Asian J. Med. Biol. Res. 2021, 7 (4), 298-311; https://doi.org/10.3329/ajmbr.v7i4.57610

Asian Journal of Medical and Biological Research
ISSN 2411-4472 (Print) 2412-5571 (Online)
https://www.ebupress.com/journal/ajmbr/

Article

Efficacy of different green manuring crops to soil fertility, yield and seed quality of T. aman rice

I.J. Irin[1*], P.K. Biswas[2] and M.A. Khan[3]

Dept. of Agronomy, Khulna Agricultural University, Bangladesh
Dept. of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
Dept. of Soil Science, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh

[*]Corresponding author: I.J. Irin, Assistant Professor, Dept. of Agronomy, Khulna Agricultural University, Bangladesh. E-mail: isratjahankau20@gmail.com

Received: 22 August 2021/Accepted: 23 October 2021/ Published: 30 December 2021

Abstract: A series of experiments were conducted on the Agronomy farm and laboratory of Sher-e-Bangla Agricultural University to demonstrated a promising way of increasing soil organic matter, total N in pre sown and postharvest land by green manure cultivation and reducing the inorganic fertilizer inputs in rice production and finally observed the quality of grown T. aman seed in laboratory condition. Several green manures were found more potential in two years regarding their plant height, dry biomass production and better performance concerning organic matter, nitrogen and potassium contribution to soil and increased rice yield. Morphological characteristics of eight green manure crops were studied and incorporated at 45DAS for decomposition. One month after decomposition of green manure, rice (BRRI dhan66) plant was transplanted with 100% NPK (F_1) and 50% NPK (F_2) and pre sown rice soil, post-harvest soil nutrient statuses were studied. Result showed that Pre shown rice soil increased 0.5 to 0.6% SOM (2nd year), 0.04% soil N (both year) and 0.04% soil K (1st year) which ultimately increase rice yield 62% to 68% (with F1) and 10% to 42% in 1st and 2nd year. Post-harvest soil nutrient status shown the positive balance of (0.1% to 1%) organic matter and total N (0.04% to 0.7%) in the 1st years and 2nd years and P was found drastically increased in 2nd year, respectively. Germination%, germination energy%, seedling length, fresh and dry weight of six month stored rice seedling also found highest from *S. rostata* and *S. aculeata* under laboratory condition. Incorporation of *Sesbania aculeata, S. rostrata, V. unguiculata* and *Crotalaria juncea* as GM with N significantly influenced the grain yield of rice and pre and post-harvest soil.

Keywords: green manuring; soil fertility; dry matter; cotyledon length; radicle length; germination energy percentage, dry weight

1. Introduction

To meet up excessive food demand for increasing population, soil fertility in Bangladesh is declining day by day and the organic matter status of soil is below 1% in more than 60% of total cultivable lands whereas ideal level is 3% (Islam, 2006). Inorganic fertilizers are very expensive to make the soil fertile even though green manure is a very low cost technology in reducing fertilizer costs and increasing soil fertility. Green manure crops are one of the most effective ways to improve the soil. Green manures belonging to the pea and bean family (legumes) have the additional capacity of storing (fixing) nitrogen from the air to their root nodules. Green manure is a glimmer of hope in that aspect as it has the ability to fix atmospheric nitrogen and improves soil fertility. Khind *et al.* (1983) spotted that, when 30, 45 and 60 days old crop with dhaincha (*Sesbania aculeata*) incorporated one day before transplanting of rice the amount of green matter, dry matter accumulation and nitrogen added increased progressively with the increase in age of dhaincha and the increase in the yield with the incorporation of 60 days old dhaincha was equivalent to yield from 120 kg N ha^{-1} through urea. Kumar (2010) opined that dhaincha helps to improve the physical and biochemical structure of the soil, prevent leaching losses of nutrients, enhancing water holding capacity, preventing weed growth, reducing residual effect of chemicals and also helps in reducing the soil borne inoculum of phytopathogens. Growing of green manure crops in the off season reduces weed proliferation and weed growth. Sarwar *et al*. (2017) 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). 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. Noor *et al*. (2015) stated that rice grain yield increased 32% to 77% over the control due to (*dhaincha)* green manure incorporation with different doses of NPK fertilizers application. 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). Pramanik *et al.* (2004) documented the best performance of *Sesbania rostrata* influencing plant height and total number of tillers hill^{-1} of rice and added that the application of various organic manures improved the plant growth of rice and wheat crops. According to Biswas *et al*. (1996), the inclusion of green manure crop in the soil has reduced 50 percent of the recommended N levels for subsequent rice. The introduction of green manure crops not only improves the nitrogen quality of the soil but also helps to reduce the cost of fertilizer. But the lack of financial benefits, the planting of green manure is ignored by many people. But, after harvesting Boro rice, the main field usually remains unploughed for about 2-3 months. This time can be used to grow green manure without sacrificing main crops. To improve soil and crop production, the integration of legume cover crops into planting systems has now been emphasized by tropical farmers (Odhiambo *et al*., 2010). For the above facts, the current experiments were conducted to identify suitable green manure crops and their ability to improve rice yield and soil fertility.

2. Materials and Methods

A group of experiments was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University during April, 2015 to April, 2017 to evaluate the morphological performance of different green manuring crops and its residual effect on rice yield and post-harvest rice soil performances through adding biomass, dry matter, organic matter, N, K and P accumulation and finally stored T. aman seed performance in laboratory. The eight green manure crops viz. Desi dhaincha (*Sesbania aculeata*), African dhaincha (*Sesbania rostrata*), Sunn Hemp (*Crotalaria juncea*), Mungbean (*Vigna radiata*), Blackgram (*Vigna mungo*), Cowpea (*Vigna unguiculata*), Ipil-ipil (*Leucaena leucocephala*) and Mimosa (*Mimosa pudica*) were planted (experiment laid out in a randomized complete block design) from seed and different morphological data were taken at 45 DAS. After 45 DAS, all green manuring crops were incorporated to soil and thirty days after incorporation of green manuring crops, transplant aman (BRRI dhan64) were planted along with two nitrogen Fertilizer doses (100% and 50% NPK fertilizer doses from recommended fertilizer dose of rice). The initial and final soil sample of each experimental plot (0-15 cm) was collected for analyzing soil chemical properties. Two fertilizer doses and eight types of green manures were tested on rice (succeeding crop) in a split-plot design with three replications, where fertilizer doses (100% and 50% recommended doses of urea) was assigned in the main plots and green manure crops (previous crop field) in the sub-plot. The size of each plot was 17.50 m^2 (5m x 3.5m). The experimental plots were fertilized with 20-17.6-24.9 kg N, P and K ha^{-1} from their sources of Urea, TSP and MoP. Different yield contributing average data were taken from rice field. Analyzed statistically by using the Statistic-10 computer package. The mean comparisons of all parameters were done with Tukey’s W- procedure (Gomez and Gomez, 1984).

2.1. Species description

Eight species viz. *Sesbania aculeata, Sesbania rostrata, Crotalaria juncea, Vigna unguiculata, Vigna mungo, Vigna radiata, Leaucena leaucocephala, Mimosa pudica* were selected as green manuring crop species. The leaves of these plants are easily decomposable and reported to contain more protein, and rich source of nitrogen and phosphorus when used as green manure. Total biomass was estimated each time before incorporation. At the age of 45 days, all green manuring plants were harvested, chopped into small pieces incorporated to the individual plot and allowed for decomposition for one month.

2.2. Transplanting of rice seedling

Sprouted of BRRI dhan66 seeds were sown in the wet nursery bed on 13 June 2015 (for 1st experiment) and 5 July 2016 (for 2nd experiment). Proper care was taken to raise the seedlings in the nursery bed. The 30 days old seedlings were uprooted carefully without causing mechanical injury to the roots and were transplanted on 13 July 2015 (for 1st experiment) and 5 August 2016 (for 2nd experiment) in 54 (3× 18) experimental plots those were puddled further with spade on the day of transplanting. Three seedlings were transplanted in each hill with 20 cm and 20 cm spacing between the rows and hills respectively.

2.3. Soil sample collection & soil chemical analysis

Composite soil sample from each plot for the two years were collected in following sequences:

I. Pre-sowing
II. After decomposition of green manure (1st year and 2nd year)
III. Post harvest of Aman rice (1st year and 2nd year) and

All collected samples were sun dried and sieved through a 2mm sieve. The soil samples were analyzed for organic matter, total nitrogen, available phosphorus and exchangeable potassium following standard methods.

3. Results and Discussion

3.1. Morphological characteristics of different green manuring crops

There were significant differences observed in plant height among the green manure crops throughout the growth period in two years (Table 1). At 45 DAS (1st year), *S. rostrata* showed 148% tallest plant height followed by *S. aculeata* (104%), *V. unguiculata* (102%) and *L. leucocephala* (86%) compared to *V. mungo*. In 2nd year, *S. rostrata* and *S. aculeata* showed 8% and 2.9% more plant height whereas *C. juncea* showed 20% more plant height compared to 1st year. On the other hand *V. mungo and V. radiata* showed the shortest plant height in both years. Pramanik *et al.* (2009) also obtained the similar result, reporting higher plant height in *Sesbania* among evaluating different green manuring crops and stated that, *S. rostrata* gave the highest height followed by S. *aculeata* and *C. juncea.* Srivastava and Girjesh (2013) stated that the maximum plant height was observed with *Sesbania* spp. as 111.60 cm at the density level of 50 plants pot^{-1} at 45 DAS.

It was observed that, *S. rostrata, S. aculeata* and *C. juncea* dry biomass yield increased rapidly apparently with the age of the plant compared to other green manuring crops. The highest dry biomass was given by *Crotalaria juncea* that (5.03 t/ha) followed by *Sesbania rostrata* and *Sesbania aculeata*. Singh (1981) also agreed with the findings and reported that the most productive green manure crops yielded about 4-5 tha^{-1} of dry biomass in 50-60 days and cluster bean has generally been less productive than *Sesbania*, sunn hemp, and cowpea in descending order. Zaman *et al*. (1995) opined that in Bangladeshi condition, 60 days old dhaincha (*S. aculeata*) plants produced 5.2 t ha^{-1} dry matters which yielded 135 kg N/ha. There was significant variation on nodule production plant^{-1} observed among green manuring crops at 45 DAS (Table 1). *S. rostrata* and *S. aculeata* produced the highest nodule in both year and it was 42% and 53% higher from 1st year whereas *M. pudica* along with *V. unguiculata, V. mungo and L. leucocephala* produced the lowest nodule in two years. The results was almost similar to the findings of Pramanik *et al*. (2009) who found the highest number of nodules plant^{-1} from *S. aculeata, C. juncea* and *S. rostrata*. Variation of number of nodules plant^{-1} might be due to the individual genetic characteristics of green manure crops.

3.2. Effect of green manuring crops on chemical properties of previous and postharvest rice soil in two years

3.2.1. Soil organic matter

Soil fertility status was monitored from 2015 1017 and found that incorporation of eight diferent green manuring crops (Pre-sown rice soil) increased soil organic matter from 1.01% (initial) to 1.08% in 1st year (2015) and up to 1.61% in 2nd year (2016) (Figure1). The 0.14% higher organic matter was found in T_2 in 2015 and 0.4% to 0.6% was recorded from T_1, T_2 and T_5 in 2016.The cumulative effect of green manuring crops resulted more organic matter compared to previous year due to slow release of nutrients from decaying green manure crops and higher production of biomass from T1 and T2 crops leading to add more organic residues in soil. After harvesting rice, soil organic matter was found higher in 2nd year compared to 1st year (Table 3) and *S. aculeata* (0.7% in F_1 and 0.4% in F_2), *S. rostratra* (0.8%in $F_1$and 0.5% in F_2), *C. juncea* (0.6% in F_1 and 0.5% in F_2) and *L. leucocephala* (0.5% in F_1 and 0.5% in F_2) showed the increased trend compared to control. Microbial activity from incorporation of green manuring crops into the soil leads to the formation of mycelium and viscous materials which benefit the health of the soil by increasing its soil structure, improves water infiltration and retention, aeration. Mann *et al.* (2000) reported that after continuous green manuring of three years, the soil organic matter increased up to 1.09%. Ali *et al.* (2012) found that among green manures, *Sesbania* incorporated plot increased soil organic matter (0.79%) from its initial soil (0.67). It indicated that *Sesbania rostrata and S. aculeata* is much more beneficial to soil health than any other green manures when incorporated along with reduction doses of chemical fertilizer in the T. aman season.

3.2.2. Total N

After green manure incorporation, total N status of soil ranged from 0.04% to 0.084% for the two years (initial level 0.04%) (Figure 2) and the significantly highest amount of total N was observed in T_2 followed by T_6 and the lowest (0.03%) obtained from T_5. Post-harvest soil shown a drastically increased of total N in 2nd year compared to 1st year which was 0.10% to 0.11% (F1 and F2), where *Sesbania* species and *C. juncea* were incorporated into soil with 50% chemical fertilizer (Table 3). These results suggested that green manuring of *Sesbania* would have increased N fertility of soil because of greatest N contents in their biomass and incorporation of green manure into the soil allows the nutrients held within the green manure to be released and made available to the succeeding crops and ultimately reduced fertilizer cost. Moreover, legume crops root system is rich in rhizobium which interacts with green manure to retain atmospheric nitrogen in the soil. Mann *et al*. (2000) reported that *Sesbania* incorporated plot increased soil N (0.60%) from initial soil (0.48%). Rahman *et al*. (2013) stated that total N status of soil ranged from 0.075 to 0.098% (initial level 0.078%) after three years of continuous dhaincha biomass incorporation.

3.2.3. Other nutrients (K and P)

Among other nutrients, K showed slightly increasing trends (0.22meq/100g) in 1st year from initial soil (0.18meq/100g) and the highest K was obtained from T_1 and T_2 followed by T_3 (0.21meq /100g) and T_4 (0.20 meq/100g) that was superior to initial soils (Table 2). In the second year, there was a declining trend shown in K status in soil compared to initial soil which was same in post-harvest soil (Table 4). Increased K availability after green manuring has been reported by Kute and Mann (1969) and Debnath and Hajra (1972). In contrast, Sahu and Nayak (1971) observed a slight decline of K after green manure. In case of P in soil, a declined trend in both years was found compared to initial soil (15.83 ppm). After harvesting of rice, drastically increasing trend (T2>T1>T3>T5>T4>T8>T6) was observed among all green manures with two doses of fertilizer in 2nd year compared to 1st year and *S. aculeata* (7.8 ppm in F_1 and 11.31 ppm in F_2), *S. rostrata* (16 ppm in F_1 and 11.14 ppm in F_2), and *C. juncea* (5 ppm in F_1 and 10 ppm F_2 in), showed the increased P content (Table 4). The above plant matter releases large amounts of carbon dioxide and weak acids that react with insoluble soil minerals to release beneficial nutrients. Soils that are high in calcium minerals, given green manure can generate a higher phosphate in the soil, which in turn acts as a fertilizer. The increase in available P concentration of soil may be due to greater mobilization of native soil P by vigorous root proliferation and contribution through biomass. The excess soil P would help farmers to reduce fertilizer cost. Georgantas and Grigoropoulou (2006) opined that, in pH values less than 6 create a chemical bond between aluminum (Al) and phosphate; whereas in higher values of soil pH (6-8), adsorption of phosphate ions occur on solid Al or Fe hydroxide. The P value decrease might be due to the low pH and P fixation in soil.

3.3. Effect of green manuring crops and nitrogen levels on SPAD and Grain protein content of rice

The SPAD (Soil Plant Analysis Development) value represents the greenness of leaf. SPAD is a tool for measuring leaf chlorophyll content by which plant N level can be indirectly estimated. The SPAD value was recorded from the upper two fully expanded leaves of the main tiller and the average value was recorded. Incorporation of *Sesbania rostrata*, *S. aculeata* and *V. mungo, V. unguiculata*, with N significantly increased the SPAD reading of rice. (Table 5).The maximum SPAD value was found from T_2 (44.47) with 50% N fertilizer which was statistically similar to *V. mungo* (44.47) with 100% fertilizer. The chlorophyll content was increased with the progress of plant age, thereafter it declined regardless of treatments. However, the decreasing trend was slower in GM treated plants as it has the ability to fix atmospheric nitrogen and converts into plant–usable form. It has been reported that higher doses of nitrogen fertilizer showed significantly higher SPAD meter reading at different growth stages of rice (Gholizadeh *et al*., 2009). Green manure might be substitute of the N and other plant nutrients and helped in maintaining the higher chlorophyll content in rice. After 70 days of transplanting, the chlorophyll content was decreased regardless of treatments. This was probably because of the transferring of nutrient elements of the green leaves to the seeds. Chlorophyll meter values were closely related to grain protein content of rice (Table 5). The variation in grain protein content ranged from 7.70% to 8.41% and the highest grain protein (8.54%) was in *S. rostrata* with 50% NPKha^{-1} followed by *C. juncea* (8.235) however the value was statistically similar with other crops when subjected to different NPK levels. The lowest one was recorded in control (7.54%) plot with 50% NPKha^{-1}. Safiqual *et al*. (2015) reported that the maximum nitrogen and protein content in grain was produced when green manuring crops were incorporated, and that amount was higher than fallow with higher dose of nitrogen.

3.4. Effect of green manuring crops and nitrogen levels on 1000-grain weight and yield of rice

The 1000- grain weight was significantly influenced by interaction effect between NPK levels and green manuring crops (Table 6). In both year, the highest grain weight (23.94 g and 24.11g) was obtained from the treatment combination of the variety *S. rostrata* with 100% NPK ha^{-1} which was statistically similar to the same treatments under the 50% NPK ha^{-1} levels (23.87g and 23.54 g in 2015 and 2016 respectively) and the lowest one (22.08 g and 21.36 g) was obtained by the interaction of the control plot 100% NPK level. Many researchers also observed a significant and positive correlation between SPAD values and rice grain yield (Swain and Sandip, 2010). The combined effect of NPK levels and green manuring crops had a significant influence on grain yield (Table 6). The highest grain yield (5.23 t ha^{-1} and 5.56 tha^{-1}) was obtained from the treatment combination of the T2 followed by T1 (5.13 t ha^{-1} and 5.3 tha^{-1}) with 100% NPK fertilizer which was statistically similar to the combination of 50% NPK fertilizer in 2015 and 2016 respectively and the lowest one (3.10 t ha^{-1} and 3.43 tha^{-1}) was obtained by the interaction of the control (absent of green manure) and with F1 and F2. The increased grain yield may be due to more availability of nitrogen and other nutrients to rice crop released by incorporation of same green manure in two consecutive years. The lowest amount (3.42tha^{-1} and 3.70 tha^{-1}) of grain yield was obtained without green manure treated plot in 2015 and 2016 respectively. This result supported by Ehsan *et al.* (2014) who stated that, the rice grain yield increased 32% to 77% over control due to green manure (*dhaincha*) incorporation with different doses of NPK fertilizers application. In addition to the macro-nutrients (N, P, and K), green manuring plants also contains micro-nutrients (e.g. Ca, Mg, Si, and Zn, etc.) (Chen and Zhao, 2009), which may promote and maintain the sustainable nutrients supply to the soil. Efthimiadou *et al*. (2010) found that combining GM with N enhanced the photosynthetic rate and stomatal conductance of rice, and led to increase in the dry matter accumulation as well as rice yield versus N fertilizers alone. These positive effects of GM may be the result of the aboveground and/or belowground plant biomass, with high amount of N and a relatively low carbon-to-nitrogen ratio (C/N), leading to release of plant-available N (Gilmour *et al*., 1998).

3.5. Residual effect of different green manuring crops on stored rice seed germination%, germination energy%, radicle and cotyledon length, fresh weight and dry weight under laboratory condition

The residual effect of green manuring crops on germination of stored rice seeds were not significant (Table 7). Seed vigor as expressed in terms of seedling length was significantly affected by different fertilizer treatments at 11DAG and 13 DAG (Table. 7). Cotyledon lengths were taken after two days interval from germination. The highest cotyledon length was found from *V. unguiculata* and *S. rostrata* followed by *L. leucocephala* whereas control showed the lowest performances at 11DAG and 13DAG (Days after germination).Again radicle length showed the significant difference at 11 DAG and *Sesbania rostrata* gave the highest result. Hossain (2014) stated that, maximum seedling length (18.02 cm) was found in seeds that produced without fertilizers (T_1) which was statistically similar to seed produced under recommended NPKSZn chemical fertilizer dose with green manure 5 t/ha (T_5). The better filling of seeds indicates the better food reserves in the seeds treatments, might have resulted in better quality parameter (Krishna *et al*., 2008). In soil where nutrients are easily available, shoot growth can take more preference over roots. After the establishment phase, seedling growth rate is a function of soil nutrient status (Mishra and Salokhe, 2008). Primary stem length of seeds in laboratory condition was higher that produced with manure (Barea and Azcon, 1978). Interaction effect of fresh weight of seedling shown significant difference at 9 day after germination whereas dry weight of seedling shown significant difference at 9 DAG, 13 DAG and 15DAG. The highest weight was found from *S. rostrata* followed by *V. radiata* with 50% fertilizer dose from 9 DAG to 15 days after germination (Table 8). On the other hand, control plot seed gave the lowest result compared to other plots. In respect of viability, germination and seedling length in BRRI Dhan66, fertilizer along with green manure(F_1T_1, F_1T_2,F_1T_4 and F_1T_7) showed highest performance (Figure 3) and control seed shown disease susceptible (Figure 4).

Table 1. Plant Height (cm), Dry matter (t/h) and number of nodules plant^{-1} of different green manure crops at 45 days after sowing (DAS).

Treatment	Plant Height (cm) at 45DAS		Dry matter (t/h) at 45DAS		Nodule/plant at 45 DAS	
	1st Year	2nd Year	1st Year	2nd Year	1st year	2nd year
T1	181.97ab	186.34ab	4.35bc	4.66a	67.78b	103.76b
T2	220.44a	237.67a	5.03ab	5.2a	158.33a	224.00a
T3	138bc	166.67bO	5.6a	5.2a	32.67b	32.67c
T4	90c	92.44c	2.66d	3.06b	23.33b	24.33c
T5	88.44c	88.44c	2.66d	2.53b	23.00b	21.33c
T6	178.66ab	178.89b	3.86c	2.33b	32.33b	20.00c
T7	166.44ab	165.44b	3.77c	2.6b	21.67b	21.00c
T8	112bc	133bc	2.73d	2.63b	19.33b	20.00c
SE (±)	69.95	58.36	0.713	0.575	20.46	15.82
CV(%)	16.53	12.98	6.46	5.09	3.62	33.19

Here, T_1 = *S. aculeata*, T_2 = *S. rostrata*, T_3 = *C. juncea*, T_4 = *V. radiata*, T_5 = *V. mungo*, T_6 = *V. unguiculata*, T_7 = *L. leucocephala*, T_8 = *M. pudica*
In a column, figure(s) followed by the same letter do not differ significantly at 5% level.

Table 2. Changes of soil fertility status of P and K for the incorporation of different green manuring crops for two year.

Treatments	P (ppm)			K (meq 100g^{-1})		
	Initial soil	1st year	2nd year	Initial soil	1st year	2nd year
T_0	15.83	15.83	8.62	0.18	0.18	0.06
T_1	15.83	12.22	12.51	0.18	0.22	0.12
T_2	15.83	15.00	12.61	0.18	0.22	0.10
T_3	15.83	14.9	12.33	0.18	0.21	0.10
T_4	15.83	11.45	12.31	0.18	0.20	0.11
T_5	15.83	12.09	12.60	0.18	0.18	0.10
T_6	15.83	11.86	12.31	0.18	0.18	0.09
T_7	15.83	12.01	12.64	0.18	0.19	0.16
T_8	15.83	13.54	12.44	0.18	0.20	0.18

Here, T_1 = *S. aculeata*, T_2 = *S. rostrata*, T_3 = *C. juncea*, T_4 = *V. radiata*, T_5 = *V. mungo*, T_6 = *V. unguiculata*, T_7 = *L. leucocephala*, T_8 = *M. pudica*

Table 3. Changes in post-harvest soil nutrient status (OM and total N) of rice soil as affected by green manures and nitrogen levels.

Treatments	**N level (kg/h)**	**Initial Soil**	**Soil Organic Matter (%)**		**Initial Soil**	**Total N (%)**	
			1st year	**2nd year**		**1st year**	**2nd year**
T0	**F1**	**1.01**	1.01	1.00	**0.04**	0.04	0.05
	F2		0.54	1.00		0.05	0.07
T1	**F1**		1.21	1.97		0.06	0.09
	F2		1.41	1.72		0.05	0.10
T2	**F1**		1.02	2.01		0.08	0.11
	F2		1.14	1.77		0.07	0.10
T3	**F1**		1.14	1.80		0.06	0.11
	F2		1.03	1.77		0.08	0.10
T4	**F1**		1.08	1.80		0.05	0.10
	F2		0.81	1.72		0.05	0.10
T5	**F1**		1.75	1.56		0.09	0.09
	F2		0.87	1.72		0.05	0.10
T6	**F1**		0.87	1.72		0.05	0.10
	F2		1.21	1.56		0.04	0.09
T7	**F1**		0.94	1.76		0.05	0.11
	F2		0.94	1.77		0.05	0.10
T8	**F1**		0.94	1.23		0.05	0.11
	F2		**0.87**	1.51		0.06	0.08

Here, F1 = Recommended dose for N in 2015 and NPK in 2016, F2 = Half of recommended dose for N in 2015 and NPK in 2016, T0=Control, T1=*S. aculeata*, T2=*S. rostrata*, T3=*C. juncea*, T4=*V. radiata*, T5=*V. mungo*, T6=*V. unguiculat a*, T7=*L. leucocephala*, T8=*M. pudica,* In a column, figure(s) followed by same letter do not differ significantly at 5% level

Table 4. **Changes in post-harvest soil nutrient status (K and P) of rice as affected by green manures and nitrogen levels.**

Treatments	**N levels (kg/ha)**	**Soil K (meq 100g^{-1})**		**Available P (ppm)**	
		2015	**2016**	**2015**	**2016**
Control	F1	0.09	0.10	3.00	23.40
	F2	0.09	0.09	3.06	21.86
S. aculeata	F1	0.10	0.079	4.33	31.20
	F2	0.10	0.10	3.67	33.17
S. rostrata	F1	0.11	0.16	4.71	39.00
	F2	0.09	0.10	3.92	33.00
C. juncea	F1	0.10	0.10	4.59	28.00
	F2	0.10	0.10	3.91	31.51
V. radiata	F1	0.10	0.11	4.14	27.97
	F2	0.09	0.10	3.27	27.04
V. mungo	F1	0.10	0.06	3.89	30.77
	F2	0.10	0.10	3.06	27.70
V. unguiculata	F1	0.10	0.07	3.91	26.00
	F2	0.09	0.09	3.27	23.00
L. leucocephala	F1	0.10	0.09	4.22	24.00
	F2	0.11	0.10	3.44	22.44
M. pudica	F1	0.10	0.10	4.11	27.38
	F2	0.12	0.08	3.72	22.00

Here, F1= Recommended dose for N in 2015 and NPK in 2016, F2= Half of recommended dose for N in 2015 and NPK in 2016

Table 5. Effect of green manuring crops and nitrogen levels on leaf chlorophyll content (SPAD value) and protein content (%) of T. aman rice.

Interactions	SPAD value (%)		Protein content (%)
	1st year	2nd year	2nd year
F1 T0	43.83	36.71	7.85cd
F1 T1	42.28	39.05	8.17a
F1 T2	43.07	36.76	8.28a
F1 T3	40.35	38.70	8.23a
F1 T4	39.37	38.93	8.04a
F1 T5	44.40	38.43	8.40ab
F1 T6	42.58	38.36	8.10a-c
F1 T7	42.94	36.10	8.09a-c
F1T8	40.93	36.53	8.26a-c
F 2T0	40.28	37.65	7.54d
F2 T1	42.21	36.60	8.21a-c
F2 T2	44.47	36.60	8.54a
F 2 T3	43.40	36.33	8.22a-c
F2 T4	42.57	36.66	8.04a-d
F2 T5	42.74	37.33	8.15a-c
F 2T6	41.64	37.66	8.06a-d
F 2 T7	43.00	36.33	8.01b-d
F 2T8	40.52	36.33	8.20a-c
SE (±)	NS	NS	0.056
CV (%)	6.37	5.64	1.99

Here, F1= Recommended dose for NPK, F2= Half of recommended doses of NPK, Here, T0=Control, T1=*S. aculeata*, T2=*S. rostrata*, T3=*C. juncea*, T4=*V. radiata*, T5=*V. mungo*, T6=*V. unguiculat a*, T7=*L. leucocephala*, T8=*M. pudica*, NS = Not Significant. In a column, figure(s) followed by same letter do not differ significantly at 5% level.

Table 6. **Interaction effect of fertilizer levels and different green manuring crops on grain yield, straw yield and 1000-grain weight of transplant aman rice in two years.**

Interactions	Grain yield (tha^{-1})		1000-grain wt. (g)	
	1st year	2nd year	1st year	2nd year
F1 T0	3.10f	3.43b	21.36b	22.08b
F1 T1	5.13a-c	5.20a	23.38ab	23.91a
F1 T2	5.23a	5.56a	24.11a	23.94
F1 T3	4.93a-d	5.30a	23.56ab	23.69a
F1 T4	3.56f	4.73a	22.78ab	23.41ab
F1 T5	4.20a-f	4.73a	22.59ab	22.92ab
F1 T6	4.76a-d	5.13a	23.08ab	23.85a
F1 T7	3.96b-f	4.76a	23.23ab	23.50ab
F1T8	3.80d-f	4.83a	23.50ab	23.75a
F2T0	3.68d-f	3.97ab	22.86ab	23.07ab
F2 T1	4.86a-d	5.30a	23.07ab	23.53a
F2 T2	5.16ab	5.11a	23.54ab	23.87a
F2 T3	4.43a-e	5.13a	23.60ab	23.80a
F2 T4	3.90d-f	4.45ab	23.26ab	23.51a
F2 T5	3.93d-f	4.26ab	22.73ab	23.39ab
F2T6	4.73a-e	5.03a	21.71ab	23.44ab
F2 T7	4.26a-f	4.53ab	21.88ab	23.26ab
F2T8	4.66a-e	4.13ab	23.33ab	23.33ab
(SE (±)	**0.283**	**0.296**	**0.663**	**0.340**
CV (%)	**8.87**	**8.06**	**3.63**	**1.96**

Here, F1= Recommended dose for N in 2015 and NPK in 2016, F2= Half of recommended dose for N in 2015 and NPK in 2016

Here, T0=Control, T1=*S. aculeata*, T2=*S. rostrata*, T3=*C. juncea*, T4=*V. radiata*, T5=*V. mungo*, T6=*V. unguiculat a*, T7=*L. leucocephala*, T8=*M. pudica*, NS = Not Significant

In a column, figure(s) followed by same letter do not differ significantly at 5% level.

Table 7. Interaction effect of fertilizer levels and green manuring crops on seed quality characteristics of rice seed under laboratory condition.

ntInteractions	Germination %	Germination energy (%)	Cotyledon length (cm)				Radicle length (cm)			
			9DAG	11DAG	13DAG	15DAG	9DAG	11DAG	13DAG	15DAG
F1 T0	86.67	40.00	2.30	2.61c	4.05b	5.30	5.01	5.74bcd	5.63	5.78
F1 T1	98.33	55.00	3.20	3.86a-c	4.62ab	5.28	5.40	6.30a-d	6.46	8.00
F1 T2	96.70	66.66	3.20	4.88ab	7.16a	7.63	6.13	7.56a-c	8.00	9.13
F1 T3	91.67	48.33	3.03	4.05a-c	5.63ab	5.98	5.55	6.36a-d	7.53	8.06
F1 T4	88.33	45.00	2.51	4.53a-c	5.98ab	6.06	5.56	7.10a-d	7.46	7.93
F1 T5	98.33	66.66	3.10	4.70ab	5.61ab	6.05	5.66	6.32a-d	6.73	6.57
F1 T6	98.33	48.33	2.80	4.56a-c	5.42ab	5.90	4.97	6.60a-d	7.46	7.23
F1 T7	95.00	58.33	2.96	4.70ab	5.30ab	5.67	4.86	7.13a-d	6.83	7.26
F1T8	88.33	56.66	3.26	4.36a-c	5.17ab	5.20	5.76	6.17a-d	6.00	6.30
F 2T0	89.17	45.00	2.42	2.76bc	4.10ab	4.20	3.96	4.94d	5.69	5.84
F2 T1	95.00	80.00	3.63	4.63ab	6.56ab	6.90	5.67	7.70ab	7.66	7.33
F2 T2	96.67	70.00	3.53	4.90ab	5.56ab	6.10	5.98	7.23abc	7.80	7.86
F 2 T3	96.67	53.33	3.37	4.18a-c	5.95ab	5.69	5.97	6.35a-d	6.33	6.95
F2 T4	100.00	58.33	3.10	3.68a-c	4.64ab	4.90	5.40	5.53cd	6.48	6.36
F2 T5	93.33	56.66	2.69	3.39a-c	4.76ab	5.26	4.94	5.10d	6.54	6.17
F 2T6	93.33	63.33	3.61	5.27a	5.44ab	6.45	6.55	6.17a-d	6.93	9.26
F 2 T7	98.33	51.66	3.32	4.64ab	5.92ab	6.28	5.66	6.52a-d	7.50	8.07
F 2T8	100	66.66	2.86	3.83abc	4.83ab	5.35	5.35	6.52a-d	5.60	6.28
LSD(0.05)	NS	NS	NS	1.57	2.79	NS	NS	1.84	NS	NS
CV(%)	5.78	26.29	19.69	11.41	15.98	18.15	16.12	9.70	12.86	21.17

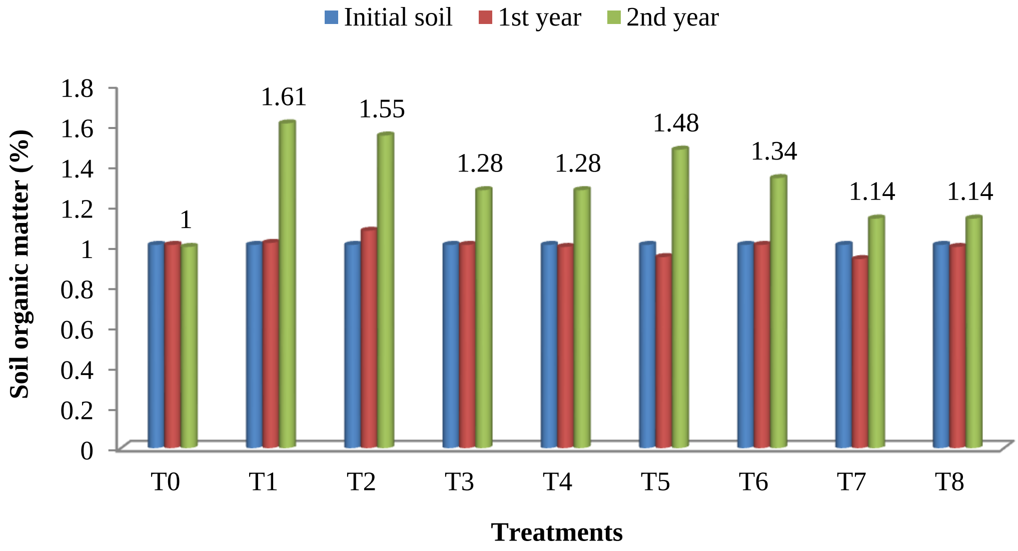
F1 = 100% Recommended fertilizer dose, F2= 50% Fertilizer dose
Here, T0 = Control, T1=*S. aculeata*, T2=*S. rostrata*, T3=*C. juncea*, T4=*V. radiata*, T5=*V. mungo*, T6=*V. unguiculata*, T7=*L. leucocephala*, T8=*M. pudica*
In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly.

Table 8. Interaction effect of fertilizer levels and green manuring crops on seed quality (fresh weight and dry weight) of rice seed.

Interactions	Fresh wt. (g)				Dry wt (g)			
	9 DAG	11DAG	13DAG	15DAG	9DAG	11DAG	13DAG	15DAG
$F_1 T_0$	0.11b	0.175	0.20	0.21	0.03c	0.05	0.05ab	0.05b
$F_1 T_1$	0.15ab	0.19	0.23	0.27	0.05a-c	0.05	0.05ab	0.06ab
$F_1 T_2$	0.21a	0.24	0.29	0.42	0.05a	0.06	0.06ab	0.06ab
$F_1 T_3$	0.16ab	0.19	0.21	0.27	0.04a-c	0.05	0.06ab	0.06ab
$F_1 T_4$	0.20ab	0.23	0.27	0.31	0.04ab	0.05	0.05ab	0.05ab
$F_1 T_5$	0.17ab	0.18	0.26	0.27	0.4a-c	0.05	0.06ab	0.06ab
$F_1 T_6$	0.18ab	0.20	0.24	0.24	0.05a-c	0.05	0.05ab	0.05ab
$F_1 T_7$	0.14ab	0.21	0.23	0.29	0.05ab	0.05	0.06ab	0.06ab
F_1T_8	0.15ab	0.17	0.26	0.27	0.05ab	0.05	0.05ab	0.06ab
F_2T_0	0.12ab	0.17	0.21	0.29	0.039	0.04	0.04b	0.05b
$F_2 T_1$	0.18ab	0.21	0.26	0.27	0.05a	0.06	0.06ab	0.06ab
$F_2 T_2$	0.22a	0.23	0.26	0.24	0.05ab	0.06	0.07a	0.07a
$F_2 T_3$	0.22a	0.21	0.24	0.29	0.05ab	0.05	0.05ab	0.06ab
$F_2 T_4$	0.16ab	0.17	0.24	0.30	0.04a-c	0.05	0.06ab	0.05ab
$F_2 T_5$	0.15ab	0.18	0.23	0.29	0.05a	0.05	0.06ab	0.06ab
F_2T_6	0.18ab	0.22	0.25	0.33	0.04ab	0.05	0.05ab	0.05b
$F_2 T_7$	0.18ab	0.23	0.30	0.32	0.05a-c	0.05	0.05ab	0.05b
F_2T_8	0.17ab	0.18	0.21	0.24	0.05a-c	0.05	0.05ab	0.05ab
(SE (±)	**0.0227**	**NS**	**NS**	**NS**	**3.0E-03**	**NS**	**5E-05**	**4.3E-03**
CV(%)	**17.65**	**16.31**	**18.26**	**26.74**	**8.25**	**11.37**	**10.94**	**9.55**

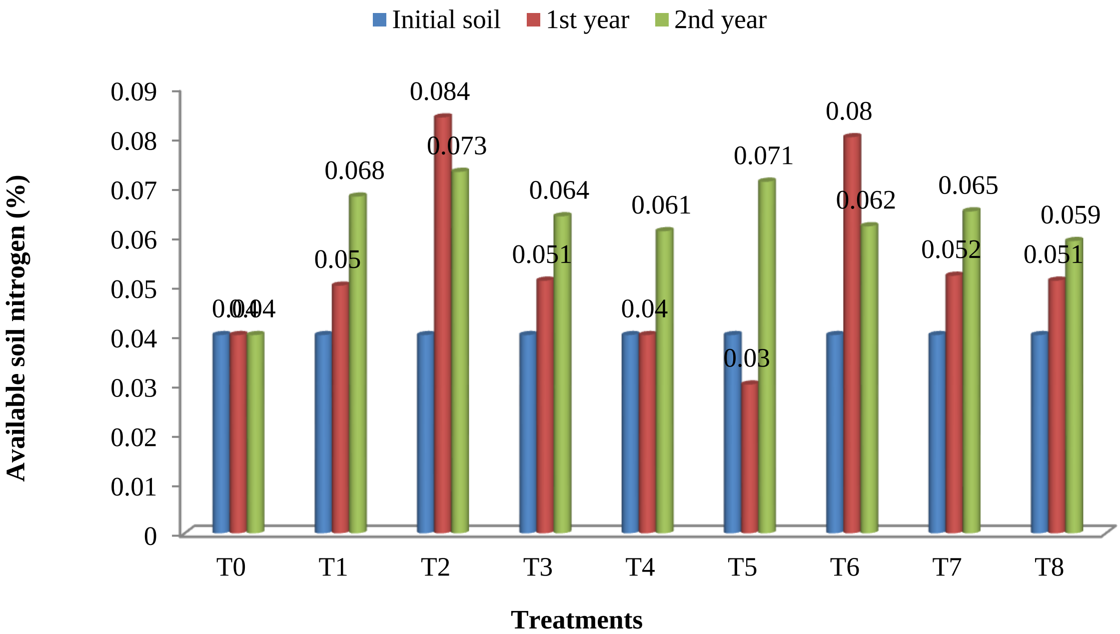
F_1 = 100% Recommended fertilizer dose, F_2= 50% Fertilizer dose, NS= Non Significant, Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*, T_4=*V. radiata*, T_5=*V. mungo*, T_6=*V. unguiculata*, T_7=*L. leucocephala*, T_8=*M. pudica*

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly



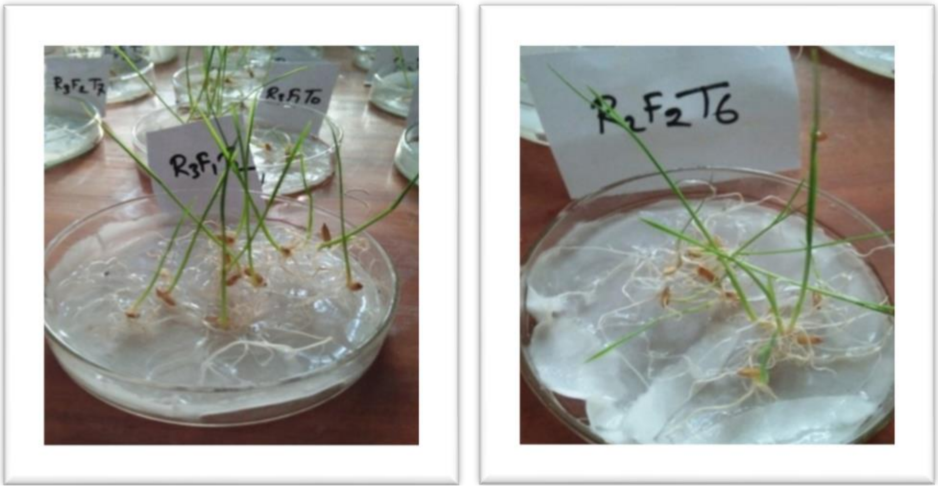
Here, T_1 = *S. aculeata*, T_2 = *S. rostrata*, T_3 = *C. juncea*, T_4 = *V. radiata*, T_5 = *V. mungo*, T_6 = *V. unguiculata*, T_7 = *L. leucocephala*, T_8 = *M. pudica*

Figure 1. Effect of different green manuring crops on organic matter content of pre-sown rice soil.



Here, T_1 = *S. aculeata*, T_2 = *S. rostrata*, T_3 = *C. juncea*, T_4 = *V. radiata*, T_5 = *V. mungo*, T_6 = *V. unguiculata*, T_7 = *L. leucocephala*, T_8 = *M. pudica*

Figure 2. Effect of different green manuring crops on total nitrogen content of pre-sown rice soil.



Sesbania rostrata *Vigna unguiculata*

Figure 3. Vigorous growth of *Sesbania rostrata* and *Vigna unguiculata* treated rice seeds unde laboratory condition.

Control ***S. rostrata***

Figure 4. Comparision between control and *Sesbania rostrata* treated rice seeds under laboratory condition.

4. Conclusions

Among different green manures, *S. rostrata, S. aculeata, C. juncea* and *V. unguiculata* green manures with 50% of recommended chemical fertilizer dose significantly increased rice yield and nutrient added quality in fallow land (pre sown rice soil) and post-harvest soil through adding biomass, N, P and K to the soil. These aforementioned green manures could be practiced in cultivable fallow land (after boro cultivation our land remain fallow for two months) for nitrogen as well as NK fertilizer saving and increased the soil fertility, rice yield and grown T. aman seed quality.

Acknowledgments

The financial support of the authority of Syed Momena Montaj Foundation during research work is gratefully acknowledged.

Conflict of interest

None to declare.

Authors' contribution

I.J. Irin: conceptualization, methodology, data collection, analysis and manuscript writing; P.K. Biswas: supervision, reviewing and editing; M.A. Khan: supervision, reviewing and editing. All authors have read and approved the final manuscript.

References

Ali RI, TH Awan, M Ahmed, MU Saleem and M Akhtar, 2012. Diversification of rice-based cropping systems to improve soil fertility, sustainable productivity and economics. The J. Anim. Plant Sci., 22: 108-112.

Becker M, M Ali, JK Ladha and JCG Ottow 1995. Agronomic and economic evaluation of *Sesbania rostrata* green manure establishment in irrigated rice. Field Crops Res., 40: 135-141.

Biswas TD and SK Mukherjee, 1991. Textbook of Soil Science. Tata McGraw–Hill Publishing Company Limited, New Delhi.

Biswas PK, M Akhteruzzaman, A Quasem and AKMR Amin, 1996. Effect of decomposition period of *Sesbania aculeata* and nitrogen doses on rice yield and soil fertility. Progress. Agric., 7: 107-109.

Caballero R, M Arauzo and PJ Hernaiz, 1996. Accumulation and redistribution of mineral elements in common vetch during pod filling. Agron J., 38: 801–805.

Chen XH and B Zhao, 2009. Arbuscular mycorrhizal fungi mediated uptake of nutrient elements by Chinese milk vetch (*Astragalus sinicus* L.) grown in lanthanum spiked soil. Biol Fertil Soils., 45:675–678.

Chadha M L, TS Brins, HS Sekhon and SK Sain, 2009. Short duration of mungbean for the diversification of the rice-wheat system. Milestones in food legume research. The Peninsular Region. Kanpur. pp. 151-177.

Debnath, NC and V Hajra, 1972. Transformation of organic matter in soil in relation to mineralization of carbon and nutrient availability. India Soc. Soil Sci., 20: 95-102.

Efthimiadou A, D Bilalis, A Karkanis and B Froud-Williams, 2010. Combined organic/inorganic fertilization enhance soil quality and increased yield, photosynthesis and sustainability of sweet maize crop. Aust. J. Crop Sci., 4: 722–729.

Georgantas DA and HP Grigoropoulou, 2006. Phosphorus and organic matter removal from synthetic wastewater using Alum and Aluminum hydroxide. Global Nest J., 8: 121-130.

Gomez KA and AA Gomez, 1984. Statistical Procedure for Agricultural Research. 2nd Ed. Intl. Rice Res. Inst., Manila, Philippines. pp. 139-207.

Gholizadeh A, M Saberioon, L Boruvka, A Wayayok and MAM Soom, 2017. Leaf chlorophyll and nitrogen dynamics and their relationship to lowland rice yield for site-specific paddy management. Inf Process Agric., 4: 259–268.

Gilmour JT, A Mauromoustakos, PM Gale and RJ Norman, 1998. Kinetics of crop residue decomposition: variability among crops and years. Soil Sci. Soc. Amer. J., 62: 750–755.

Islam MS, 2006. Use of bioslurry as organic fertilizer in Bangladesh agriculture. Presentation at the International Workshop on the Use of Bioslurry Domestic Biogas Programmes, Bankok, Thiland.

Jenkinson, DS, RH Fox and JH Rayner, 1985. Interaction between fertilizer nitrogen and soil nitrogen - The so-called "Priming" effect. J. Soil Sci., 36: 425-444.

Khind CB, AS Josan and V Beri, 1983. Age of dhaincha, green matter and nitrogen economy in rice. Int. Rice Res. Newsl., 8: 17.

Kumar R, 2010. Studies on decomposing fungi of *Sesbania aculeata* L. in soil and its effects on soil borne plant pathogens. Ph.D. Thesis, Banaras Hindu University, Varanasi.

Kute SB and HS Mann, 1969. Effect of green manuring on the composition of soil and wheat crop and the balance of major plant nutrients in the soil after crop. Indian J. Agric. Sci., 39: 10-17.

Mann RA, MS Zia and M Saleem, 2000. An improved green manuring technology for sustaining the wheat rice system. Quarterly Sci. Vision., 6: 53.

Mondal U K, G Singh, G US Victor and KL Sharma, 2003. Green manuring: its effect on soil properties and crop growth under rice-wheat cropping system. European. J. Agron., 19: 225-237.

Odhiambo JJO, JBO Ogola and T Madzivhandila, 2010. Effect of green manure-maize rotation on maize grain yield and weed infestation levels. Afr. J. Agric. Res., 5: 618–625.

Paisancharoen K, N Viboonsuk, B Boonyong, C Wongwiwatchai, S Nakaviroj, C Suwan, P Sittibusaya, Kesawapitak and P Sonnas, 1990. Influence of green manures and chemical fertilizer on the yield of 3 cassava cultivars. In: Annual Reports of Soils and Fertilizers on Field Crops. Soil Science Division. Department of Agriculture, Thailand: 296-312.

Palaniappan SP, 1990. In: Proc. International Symposium on National Resources Management for Sustainable Agriculture, 6-10 February, 1990, New Delhi. p. 220.

Pramanik MY, A Sarker, MAR Uddin and GM Fauk, 2009. Effect of phosphorous rate on growth, nodulation and biomass yield of green manure crops. J. Bangladesh Agril. Univ., 7: 23-28.

Rahman MH, MR Islam, M Jahiruddin, MY Rafii, MM Hanafi and MA Malek, 2013. Integrated nutrient management in maize-legume-rice cropping pattern and its impact on soil fertility. J. Food Agric. Environ., 11: 648-652.

Rinaudo G, B Dreyfus and Y Dommergues, 1983. Sesbania rostrata green manure and the nitrogen content of rice crop and soil. Soil Biol. Biochem., 15: 111-113.

Safiqual I, NK Paul, MD Alam, MR Uddin, UK Sarkar and MA Islam, 2015. Responses of Rice to Green Manure and Nitrogen Fertilizer Application. Online J. Bio. Sci., **15**: 207-216.

Sahu BN and BC Nayak, 1971. Soil fertilizer investigation under continuous application of ammonium sulphate alone and in combination with the organic sources in Bhuhaneswar long-term fertility trials. In: Proc. Intl. Symp. Soil Fert. Eval., 1: 873-879.

Salahin N, KM Alam, MM Islam, L Nahar and MN Majid, 2013. Effect of green manure crops and tillage practice on maize and rice yields and soil properties. Aust. J. Crop Sci., 7: 1901-1911.

Sarwar AKMG, SMZ Hossain and SC Chanda, 2017. Effect of Dhaincha accessions on soil health and grain yield of rice. J. Bio. Agric. Res., 13: 1140-1145.

Singh NT, 1981. Green manure is a source of nutrients in rice production. Organic matter and rice. IRRI. Los Banos Philippine, pp. 217-288.

Srivastava N and K Girjesh, 2013. Biomass productivity of green manure crop *Sesbania cannabina* Poir (Dhaincha) in different planting density stress. Int. Res. J. Bio. Sci., 2: 48-53.

Swarup A 1987. Effect of pre-submergence and green manuring (*Sesbania aculeata*) on nutrition and yield of wetland rice (*Oryza sativa* L.) on a sodic soil. Biol. Fert. Soil, 5: 203-208.

Swain DK and SJ Sandip, 2010. Development of SPAD values of medium-and long-duration rice variety for site-specific nitrogen management. J Agron., 9: 38–44.

ZamanSK, NI Bhuiyan and MA Samad, 1995. Age of green manure crops: an important aspect of biomass production and nitrogen accumulation. Bangladesh J. Agric. Sci., 22: 107-112.