**DOI: 10.1515/cerce-2017-0037**
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

**Original Article**

**Cercetări Agronomice în Moldova**
**Vol. L , No. 4 (172) / 2017: 75-84**

# STATUS OF *DHAINCHA* INCORPORATED SOIL AFTER RICE HARVEST IN (*BORO*) RICE–*DHAINCHA*–RICE (T. *AMAN*) CROPPING PATTERN

**SONTOSH C. CHANDA[1], A.K.M. GOLAM SARWAR[1,*]**

*E-mail: drsarwar@bau.edu.bd

Received Aug. 19, 2017. Revised: Oct. 17, 2017. Accepted: Oct. 27, 2017. Published online: Dec. 27, 2017

**ABSTRACT.** An experiment was conducted at Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, to find out the effect of *dhaincha* incorporation on subsequent rice crop yield and post-harvest soil nutrient status. The experiment was laid out in a randomized complete block design having three replications. Nine *dhaincha* accessions were used as experimental materials along with a control (without *dhaincha* plant). Seeds of *dhaincha* accessions were sown in experimental plot @ 60 kg ha$^{-1}$. Sixty days old *dhaincha* plants were mixed up with soil. Soil samples were collected twice, before sowing of *dhaincha* seeds and after rice crop harvest. Forty five days old healthy rice seedlings were transplanted in the well prepared *dhaincha* incorporated plots at the spacing of 15 cm x 25 cm (plant-plant x row-row). The pH and nutrient status were improved in *dhaincha* incorporated soil over the control. The highest grain yield (5.81 t ha$^{-1}$) was obtained from *dhaincha* Acc. 33 incorporated plot followed by Acc. 25 (5.73 t ha$^{-1}$) and the lowest in control (4.35 t ha$^{-1}$). Due to the incorporation of *dhaincha* biomass in soil, the rice grain yield increased 7.82% to 33.56% over the control. Among the *dhaincha* accessions, number 33 showed the best performance in terms of influencing grain yield. A precise conclusion to be built up through collection of large number of germplasms from Bangladesh is needed.

**Keywords:** *Dhaincha* incorporation; grain yield; rice; residual nutrient status.

## INTRODUCTION

Bangladesh, one of the most densely populated countries of the world, faces great challenges of food and nutritional security as a result of socioeconomic and climate change (Osmani *et al*., 2016). To meet the ever increasing food demand, farmers are compelled to go for intensive

1 Laboratory of Plant Systematics, Department of Crop Botany, Bangladesh Agricultural University Mymensingh, Bangladesh

cereal crop cultivation (Dhaka *et al*., 2015), following rice-rice and/or rice-rice-rice based cropping pattern. Therefore, soil fertility and organic matter reduction have emerged as major threats to crop production (Rahman *et al*., 2013), and cultivable land loses its productivity day by day (Alam & Salahin, 2013). Due to intensive land use without green/organic manure, soil fertility has caused exhaustion in Bangladesh. In this situation, physical and nutritional characteristics of cultivable lands in Bangladesh become worse and crop production is moving downward (Anonymus, 2012). Green manure crops like *dhaincha* (*Sesbania* spp.) cultivation may be one of the best options to overcome this situation. Green manure is the ideal source of organic matter, which influences on the crop production quality and soil fertility (Hemalatha *et al*., 2000; Sarwar *et al*., 2017).

*Dhaincha* is the cheapest green manure crop and available source of organic matter (Sarwar *et al*., 2017). It is sometimes cultivated in some places of Bangladesh during monsoon season, following (*Boro*) rice-fallow (*Dhaincha*)-rice (T. *Aman*) or (*Boro*) rice-fallow (*Dhaincha*)-winter vegetables cropping pattern. *Dhaincha* is an ideal green manure crop, quick growing, succulent, easily decomposable and produce maximum amount of organic matter, as well as nitrogen in soils (Palaniappan & Siddeswaran, 2001). It enhances soil physical properties and water holding capacity, reduces the leaching of nutrients from the soil, and increases the crop yield (Heering, 1995; Abro & Abbasi, 2002). Sixty days old *dhaincha* [*S. bispinosa* (Jacq.) W.F. Wight] crop may produce up to 80 t $ha^{-1}$ total dry mass in the monsoon season of Bangladesh (Chanda *et al*., 2017). Sarwar *et al*. (2017) also reported that the increment of rice grain yield was 7% to 39% in *dhaincha* incorporated soil with the recommended doses of PKS fertilizers over the control (no green manure). Moreover, rice grain yield increased 32% to 77% over the control due to (*dhaincha*) green manure incorporation with different doses of NPK fertilizers application (Ehsan *et al*., 2014; Noor-A-Jannat *et al*., 2015). Most of the published research reports are based on effect of *dhaincha* incorporation on soil nutritional status and succeeding crop yield (Abro and Abbasi, 2002; Rahman *et al*., 2012; Sarwar *et al*., 2017). However, information on the residual effect of *dhaincha* incorporation in soil after the succeeding crop harvest is scanty (Rahman *et al*., 2013; Ganapathi *et al*., 2014). Based on the aforesaid situation, the objectives of the present study were, therefore, to find out the effect of green manure from different *dhaincha* accessions on subsequent rice crop, and nutritional status of soils after the rice crop harvest.

## MATERIALS AND METHODS

An experiment was conducted at Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural

University, Mymensingh, during the period of May to December 2016. Nine *dhaincha* accessions were collected (and pre-selected based on their biomass yield) from different locations of Bangladesh. The collection information of *dhaincha* accessions is shown in *Table 1*. The experiment was laid out in a randomized complete block design, having three replications. The treatment combinations were incorporation of different *dhaincha* accessions in soil and a control (without incorporation of *dhaincha*). The unit plot size was 2.5 m x 2 m. *Dhaincha* crop was cultivated in the (*Boro*) rice-fallow (*Dhaincha*)-rice (T. *Aman*) cropping pattern. *Dhaincha* seeds (@ 60 kg ha$^{-1}$ and germination percentage above 80% were sown first week of June and 60 days old *dhaincha* plants were incorporated into the soil as green manure before transplanting of *Aman* rice 'BRRI *dhan*49'. Soil samples were collected before the sowing of *dhaincha* seeds (initial/pre-sowing) and after T. *Aman* rice harvest (post-harvest), following standard method. Both the initial and post-harvest soil samples were analyzed and compared with their initial soil nutritional status. Different soil component/nutrients, *viz.* organic matter (OM %), total nitrogen (N %), available phosphorus (P), exchangeable potassium (K), sulfur (S) and soil pH were determined in the Laboratory of Soil Resource Development Institute, Mymensingh, following standard analytical procedures.

**Table 1** - ***Dhaincha* accessions used as green manure and their sources**

| Accession number | Collection information |
|---|---|
| Acc. 25 | Mymensingh, Shikarikanda |
| Acc. 27 | Mymensingh, Chor Gobordia |
| Acc. 33 | Khulna, Dumuria, Badurgacha |
| Acc. 57 | Sirajganj, Kamarpur, Haluakandi |
| Acc. 82 | Sirajgang, Kazipur, Sonamukhi |
| Acc. 87 | Rangpur, Sadar, Panichorahat, Keshobpur |
| Acc. 95 | Gaibandha, Thansinghpur |
| Acc. 96 | Gaibandha, Thansinghpur |
| Acc. 109 | Faridpur, Sadar |
| Control | No. *dhaincha* incorporation |

For rice cultivation, the recommended dose (Urea-Triple Super Phosphate-Muriate of Potash-Gypsum @ 20-7-11-8 kg/*Bigha*, respectively) of TSP, MOP and gypsum fertilizers was applied during final land preparation (BRRI, 2015). Forty five days old healthy rice seedlings were transplanted in the experimental plot at the spacing of 15 cm x 25 cm (plant-plant x row-row, respectively). The standard rice cultivation and management practices were followed (BRRI, 2015). The crop was harvested and data on rice yield and yield contributing descriptors were recorded. Harvest index (%) was calculated using the following formula:

$$\text{Harvest index} = (\text{Economic yield} \div \text{Biological yield}) \times 100$$

Data were analyzed statistically following the analysis of variance (ANOVA) technique, using Statistix 10 software package and means were separated by Duncan's new multiple range test (DMRT) at 5% level of significance.

## RESULTS AND DISCUSSION

Status of soil pH and nutrients, *viz*. OM (%), total N (%), available P, S and exchangeable K value, in initial and post-harvest soils are presented in *Table 2*. Soil pH value ranges from 6.05 to 6.63 (initial) and 5.93 to 6.63 (post-harvest); the pH value changes could be due to the incorporation of *dhaincha* crop in soil. Nierves & Salas (2015) explained that the decomposed organic matter producing humic acid, nitric acid and sulfuric acid those increase the $H^+$ ion in the soil. Rainfall which causes leaching that tends to wash away the basic cations *viz*. $K^+$, $Mg^{++}$ and $Ca^{++}$ those are replaced by acidic cations like $H^+$ making soil acidic. However, microbial activity and root respiration release $CO_2$, which is slightly acidic as a result enhance the acidity of the soil. The increased availability of P, and changes soil pH due to green manure application are also supported by Hundal *et al*. (1987). The soil OM varied from 2.30% to 2.95% at initial stage and 2.71% to 2.98% at post-harvest stage (*Table 2*). Organic matter status increased may be incorporation of *dhaincha* in soil and succeeding crop rice intake nutrients from it. The increase of OM content in soil could also be attributed root growth and crop debris addition after crop harvest (Sarwar *et al*., 2017). Thus crop residual effect increased higher soil nutrients in post-harvest soil. However, OM decreased in control plot (no green manure use) due to rice crop intake nutrient from soil and soil may become exhausted. Rahman *et al*. (2012) found similar result in maize-*dhaincha*-rice cropping pattern. Khalequzzaman *et al*. (2005) opined that OM resulted in the enhancement of organic carbon of the post-harvest soil in excess of the control. The total N status ranged from 0.13 to 0.17 at the initial soil and 0.16 to 0.17 at the post-harvest soil (*Table 2*). The increase in total N content of soil may be the effect of incorporation of *dhaincha* in soil. Green manure may be attributed to the mineralization of soil nutrients from organic matter. Islam *et al*. (2006) reported that nitrogen content increased in *dhaincha* incorporated plot, but static in unincorporated plot.

The available P value in soil varied from 6.08 to 9.45 ppm (initial) and 6.12 to 8.38 ppm (post-harvest) (*Table 2*). Available P value is decreased in the accessions number 25, 27, 33, 82, 95 and 109 incorporated plot. The form and availability of phosphorus in soil is highly depending on soil pH (McKenzie, 2003). In pH values less than 6 create a chemical bond between aluminum (Al) and phosphate; on the other hand, in higher values of soil pH (6-8), adsorption of phosphate ions occur on solid Al or Fe hydroxide (Georgantas & Grigoropoulou, 2006). The P value decrease may be due to the low pH and P fixation in soil. Nierves & Salas (2015) reported that cycling of organic matter is slower due to acidic soil (low soil pH) and the amount of major elements, *viz*. N, P and S, is reduced. Moreover, decomposed organic matter releases organic molecules, which form complex compound with Fe and Al ions and those are also responsible for P fixation (Ghosal *et al*., 2011). Rahman *et al*. (2012) also obtained similar result in maize-*dhaincha*-T. *Aman* cropping system in Bangladesh condition. Exchangeable K level was more or less static or equal in initial and post-harvest soils (*Table 2*). It indicates that the soil (of Mymensingh region) is rich in K minerals content. The S level of soil ranges from 9.29 to 14.35 ppm at initial stage and 11.31 to 13.85 ppm at the post-harvest soil. The available S was increasing in post-harvest soil might be due to the residual effect of *dhaincha* incorporation in soil (*Table 2*). Assefa *et al*. (2014) explained that microorganisms break down organic compounds to acquire organic C for their energy metabolism and S released sulfate as by-product. Moreover, the sulfate releases from sulfate-esters through enzymatic hydrolysis process. The mineralized S and C-bonded are strictly dependent on microbial activity. Sulfate-esters can be readily hydrolyzed by sulfatase enzymes in the soil; however, biochemical mineralization is controlled by the supply of S release from organic matter. Moreover, in *Sesbania* green manured soils, the leaching losses of sulfur were lower, as compared to control (Vaneet & Nayyar, 2000). Those might be the probable causes of increase in S content of *dhaincha* incorporated soils. The use of green manure slightly increased the organic matter, total N, available P, exchangeable K and S in the post-harvest soil reported by Ehsan *et al*. (2014) and Hoque *et al*. (2016). Green manure also contributes to long term residual effects on soil productivity (Becker *et al*., 1995).

Incorporation of *dhaincha* biomass significantly influenced the yield and yield contributing characters of subsequent T. *Aman* rice, as compared to the control (without *dhaincha* incorporation). Plant height, total number of tillers hill$^{-1}$, effective tillers hill$^{-1}$, primary branches panicle$^{-1}$, number of filled grains panicle$^{-1}$, grain yield and straw yield significantly differed, however, panicle length did not differ after biomass incorporation of different *dhaincha* accessions (*Table 3*). The morphological descriptors may be controlled by genetic make-up of the rice cultivars (BRRI, 2015). Sarwar *et al*. (2017) also reported similar results in (*Boro*) rice-*dhaincha*-rice (T. *Aman*) cropping pattern, where *dhaincha* was used as a green manure crop. The tallest plant height (84.90 cm) was found in Acc. 25 and shortest in control (79.40 cm). The highest number of tiller hill$^{-1}$ was recorded in Acc. 33 and lowest in control (*Table 3*). However, highest effective tiller hill$^{-1}$ was found in Acc. 95 and lowest in control.

Table 2 - Initial and post-harvest soil nutrients status of *Dhaincha* incorporated plot

| Treatment | Soil pH | | OM (%) | | N (%) | | P (ppm) | | K (meq/100 g) | | S (ppm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | before | after | before | after | before | after | before | after | before | after | before | after |
| Acc. 25 | 6.30 | 6.63 | 2.64 | 2.84 | 0.15 | 0.17 | 8.55 | 8.21 | 0.08 | 0.08 | 12.11 | 12.53 |
| Acc. 27 | 6.29 | 6.44 | 2.50 | 2.98 | 0.15 | 0.17 | 8.23 | 7.02 | 0.07 | 0.07 | 12.03 | 13.18 |
| Acc. 33 | 6.63 | 6.44 | 2.37 | 2.88 | 0.14 | 0.17 | 9.45 | 7.37 | 0.07 | 0.08 | 12.09 | 13.12 |
| Acc. 57 | 6.45 | 6.21 | 2.91 | 2.84 | 0.17 | 0.16 | 6.08 | 6.12 | 0.07 | 0.07 | 11.46 | 13.07 |
| Acc. 82 | 6.05 | 6.43 | 2.36 | 2.81 | 0.14 | 0.16 | 7.75 | 6.15 | 0.08 | 0.07 | 11.31 | 13.85 |
| Acc. 87 | 6.39 | 6.39 | 2.60 | 2.96 | 0.15 | 0.17 | 7.32 | 8.38 | 0.07 | 0.08 | 11.54 | 13.02 |
| Acc. 95 | 6.25 | 6.29 | 2.78 | 2.74 | 0.16 | 0.16 | 8.67 | 6.22 | 0.07 | 0.07 | 10.64 | 11.31 |
| Acc. 96 | 6.29 | 5.93 | 2.30 | 2.81 | 0.13 | 0.16 | 8.35 | 7.99 | 0.07 | 0.08 | 9.29 | 12.34 |
| Acc. 109 | 6.47 | 6.29 | 2.74 | 2.71 | 0.16 | 0.16 | 8.33 | 7.39 | 0.08 | 0.08 | 14.35 | 11.52 |
| Control | 6.09 | 6.46 | 2.95 | 2.92 | 0.17 | 0.17 | 6.55 | 8.21 | 0.08 | 0.07 | 12.08 | 12.21 |

Table 3 - Yield and yield contributing descriptors of T. *Aman* rice

| Treatment | Plant height (cm) | Total tiller (No.) | Effective tiller (No.) | Panicle length (cm) | Primary branch panicle$^{-1}$ | Filled grain (No.) | Unfilled grain (No.) | Grain yield (g10hill$^{-1}$) | Straw yield (g10hill$^{-1}$) | Harvest index (%) | Grain yield (tha$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Acc. 25 | 84.90a | 8.37abc | 6.53c | 22.17a | 9.57bc | 117.60c | 16.70bcd | 214.79a | 230.11bcd | 48.28 | 5.73 |
| Acc. 27 | 81.17ab | 7.73cde | 6.67bc | 22.30a | 9.13c | 109.33d | 17.67ab | 175.69d | 205.62de | 46.08 | 4.69 |
| Acc. 33 | 82.63ab | 8.67a | 7.20ab | 22.30a | 10.30a | 135.07a | 14.83d | 217.78a | 281.30a | 43.64 | 5.81 |
| Acc. 57 | 81.53ab | 8.10ab | 6.93abc | 22.30a | 9.27bc | 116.30cd | 15.20cd | 188.85c | 219.46cd | 46.25 | 5.04 |
| Acc. 82 | 80.57ab | 7.77b-e | 7.00abc | 21.87a | 9.57bc | 116.50cd | 17.57ab | 200.69bc | 243.86bc | 45.14 | 5.35 |
| Acc. 87 | 82.73ab | 8.37abc | 7.13ab | 22.30a | 9.47bc | 127.43ab | 15.90bcd | 199.67bc | 225.27cd | 46.99 | 5.32 |
| Acc. 95 | 82.53ab | 8.40ab | 7.47a | 23.00a | 9.87ab | 121.23bc | 16.17bcd | 206.57ab | 252.11b | 45.04 | 5.51 |
| Acc. 96 | 82.70ab | 7.67de | 6.83bc | 22.33a | 9.43bc | 120.67bc | 18.93a | 200.71bc | 221.00cd | 47.59 | 5.35 |
| Acc. 109 | 79.73b | 7.70de | 7.23ab | 22.47a | 9.87ab | 118.73c | 17.03abc | 209.10ab | 233.53bc | 47.24 | 5.58 |
| Control | 79.40b | 7.23e | 6.50c | 21.90a | 9.20bc | 108.77d | 16.70bcd | 162.98e | 192.18e | 45.89 | 4.35 |
| LSD | 4.47 | 0.66 | 0.58 | 1.50 | 0.71 | 8.14 | 1.91 | 11.91 | 24.68 | - | - |

The highest number of branch panicle$^{-1}$ was observed in Acc. 33 and lowest in Acc. 27. The highest number of filled grain was recorded in Acc. 33 (135.07) and lowest in control (108.77). It may be occurred due to availability of nutrients released after incorporation of *dhaincha* biomass and other beneficial effect increased grain yield. Millan *et al*. (1985) opined that basal dose of N had been exhausted within 45-50 days and at that time, rice plant is incoming to panicle initiation stage. The incorporation of *Sesbania* spp. in soil influenced plant growth, yield and yield contributing parameters of rice was also reported by Hiremath & Patel (1998). Decomposed organic matter quickly released plant nutrients and transformed available form in soil (Sarwar *et al*., 2017). Plant gets enough nutrients, as a result it showed a vigorous growth and increased grain yield.

The results of present study are in consequence with the results of Sarwar *et al*. (2017). They reported that the highest number of filled grain panicle$^{-1}$, obtained from *dhaincha,* incorporated plot over the control (Rahman *et al*., 2012). However, the highest unfilled grain was counted in Acc. 96 and lowest in Acc. 33.

The highest grain yield (5.81 tha$^{-1}$) was produced in *dhaincha* Acc. 33 incorporated plot, followed by Acc. 25 (5.73 t ha$^{-1}$) and the lowest in control (4.35 t ha$^{-1}$) (*Table 3*). Sarwar *et al*. (2017) found that Acc. 95 (4.00 t ha$^{-1}$) produced highest grain yield, followed by Acc. 96 (3.74 t ha$^{-1}$) and Acc. 87 (3.67 t ha$^{-1}$). Though the accession number 95 simultaneously performed better, no significant yield difference with Acc. 33, this year compared to the previous year experiment (*Table 3*) (Sarwar *et al*., 2017). These variations in grain (and straw) yield, due to incorporation of same *dhaincha* accessions in two consecutive years, may be due to differences in prevailing weather condition during the growing periods. The highest amount of straw also produced in Acc. 33 and lowest in control (*Table 3*). It may occur due to the sufficient nutrients availability in soil from *dhaincha* incorporated plots. The slow released of nutrients from organic matter remains available throughout the growing periods of rice. These results are supported by Rahman *et al*. (2012) and Sarwar *et al*. (2017). They have reported that the highest grain and straw yield of T. *Aman* rice obtained from *dhaincha* incorporated plots over the control. However, harvest index (HI) of rice was higher in Acc. 25 and lower in Acc. 33 (*Table 3*). It may be occurred due to the different nutrients status remains in different *dhaincha* accessions. Due to the incorporation of *dhaincha* green manure in the plot, the rice grain yield increased 7.82% to 33.56% over the control (*Table 3*). The findings are matched with Sarwar *et al*. (2017). They stated that recommended doses of PKS with *dhaincha* green manuring in T. *Aman* plot, grain yield increased 6.60% to 38.89% over the control. In the rice based cropping system, rice grain yield increased 32% to 77% over control due to *dhaincha* incorporation with different doses of NPK fertilizers application (Ehsan *et al*., 2014; Noor-A-Jannat *et al*., 2015). In Indian perspective, the yield of high yielding rice varieties was increased from 0.65 to 3.1 t $ha^{-1}$ due to use of green manure (Singh *et al*., 1991).

## CONCLUSION

The pH value, organic matter and total nitrogen slightly increased, however, available phosphorus and potassium more or less static, and available sulfur increased due to *dhaincha* incorporation in post-harvest soil, compared to initial soil sample. Out of nine *dhaincha* accessions, the accession number 33 incorporation produced the highest grain yield (5.81 t $ha^{-1}$), followed by accession number 25 (5.73 t $ha^{-1}$) and accession number 109 (5.58 t $ha^{-1}$). A precise conclusion to be built up through collection of large number of germplasms from Bangladesh is needed.

**Acknowledgement.** The corresponding author gratefully acknowledges the partial financial supports of Bangladesh Agricultural University Research System (#2014/70/BAU) and the Ministry of Science & Technology, Bangladesh (#39.009.002.01.00.053.2014-2015/BS–27/460) during conduction of this research work.

## REFERENCES

**Abro, M.B. & Abbasi, Z..A. (2002).** Effect of *Sesbania rostrata* (*Dhaincha*) green manure on the yield of rice. *J.Appl.Sci*., 2(7): 768-769.

**Alam, M.K. & Salahin, N. (2013).** Changes in Soil physical properties and crop productivity as influenced by different tillage depths and cropping patterns. *Bangladesh J.Agril.Res*., 38: 289-299.

**Anonymous (2012).** Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council, Farm gate, Dhaka 1215, p. 275.

**Assefa, M.K., von Tucher, S. & Schmidhalter, U. (2014).** Soil sulfur availability due to mineralization: Soil amended with biogas residues. *J. Soil Sci.Environ.Manage*., 5(1): 13-19. DOI:10.5897/JSSEM13.0408

**Becker, M., Ladha, J.K. & Ali, M. (1995).** Green manure technology: potential, usages and limitations, A case study for low land rice. *Plant Soil*, 174: 181-195.

**BRRI (2015).** Modern Rice Cultivation. 18th ed. (In Bangla). *Bangladesh Rice Res. Inst.,* Gazipur. pp. 1-80.

**Chanda, S.C., Prodhan, A.K.M.A. & Sarwar, A.K.M. Golam (2017).** Screening of *dhaincha* accessions based on biomass yield. *Conf. Proc. AGROTECH-2017*, Kalimpong, India. p: 1.

**Dhaka, A.K., Kumar, S., Pannu, R.K., Ramprakash, Singh, B. & Singh, K. (2015).** Yield performance and economics of pearl millet (*Pennisetum glaucum*) influenced in seed crop of *dhaincha* (*Sesbania aculeata*). *Environment and Ecology*, Vol. 33, No.4B, pp.1905-1910.

**Ehsan, S., Niaz, A., Saleem, I. & Mehmood, K. (2014).** Substitution of major nutrient requirement of rice-wheat cropping system through *Sesbania* green manuring. *Sci.Agri.*,

8(3): 99-102. DOI:10.15192/PSCP.SA.2014.4.3.99102

**Ganapathi, D., Shetty Y.V., Pradeep, S., Chidanandappa, H.M., Nawaj, N. & Dhananjaya, B.C. (2014).** Organic farming on productivity of rice and soil fertility under alfisols of southern transition zone of Karnataka, India. In: Rahmann, G. & Aksoy, U. (eds.). *Proc. 4th ISOFAR Sci. Conf. 'Building Organic Bridges', Org. World Cong. 2014,* 13-15 October, Istanbul, Turkey. pp. 635-638.

**Georgantas, D.A. & Grigoropoulou, H.P. (2006).** Phosphorus and organic matter removal form synthetic wastewater using Alum and Aluminum hydroxide. *Global NEST J*., 8(2): 121-130.

**Ghosal, P., Chakraborty, T., & Banik, P. (2011).** Phosphorus fixing capacity of the Oxic Rhodustaf-alfisol soil in the Chotanagpur plateau region of Eastern India. *Agril.Ecol.Res.Unit.,* Indian Stat. Inst., Kolkata, India. 4: 487-490.

**Heering, J.H. (1995).** Botanical and agronomic evaluation of a collection of *Sesbania sesban* and related perennial species. Doctoral Thesis, Wageningen Agril. Univ., Wageningen. The Netherlands, p.127.

**Hemalatha, M., Thirumurugan, V. & Balasubramanian, R. (2000).** Effect of organic sources of nitrogen on productivity, quality of rice (*Oryza sativa*) and soil fertility in single crop in wetlands. *Indian J.Agron*., 45(3): 564-567.

**Hiremath, S.M. & Patel, Z.G. (1998).** Effect of winter green manuring and nitrogen application on summer rice. *Indian J.Agron*., 43: 71-76.

**Hoque, T.S., Akhter, F. & Islam, M.R. (2016).** Residual effects of different green manures on the growth and yield of wheat. *Asian J.Med.Biol.Res*., 2(4): 624-630. DOI: http://dx.doi.org/10.3329/ajmbr.v2i4.31006

**Hundal, H.S., Biswas, C.R. & Vig, A.C. (1987).** The utilization of phosphorus by rice from 32P labeled green manure. *Biol. Wastes*, 22: 97-105.

**Islam, M.S. (2006).** Use of bioslurry as organic fertilizer in Bangladesh agriculture. Inter. *Works. on the use of Bioslurry Domestic Biogas Programme.* Bangkok, Thailand.

**Khalequzzaman, M., Haque, A., Hashem, M.A. & Sattar, M.A. (2005).** Integrated use of various organic sources of nitrogen and urea on growth yield and nutrient uptake by wheat. *J. Bangladesh Soc.Agril.Sci.Tech*., 2(3&4): 157-160.

**McKenzie, R.H. (2003).** Soil pH and plant nutrients. *Agri-Facts. Practical information for Alberta's Agriculture Industry*, pp: 1-2.

**Millan, M.A., Aslam, M. & Khalid, M. (1985).** Fertilizer use efficiency in rice as influenced by organic manuring. *Paper pres. 1st Nat. Cong. Soil Sci.*, 6-8 October, Lahore, Pakistan.

**Nierves, M.C.P. & Salas, F.M. (2015).** Assessment of soil phosphorus and phosphorus fixing capacity of three vegetable farms at Cabintan, Ormoc city, Leyte. *World J.Agril.Res*., 3(2): 70-73. DOI: 10.12691/wjar-3-2-6

**Noor-A-Jannat, Ahmed, S., Abuyusuf, M., Hassan, M.Z., Lipi, N.J. & Biswas, K.K. (2015).** Nitrogen fertilizer after green manuring on the yield of T. *Aman* rice. *American Res.Thoughts,* 1: 2898-2909.

**Osmani, S.R., Ahmed, A., Ahmed, T., Hossain, N., Huq, S. & Shahan, A. (2016).** *Strategic Review of Food Security & Nutrition in Bangladesh*. World Food Programme, Dhaka, Bangladesh.

**Palaniappan, S.P. & Siddeswaran, K. (2001).** Regional overview on green manure in rice-based cropping systems. In: Gowda, C.L.L., Ramakrishna, A., Rupela, O.P. and Wani, S.P. (eds). *Legumes in rice based cropping systems in Tropical*

*Asia: constraints and opportunities*. International Crop Research Institute for Semi-Arid Tropics, Patancheru, India, pp. 126-135.

**Rahman, M.H., Islam, M.R., Jahiruddin, M. & Haque, M.Q. (2012).** Management of organic manure and inorganic fertilizer in the maize-mungbean/*dhaincha*-T. *aman* rice cropping pattern for increased crop production. *Bangladesh J.Agril.Res*., 37(2): 225-234. DOI: http://dx.doi.org/10.3329/bjar.v37i2.11224

**Rahman, M.H., Islam, M.R., Jahiruddin, M., Rafii, M.Y., Hanafi, M.M. & Malek, M.A. (2013).** Integrated nutrient management in maize-legume-rice cropping pattern and its impact on soil fertility. *J. Food Agric. Environ*., 11(2): 648-652.

**Sarwar, A.K.M. Golam, Hossain, S.M.Z. & Chanda, S.C. (2017).** Effect of *Dhaincha* accessions on soil health and grain yield of rice. *J.Biosci.Agric.Res*., 13: 1140-1145.

**Singh, Y., Khind, C.S. & Singh, B. (1991).** Efficient management of leguminous green manures in wetland rice. *Adv.Agron*., 45: 135-189.

**Vaneet, A. & Nayyar, V.K. (2000).** Leaching losses of sulphur in loamy sand and sandy loam soils as influenced by long-term use of *Sesbania* green manure. *J. Indian Soc. Soil Sci*., 48: 38-42.