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Residual Effect of Green Manure on Soil Properties in Green Manure-Transplant Aman-Mustard Cropping Pattern

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ABSTRACT

Background: Conventional monoculture or cereal-cereal sequence systems insist farmers to use excessive application of chemical fertilizer in agriculture resulting reduce the soil organic matter contents and structures. The inclusion of green manuring crops in a rotation is vital to improve the biochemical and physical properties of the soil *via* increasing the labile of organic matter and ultimately increased crops yield. Some complex molecules of green manuring crops takes a longer time of decomposition and thus nutrients reserve in soil and release latter which provide nutrients to the succeeding and following crops. So the current experiment aimed to study the residual effect of different *in situ* green manuring crops to the sub-sequent and following soil.

Methods: The field experiment conducted during 2015 to 2016 with eight green manuring crops and rice and mustard was the subsequent and following crop. *In situ* incorporation of GM crops with 100% (F1) and 50% (F2) fertilizer, the prior and post-harvest soil (cropping pattern) of experiment field (0-15 cm) was collected and analyzed.

Result: After two consecutive year, GM-T.aman-Mustard cropping pattern increased soil organic matter 0.04% to 0.07% and 0.02% to 0.03% (T1 and T2 with F1 and F2) and nitogen 0.05% (T1, T2 and T7 with F1 and F2) and K 0.2 to 0.5 meq/100 g (*M. pudica* with F1 and F2) and P 2 ppm to 15 ppm (T1, T2, T3 and T7 with F1 and F2) compared to initial soil. Rice yield with T1, T2, T3 and T6 shown higher with both fertilizer doses. Nitrogen fertilizer rates could be reduced after the incorporation of green manures in the succeeding and following crops.

Key words: Green manuring crops, Mustard, Organic matter, Post-harvest soil, Soil fertility, Succeeding crop, Transplant aman.

INTRODUCTION

The intensive cultivation as well as monoculture of rice has brought a positive impact on food production in Bangladesh, nevertheless it has resulted in a serious depletion of soil fertility. In Bangladesh, most soils have less than 1.5% organic matter. However, excessive use of chemical fertilizers has led to several issues such as serious soil degradation, nitrogen leaching, soil compaction, reduction in soil organic matter and loss of soil carbon. Lin *et al*., (2019) found from a study and stated that the contents of heavy metals (Cu, Pb, Cd, As) were lower in soil and plant samples under organic fertilizer treatment compared to those treated with chemical fertilizer. Intensive land uses with continuous growing of similar crops significantly affect soil health and crop growth. In this context, green manures based cropping pattern is the way of hope as an alternative of inorganic fertilizer. Green manure helps in gaining back the deteriorated soil quality. The effect of decomposition of a green manure crop can be largely attributed to the increase of plant nutrients availability in soil and to the following crop. *Sesbania* green manures could have benefits for soil N dynamics by recovering residual mineral N in soil, by fixing N from the atmosphere for leguminous green manures and thereby contributing to subsequent crop N nutrition (Becker *et al.,* 1995, Griffin *et al.,* 2000). Similarly, Cavigelli and Thien (2003) postulated that incorporating green manure crops into soil might increase P bioavailability for succeeding crops. Incorporation of *Sesbania rostrata* and *Sesbania aculeata* added more organic matter and nitrogen to the soil than the prior soil (Irin *et al*., 2019) and reduced 50 percent of recommended N-levels of rice (Irin *et al*., 2020). Application of green manure plus chemical fertilizers is found to produce significantly higher yield than that of sole application of chemical fertilizer (Aktar *et al*., 1993). Ali *et al*. (2012) stated that the green manuring and leguminous cropping patterns gave higher paddy yield compared to rice-wheat cropping pattern. To reduce production cost and improve soil and crop productivity, integration of legume cover crops in cropping systems is now being highly emphasized among farmers in the tropics (Odhiambo *et al*., 2010). In Bangladesh, a few research works was done scattered but intensive work should be undertaken to study the different green manure crops based cropping pattern and its residual effect on subsequent (T. aman) and following soil (Mustard). Considering the above facts, the present experiment was undertaken to study the residual effect of different green manuring crops on soil properties in green manure- T. aman- Mustard cropping pattern.

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MATERIALS AND METHODS

The experiment was carried out at Sher-e-Bangla Agricultural University field during 2015 to 2016. The soil of the experimental field was sandy loam in texture having pH 5.9.

Cultivation of green manure crops during the fallow period prior T. aman rice and mustard cropping season

During 1st week of May, the eight green manure crops *viz.* Deshi dhaincha (*Sesbania aculeata*), African dhaincha (*Sesbania rostrata*), Sunnhemp (*Crotolaria juncea*), mungbean (*Vigna radiata*), blackgram (*Vigna mungo*), cowpea (*Vigna unguiculata*), Ipil-ipil (*Leucaen aleucocephala*) and Mimosa (*Mimosa pudica*) sown from seed and in situ incorporated at 45 DAS. The final soil samples of each experimental plot (0-15 cm) were collected and analyzed at 30 days after decomposition. The experiment was laid out in a randomized complete block design with three replications. The size of each plot was 17.50 m^2 (5 m × 3.5 m).

Experimental design and layout for rice and mustard

Seedling of (35 days old) T. aman rice (BRRI dhan 66) were transplanted on 13 July and BARI Sarisha-14 were sown on 25 November. The recommended fertilizer used for T. aman and mustard were 200-74-100-67-10 kg and 83-30-57-21-2 kg N, P, K, S and Zn ha^{-1} from their sources of urea, triple super phosphate, murate of potash, gypsum and zinc sulphate respectively. To supply nitrogen, two levels of urea *i.e.* 100% urea and 50% Urea from their recommended doses were applied in three equal splits. Two fertilizer doses and eight types of green manures were tested on rice (succeeding crop) and mustard (following crop) in a split-plot design with three replications.

Soil analysis

After harvesting T. aman and mustard crops, final soil sample were taken following standard methods. Soil organic matter was determined by wet oxidation method total N by modified Kjeldahl method, available phosphorus by the Olsen method.

Data analysis

The collected data were 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).

RESULTS AND DISCUSSION

Soil chemical properties

The chemical properties of initial soil are shown in Table 1. The pH, organic matter, nitrogen, P and K concentration of initial soil were taken before green manure sown.

Effect of *in situ* green manure incorporation on soil properties at two consecutive years

Incorporation of eight different green manures increased soil organic matter from 1.01% (initial) to 1.08% in 1st year and 1.61% in 2nd year (2016). The 0.14% higher organic matter was found in T2 compared to T7 in 2015 and 0.5%, 0.4% and 0.3% was recorded from T1, T2, T5 in 2016 (Fig 1). Total N status of soil increased from 0.04% (initial soil) to 0.084% in 2015 and 0.081% in 2016 (Fig 1) and T2, T6 showed the increased trend followed by T5 and T7 in both year. K showed slightly increasing trends (0.22 meq/100 g) from initial soil (0.18 meq/100 g) in 1st year but it decreased in 2nd year (Fig 1). The nutrient balance of soil after incorporation of different green manuring crops specially *S. rostrata, S. aculeata* and *C. juncea* showed positive balance of nutrients than other green manures (Irin *et al*., 2019).

Table 1: Initial soil data prior cropping.

pH	OM (%)	N (%)	P (ppm)	K (meq/100 g)
5.9	1.01	0.04	15.83	0.18

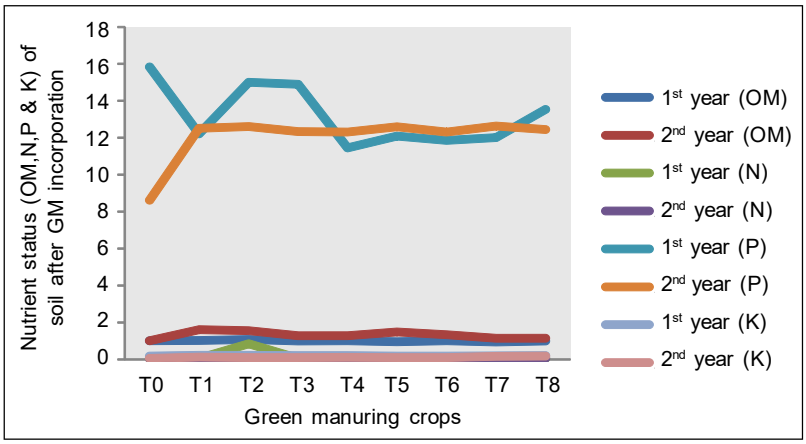


Fig 1: Effect of different *in situ* green manuring on soil organic matter (%), N (%), P (ppm) and K (meq/100 gm) contribution on pre sown rice soil in 2015 and 2016.

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*.

Effect of green manuring crops and nitrogen levels on grain weight, protein content of rice and yield of rice and mustard

The combined effect of NPK levels and residual effect of green manuring crops had a significant influence on 1000 grain weight, protein content and grain yield of rice and mustard (Table 2 and Fig 4). In both years, the highest 1000-grain weight of rice was obtained from the treatment combination of T2 with F1 which was statistically similar to F2 levels. The highest T. aman yield, mustard yield and grain protein (5.56 t ha^{-1} with F1 and 5.11 t/ha with F2), (1592.3 kg/ha) and (8.54%) was obtained from T2 followed by T1 and T3 which was statistically similar to the combination of F2 fertilizer in 2015 and 2016. The nutrients contributed from legumes could be partly responsible for yield improvement and up to reduction of 50% inorganic N fertilizer. The increased grain yield and protein content may be due to more availability of nitrogen and other nutrients to rice crop released by incorporation of green manure. 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.

Residual effect of green manure and N fertilizer on post-harvest rice (succeeding crop) and mustard (following crop) soil

Soil organic matter

After two years (post-harvest rice soil) SOM was increased 0.8% and 0.3% (T1) and 1% and 0.6% (T2) with F1 and F2 whereas 1.21% (T1 and T2) increased in post-harvest mustard soil followed by T3 (1.08) with F1 (Fig 2). Soft part of green manure crops are easy to break down wherever more recalcitrant molecules like lignin takes a longer time of decomposition and thus nutrients reserve in soil and release latter (Berg *et al.,* 2007) and thus continuous cultivation of GM crops increased soil OM varied from 2.30% to 2.95% at initial stage and 2.71% to 2.98% at postharvest stage (Chanda and Sarwar, 2017). The incorporation of *Sesbania* improved the soil nutrient status and residual effects lasted up to 3 years (Onim *et al.,* 1990).

Total soil nitrogen

In post-harvest rice soil (after two years), soil N increased 0.04% and 0.05% (F1 and F2) from T1 and T2 and 0.041 to 0.094% in post-harvest mustard soil (Fig 2). It may be attributed to the mineralization of N by organic manure in

Table 2: Interaction effect of fertilizer levels and different green manuriing crops on grain yield, 1000-grain weight, protein content of transplant aman rice yield in two years.

Interactions	Grain yield (tha^{-1})		1000-grain wt. (g)		Grain protein (%)
	1st year	2nd year	1st year	2nd year	2nd year
F1T0	3.10f	3.43b	21.36b	22.08b	7.85cd
F1T1	5.13a-c	5.20a	23.38ab	23.91a	8.17a
F1T2	5.23a	5.56a	24.11a	23.94	8.28a
F1T3	4.93a-d	5.30a	23.56ab	23.69a	8.23a
F1T4	3.56f	4.73a	22.78ab	23.41ab	8.04a
F1T5	4.20a-f	4.73a	22.59ab	22.92ab	8.40ab
F1T6	4.76a-d	5.13a	23.08ab	23.85a	8.10a-c
F1T7	3.96b-f	4.76a	23.23ab	23.50ab	8.09a-c
F1T8	3.80d-f	4.83a	23.50ab	23.75a	8.26a-c
F2T0	3.68d-f	3.97ab	22.86ab	23.07ab	7.54d
F2T1	4.86a-d	5.30a	23.07ab	23.53a	8.21a-c
F2T2	5.16ab	5.11a	23.54ab	23.87a	8.54a
F2T3	4.43a-e	5.13a	23.60ab	23.80a	8.22a-c
F2T4	3.90d-f	4.45ab	23.26ab	23.51a	8.04a-d
F2T5	3.93d-f	4.26ab	22.73ab	23.39ab	8.15a-c
F2T6	4.73a-e	5.03a	21.71ab	23.44ab	8.06a-d
F2T7	4.26a-f	4.53ab	21.88ab	23.26ab	8.01b-d
F2T8	4.66a-e	4.13ab	23.33ab	23.33ab	8.20a-c
SE (±)	0.283	0.296	0.663	0.340	0.056
CV (%)	8.87	8.06	3.63	1.96	1.99

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*.

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.

soil and greater multiplication of soil microbes, which could convert organically bound N to inorganic form. Rahman *et al.* (2013) showed the similar results and stated that total N status of soil ranged from 0.07 to 0.09% (initial level 0.07%).

Soil potassium

Post-harvest rice (both year) and mustard (1st year) soil shown little decreased trend of soil K from initial soil (0.18 meq100 g^{-1}) but drastically increased trend was observed in 2nd year from T1,T2, T6 and T8 showed the highest result.

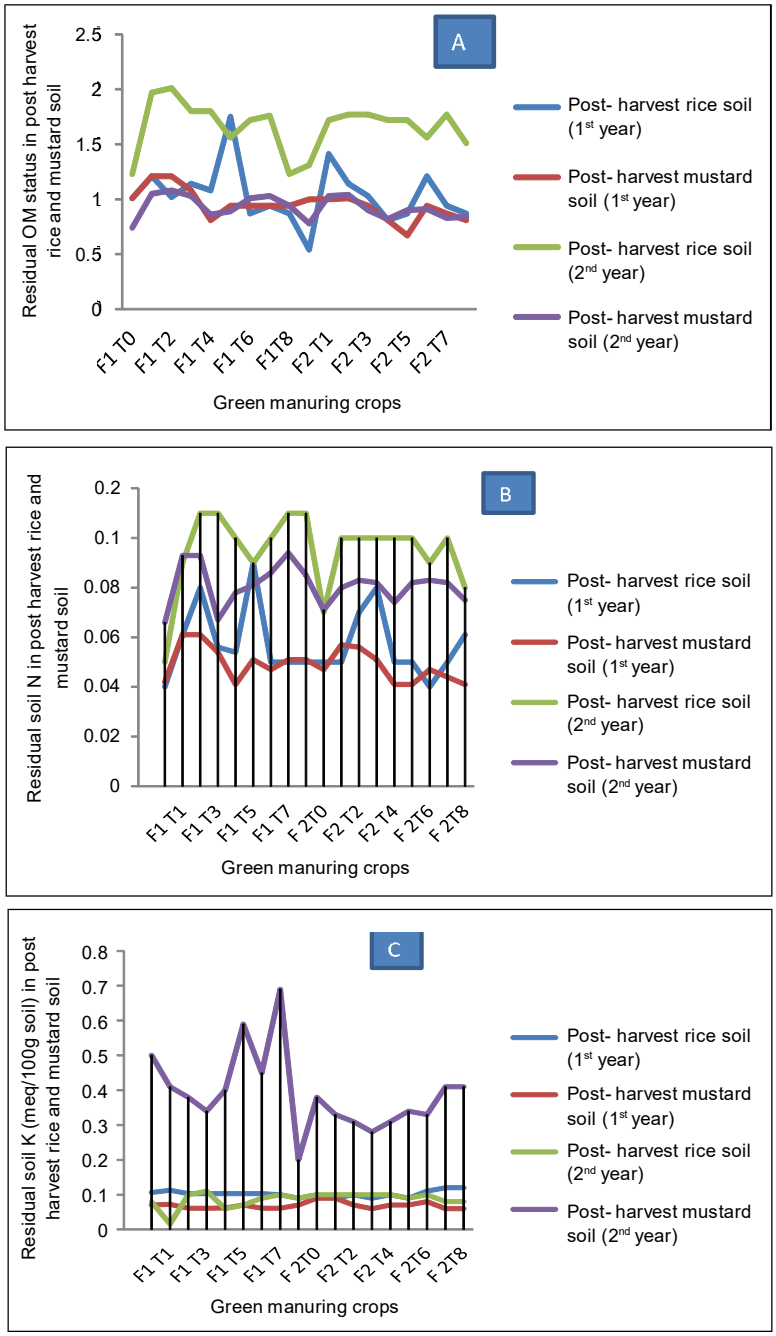


Fig 2: Residual effect of green manuring crops on (A) organic matter (%), (B) soil N (%), (C) K (meq/100 g soil) contribution in post- harvest rice and mustard soil in 2015 and 2016.

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*. 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.

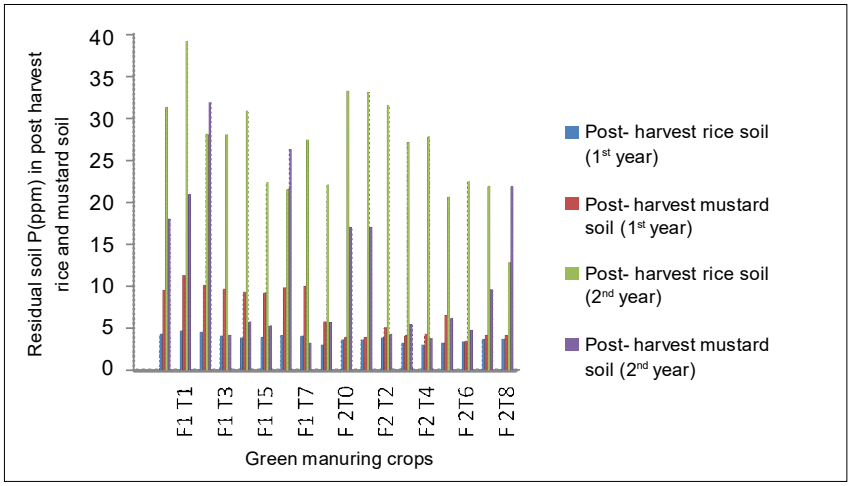


Fig 3: Residual effect of green manuring crops on soil P (ppm) contribution in post- harvest rice and mustard soil in 2015 and 2016. Here, T0= Control, T1= *S. aculeata*, T2= *S. rostrata*, T3= *C. juncea*, T4= *V. radiata*, T5= *V. mungo*, T6= *V. unguiculata*, T7= *L. leucocephala*, T8= *M. pudica*. 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.

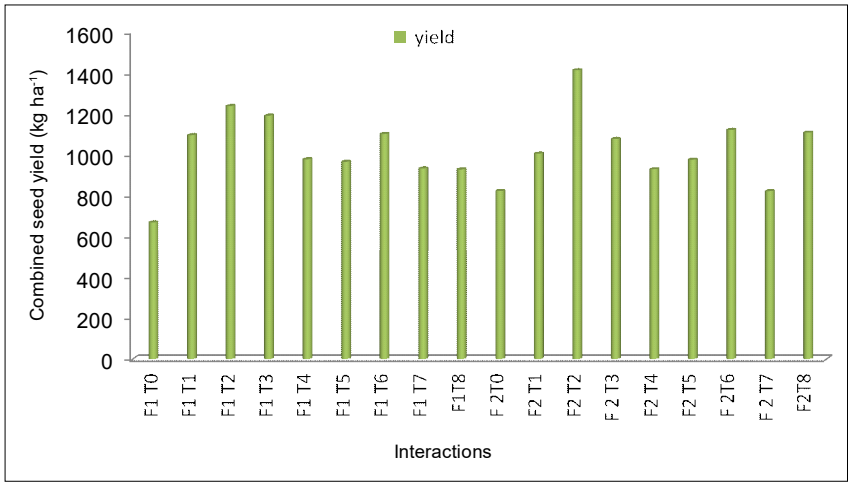


Fig 4: Interaction effect of pervious fertilizer levels and green manuring crops on seed yield of mustard in two pooled years. Here, T0= Control, T1= *S. aculeata*, T2= *S. rostrata*, T3= *C. juncea*, T4= *V. radiata*, T5= *V. mungo*, T6= *V. unguiculata*, T7= *L. leucocephala*, T8= *M. pudica.*

(Fig 2). The higher exchangeable K obtained with green manuring along with K fertilizer was due to the extensive root systems of green manure crops may improve the physical condition of soil and liberated CO_2 and organic acid which helped in dissolving native K in soil and thus increasing the availability of K (Singh *et al.*, 2009).

Soil phosphorous

In 1st year post-harvest rice and mustard soil shown decreased trend of soil P than the initial level (15.83 ppm) (Fig 3) whereas incredibly increased trend was observed in 2nd year from T1 (7.8 ppm in F1 and 11.31 in F_2 ppm), T2 (16 ppm in F_1 and 11.14 in F2 ppm) followed byT3. Again, T3 (31.30 ppm) followed by T7 (26.20 ppm), T2 (20.90 ppm) with F1 dose showed increased trend of P in post-harvest mustard soil. Green manure crops accumulate large amount of P and upon decomposition form bicarbonates (H_2CO_3) resulting solublize soil mineral P and makes the phosphorus sufficiency for the succeeding crops (Tissen *et al.*, 1994). Addition of green manures increases the soil organic carbon subsequently reduce soil pH which reduce phosphate fixation in soil with iron and aluminium and ultimately P availability increased (Dey and Nath, 2015). The excess soil P would help farmers to reduce fertilizer cost. Repeated application of green manure crops also result in decreased soil bulk density and increased soil aggregation and moisture retention, all factors that may help increase P uptake by succeeding crops via their effects on increased root and mycorrhizal growth (MacRae and Mehuys, 1985).

CONCLUSION

The residual effect of green manure improved soil fertility in GM- T. aman- Mustard cropping pattern by adding organic matter, nitrogen, P and K to the soil resulting reduced fertilizer cost. For betterment of soil, GM - T. aman - Mustard cropping pattern could be practiced instead of Fallow - T. aman - Mustard cropping pattern. The 50% reduction of N and P fertilizer can be recommended for succeeding T. aman rice from followed by growing *Sesbania rostrata, Sesbania aculeata, Crotalaria juncea* or *Vigna unguiculata* and *L. leucocephala* as a preceeding green manuring crop. As recommended cropping patterns needed 207 days, so it can be possible to include another short duration crop like mungbean in existing cropping patterns during the gap between mustard and green manuring crops. Hence in such case, GM- T. aman- mustard-mungbean may be a more effective cropping pattern in respect of yield and soil quality concern that can be tested in future studies.

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Conflict of interest: None.

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