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Article

Residual effects of different green manures on the growth and yield of wheat

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Abstract: Green manures can enrich soils with organic matter and nitrogen. An experiment was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh, Bangladesh to evaluate the residual effects of different green manures on the growth and yield of wheat (BARI Gom-26). The experiment containing nine treatments were laid out in a randomized complete block design with three replications. The treatments were T_1 [No green manure + 100% Recommended dose of nitrogen (RDN)], T_2 (*Sesbania aculeata* + 75% RDN), T_3 (*Sesbania aculeata* + 50% RDN), T_4 (*Sesbania rostrata* + 75% RDN), T_5 (*Sesbania rostrata* + 50% RDN), T_6 (*Vigna radiata* + 75% RDN), T_7 (*Vigna radiata* + 50% RDN), T_8 (*Vigna mungo* + 75% RDN), and T_9 (*Vigna mungo* + 50% RDN). Residual effects of green manures with RDN significantly increased the yield attributes as well as grain and straw yields of wheat. Further, green manures exerted significant residual effects on grain, straw and total N uptake of wheat. Among various treatments with green manures, the performance of T_4 (*Sesbania rostrata* + 75% RDN) was the best as it produced the highest grain yield (4.28 t ha^{-1}), straw yield (4.74 t ha^{-1}) and total N uptake (108.02 kg ha^{-1}). The use of green manures slightly increased the organic matter content, total N and available P, K, and S contents of the post-harvest soils. As regards to the contribution of various green manures on yield contributing characters and yield of wheat, performances of two *Sesbania* species viz., *S. aculeata* and *S. rostrata* in association with 75% N fertilizer were effective.

Keywords: green manures; wheat; residual effects; growth; yield

1. Introduction

Wheat is one of the leading cereal crops grown around the world in diverse environments.

In Bangladesh wheat ranks next to rice and its popularity is increasing consistently as it has great importance in human nutrition and industrial uses. The total area and production of wheat in Bangladesh are about 4,29,607 ha and 13,02,998 metric tons, respectively (BBS, 2014). The average yield of wheat in this country is quite low as compared to that of other wheat growing countries of Asia like China, India, Pakistan, etc. In Bangladesh, wheat can be a good supplement of rice and it might play a vital role in the national economy. But soil fertility status in Bangladesh is gradually declining, and the yield of major crops is showing a stagnating trend even with high doses of chemical fertilizers. The present decline or stagnation of major crop yields in Bangladesh is the cumulative effect of many soil related constraints including depletion of soil organic matter, nutrient mining, and scant use of bio- and organic fertilizers and poor organic management (Martius *et al.*, 2002; Jahiruddin and Sattar, 2010). The depletion of soil organic matter caused by high cropping intensity, use of modern crop varieties, very little use of crop residues, limited practices of green manure-based cropping patterns are the main reasons of low productivity and this organic matter depletion is considered as one of the most serious threats to future sustainability of agriculture in Bangladesh (Salahin *et al.*, 2013).

To overcome these constraints, efficient soil fertility and fertilizer management through maximum return of crop and animal residues to soil, balanced use of chemical fertilizers, use of bio-fertilizers, green manures in crop rotation; and proper utilization of farm manures, composts and nitrogenous organic materials are important. Sustainable farming puts emphasis on the nutrient supply through integrated approach. Green manures are the crops which are returned into the soil in order to improve the growth of subsequent crops and they offer considerable potential as a source of plant nutrients and organic matter (Singh *et al.*, 1991). Green manure crops improve the physical, chemical and biological condition of soils and the long term benefit of green manure crops is to stabilize yields of subsequent crops during dry seasons (MacRae and Mehuys, 1988). Legumes including *Sesbania aculeata, Sesbana rostrata, Vigna radiata and Vigna mungo* are the potential green manure crops for their capability of nodule formation and nitrogen fixation. Mungbean can fix N in the range of 30-40 kg ha^{-1} (Rupela and Saxena, 1987). On the other hand, green manuring of *Sesbania rostrata* can significantly improve the yield of following rice crop saving about 50-60% N and continuous green manuring of *Sesbania rostrata* for 3 years can result into significant residual effect on the second wheat crop and improve physico-chemical properties of the soil (Mann *et al.,* 2000).

Thus, pre-rice green manuring with legumes can greatly contribute to the improvement of N fertility and organic matter build up of the soils in rice-wheat-rice or other important cropping patterns. It is therefore, important to undertake a study with different green manure crops for ameliorating N deficiency and low organic matter problems of most of our rice-wheat growing soils. The residual effect of green manures can provide the most effective way to improve N supply for succeeding crops (Thorup-Kristensen *et al.*, 2003). A comprehensive and systematic research effort on residual effect of green manure crops on subsequent crop yields under rice-wheat sequence is yet to be well established. Therefore, the present study was performed to find out the residual effect of green manure crops on the growth and yield of wheat (BARI Gom-26) and to observe the changes in soil properties after incorporation of green manuring crops.

2. Materials and Methods

2.1. Experimental site and soil

The experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh during rabi season of 2013. The soil of the experimental site belongs to Sonatala series under the AEZ-9 (Old Brahmaputra Floodplain). The soil had silt loam texture, pH 6.29, organic matter content 1.15%, total N 0.11%, available P 5.57 ppm, available K 24.29 ppm (express it as meq/100 g soil) and available S 10 ppm.

2.2. Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with nine treatments and three replications. The treatments were T_1 (No green manure + 100% RDN), T_2 (*Sesbania aculeata* + 75% RDN), T_3 (*Sesbania aculeata* + 50% RDN), T_4 (*Sesbania rostrata* + 75% RDN), T_5 (*Sesbania rostrata* + 50% RDN), T_6 (*Vigna radiata* + 75% RDN), T_7 (*Vigna radiata* + 50% RDN), T_8 (*Vigna mungo* + 75% RDN), and T_9 (*Vigna mungo* + 50% RDN). In previous rice crop, these four leguminous crops were used as pre-rice green manuring crops which were incorporated into the soil at 50 DAS (days after sowing) as per treatments.

2.3. Seed sowing

BARI Gom-26, a modern variety of wheat was used as a test crop in this experiment. Seeds were sown @ 125 kg ha^{-1} in lines and were covered with soil by hand. The line to line distance was 20 cm and the depth of furrow was about 6 cm. A strip of wheat crop was established around the experimental field as border crop.

2.4. Fertilizer application

The full amount of triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc oxide, and boric acid were applied as the sources of P, K, S, Zn and B at the time of final land preparation. The rates of P, K, S, Zn and B were 20, 60, 10, 3, and 2 kg ha^{-1}, respectively. The recommended rate of nitrogen was 100 kg ha^{-1} as per Fertilizer Recommendation Guide (BARC, 2005). To supply nitrogen, two levels of urea i.e. 50% and 75% of the recommended dose were applied in three equal splits. The one-third dose of urea and full dose of all other fertilizers were applied as basal to all the plots during final land preparation. The second split of urea was applied after 30 days of sowing (crown root stage) and the third split after 56 days (booting stage).

2.5. Intercultural operations

Irrigation was provided at 24 days and at 55 days after sowing. Other intercultural operations viz. weeding and insecticide spraying were done whenever required.

2.6. Harvesting

The crop was harvested at maturity. The grain yield was obtained on 14% moisture basis while the straw yield was recorded on sun dry basis. Five hills were selected randomly from each plot and data on yield components including plant height, effective tillers per hill, spike length, grains spike^{-1} and 1000-grain weight were recorded.

2.7. Determination of N in plant samples

The N content in wheat grain and straw was determined by Semi-micro Kjeldahl method. Nitrogen uptake was then calculated from N content and yield data.

2.8. Collection and preparation of soil samples

Soil samples were collected at a depth of 0-15 cm from the surface. The soil samples were collected by means of auger from each plot of block in two installments, initially before green manure application and finally after harvest of wheat crop. After removing weeds, plant roots, stubbles, stones, etc., the samples were air dried and ground to pass through a 2 mm (10 meshes) sieve. The samples were then stored in clean plastic bags for chemical and mechanical analyses.

2.9. Analysis of soil samples

Soil samples were analyzed for physical and chemical properties following standard methods. Particle size analysis of soil was done by hydrometer method (Black, 1965) and the textural class was determined by plotting of the values for % sand, % silt and % clay to the Marshall's Triangular Coordinate following the USDA system and soil pH (1:2.5 soil-water) was measured by glass electrode pH meter method (Peech, 1965). Organic matter was determined by Walkley and Black method (Walkley and Black, 1934), total N by Semi-micro Kjeldahl method (Bremner and Mulvaney, 1982), available P by Olsen method (Olsen *et al.*, 1954), available K by flame photometer after extraction with 1N NH_4OAc at pH 7.0 (Knudsen *et al.*, 1982), available S by extracting soil samples with $CaCl_2$ solution (0.15%) and by measuring turbidity by spectrophotometer (Williams and Steinbergs, 1959) method.

2.10. Statistical analysis

The collected data were analyzed statistically by F-test to examine the treatment effects and the mean differences were examined by Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Growth and yield contributing characters

Plant height, effective tillers hill^{-1}, spike length, and number of grains spike^{-1} of BARI Gom-26 responded significantly to the residual effects of green manures with different levels of nitrogen (Table 1). The tallest plant of 83.13 cm was found in T_4 (*Sesbania rostrata* + 75% RDN) which was identical to T_7 (*Vigna radiata* + 50% RDN), T_6 (*Vigna radiata* + 75% RDN) and T_2 (*Sesbania aculeata* + 75% RDN) with the values of 83, 82.70 and 82.50 cm, respectively. The shortest plant of 79.50 cm was observed in T_3 (*Sesbania aculeata* + 50% RDN). The highest number of effective tillers hill^{-1} of 5 was found in T_4 and the lowest value of 4 was observed in T_7. The maximum spike length (10 cm) was found both in T_4 and T_6 which was at par with T_2, T_7, and T_6 with the values of 9.62, 9.50 and 9.46 cm, respectively. The minimum spike length (8.47 cm) was found in T_9 (residual effect of *Vigna mungo* +50% RDN). The number of grains spike^{-1} varied from 40.50 to 54.50 with the highest value in T_4 and the lowest in T_3. Again, for 1000-grain weight, the highest value (36 g) was observed in T_2, T_3, and T_5 treatments and the lowest value (35.8 g) was recorded in T_1 and T_8 treatments. The positive residual effect of green manures on the wheat crop might be due to the release of N from green manures. The release of nutrients from green manures is rather slow; so it acts like a spontaneous supply of nutrients throughout the crop growth period compared to fertilizer N application. Ehsan *et al.* (2014) and Boparai *et al.* (1992) studied the residual effects of green manures on wheat crop and reported that incorporation of green manure *(Sesbania aculeata)* produced the highest plant height, spike bearing tillers m^{-2}, number of grains spike^{-1} and 1000-grain weight and increased root density of wheat grown after rice. Besides, Sultani *et al.* (2004) observed a significant but variable effect of incorporation of various green manure legumes on wheat growth and yield and the maximum tillering as well as total biomass were produced by *Sesbania* incorporation. Mandal *et al.* (2003) also observed better growth and yields of wheat in green manure-treated plots. Moreover, Aulakh *et al.* (2000) studied the residual effect of green manures on wheat and suggested that N fertilizer application to wheat could be reduced by 25% when incorporation with green manures.

Table 1. Residual effects of different green manures with different levels of nitrogen on growth and yield components of wheat.

Treatments	Plant height (cm)	Effective tillers hill^{-1} (no.)	Spike length (cm)	Grains spike^{-1} (no.)	1000- grain weight (g)
T_1 (No green manure + 100% RDN)	80.60 bc	4.50	8.64 d	44.0 bc	35.8
T_2 (*Sesbania aculeata* + 75% RDN)	82.50 ab	4.75	9.62 ab	47.5 bc	36.0
T_3 (*Sesbania aculeata* + 50% RDN)	79.50 c	4.50	9.46 abc	40.5 d	36.0
T_4 (*Sesbania rostrata* + 75% RDN)	83.13 a	5.00	10.00 a	54.5 a	35.9
T_5 (*Sesbania rostrata* + 50% RDN)	77.50 d	4.50	8.85 cd	42.5 cd	36.0
T_6 (*Vigna radiata* + 75% RDN)	82.70 a	4.75	10.00 a	46.5 bc	35.9
T_7 (*Vigna radiata* + 50% RDN)	83.00 a	4.00	9.50 ab	43.0 bcd	35.9
T_8 (*Vigna mungo* + 75% RDN)	80.50 bc	4.50	9.00 bcd	45.0 bc	35.8
T_9 (*Vigna mungo* + 50% RDN)	80.60 bc	4.16	8.47 d	42.0 cd	35.9
SE (±)	0.635	0.223	0.196	1.38	0.09
CV (%)	1.36	8.57	3.68	5.30	2.68
Sig. level	***	NS	***	***	NS

Figure (s) in a column having common letters do not differ significantly at 5% level of significance. RDN = Recommended dose of nitrogen; SE (±) = Standard error of means; CV= Coefficient of variation; NS= Non significant; *** = P< 0.001

3.2. Grain and straw yield

Residual effects of green manures with different levels of nitrogen showed a positive effect on grain and straw yields of BARI Gom-26 (Figure 1). The grain yield ranged from 3.12 to 4.28 t ha^{-1}. The highest grain yield (4.28 t ha^{-1}) was observed in T_4 (*Sesbania rostrata* + 75% RDN) and the lowest value (3.12 t ha^{-1}) was recorded in T_9 (*Vigna mungo* + 50% RDN). The second highest grain yield was produced by T_2 (*Sesbania aculeata* + 75% RDN) which was statistically similar with T_6 (*Vigna radiata* + 75% RDN), T_8 (*Vigna mungo* + 75% RDN) and T_1 (No green manure + 100% RDN), although there was a numerical variation in grain yield among the treatments. Based on grain yield the treatments may be ranked in order of $T_4 > T_2 > T_6 > T_8 > T_1 > T_5 > T_7 > T_3 > T_9$. The yields of straw ranged from 3.43 to 4.74 t ha^{-1}. The maximum straw yield of 4.74 t ha^{-1} was found in T_4 and the minimum value of 3.43 t ha^{-1} was noted in T_9 treatment. The treatments may be ranked in the order of $T_4 > T_2 > T_1 > T_6 > T_5 > T_8 > T_7 > T_3 > T_9$ in terms of straw yield.

These results indicate that application of green manures with 75% RDN significantly increased the yields of wheat and that increased yields were comparable with the yield obtained from 100% RDN alone. It is also evident from our study that the treatments with green manures along with 75% RDN performed better for improving wheat yield compared to those with 50% RDN. The nutrients contributed from legumes could be partly responsible for yield improvement and up to 25% reduction of inorganic N fertilizer.

These results are in agreement with the findings of many investigators (Ehsan *et al.*, 2014; Shah *et al.*, 2011 and Boparai *et al.*, 1992) who reported that grain and straw yields of wheat were significantly increased due to application of green manures with inorganic fertilizers. Furthermore, Sultani *et al.* (2004) observed that the average residual effect of green manure crops along with inorganic fertilizer was consistent and significant whereas green manuring alone had 9% residual effect on wheat growth and yield.

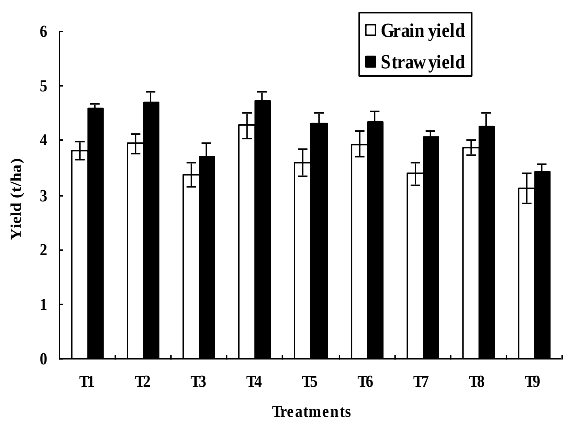

Figure 1. Residual effects of different green manures with different levels of nitrogen on grain and straw yield of BARI Gom-26.

3.4. Nitrogen uptake by BARI Gom-26

A significant variation in N uptake by grain and straw as well as total N uptake by BARI Gom-26 was observed due to residual effect of green manure in combination with N fertilizer (Table 2). The N uptake by grain varied from 65.91 to 96.39 kg ha^{-1}. The N uptake by grain was the highest (96.39 kg ha^{-1}) in treatment T_4 (*Sesbania rostrata* + 75% RDN) and the lowest (65.91 kg ha^{-1}) in treatment T_9 (*Vigna mungo* + 50% RDN). The N uptake by grain may be ranked in the order of $T_4>T_2>T_6>T_8>T_1>T_5>T_7>T_3>T_9$.

The N uptake by straw varied from 8.70 to 12.25 kg ha^{-1}. The highest N uptake (12.25 kg ha^{-1}) by straw was obtained in treatment T_2 (*Sesbania aculeata* + 75% RDN) which was statistically similar with the values obtained in T_4, T_6 (*Vigna radiata* + 75% RDN), T_5 (*Sesbania rostrata* + 50% RDN) and T_9 (*Vigna mungo* + 50% RDN). The treatment T_8 (*Vigna mungo* + 75% RDN) produced the lowest N uptake (8.7 kg ha^{-1}) by wheat straw. The treatments may be ranked in the order of $T_2>T_4>T_6>T_5>T_9>T_1=T_3>T_7>T_8$ in terms of N uptake by straw.

The total N uptake by BARI Gom-26 ranged from 77.53 to 108.02 kg ha^{-1}. The treatment T_4 produced the highest total N uptake (108.02 kg ha^{-1}) and the lowest total N uptake (77.53 kg ha^{-1}) was obtained in the treatment T_9. The total N uptake obtained from different treatments may be ranked in the order of $T_4>T_2>T_6>T_8>T_5>T_1>T_7>T_3>T_9$.

Similar to the above findings, a significant increase in N uptake by wheat grain and straw with the application of green manures has been reported by Shah *et al.* (2011) and the highest N uptake was found in *Sesbania*-incorporated plots.

Table 2. Residual effects of different green manures with different levels of nitrogen on N uptake by wheat.

Treatments	N uptake by grain (kg ha^{-1})	N uptake by straw (kg ha^{-1})	Total N uptake (kg ha^{-1})
T_1 (No green manure + 100% RDN)	74.14 cd	9.80 b	83.94 cd
T_2 (*Sesbania aculeata* + 75% RDN)	84.34 b	12.25 a	96.59 b
T_3 (*Sesbania aculeata* + 50% RDN)	69.07 de	9.80 b	78.87 de
T_4 (*Sesbania rostrata* + 75% RDN)	96.39 a	11.63 a	108.02 a
T_5 (*Sesbania rostrata* + 50% RDN)	72.89 d	11.60 a	84.49 cd
T_6 (*Vigna radiata* + 75% RDN)	83.74 b	11.62 a	95.36 b
T_7 (*Vigna radiata* + 50% RDN)	70.24 de	9.43 bc	79.66 de
T_8 (*Vigna mungo* + 75% RDN)	78.83 bc	8.70 c	87.53 c
T_9 (*Vigna mungo* + 50% RDN)	65.91 e	11.25 a	77.16 e
SE (±)	1.78	0.31	1.90
CV (%)	4.01	5.03	3.76
Sig. level	***	***	***

Figure (s) in a column having common letters do not differ significantly.

GM= Green manure; RDN= Recommended dose of nitrogen; SE= Standard error of means; CV= Coefficient of variation; NS= Non significant; *** = P< 0.001

3.5. Fertility status of soil

The initial and the post-harvest soil samples were analyzed to study the soil properties such as organic matter, total N, available P, K and S contents. Although not significant, the residual effect of green manures in combination with N fertilizer had a considerable influence on the soil properties (Table 3). The use of green manures slightly increased the organic matter content, total N, available P, K, and S in the post-harvest soil. The results are in agreement with the findings of some researchers (Ehsan *et al.*, 2014; Mandal *et al.*, 2003 and Mann *et al.*, 2000) who observed improved physical and chemical environment of soil with incorporation of green manures in the experimental plots. The improvement gained in wheat yield from green manure legumes could be attributed to improvement in the soil conditions and nutrient status of the soil. It is therefore recommended that green manure legumes should be encouraged for sustainable soil and crop productivity in rice-wheat system.

Table 3. Residual effects of different green manures with different levels of nitrogen on post harvest soil.

Treatments	Organic matter (%)	Total N (%)	Available P (ppm)	Available K (ppm)	Available S (ppm)
T_1 (No green manure + 100% RDN)	1.09±0.03	0.101±0.00	6.183±0.09	24.44±0.00	9.337±1.39
T_2 (*Sesbania aculeata* + 75% RDN)	1.21±0.00	0.128±0.00	6.813±0.23	25.46±1.02	12.857±1.06
T_3 (*Sesbania aculeata* + 50% RDN)	1.14±0.04	0.106±0.00	6.543±0.05	29.54±1.02	10.950±2.40
T_4 (*Sesbania rostrata* + 75% RDN)	1.13±0.15	0.110±0.01	6.893±0.23	24.44±2.04	10.373±2.52
T_5 (*Sesbania rostrata* + 50% RDN)	1.35±0.10	0.125±0.00	6.403±0.19	24.44±2.04	9.120±0.31
T_6 (*Vigna radiata* + 75% RDN)	1.38±0.18	0.114±0.01	6.330±0.04	26.48±0.00	9.430±1.89
T_7 (*Vigna radiata* + 50% RDN)	1.21±0.00	0.122±0.01	6.640±0.18	24.44±4.08	10.573±2.25
T_8 (*Vigna mungo* + 75% RDN)	1.21±0.04	0.118±.02	6.780±0.19	23.43±1.02	10.753±1.65
T_9 (*Vigna mungo* + 50% RDN)	1.24±0.06	0.132±0.00	6.820±0.15	30.56±0.00	9.273±2.05
Initial value	1.15	0.11	5.57	24.29	10

4. Conclusions

Green manuring with leguminous crops is a widely used practice that has a potential for reducing use of fertilizer-N application besides improving soil fertility. In the present study we found that plant height, spike length, number of grains spike^{-1}, grain and straw yield and N uptake were significantly higher in the plots treated with green manures in combination with 75% recommended N-fertilizer. Among different green manuring crops used in the experiment *Sesbania rostrata* and *Sesbania aculeata* performed better and the residual effect of green manures can compensate up to 25% reduction of recommended fertilizer N but not 50%. Therefore, the use of green manures with 75% N along with other inorganic fertilizers should be recommended for BARI Gom-26 production in rabi season of Bangladesh. However, more study is needed to confirm the results in other AEZ of Bangladesh with inclusion of other green manuring crops.

Conflict of interest

None to declare.

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