J., Jackson, B.S., Stockle, C.O. and Rosenthal, W.D. 1994. Plant nitrogen status and boll load of cotton. Agron. J. 86:514-518.

Girma, K., Teal, R. K., Freeman, K. W., Boman, R. K. and Raun, W. R. 2007. Cotton Lint Yield and Quality As Affected by Applications of N, P, and K Fertilizers The Journal of Cotton Science 11:12–19.

Griffin, T.S. and Honeycutt, C.W. 2000. Using growing degree days to predict nitrogen availability from livestock manures. Soil Sci. Soc. Am. J. 64:1876–1882.

Griffin, T.S., Honeycutt, C.W. and He, Z. 2002. Effects of temperature, soil water status, and soil type on swine slurry nitrogen transformations. Biol. Fert. Soils 36:442–446.

Grimes, J., Carter, T. and Godwin, J. 2006. Use of a Litter Material Made From Cotton Waste, Gypsum, and Old Newsprint for Rearing Broiler Chickens. Poultry Science 85:563–568.

Hadas, A., Bar-Yosef, B., Davidov, S. and Sofer, M. 1983. Effect of pelleting, temperature, and soil type on mineral nitrogen release from poultry and dairy manures. Soil Sci. Soc. Am. J. 47:1129–1133.

Howard, D.D., Gwathmey, C.O., Essington, M.E., Roberts, R.K. and Mullen, M.D. 2001. Nitrogen fertilization of no-till cotton on loess-derived soils. Agron. J. 93: 157-163.

Liebhardt, W.C., Golt, C. and Turpin, J. 1979. Nitrate and ammonium concentration of ground water resulting from poultry manure applications. J. Environ Qual. 8:99-125.

Linn, D.M. and Doran, J.W. 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and non-tilled soils. Soil Sci. Soc. Am. J. 48: 1267–1272.

Makhdum, M. I., Malik, M. N. A., Chaudhry, F. L. and Uddin, S. 2001. Effects of Gypsum as a Sulphur Fertilizer in Cotton (*Gossypium hirsutum* L.) Production. Int. J. Agri. Biol. 3(4):375-377.

Mascagni, H.J., Sabbe, W.E., Maples, R.L., Terhune, M.E. and Miley, W.N., 1991. Influence of sulphur on cotton yield on a sandy soil. Proc. Beltwide Cotton Conf., pp. 928–30. National Cotton Council, Memphis, T.N. USA.

Matthews, G.A. 1972. Effects of nitrogen, sulphur, phosphorus and boron on cotton in Malawi. Expt. Agric. 8: 219–24.

McGrath, S., Maguire, R.O., Tracy, B.F. and Fike, J.H. 2010. Improving soil nutrition with poultry litter application in low-input forage systems. Agron. J. 102:48–54.

Mullins, G.L. and Burmester, C.H. 1990. Dry matter, nitrogen, phosphorus and potassium accumulation by four cotton cultivars. Agron. J. 82:729-736.

Palm, A.C., Gachengo, C.N., Delve, R.J., Cadisch, G. and Giller, K.E. 2001. Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. Agric. Ecosys. Environ. 83:27–42.

Paul, E.A. and Clark, F.E., 1989. Soil Microbiology and Biochemistry. Academic Press, Inc., New York.

Pratt, F.P. 1979. Management restrictions in soil application of manure. J. Anim. Sci. 48:134-43.

Rao, S.C. 1996. Evaluation of nitrification inhibitors and urea placement in no-tillage winter wheat. Agron. J. 88: 904-908.

Reddy, K. C., Malik, R. K., Reddy, S.S. and Nyakatawa, E.Z. 2007. Cotton growth and yield response to nitrogen applied through fresh and composted poultry litter. The Journal of Cotton Science. 11:26-34.

Roberts, T. L. 2008. Improving Nutrient Use Efficiency. Turk J. Agric. For. 32: 177-182.

Sallade, Y.E. and Sims, J.T. 1992. Evaluation of thiosulphate as a nitrification inhibitor for manures and fertilizers. Plant Soil. 147:283-291.

Sharpley, A.N., Troeger, W.W. and Smith, S.J. 1991. The measurement of bioavailable phosphorus in agricultural runoff. J. Environ. Qual. 20:235-238.

Sistani, K.R., Sikora, F.J. and Rasnake, M. 2008. Poultry litter and tillage influences on corn production and soil nutrients in a Kentucky silt loam soil. Soil Tillage Res. 98:130–139.

Soumare, M., Tack, F.M.G. and Verloo, M.G. 2003. Effects of a municipal solid waste compost and mineral fertilization on plant growth in two tropical agricultural soils of Mali. Bioresour. Tech. 86:15–20.

Stamatiadis, S., Doran, J.W. and Kettler, T. 1999. Field and laboratory evaluation of soil quality changes resulting from injection of liquid sewage sludge. App. Soil Ecol. 12: 263–272.

Tandon, H.L.S. 1995. Sulphur in Indian Agriculture: Update 1995. Sulphur in Agriculture. 19: 3–8.

Tewolde, H. and Fernandez, C.J. 1997. Vegetative and reproductive dry weight inhibition in nitrogen and phosphorus deficient Pima cotton. J. Plant Nutr. 20:219-232.

Tewolde, H., Shankle, M.W., Sistani, K.R., Adeli, A. and Rowe, D.E. 2008. No-till and conventional-till cotton response to broiler litter fertilization in an upland soil: Lint yield. Agron. J. 100:502–509.

Touchton, J.T. and Bosewell, F. C. 1980. Performance of nitrification inhibitors in the south east. In: j. J. Meisinger (ed.), Nitrification inhibitors: potential and limitation. ASA Spec. Publ. ASA and SSSA, Madison, WI.

Unruh, B.L. and Silvertooth, J. C. 1996. Comparisons between and Upland and Pima Cotton Cultivar: II. Nutrient uptake and partitioning. Agron. J. 88:589-595.

Zubillaga, M.M., Aristi, J.P. and Lavado, R.S. 2002. Effect of phosphorus and nitrogen fertilization on sunflower (*Helianthus annus* L) nitrogen uptake and yield. J Agron Crop Sci. 188: 267–74.