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Article

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

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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 (F₁) and 50% NPK (F₂) and pre sown rice soil, post-harvest soil nutrient statuses were studied. Result showed that pre sown 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 Mimosas (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, Leucaena leucocephala, 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 (3x18) 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 t/ha 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 manuring 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 different 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) (Figure 1). The 0.14% higher organic matter was found in T2 in 2015 and 0.4% to 0.6% was recorded from T1, T2 and T3 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 F1 and 0.4% in F2), S. rostratra (0.8% in F1 and 0.5% in F2), C. juncea (0.6% in F1 and 0.5% in F2) and L. leucocephala (0.5% in F1 and 0.5% in F2) 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...
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 T₂ followed by T₃ and the lowest (0.03%) obtained from T₁. 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 T₁ and T₂ followed by T₃ (0.21meq/100g) and T₄ (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 F₁ and 11.31 ppm in F₂), S. rostrata (16 ppm in F₁ and 11.14 ppm in F₂), and C. juncea (5 ppm in F₁ and 10 ppm F₂ 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 T₃ (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% NPK ha\(^{-1}\). 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 24.11 g) 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 (23.87 g 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 t ha\(^{-1}\)) was obtained from the treatment combination of the T2 followed by T1 (5.13 t ha\(^{-1}\) and 5.3 t ha\(^{-1}\)) 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 t ha\(^{-1}\)) 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 (3.42 t ha\(^{-1}\) and 3.70 t ha\(^{-1}\)) 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\(_1\)T\(_1\), F\(_1\)T\(_2\), F\(_1\)T\(_3\) and F\(_1\)T\(_4\)) 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, 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, 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 |
| T0         | 15.83           | 15.83       | 8.62       | 0.18         | 0.18       | 0.06        |
| T1         | 15.83           | 12.22       | 12.51      | 0.18         | 0.22       | 0.12        |
| T2         | 15.83           | 15.00       | 12.61      | 0.18         | 0.22       | 0.10        |
| T3         | 15.83           | 14.9        | 12.33      | 0.18         | 0.21       | 0.10        |
| T4         | 15.83           | 11.45       | 12.31      | 0.18         | 0.20       | 0.11        |
| T5         | 15.83           | 12.09       | 12.60      | 0.18         | 0.18       | 0.10        |
| T6         | 15.83           | 11.86       | 12.31      | 0.18         | 0.18       | 0.09        |
| T7         | 15.83           | 12.01       | 12.64      | 0.18         | 0.19       | 0.16        |
| T8         | 15.83           | 13.54       | 12.44      | 0.18         | 0.20       | 0.18        |

Here, T1 = S. aculeata, T2 = S. rostrata, T3 = C. juncea, T4 = V. radiata, T5 = V. mungo, T6 = V. unguiculata, T7 = L. leucocephala, T8 = 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 (%) | 1<sup>st</sup> year | 2<sup>nd</sup> year | Initial Soil | Total N (%) | 1<sup>st</sup> year | 2<sup>nd</sup> year |
|------------|----------------|--------------|-------------------------|------------------|-----------------|--------------|-------------|------------------|-----------------|
| T0         | F1             | 1.01         | 1.00                    | 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. unguiculata, 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<sup>-1</sup>) 2015 | Available P (ppm) 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  |
| F1 T8        | 40.93          | 36.53               | 8.26a-c  |
| F2 T0        | 42.21          | 36.60               | 8.21a-c  |
| F2 T1        | 44.47          | 36.60               | 8.54a    |
| F2 T2        | 43.40          | 36.33               | 8.22a-c  |
| F2 T3        | 42.57          | 37.33               | 8.15a-c  |
| F2 T4        | 44.57          | 36.60               | 8.04a-d  |
| F2 T5        | 42.74          | 37.33               | 8.15a-c  |
| F2 T6        | 41.64          | 37.66               | 8.06a-d  |
| F2 T7        | 43.00          | 36.33               | 8.01b-d  |
| F2 T8        | 40.52          | 36.33               | 8.20a-c  |

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. unguiculata, 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    | 23.56b   | 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  |
| F1 T8        | 3.80d-f  | 4.83a    | 23.50ab  | 23.75a   |
| F2 T0        | 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  |
| F2 T6        | 4.73a-e  | 5.03a    | 21.71ab  | 23.44ab  |
| F2 T7        | 4.26a-f  | 4.53ab   | 21.88ab  | 23.26ab  |
| F2 T8        | 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. unguiculata, 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.

| Interaction | Germination % | Germination energy (%) | Cotyledon length (cm) 9DAG | 11DAG | 13DAG | 15DAG | Radicle length (cm) 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   |
| F1 T8       | 88.33          | 56.66                  | 3.26                        | 4.36a-c| 5.17ab | 5.20   | 5.76                     | 6.17a-d | 6.00   | 6.30   |
| F2 T0       | 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   |
| F2 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   |
| F2 T6       | 93.33          | 63.33                  | 3.61                        | 5.27a  | 5.44ab | 6.45   | 6.55                     | 6.17a-d | 6.93   | 9.26   |
| F2 T7       | 98.33          | 51.66                  | 3.32                        | 4.64ab | 5.92ab | 6.28   | 5.66                     | 6.52a-d | 7.50   | 8.07   |
| F2 T8       | 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 |
| F₁ T₀        | 0.11b | 0.175 | 0.20  | 0.21  | 0.03c | 0.05  | 0.05ab| 0.05b |
| F₁ T₁        | 0.15ab| 0.19  | 0.23  | 0.27  | 0.05a-c| 0.05  | 0.05ab| 0.06ab|
| F₁ T₂        | 0.21a | 0.24  | 0.29  | 0.42  | 0.05a  | 0.06  | 0.06ab| 0.06ab|
| F₁ T₃        | 0.16ab| 0.19  | 0.21  | 0.27  | 0.04a-c| 0.05  | 0.06ab| 0.06ab|
| F₁ T₄        | 0.20ab| 0.23  | 0.27  | 0.31  | 0.04ab | 0.05  | 0.05ab| 0.05ab|
| F₁ T₅        | 0.17ab| 0.18  | 0.26  | 0.27  | 0.4ab  | 0.06  | 0.06ab| 0.06ab|
| F₁ T₆        | 0.18ab| 0.20  | 0.24  | 0.24  | 0.05a-c| 0.05  | 0.05ab| 0.05ab|
| F₁ T₇        | 0.14ab| 0.21  | 0.23  | 0.29  | 0.05ab | 0.05  | 0.06ab| 0.06ab|
| F₁ T₈        | 0.15ab| 0.17  | 0.26  | 0.27  | 0.05ab | 0.05  | 0.05ab| 0.06ab|
| F₂ T₀        | 0.12ab| 0.17  | 0.21  | 0.29  | 0.039  | 0.04  | 0.04ab| 0.05b |
| F₂ T₁        | 0.18ab| 0.21  | 0.26  | 0.27  | 0.05a  | 0.06  | 0.06ab| 0.06ab|
| F₂ T₂        | 0.22a | 0.23  | 0.26  | 0.24  | 0.05ab | 0.06  | 0.07a | 0.07a |
| F₂ T₃        | 0.22a | 0.21  | 0.24  | 0.29  | 0.05ab | 0.05  | 0.05ab| 0.06ab|
| F₂ T₄        | 0.16ab| 0.17  | 0.24  | 0.30  | 0.04a-c| 0.05  | 0.06ab| 0.05ab|
| F₂ T₅        | 0.15ab| 0.18  | 0.23  | 0.29  | 0.05a  | 0.05  | 0.06ab| 0.06ab|
| F₂ T₆        | 0.18ab| 0.22  | 0.25  | 0.33  | 0.04ab | 0.05  | 0.05ab| 0.05b |
| F₂ T₇        | 0.18ab| 0.23  | 0.30  | 0.32  | 0.05a-c| 0.05  | 0.05ab| 0.05b |
| F₂ T₈        | 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    |

F₁ = 100% Recommended fertilizer dose, F₂ = 50% Fertilizer dose, NS= Non Significant, 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
Here, $T_1 = S. \text{ aculeata}$, $T_2 = S. \text{ rostrata}$, $T_3 = C. \text{ juncea}$, $T_4 = V. \text{ radiata}$, $T_5 = V. \text{ mungo}$, $T_6 = V. \text{ unguiculata}$, $T_7 = L. \text{ leucocephala}$, $T_8 = M. \text{ pudica}$.

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

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

Figure 2. Effect of different green manuring crops on total nitrogen content of pre-sown rice soil.
Figure 3. Vigorous growth of *Sesbania rostrata* and *Vigna unguiculata* treated rice seeds under laboratory condition.

Figure 4. Comparison 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.

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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.

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