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Responses of Rice to Green Manure and Nitrogen Fertilizer Application

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Abstract: The effect of green manure and nitrogen fertilizer applications on rice performance and post-harvest nutrient status of the soil was studied at the Regional Wheat Research Station of Bangladesh Agricultural Research Institute (BARI), Shyampur, Rajshahi, Bangladesh. The experiment comprised two sets of treatments: (i) green manure application (*Crotalaria jusncea, Sesbania aculeata, Sesbania rostrata, Vigna radiata*, and *Phaseolus mungo*) and (ii) application of different nitrogen levels (0, 40, 80, and 120 kg ha^{-1}). Both treatments had a significant effect on the growth and yield of transplanted aman (T. aman) rice. We show that soil fertility can be maintained and rice yield can be improved through incorporation of green manuring and nitrogen fertilizer management. Green manure and nitrogen management generated positive responses in important morpho-physiological traits such as leaf area index (LAI), specific leaf area (SLA), crop growth rate (CGR), leaf relative growth rate (LRGR), leaf weight ratio (LWR), and net assimilation rate (NAR), which may result in a greater contribution of yield-determining traits and eventually higher grain yield. The results indicate that all green manures in combination with higher N levels accelerate SLA, LWR, LAI and CGR. Better performance of potential yield-contributing characters and relatively higher nitrogen uptake and higher N and protein content in grain and straw were found in combination with all green manure and higher N level treatments. An increasing level of post-harvest soil nitrogen content was observed with the application of higher levels of nitrogen in combination with green manures. Therefore, green manuring in combination with judicial nitrogen fertilizer management is deemed necessary for sustainable T. aman rice cultivation.

Keywords: Green Manure, Nitrogen, Growth, Yield, T. Aman Rice

Introduction

The inclusion of summer mungbean, with or without its residue, in a rice-wheat system, helped to increase soil microbial population as compared to fallow. More pronounced effects were observed with residue incorporation. Residue incorporation not only increases the microbial population but also results in more CO_2 evolution and dehydrogenase activity in the uppermost 0-15 cm of the soil. The increased microbial activity later helps in the mineralization and immobilization of nutrients, especially N and P. Previously it was reported that addition of a legume in the rice-wheat system improves soil microbial biomass and activity (IARI, 1995). Green manuring improves the physical condition of the soil when mungbean biomass is incorporated in a rice-wheat-mungbean sequence (IARI, 1995).

Low soil fertility due to organic matter depletion severely affects crop production in Bangladesh (BARC, 2012). Organic matter contributes to soil fertility and productivity through its positive effect on different soil properties. Bangladesh agriculture has moved to a stage

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in which intensive cropping and higher yields per unit area are being increasingly sought. Higher crop yields remove higher quantities of nutrients from the soil. Because of intensive cropping and monoculture of modern varieties of rice, soil fertility declines and deficiencies of nutrients arise. Naturally, all soils contain all nutrients, but their reserves are not similar and unlimited. Nutrients may be depleted because of increased cropping intensity, use of smaller amounts of organic matter, high rainfall, soil erosion, and leaching. Low organic matter content appears to be associated with rapid decomposition of organic matter on the one hand, and very little addition of organic matter on the other. The country's sub-tropical climate and frequent tillage operations for increasing cropping intensity have resulted in enhanced rates of organic matter decomposition. Rijpma and Jahiruddin (2004) reported that the nutrient balance for N is moderately negative, for P is slightly negative, and for K is highly negative in this country's soils.

This undesirable consequence may be overcome by the addition of adequate amounts of organic matter to the soil from different sources such as leaf manure and green manure, compost, cowdung, oilcake, crop residues, and other organic wastes. Inclusion of leguminous green manure in the rice-wheat cropping system enhanced and sustained rice production in the wet season (IRRI, 1988). The addition of green manure alone can help to make soil fertile, but the combined application of green manure and nitrogenous fertilizer increases the yield of rice further, as well as the availability of NPK in the soil and the nutrient uptake capacity of rice plants (Tiwari *et al*., 1980). If green manuring is applied along with nitrogenous fertilizer, it helps to release nutrient elements slowly during the whole period of crop growth (Singh *et al*., 1990). In another study it was found that addition of green manure in combination with chemical fertilizers produced a higheryield than did a single application of chemical fertilizer alone (Aktar *et al*., 1993). Thus, an integrated use of green manure and chemical fertilizer is needed to supply the nutrients needed to obtain a higher rice yield. Fertilizer is a major input in modern farming since about 50% of the world's crop production depends on this input (Pradhan, 1992). However, sustainable higher crop production cannot be maintained by using inorganic fertilizers alone, nor it is possible to obtain higher crop yields by using only organic manure. In this context, integrated plant nutrient management with a combined use of inorganic and organic sources of nutrients can be a good approach to combat nutrient depletion and promote sustainable crop production. Therefore, the aim of our work was to develop a package of organic and inorganic components and to understand the effect of those components on the growth and yield of transplanted aman (T. aman) rice, as well as to study their influence on post-harvest soil nutrient status.

Materials and Methods

Site and Soil Conditions

The experiment was carried out at the Regional Wheat Research Station of the Bangladesh Agricultural Research Institute, Shyampur, Rajshahi, Bangladesh (28027/N latitude and 92058/E longitude) for two consecutive years. The experimental land is high in topography and characterized by a clay loam texture having pH 8.10, OM 1.08%, total N 0.06%, P 9.57 mg kg^{-1}, K 0.217 mg $100g^{-1}$, S 21.89 mg kg^{-1}, and Zn 0.460 mg kg^{-1}.

Experimental Treatments and Design

The treatments included in the study were five green manuring crops (*Crotalaria juncea, Sesbania rostrata, Sesbania aculeata, Vigna radiata*, and *Phaseolus mungo*), seasonal fallow, and four levels of nitrogen (0, 40, 80, and 120 kg ha^{-1}). The experiment was laid out in a split-plot design assigning green manuring crops in the main plot and nitrogen doses in the sub-plots with three replications. The unit size of the sub-plots was 4 m×3 m and that of main plot was 48 m^2.The variety BRRI dhan39 (*Oryza sativa* L.) of T. aman rice was grown as the test variety.

Cultural Practices

Seeds of green manuring crops were sown on 10 May in the first year and on 8 May in the second year. They were fertilized with N, P, K, and S at 10, 20, 30, and 15 kg ha^{-1}, respectively, in the form of urea, triple super phosphate (TSP), muriate of potash (MOP), and gypsum. The seedlings of transplanted aman rice were raised in a wet nursery-bed. Sprouted rice seeds were sown on 24 June during the first year and on 22 June during the second year in a well-prepared nursery-bed. Irrigation and insect pest management were performed as needed. The experimental plots were irrigated, ploughed, and cross-ploughed, followed by laddering to create a good puddled condition. At the final stage of land preparation, the experimental plots were fertilized with P, K, S and Zn at a rate of 18, 40, 12, and 2 kg ha^{-1}, respectively, in the form of TSP, MOP, gypsum, and zinc sulfate. Different doses of nitrogen (0, 40, 80, and 120 kg N ha^{-1}) were applied to the plots in the form of urea in three equal installments as per treatment specifications at 20, 35, and 50 days after transplanting (DAT). Green manuring crops were incorporated at 55 days after sowing. Twenty five-day-old healthy seedlings were uprooted carefully from the seed bed and were transplanted at the rate of three seedlings $hill^{-1}$ in the unit plots on 19 July in the first year and 17 July in the second year, respectively, with a spacing of 20 cm×15 cm.

Measurement of Growth Parameters for T. Aman Rice

Number of tillers hill^{-1}, leaf area, and dry matter yield of transplanted aman rice were recorded at the flowering and grain filling stages. Plant height and number of tillers hill^{-1} were recorded from five randomly selected hills in each plot, excluding border hills. Leaf area, leaf dry weight, and total dry weight were recorded from another set of five hills, excluding border hills, randomly selected for destructive sampling in each plot. Each time, destructive samples were uprooted and washed with water. The leaf blades were separated from the leaf sheath, and leaf area was measured by a leaf area meter. After measurement of leaf area, the plant samples were dried in an electric oven at 65°C for 72 h until they reached a constant weight, and then their dry weights were recorded. Leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR), relative leaf growth rate (RLGR), specific leaf area (SLA) and leaf weight ratio (LWR) were calculated following the standard formulae (Radford, 1967; Hunt, 1978).

Measurements of Yield and Yield Components of T. Aman rice

Yield and yield component parameters (plant height and number of total tillers hill^{-1}, number of non-bearing tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of total spikelets panicle^{-1}, number of unfilled spikelets panicle^{-1}, number of grains panicle^{-1}, and 1000-grain weight) were recorded from the set of five hills.

Sampling and Chemical Analysis of Grain and Straw

From the first and second year's experiments with transplanted aman rice, plant samples were collected for chemical analysis at harvest from five selected hills plot^{1} to make a composite sample. Grains and straws were separated from each composite sample and oven dried at 65°C for 72 h. The samples were ground separately by a grinding machine and 12g of each sample was bottled for chemical analysis. Grain and straw samples were then analyzed to determine their nitrogen content. A total of 72 grain and 72 straw samples were prepared for chemical analysis in the Soil Resources Development Institute (SRDI), Shyampur, Rajshahi, Bangladesh. Nitrogen content of the grain and straw were determined by the micro-Kjeldahl method. A 0.1g grain/straw sample and a 1.1g digestion tablet (K_2SO_4:$CuSO_4$+$5H_2O$: Se = 10:1:0.1) were placed in a digestion tube and then 5 mL conc. H_2SO_4 and 2 mL H_2O_2 (30%) were added to it. The flasks were taken to the digestion chamber and the block digester was set at 350°C for 2 h. After completion of digestion the tubes were cooled down for 30 min. The digest was transferred to a volumetric flask and the volume was raised to 100 mL with distilled water and with 40% NaOH solution. The distilled NH_3 was absorbed in H_3BO_3 indicator solution and titrated with 0.01N H_2SO_4. Results were expressed as percentages. Protein content of the straw and grain was determined by multiplying the nitrogen content of the straw and grain by 6.25. Results were expressed as percentages.

Nuptake by grain and straw also were calculated by the following formula:

$$N - uptake\, by\, grain\,(kg\, ha^{-1}) = \frac{Total\, N(\%)\, in\, grain \times grain\, yield\,(kg\, ha^{-1})}{100}$$

$$N - uptake\, by\, straw\,(kg\, ha^{-1}) = \frac{Total\, N(\%)\, in\, straw \times straw\, yield\,(kg\, ha^{-1})}{100}$$

Results

Physiological Changes of Rice Due to Green Manure and Nitrogen

Relative Leaf Growth Rate (RLGR)

The relative leaf growth rate (RLGR) of T. aman rice was influenced significantly by green manure and nitrogen addition at both the flowering stage (FS) and the grain filling stage (GFS) in both years, except during the flowering stage of year 2 (Table 1). *P. mungo* and seasonal fallow with no N fertilizer exhibited the highest RLGR at the flowering stage, followed by *V. radiata* and *S. rostrata* with no N fertilizer, and seasonal fallow with 80 kg ha^{-1} N. Green manures with all additional N levels showed significantly higher RLGR at GFS, except *V. radiata* with 0 and 40 kg ha^{-1} N. With little variation, a similar pattern of response was also observed in year 2. The negative value of RLGR at the flowering stage indicated that RLGR gradually decreased with an increase in the age of the plant.

Specific Leaf Area (SLA)

The combined effect of green manure and nitrogen level increase exerted a significant influence on specific leaf area (SLA) at both stages only in year 1. The maximum SLA was noted in seasonal fallow with 120, 80, and 40 kg ha^{-1} N, *S. rostrata* with 80 kg ha^{-1} N, and *V. radiata* with 0 and 80 kg ha^{-1} N (Table 1). However, the lowest SLA at FS was recorded in *C. juncea* with 120 kg and *P. mungo* with no N. *S. aculeata* with 0 and 40 kg ha^{-1} N showed significantly higher SLA at GFS.

Table 1. Changes in morpho-physiological traits of T.aman rice (cv. BRRI dhan39) as affected by green manures and nitrogen levels

		Relative leaf growth rate ($cm^2cm^{-2}day^{-1}$)				Specific leaf area ($cm2\ g^{-1}$)				Leaf weight ratio ($g\ g^{-1}$)			
		FS		GFS		FS		GFS		FS		GFS	
Green manures	N levels ($kg\ ha^{-1}$)	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Crotalaria juncea	0	0.0188c-g	0.0216	-0.0183ab	-0.0189cd	285.00b-f	281.47	238.87d	221.95	0.2931b-e	0.2864b-e	0.1448bcd	0.1500d-g
	40	0.0171d-g	0.0199	-0.0162ab	-0.0150a-d	264.91cef	271.29	238.99d	224.44	0.3220bc	0.3044abc	0.1580ab	0.1601b-e
	80	0.0161efg	0.0196	-0.0149ab	-0.0120a	285.42b-f	282.50	226.16d	219.65	0.3012bcd	0.2941a-e	0.1645a	0.1742a
	120	0.0149fg	0.0184	-0.0141a	-0.0143abc	237.39f	256.79	253.40cd	229.74	0.3694a	0.3309a	0.1552abc	0.1725ab
Sesbania aculeata	0	0.0209cde	0.0243	-0.0153ab	-0.0163a-d	255.68def	266.36	347.46a	263.55	0.3015bcd	0.2892a-e	0.0961k	0.1255i-l
	40	0.0180d-g	0.0207	-0.0177ab	-0.0164a-d	274.64b-f	276.65	331.90ab	259.94	0.3086bcd	0.2956a-e	0.1016jk	0.1321h-k
	80	0.0170d-g	0.0207	-0.0146ab	-0.0135ab	269.44cef	274.57	236.53d	223.19	0.3033bcd	0.2969a-e	0.1558abc	0.1666abc
	120	0.0168d-g	0.0201	-0.0144ab	-0.0149a-d	274.74cef	277.50	252.38cd	229.51	0.3005bcd	0.2988a-d	0.1527abc	0.1661abc
Sesbania rostrata	0	0.0217bcd	0.0245	-0.0164ab	-0.0143abc	248.18ef	262.07	258.33cd	233.19	0.3203bc	0.2975a-e	0.1211e-i	0.1375ghi
	40	0.0180d-g	0.0215	-0.0187ab	-0.0166a-d	274.74cef	276.97	263.12cd	235.30	0.2956bcd	0.2901a-e	0.1236e-i	0.1411fgh
	80	0.0144g	0.0211	-0.0154ab	-0.0165a-d	299.38a-e	289.16	297.67bc	246.38	0.2774c-g	0.2850b-e	0.1197f-I	0.1422fgh
	120	0.0180d-g	0.0222	-0.0147ab	-0.0145abc	252.30def	265.38	245.45d	226.15	0.3353ab	0.3159ab	0.1478abc	0.1626a-d
Vigna radiata	0	0.0236bc	0.0276	-0.0213b	-0.0201d	299.09a-d	289.95	240.62d	231.99	0.2398fg	0.2584de	0.1087hijk	0.1227jkl
	40	0.0219cd	0.0255	-0.0213b	-0.0203d	290.12b-f	283.86	249.24cd	234.39	0.2716c-g	0.2836b-e	0.1173ghij	0.1301h-k
	80	0.0177d-g	0.0224	-0.0178ab	-0.0180bcd	288.13a-f	283.93	250.81cd	232.65	0.2737c-g	0.2797b-e	0.1288d-g	0.1404fgh
	120	0.0187c-g	0.0222	-0.0167ab	-0.0148a-d	283.96b-f	281.63	235.00d	230.03	0.2866b-f	0.2897a-e	0.1390cde	0.1534c-f
Phaseolus mungo	0	0.0291a	0.0282	-0.0196ab	-0.0185bcd	246.59f	272.07	243.55d	229.81	0.2989bcd	0.2808b-e	0.1165g-j	0.1293h-k
	40	0.0195c-g	0.0241	-0.0201ab	-0.0192cd	283.95b-f	292.38	247.51d	231.90	0.2805c-g	0.2742b-e	0.1268d-h	0.1362g-j
	80	0.0179d-g	0.0223	-0.0172ab	-0.0176a-d	274.02cef	288.00	262.25cd	236.92	0.2893b-f	0.2824b-e	0.1285d-g	0.1417fgh
	120	0.0186c-g	0.0223	-0.0156ab	-0.0147abc	246.15ef	272.03	239.37d	228.37	0.3361ab	0.3020a-d	0.1498abc	0.1593b-e
Seasonal fallow	0	0.0266ab	0.0286	-0.0160ab	-0.0179bcd	251.25def	266.61	298.56bc	244.07	0.2678d-g	0.2640cde	0.0969k	0.1155 l
	40	0.0218cd	0.0259	-0.0196ab	-0.0187bcd	321.23abc	300.07	273.97cd	238.02	0.2327g	0.2527e	0.1075ijk	0.1219kl
	80	0.0218bcd	0.0250	-0.0208ab	-0.0201d	330.41ab	303.08	224.65d	216.31	0.2445efg	0.2604cde	0.1391cde	0.1421fgh
	120	0.0201c-f	0.0242	-0.0197ab	-0.0192cd	342.08a	308.84	236.54d	222.13	0.2332g	0.2588de	0.1372c-f	0.1469efg
Level of significance		0.01	NS	0.01	0.01	0.01	NS	0.01	NS	0.01	0.01	0.01	0.05
CV (%)		13.66	15.52	-5.8	-14.78	7.66	7.72	7.56	10.47	6.67	7.87	5.3	5.18

FS = Flowering stage GFS = Grain filling stage

Leaf Weight Ratio (LWR)

Leaf weight ratio (LWR) differed significantly due to the combined effect of green manure and nitrogen addition at both growth stages in both years. The highest LWR at FS was recorded in *C. juncea*, *S. rostrata*, and *P. mungo* with 120 kg ha^{-1} N in both years (Table 1). *S. aculeata* with all levels of additional N demonstrated higher LWR in year 2. The highest LWR at GFS was found in *C. juncea* with 40, 80, and 120 kg ha^{-1} N, *S. aculeata* with 80 and 120 kg ha^{-1} N, *S. rostrata* with 120 kg ha^{-1} N, and *P. mungo* with 120 kg ha^{-1} N in year 1. More or less similar responses were noted in year 2.

Leaf Area Index (LAI)

Leaf area index (LAI) was significantly affected by the combination of green manure and N level in both years. The highest LAI at FS was attained by *C. juncea*, *S. aculeata,* and *S. rostrata* coupled with 80 and 120 kg ha^{-1} N, and *V. radiata* and *P. mungo* with 120 kg ha^{-1} N (Table 2). With some variation, a similar response was noted at GFS in both years. An increase in LAI was observed at higher levels of nitrogen in all the treatment combinations, irrespective of the green manuring species used. However, the lowest LAI was recorded in seasonal fallow without any N fertilizer. The results also indicated that the value of LAI was relatively higher than GFS at FS in both years.

Crop Growth Rate (CGR)

Crop growth rate responded significantly to the combined effect of green manures and N addition (Table 2). The results generally showed that all green manure crops and seasonal fallow, coupled with any N fertilizer rate except 0 kg ha^{-1}, showed significantly higher CGR at FS in both study periods (Table 2). It seems that CGR at FS increases with higher levels of N in all the treatment combinations irrespective of green manure type. Similar CGR results were observed at GFS in year 2. However, CGR at GFS did not respond to the combination of green manure and N level in year 1 (Table 2).

Net Assimilation Rate (NAR)

Net assimilation rate (NAR) was also significantly influenced by the combined effect of green manure and N addition. Except for a little variation, we observed that green manure crops, particularly *S. aculeata, S. rostrata*, *V. radiata*, and *P. mungo*, in combination with lower N levels, increased NAR at FS in the study period (Table 2). The NAR at GFS showed variation when compared to FS. All increased N levels, along with *S. rostrata*, *V. radiata*, and seasonal fallow, resulted in higher NAR at GFS. A non-significant response was noted for NAR at GFS in year 2.

Yield and Yield Contributing Characters

The number of effective tillers $hill^{-1}$ of T.aman rice was significantly influenced by green manure and nitrogen addition in both years (Table 3). All green manure crops combined with 40, 80, and 120 kg ha^{-1} N, and seasonal fallow with 120 kg ha^{-1} N, produced the highest number of effective tillers $hill^{-1}$. Seasonal fallow with zero nitrogen gave the lowest number of effective tillers $hill^{-1}$ in both years (Table 3). The combination of green manure and nitrogen level had a significant effect on grains $panicle^{-1}$. In both study periods, all green manure crops with different levels of additional N showed significantly higher numbers of grains $panicle^{-1}$, except *V. radiata* and *P. mungo* with 0 kgN ha^{-1}, and seasonal fallow with 0 and 40 kg N ha^{-1} (Table 3). The combined effect of green manure and nitrogen level on 1000-grain weight was also found to be non-significant in both years (Table 3).

Table 2. Changes in morpho-physiological traits of T.aman rice (cv. BRRI dhan39) as affected by green manures and nitrogen levels

		Leaf area index				Crop growth rate (g m^{-2} day^{-1})				Net assimilation rate (mg cm^{-2} day^{-1})			
		FS		GFS		FS		GFS		FS		GFS	
Green manures	N levels (kg ha^{-1})	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Crotalaria juncea	0	3.99f-j	4.01f-j	2.47g-l	2.47f-j	12.44bc	13.60c-f	6.45	7.29abc	0.3582bc	0.3981bcd	0.2294cde	0.2514
	40	4.68b-f	4.71a-f	2.95c-g	3.05b-f	14.38abc	16.03a-e	7.55	8.47ab	0.3487bc	0.3950bcd	0.2284cde	0.2449
	80	5.09abc	5.16abc	3.36a-d	3.53abc	15.56abc	17.41ab	8.58	9.17a	0.3443bc	0.3905bcd	0.2281cde	0.2344
	120	5.46a	5.54a	3.76a	3.82a	16.25abc	18.19a	8.61	8.56ab	0.3324bc	0.3768cd	0.2080e	0.1979
Sesbania aculeata	0	3.75g-j	3.77g-j	2.37i-l	2.39f-j	14.08abc	14.20b-f	6.45	6.77bc	0.4410abc	0.4503a-d	0.2415b-e	0.2461
	40	4.44c-g	4.48b-h	2.77e-j	2.85c-g	12.73bc	14.77b-f	8.08	7.85ab	0.3283c	0.3846bcd	0.2549a-e	0.2392
	80	4.85a-d	4.92a-e	3.23b-e	3.33a-d	16.56ab	16.85abc	8.88	8.58ab	0.3872bc	0.3991bcd	0.2483b-e	0.2288
	120	5.22ab	5.31ab	3.53ab	3.60ab	17.44a	18.25a	8.92	8.86ab	0.3782bc	0.3992bcd	0.2261de	0.2163
Sesbania rostrata	0	3.64hij	3.66hij	2.20klm	2.28g-k	11.81c	13.09ef	7.55	7.00abc	0.3823bc	0.4287bcd	0.3060ab	0.2721
	40	4.35c-h	4.40c-i	2.63f-k	2.73d-i	16.07abc	15.93a-e	8.76	8.52ab	0.4226abc	0.4245bcd	0.2911a-d	0.2713
	80	4.79a-e	4.85a-f	3.08b-f	3.08b-f	14.80abc	16.24a-e	8.78	8.00ab	0.3438bc	0.3915bcd	0.2536a-e	0.2258
	120	5.13abc	5.21abc	3.40abc	3.45a-d	14.65bc	16.60a-d	9.97	8.82ab	0.3261c	0.3759d	0.2621a-e	0.2258
Vigna radiata	0	3.29jk	3.40jk	1.77m	1.92jk	11.99bc	13.03ef	6.21	6.71bc	0.4323abc	0.4690ab	0.3015abc	0.2949
	40	4.11d-i	4.15d-j	2.25j-m	2.40f-j	13.96abc	14.47b-f	7.45	6.96abc	0.3982bc	0.4210bcd	0.2835a-d	0.2442
	80	4.37c-h	4.49b-h	2.70e-k	2.79d-i	15.24abc	15.92a-e	8.49	7.45abc	0.3969bc	0.4185bcd	0.2767a-e	0.2295
	120	4.78a-e	4.87a-e	2.92c-h	3.21a-e	14.30abc	16.05a-e	9.00	8.06ab	0.3427bc	0.3885bcd	0.2737a-e	0.2211
Phaseolus mungo	0	3.37ijk	3.50jk	1.99lm	2.06ijk	12.47bc	13.13ef	7.12	6.90bc	0.4573ab	0.4611abc	0.3077ab	0.2865
	40	4.07d-i	4.23d-j	2.43g-l	2.53e-j	14.20abc	14.47b-f	7.30	7.54abc	0.4029bc	0.4087bcd	0.2566a-e	0.2532
	80	4.43c-g	4.62b-g	2.84d-i	2.90b-g	14.18abc	15.55a-e	7.76	7.51abc	0.3653bc	0.3973bcd	0.2393b-e	0.2227
	120	4.80a-e	4.99a-d	3.21b-e	3.35a-d	15.39abc	16.85abc	8.19	8.29ab	0.3681bc	0.3979bcd	0.2264cde	0.2182
Seasonal fallow	0	2.68k	2.772k	1.74m	1.67k	11.93c	11.84f	6.46	5.53c	0.5402a	0.5261a	0.3279a	0.2844
	40	3.48ij	3.570ij	2.06lm	2.08h-k	13.20abc	13.52def	7.14	6.93bc	0.4451abc	0.4583a-d	0.2985a-d	0.2847
	80	4.02e-j	4.079e-j	2.40h-l	2.43f-j	13.55abc	14.45b-f	7.20	7.63abc	0.3955bc	0.4257bcd	0.2557a-e	0.2653
	120	4.39c-h	4.51b-g	2.76e-j	2.81c-h	14.64abc	15.72a-e	8.36	7.73ab	0.3865bc	0.4170bcd	0.2602a-e	0.2344
Level of significance		0.01	0.01	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.05	0.01	NS
CV (%)		7.01	7.52	7.78	10.31	12.09	8.12	14.3	10.85	3.02	10.12	10.83	9.33

FS = Flowering stage GFS = Grain filling stage

Table 3. Influence of green manuring crops and nitrogen levels on yield and yield contributing traits of T.aman rice (cv. BRRI dhan39)

		No. of effective tillers $hill^{-1}$		No. of grains $panicle^{-1}$		Weight of 1000 grains (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest index (%)	
Green manures	Nitrogen levels (kg ha^{-1})	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Crotalaria juncea	0	7.79bg	8.15a-e	115.31ab	114.19abc	22.24	22.97	3.88 bc	3.93c	4.86c-g	4.93b-h	44.39	44.41
	40	8.89abc	9.45a-d	128.86a	129.13abc	22.98	23.84	5.01a	5.06ab	5.96abc	6.00a-g	45.66	45.76
	80	9.26a	9.84ab	129.37a	129.93ab	23.22	24.31	5.11a	5.18a	6.46a	6.48ab	44.17	44.41
	120	9.44a	10.10a	131.49a	131.33a	22.88	24.19	5.16a	5.22a	6.57a	6.70a	43.98	43.78
Sesbania aculeata	0	7.53dg	7.92a-e	112.13ab	111.01abc	22.52	23.01	3.66cd	3.75cd	4.68b-g	4.77d-h	43.91	44.02
	40	8.70a-e	9.31a-d	125.26ab	125.10abc	22.75	23.60	4.87a	4.91ab	5.80a-d	5.85a-g	45.63	45.62
	80	9.09ab	9.67a-d	126.85ab	127.00abc	22.86	24.10	4.92a	5.01ab	6.18ab	6.26a-d	44.39	44.43
	120	9.29a	9.91a	130.08a	129.19abc	22.71	24.17	4.95a	5.05ab	6.33a	6.50ab	43.88	43.73
Sesbania rostrata	0	7.49efg	7.82a-e	109.02ab	108.36a-d	22.32	22.82	3.66cd	3.67cd	4.57efg	4.66eh	44.53	44.04
	40	8.59a-e	9.20a-d	124.20ab	123.46abc	22.59	23.60	4.71a	4.85ab	5.75a-d	5.78a-g	45.00	45.62
	80	8.94abc	9.61a-d	123.48ab	124.20abc	22.73	23.78	4.86a	4.91ab	6.07ab	6.15a-f	44.47	44.38
	120	9.18a	9.80ab	127.46ab	127.31abc	22.50	24.05	4.93a	4.99ab	6.31ab	6.42abc	43.84	43.73
Vigna radiata	0	7.08fgh	7.42cde	104.27bc	103.81cd	22.12	22.75	3.16b	3.30d	4.41fg	4.46gh	41.70	42.54
	40	8.20a-f	9.08a-d	113.46ab	113.07abc	22.40	23.74	4.47ab	4.50b	5.50a-f	5.54a-g	44.81	44.86
	80	8.72a-e	9.28a-d	119.47ab	119.41abc	22.53	23.61	4.54a	4.63ab	5.88abc	5.95a-g	43.59	43.80
	120	8.99abc	9.62a-d	122.68ab	122.69abc	22.67	23.83	4.80a	4.91ab	6.12ab	6.23a-e	43.90	44.11
Phaseolus mungo	0	7.13fgh	7.54b-e	104.96bc	105.24bcd	22.25	22.87	3.45cd	3.49cd	4.51efg	4.57f-h	43.33	43.34
	40	8.31a-f	9.14a-d	115.06ab	116.35abc	22.50	23.84	4.57a	4.61ab	5.55a-e	5.62a-g	45.19	45.06
	80	8.85a-d	9.45a-d	120.25ab	121.19abc	22.81	23.94	4.70a	4.70ab	5.83abc	5.98a-g	44.68	44.04
	120	9.03ab	9.70abc	121.48ab	123.18abc	22.89	23.95	4.87a	4.89ab	6.21ab	6.33a-d	43.92	43.60
Seasonal fallow	0	5.97h	6.29e	85.23c	85.04d	21.61	22.28	2.23e	2.31e	2.92h	3.78h	43.32	37.91
	40	6.86gh	7.33de	104.12bc	105.03bcd	22.15	22.95	3.46cd	3.39cd	4.26g	4.84c-h	44.85	41.21
	80	7.65e-g	8.14a-e	111.91ab	112.28abc	22.45	23.36	4.55a	4.59ab	5.15b-g	5.26a-h	46.90	46.58
	120	8.35a-f	8.96a-d	118.74ab	119.59abc	22.51	23.51	4.67a	4.62ab	5.78a-d	5.89a-g	44.68	44.00
Level of significance		0.01	0.01	0.01	0.05	NS	NS	0.01	0.01	0.01	0.01	NS	NS
CV (%)		7.61	10.05	5.4	10.94	8.1	6.94	6.13	5.35	5.85	10.75	9.84	7.94

The combined effect of green manure and N addition had a significant influence on grain yield (Table 3). It was observed that all green manures (*C. juncea,S. aculeata, S. rostrata*, *P. mungo*, and *V. radiata*) in combination with 120, 80, and 40 kg N ha^{-1}, and seasonal fallow in combination with 80 kg N ha^{-1}, produced significantly and identically higher grain yields. The highest grain yield of 5752 kg ha^{-1} was observed in the plot treated with a 75% recommended dose of nitrogen (RDN) and green manure incorporated at 50 DAS (Islam *et al*., 2014). All green manure, and seasonal fallow with 0 kg N, resulted the lowest grain yield. The combination of green manure and nitrogen level had a significant effect on straw yield. In both study periods, all green manure crops with 40, 80, and 120 kg ha^{-1} N, and seasonal fallow with 120 kg ha^{-1} N, showed significantly higher straw yield, whereas green manure and seasonal fallow with lower N produced the lowest straw yield (Table 3). The harvest index (HI) of T.aman rice was not significantly influenced by the application of green manure in year 1 (Table 3). However, harvest index in year 2 was higher due to green manuring over seasonal fallow. Different levels of added N in combination with green manure did not exert significant influence on the HI of T.aman rice (Table 3).

Changes in Nitrogen and Protein Content in Grain and Straw

N Content in Grain and Straw

Nitrogen content of grain and straw of T.aman rice varied significantly due to the application of green manure and N fertilizer (Table 4). The N content in rice grain ranged from 1.127 to 1.304% and in rice straw from 0.382 to 0.528% during year 1 (Table 4). The highest N content in both rice grain (1.304%) and straw (0.528%) was observed using the treatment *C. juncea* with 120 kg ha^{-1} N, and the lowest value was noted in seasonal fallow with no nitrogen application. During second year, N content in grain was non-responsive to all the treatments, and N content in straw exhibited a more or less similar trend.

Protein Content in Grain and Straw

Protein content in the grain and straw was significantly influenced by the combined effect of green manure and increased nitrogen in year 1 (Table 4). Protein content increased in the grain and straw with higher levels of nitrogen in all the treatment combinations irrespective of the green manuring species used. Similar protein content in the grain and straw was observed in year 2 from the combined effect of green manure and increased nitrogen as in the previous year (Table 4).

Changes in Nitrogen Uptake by Grain and Straw

Nitrogen uptake by rice grain ranged from 25.13 to 67.29 kg ha^{-1} in year 1(Table 5). The maximum N uptake (67.29 kg ha^{-1}) by rice grain was observed in *C. juncea* with 120 kg N ha^{-1}. The minimum N uptake of 25.13 kg ha^{-1} was observed in seasonal fallow with no nitrogen application. In the case of rice straw during year 1, N uptake ranged from 11.16 to 34.68 kg ha^{-1}. The maximum N uptake by straw (34.68 kg ha^{-1}) was observed in *C. juncea* with 120 kg N ha^{-1} (Table 5). The minimum N uptake by rice straw (11.16 kg ha^{-1}) was recorded in seasonal fallow with no nitrogen application. The results reveal that N uptake in rice grain was higher than in straw.

Changes in Soil Properties After Harvest of T. Aman Rice

Soil pH was not significantly influenced by the incorporation of green manure and additional nitrogen after harvest in either year (Table 6). With a few exceptions, a numerically increasing trend in soil pH was observed with higher levels of nitrogen in all the treatment combinations, irrespective of green manures, in both years. The combined effect of green manure and nitrogen was significant for total N and exchangeable K in both years and for soil organic matter in year 2.An increase in post-harvest soil nitrogen content was observed with the application of higher levels of nitrogen in combination with green manures in both years (Table 6). *C. juncea* combined with higher doses of nitrogen gave higher K availability in the soil, and the seasonal fallow with 40 kg N ha^{-1} gave lower K availability in the soil in year 1. A similar trend in soil K status was observed with the combined treatment in year 2. *C. juncea* combined with zero nitrogen gave higher organic matter content in the soil, and seasonal fallow with 120 kg N ha^{-1} gave the lowest organic matter content in the soil (Table 6).

Table 4. Influence of green manuring crops and nitrogen levels on N and Protein content in rice grain and straw of T.aman rice (cv. BRRI dhan39)

	Nitrogen levels (kg ha^{-1})	N content in grain (%) Yr. 1	N content in grain (%) Yr. 2	N content in straw (%) Yr. 1	N content in straw (%) Yr. 2	Protein content in grain (%) Yr. 1	Protein content in grain (%) Yr. 2	Protein content in straw (%) Yr. 1	Protein content in straw (%) Yr. 2
Crotalaria juncea	0	1.217abc	1.235	0.433abc	0.442a-d	7.61abc	7.72	2.70abc	2.76a-d
	40	1.254abc	1.297	0.451abc	0.485a-d	7.83abc	8.11	2.82abc	3.03a-d
	80	1.284ab	1.320	0.509ab	0.527ab	8.02ab	8.25	3.18ab	3.29ab
	120	1.304a	1.330	0.528a	0.536a	8.15a	8.31	3.30a	3.35a
Sesbania aculeata	0	1.197abc	1.235	0.423abc	0.442a-d	7.48abc	7.72	2.64abc	2.76a-d
	40	1.243abc	1.286	0.432abc	0.468a-d	7.77abc	8.03	2.70abc	2.93a-d
	80	1.264abc	1.289	0.460abc	0.478a-d	7.90abc	8.06	2.88abc	2.98a-d
	120	1.284ab	1.299	0.509ab	0.527ab	8.02ab	8.12	3.18ab	3.29ab
Sesbania rostrata	0	1.197abc	1.224	0.402bc	0.431a-d	7.48abc	7.65	2.52bc	2.69a-d
	40	1.223abc	1.266	0.432abc	0.445a-d	7.64abc	7.91	2.70abc	2.78a-d
	80	1.243abc	1.265	0.490abc	0.507a-d	7.77abc	7.91	3.06abc	3.17abc
	120	1.258abc	1.289	0.509ab	0.517abc	7.86abc	8.06	3.18ab	3.23abc
Vigna radiata	0	1.141bc	1.187	0.385c	0.403cd	7.13bc	7.42	2.41c	2.52cd
	40	1.182abc	1.213	0.421abc	0.443a-d	7.39abc	7.58	2.63abc	2.77a-d
	80	1.207abc	1.241	0.439abc	0.456a-d	7.54abc	7.76	2.75abc	2.85a-d
	120	1.237abc	1.266	0.458abc	0.486a-d	7.73abc	7.91	2.87abc	3.03a-d
Phaseolus mungo	0	1.167abc	1.203	0.412abc	0.421a-d	7.29abc	7.52	2.58abc	2.63a-d
	40	1.203abc	1.225	0.422abc	0.425a-d	7.52abc	7.66	2.64abc	2.66a-d
	80	1.223abc	1.238	0.451abc	0.458a-d	7.64abc	7.74	2.82abc	2.86a-d
	120	1.243abc	1.269	0.470abc	0.488a-d	7.77abc	7.93	2.94abc	3.05a-d
Seasonal fallow	0	1.127c	1.152	0.382c	0.389d	7.04c	7.20	2.39c	2.43d
	40	1.155abc	1.186	0.397bc	0.409bcd	7.22abc	7.41	2.48bc	2.56bcd
	80	1.185abc	1.209	0.426abc	0.432a-d	7.41abc	7.56	2.66abc	2.70a-d
	120	1.225abc	1.23	0.444abc	0.441a-d	7.66abc	7.69	2.78abc	2.76a-d
Level of significance		0.05	NS	0.01	0.05	0.05	NS	0.01	0.05
CV (%)		6.16	7.84	10.23	12.8	6.15	7.84	10.19	12.8

Table 5. Influence of green manuring crops and nitrogen levels on N uptake by grain and straw of T.aman rice (cv. BRRI dhan 39)

	Nitrogen levels	*N uptake by grain (Kg ha^{-1})*		*N uptake by straw (Kg ha^{-1})*		*Total N uptake (Kg ha^{-1})*	
	(kg ha^{-1})	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Crotalaria juncea	0	47.23def	48.55b-g	21.02e-i	21.79d-h	68.25f-i	70.34e-i
	40	63.31abc	65.65ab	26.89b-f	29.09a-f	90.19a-e	94.73a-d
	80	65.73ab	68.35a	32.86ab	34.12ab	98.59ab	102.47ab
	120	67.29a	69.41a	34.68a	35.92a	101.97a	105.33a
Sesbania aculeata	0	43.82efg	46.30c-g	19.77f-i	21.08e-h	63.59g-j	67.38e-i
	40	60.55abc	63.12abc	25.05c-h	27.38a-g	85.60b-e	90.50a-d
	80	62.17abc	64.58ab	28.45a-e	29.90a-e	90.62a-e	94.47a-d
	120	63.55abc	65.62ab	32.20abc	34.23ab	95.75abc	99.85abc
Sesbania rostrata	0	43.93efg	44.93d-g	18.39hi	20.08fgh	62.32hij	65.01f-i
	40	57.61a-d	61.39a-d	24.84c-h	25.72b-g	82.45c-f	87.12a-e
	80	60.43abc	62.11a-d	29.71a-d	31.19a-d	90.14a-e	93.29a-d
	120	62.00abc	64.32abc	32.10abc	33.16abc	94.10a-d	97.49a-d
Vigna radiata	0	36.06g	39.17gh	16.99ij	17.98gh	53.05j	57.14ij
	40	52.83cde	54.60a-g	23.14d-i	24.55b-g	75.96e-h	79.15d-h
	80	54.80bcd	57.47a-f	25.83b-h	27.14a-g	80.63c-f	84.61b-f
	120	59.26abc	62.14a-d	28.05a-e	30.25a-e	87.32a-e	92.38a-d
Phaseolus mungo	0	40.26fg	42.00e-h	18.60ghi	19.24gh	58.86ij	61.24ghi
	40	54.97bcd	56.48a-g	23.44d-i	23.89c-h	78.41d-g	80.37c-g
	80	57.61a-d	58.17a-e	26.30b-g	27.39a-g	83.91b-e	85.57a-e
	120	60.55abc	62.04a-d	29.21a-d	30.86a-e	89.76a-e	92.91a-d
Seasonal fallow	0	25.13h	26.61h	11.16j	14.72h	36.29k	41.33j
	40	39.97fg	40.21fgh	16.92ij	19.81fgh	56.89ij	60.02hi
	80	53.93cde	55.49a-g	21.92d-i	22.73d-h	75.84e-h	78.22d-h
	120	57.21a-d	56.84a-g	25.69b-h	25.99b-g	82.90b-f	82.83b-f
Level of significance		0.01	0.01	0.01	0.01	0.01	0.01
CV (%)		7.9	12.42	12.15	14.35	7.84	9.62

Table 6. Changes in post-harvest soil nutrient status as affected by green manures and nitrogen levels

	Nitrogen levels	pH		Organic matter (%)		Total N (%)		Available P (mg Kg^{-1})		Exchangeable K (me 100g^{-1})		Available S (mg Kg^{-1})		Available Zn (mg Kg^{-1})	
	kg ha^{-1})	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Crotalaria juncea	0	8.01	8.23	1.176	1.21a	0.067a-d	0.071a-e	9.83	10.48	0.325ab	0.290b-f	22.39	22.55	0.513	0.558
	40	8.01	8.26	1.152	1.17abc	0.071ab	0.075a-d	9.87	10.69	0.307abc	0.392a	22.57	22.89	0.492	0.537
	80	8.02	8.29	1.160	1.15abc	0.072a	0.078ab	10.16	10.58	0.325ab	0.392a	22.70	22.70	0.524	0.563
	120	8.06	8.29	1.128	1.17abc	0.074a	0.080a	10.03	10.78	0.343a	0.358ab	22.87	23.01	0.529	0.574
Sesbania aculeata	0	8.02	8.25	1.160	1.18ab	0.066a-d	0.069a-f	9.80	10.33	0.253a-d	0.256c-g	22.26	22.50	0.471	0.511
	40	8.02	8.29	1.128	1.14abc	0.069a-d	0.073a-d	9.69	10.45	0.289a-d	0.307a-e	22.55	22.32	0.492	0.532
	80	8.10	8.32	1.120	1.16abc	0.068a-d	0.075a-d	9.95	10.73	0.307abc	0.341abc	22.45	22.67	0.519	0.548
	120	8.05	8.30	1.104	1.13abc	0.070abc	0.076abc	10.07	10.60	0.307abc	0.324a-d	22.79	22.87	0.508	0.537
Sesbania rostrata	0	7.98	8.28	1.136	1.17abc	0.065 a-d	0.066b-g	9.60	10.41	0.235a-d	0.238d-g	22.15	22.12	0.460	0.495
	40	8.05	8.25	1.104	1.15abc	0.066 a-d	0.073a-d	9.83	10.24	0.271a-d	0.290b-f	21.98	22.30	0.476	0.526
	80	8.01	8.28	1.112	1.14abc	0.067 a-d	0.071a-e	9.73	10.51	0.289a-d	0.307a-e	22.30	22.62	0.492	0.516
	120	8.07	8.30	1.096	1.12abc	0.067 a-d	0.074a-d	9.98	10.65	0.289a-d	0.324a-d	22.45	22.47	0.497	0.532
Vigna radiata	0	8.06	8.30	1.088	1.11abc	0.054de	0.059efg	9.46	10.12	0.217bcd	0.213fg	21.83	21.96	0.436	0.468
	40	8.06	8.35	1.084	1.09abc	0.060 a-e	0.061d-g	9.57	10.13	0.226a-d	0.221efg	21.81	21.99	0.436	0.495
	80	8.13	8.35	1.068	1.07abc	0.059 a-e	0.062c-g	9.82	10.32	0.217bcd	0.230efg	22.07	22.26	0.458	0.492
	120	8.14	8.37	1.064	1.07abc	0.060 a-e	0.064c-g	9.69	10.45	0.244a-d	0.255c-g	22.09	22.27	0.466	0.502
Phaseolus mungo	0	8.00	8.28	1.120	1.14abc	0.059 a-e	0.064c-g	9.53	10.22	0.235a-d	0.221efg	21.76	21.92	0.466	0.490
	40	8.05	8.32	1.096	1.13abc	0.064 a-d	0.068a-g	9.55	10.10	0.271a-d	0.256c-g	22.02	22.20	0.450	0.516
	80	8.09	8.33	1.080	1.10abc	0.062 a-e	0.067a-g	9.64	10.34	0.235a-d	0.256c-g	22.18	22.10	0.476	0.516
	120	8.12	8.34	1.088	1.11abc	0.064 a-d	0.069a-f	9.83	10.46	0.271a-d	0.290b-f	21.91	22.32	0.487	0.521
Seasonal fallow	0	8.11	8.32	1.056	1.07abc	0.049e	0.055g	9.45	9.85	0.199cd	0.204fg	21.52	21.83	0.407	0.447
	40	8.07	8.38	1.072	1.06bc	0.055cde	0.056fg	9.28	10.03	0.181d	0.187g	21.64	21.71	0.423	0.474
	80	8.17	8.37	1.056	1.04c	0.055cde	0.058efg	9.56	10.15	0.199cd	0.204fg	21.84	21.92	0.439	0.469
	120	8.15	8.41	1.039	1.03c	0.056b-e	0.059efg	9.68	10.27	0.217bcd	0.221efg	21.73	21.36	0.444	0.484
Level of significance		NS	NS	NS	0.05	0.05	0.01	NS	NS	0.01	0.01	NS	NS	NS	NS
CV (%)		5.93	5.2	7.08	6.01	11.95	9.27	12.36	11.59	14.4	10.81	12.91	12.57	13.97	10.89

Discussion

We have evaluated the effect of both green manure (GM) and N application on T.aman rice in terms of crop growth, yield, and yield-contributing characters. The GM crops in situ were incorporated into the soil during land preparation a few days before transplantation of rice seedlings. Nitrogen at the rate of 40, 80, and 120 kg N ha^{-1} from urea was applied in three equal installments at basal, tillering, and panicle initiation stages. There were also fallow plots where neither GM nor N was added.

In general, RLGR decreased with the advancement of plant age in both years. The negative RLGR values observed at the later stages were due to variation in treatment and age of the plant in both years. This might be due to more uptake of N at the early growth stages, resulting in more leaf area coverage and thereby producing more leaf dry weight, but abscission of mature leaves at the later stages of plant growth reduced leaf area. These results are similar to the findings of Alam and Haider (2006) in barley and of Rahman (2004) in wheat. More or less higher SLA values were found in the seasonal fallow treatment at most of the growth stages, and lower SLA values were found where GM crops were incorporated to the soil. SLA started with a maximum value of 30 DAT and declined with the progress of the growth period towards maturity. The decline of SLA with increasing plant age was noticed by Sarker and Paul (1998) in wheat. In both years, LWR increased for a very short time (30 DAT) and thereafter gradually declined with plant age. The decrease of LWR was caused by increased total dry matter (TDM) and decreased LAI at the later stages. Mollah (2007) studied LWR in wheat and reported that the sharp decrease in LWR at the later stages might be due to the sharp increase of TDM. Green leaf area is the source of food production in green plants. Leaf area index (LAI) increased steadily as the crop growth period advanced and reached its highest peak at 60 DAT and then started falling until the final harvest. Increases in LAI because of using GM might be due to the additional supply of N in the soil from the green manuring. Similar results were also reported by Hossain *et al.* (1995). The probable reason for the LAI increase in the nitrogen-treated plants is greater expansion of the leaf blades. The decrease in LAI at the later stages was possibly due to the senescence and abscission of the older leaves. These observations are in agreement with the findings of Hossain *et al.* (1995) and Pramanik (2006) in rice. CGR is regarded as the most meaningful growth function, since it represents the net results of photosynthesis, respiration, and canopy area interaction. CGR increased progressively with the age of the plants up to 45-60 DAT and thereafter decreased slowly. The decreasing trend might be due to leaf abscission at the later growth stages. This result agrees with the observations of Alam and Haider (2006) on barley. NAR decreased progressively with the age of the plants up to 75-90 DAT, perhaps due to mutual leaf shading from the increase in the number of older leaves that had lost photosynthetic ability, and thereafter it showed an increasing trend up to 90-105 DAT. Pramanik (2006) reported similar results in rice. NAR calculated from the quadratic fitted values showed that it decreased slowly with fluctuations in most cases, and thereafter declined sharply at the later stages of growth, in many cases reaching negative values.

The number of effective tillers hill^{-1} was significantly affected by the combination of green manure and nitrogen addition throughout the growth period of the crop. Nitrogen encouraged tiller production, and so the number of effective tillers plant^{-1} increased with the increase in Nfertilization. These observations are in agreement with the findings of Saha *et al.* (2007) in rice. Different green manure crops and nitrogen application had significant effects on the grains panicle^{-1} of T. amanrice in each year of experimentation. Grains panicle^{-1} of T. aman in different green manuring plots was significantly higher than in the seasonal fallow and the plots with no nitrogen application. The increase in grains panicle^{-1} under GM might be due to the additional supply of N in the soil through green manuring. Pramanik (2006) found higher numbers of grains panicle^{-1} when *S. rostrata* was incorporated in the soil. These results are also in agreement with the findings of some other authors (Hossain *et al*., 1995; Bhander *et al*., 1998). Grain yield of T.aman rice is a complex variable depending upon a large number of environmental, morphological, and physiological characters. Grain yields also depend upon other yield components. In the present investigation, grain yield of T.aman rice was significantly influenced by the incorporation of green manure crops and nitrogen. The nutrients contributed through green manuring and nitrogen addition might be the reason for the increase in grain yield. These results are in agreement with the findings of Saha *et al.* (2007) and Islam *et al*. (2014). The combination of green manure and nitrogen had a significant effect on straw yield in both years. An increasing trend of straw yield was observed with higher levels of N in combination with green manures in both years. Saha *et al.* (2007) reported similar results in rice. The combination of green manure and N addition did not have a significant effect on harvest index in either year. A similar result was obtained by Pramanik (2006).

The maximum nitrogen and protein content in grain was produced when green manure crops were incorporated, and that amount was higher than during seasonal fallow and with higher doses of N; the minimum nitrogen/protein result was observed when the crop was not fertilized at all. This result corroborates the findings of Salam (2005) in rice, Islam (2001) in wheat, and Hossain (2007) in mungbean. Significantly, an increase in nitrogen and protein content in straw was observed with higher levels of nitrogen in all the treatment combinations in both years, irrespective of green manuring. Pramanik (2006) noticed similar findings in rice. Significantly higher nitrogen uptake by grain and straw was found with the incorporation of all the GM crops compared to the seasonal fallow. Nitrogen contributed through green manuring might be the reason for increased nitrogen uptake by grain and straw. This finding is similar to that of Singh *et al.* (1996) in rice.

The increase in N content was directly related to biological N_2 fixation and organic matter addition to the soil. This result is in agreement with the findings of Nur-E-Elahi (1991). With a few exceptions, a linearly increasing trend of soil P was observed with higher levels of nitrogen in all the treatment combinations, irrespective of the addition of GM crops. The slight variation observed between the treatments might be due to variation in the nitrogen levels. A similar result was obtained by Panda *et al*. (1994). Except in some cases, the combination of GM and nitrogen addition increased significantly the availability of K in the soil. This result is in agreement with the findings of Bellakki and Badanur (1997).

Conclusion

Crotalaria juncea, Sesbania aculeata and *Sesbania rostrata* were found to be effective green manure crops in terms of biomass, nodulation, and nitrogen contribution, and especially in the positive effect they exerted on the immediate and next crops in our rice-wheat system. These plants, when incorporated into soil, along with urea application at 40 kg N ha^{-1}, produced higher and more satisfactory yields of T.aman rice than were obtained from the application of urea alone at 80 kg N ha^{-1}. The GM addition also had a considerable positive effect, although not significant, on the following crop (wheat). The GM-amended soil also yielded higher protein content (%) in rice grain. As observed from soil analysis (after one crop cycle), both organic matter and N content significantly increased in the GM-treated plots. Hence, for improvement and sustainability of soil fertility, and for crop productivity, an integrated management approach that combines the use of fertilizers and manures is essential.

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Author's Contributions

Md. Shafiqul Islam: Performed the experiments and analyzed the data.

Nishit Kumar Paul: Designed the experiments and analyzed the data.

Md. Robiul Alam: Performed the experiments and analyzed the data.

Md. Romij Uddin: Wrote the manuscript and analyzed the data.

Uttam Kumer Sarker: Wrote the manuscript and analyzed the data.

Md. Ariful Islam: Performed the experiments and analyzed the data.

Sung Un Park: Designed the experiments and analyzed the data.

Ethics

This manuscript has not been published or presented elsewhere in part or in entirely, and is not under consideration by another journal. All the authors have approved the manuscript and agree with submission to your esteemed journal. There are no conflicts of interest to declare.

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