INFLUENCE OF GREEN MANURING ON SOIL QUALITY IMPROVEMENT, FERTILIZER ECONOMY AND MONETARY ADVANTAGES OF GM-T. AMAN-MUSTARD CROPPING PATTERN

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CERTIFICATE

This is to certify that the thesis entitled, "INFLUENCE OF GREEN MANURING ON SOIL QUALITY IMPROVEMENT, FERTILIZER ECONOMY AND MONETARY ADVANTAGES OF GM- T. AMAN- MUSTARD CROPPING PATTERN" submitted to the faculty of Agriculture,Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the DEPARTMENT OF AGRONOMY, embodies the result of a piece of bona fide research work carried out by ISRAT JAHAN IRIN Registration No. 15-06896 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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ABSTRACT

Six field experiments and one laboratory experiment were conducted at Sher-e-Bangla Agricultural University during uninterrupted years of 2015-2016 to 2016-2017. The main objective of the experiments was to evaluate the impact of different kind of green manures on soil nutrient balance through adding biomass and N-accumulation along with its subsequent impact on crops yield and monetary advantages under Green manure-T. Aman rice-Mustard cropping patern.The green manure crops *viz.* Deshi dhaincha (*Sesbania aculeata*), African dhaincha (*Sesbania rostrata*), sunnhemp (*Crotolaria juncea* L.), Mungbean (*Vigna radiata*), Blackgram (*Vigna mungo*), Cowpea (*Vigna unguiculata*), Ipil-ipil (*Leucaena leucocephala*) and Mimosa (*Mimosa pudica*) were grown during two consecutive years for establishing a new cropping pattern of GM-Rice-Mustard. Fifty days-old green manure crops were incorporated after *in situ* cultivation and then both T. aman (subsequent crop) and mustard crops (following crop) were grown with recommended dose of N and half of recommended dose of N ha^{-1} in 1^{st} year (2015) for T. aman rice and recommended dose and half recommended doses of NPK fertilizers in 2^{nd} year (2016) for T. aman rice as well. Results showed that, the biomass incorporation reduced the N applicationin rice. The biomass from *Sesbania rostrata* , *Sesbania aculeata* and *Crotalaria juncea* with decreasing levels (half of recommended dose of NPK fertilizer) of fertilizer in T. aman rice gave the yield which was at par to increased level (recommended dose) of fertilizer application. Incorporation of *Sesbania rostrata* and *Sesbania aculeata* added more organic matter and nitrogen to the soil prior to T. aman rice planting. However, the higher grain yield of subsequent T. aman rice (BRRI dhan66) was recorded at both from recommended and half of recommended dose of $Nha^{-1}$and NPK with *S. rostrata* and *S. aculeata* followed by *C. juncea* and *V. unguiculata* incorporation as compared to control (no green manures). Green manuring (*S. rostrata* and *C. juncea*) residues incorporation prior to rice transplanting substantially increased (1549 $kgha^{-1}$ and 1309 $kgha^{-1}$for 2015 and 2016 respectively) the yield of the succeeding crop mustard as well. In case of mustard, *S. rostrata* incorporated plots gave the highest seed yield followed by *C. juncea* and *V. unguiculata*. The nutrient balance of soil after incorporation of different green manure crops specially *S. rostrata, S. aculeata* and *C. juncea* showed positive balance of nutrients than other green manures. Inclusion of *S. rostrata* as a GM crop in the GM-Rice-Mustard cropping sequence showed higher rice equivalent yield (REY) and production efficiency. This cropping sequence gave on an average 67% higher rice equivalent yield (REY) compared to the existing Fallow-Rice-Mustard sequence.

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LIST OF ABBREVIATIONS AND ACHRONYMS

ABBREVIATION	FULL WORD
%	Percentage
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Appl.	Applied
Biol.	Biology
cm	Centi-meter
CV	Coefficient of Variance
DAG	Days After Germination
DAS	Days After Sowing
DAT	Days After Transplanting
Ecol.	Ecology
Environ.	Environmental
et al	et alii, And Others
Exptl.	Experimental
F	Fertlizer
g	Gram
GM	Green manuring
i.e.	*id est* (L), that is
J.	Journal
kg	Kilogram
m^2	Meter squares
mg	Milligram
N	Nitrogen
Nat.	Natural
Nutr.	Nutrition
OM	Organic Matter
Physiol.	Physiological
RCBD	Randomized Complete Block Design
Res.	Research
REY	Rice Equivalent Yield
Sci.	Science
SE	Standard Error
Soc.	Society
SOM	Soil Organic Matter
SPAD	Soil Plant Analysis Development
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter
viz	*videlicet* (L.), Namely

CHAPTER 1

INTRODUCTION

Soil is fundamental to crop production and constitutes the natural resources that provide mankind the most of its food and nutrients. More than 99.7 % of human food (calories) comes from the terrestrial environment or agriculture environment or agricultural land (Pimentel and Wilson 2004). Since the advent of settled agriculture and cultivation of the soil, the major factor in influencing soil properties is man. In recent years, there has been renewed awareness of the earth's capacity to produce enough food to sustain the world's burgeoning population. As nutrients supplied by mineral fertilizers are important from both the yield and food quality perspectives, the challenge ahead is to manage fertilizers and soil in a sustainable way so that not only food demands are continuously met, but soil remains healthy to support adequate food production with minimal environmental impact in the future.

Food production levels of Bangladesh will have to increase rapidly without deteriorating soil quality, if the increasing population of Bangladesh will feed itself by following a suitable eco-friendly cropping pattern. Now adays, crop response to fertilizers is low and declining continuously of which 75% of total fertilizer would be consumed for rice production and the rest 25% for other crops. Rice production estimate is reduced slightly to 32.65 million metric tons (MMT) on lower aman production (planted in July/August and harvested in November/December) due to three days of unusually heavy rains from December 10-12, 2017. Bangladesh produced about 12.80 million tons of Transplant Aman (T. aman) rice with a productivity of 2.3 t ha^{-1} in 2010-11 (BBS, 2012) but productivity is below the potential yield of 5–6 t ha^{-1} in Transplant Aman rice (BRRI, 2010). In recent, Bangladesh produced 13.10 million tons of Transplant aman rice with 56 lac hectare area (BGFA, 2017). The use of chemical fertilizers without nutrient recycling has led to an immense loss of soil fertility and productivity (Nand Ram, 2000). It has also been established that cereal-cereal sequences are more exhaustive and put a heavy demand on soil resources as compared to cereal-legume sequences (Singh *et al.*, 2011). Abrol and Palaniappan (1988) cautioned about the non-sustainability of the rice-wheat or rice-rice system due to occurrence of multi-nutrient deficiencies in intensively cropped soils, an overall decline in soil productivity and escalating prices of inorganic fertilizers. In this context, green manures based cropping pattern is the way of hope as an alternative of inorganic fertilizer. The benefit of incorporating green manure crops into a monoculture system are widely known. One benefit of using green manures is their ability to provide nutrients to the following crop. The provision of nitrogen by legume green manure crops has been extensively reported by Aulakh *et al.* (2000). Becker *et al. (*1995) stated that the average amount of nitrogen accumulated by *Sesbania* species can entirely substitute the mineral fertilizer N in the subsequent rice crop. Griffin *et al*. (2000) concured that legume cover crops can supply all, or most, of the N required by a subsequent crop under certain conditions. Easily decomposable organic material such as green manure residues made fertilizer phosphate more effective. Similarly, Cavigelli and Thien (2003) postulated that incorporating green manure crops into soil might increase P bioavailability for succeeding crops. Nakapraves *et al.* (2002) noticed a non-significant trend for green manure crops (*Sesbania*, *Crotalaria*, *Vigna* and *Canavalia* species) to increase soil pH, N, P, K, Ca, Mg and S.

This is an important fact that soil organic matter through green manuring may be an essential reservoir of carbon (C), and its management in the soil can have far reaching significant implications on the global C balance and thus on climate change (Craswell and Lefroy, 2001). Green manure (GM) application has also been found to influence N cycling in soil. 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. However, estimating the amount of N released from green manures is difficult because of the many interacting factors, including temperature, moisture conditions and physical and chemical properties of the residues, involved in the mineralization process (Parr and Papendick, 1978; Bending and Turner, 1999). Green manure along with nitrogenous fertilizer helps to release nutrient elements slowly during the period of crop growth (Singh *et al*., 1990). 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). According to (Biswas *et al.,* 1996), incorporation of green manuring crop to the soil reduced 50 percent of recommended N-levels of rice. Introducing green manure crops in a cropping pattern are not only improve soil quality but also helps to reduce fertilizer cost. After harvesting of Boro rice, a large area remains fallow for about 2-3 months. This period could be used to raise green manures without sacrificing main crops. There is scope of introducing green manure in fallow period after wheat and some farmers already started growing green manure in Kharif I after wheat. In some places of northwestern part of Bangladesh, for growing early potato most of the lands remain fallow during Kharif II season due to lack of knowledge or short duration Aman rice varieties. After wheat, farmers are growing maize or mungbean and then transplanted (T) Aman rice. In order to produce more food within a limited area, the most important options are to increase the cropping intensity, producing three or more crops over the same piece of land in a year and to increase the production efficiency of the individual crop by using optimum management practices.

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). Experimental evidence supporting claims of beneficial effects of legume crop integration in tropical agriculture is provided by a number of studies conducted largely in humid or sub humid regions. Cover crops legumes are believed to have the potential to enhance yields of subsequent crops through atmospheric nitrogen fixation as well as enhanced mineralization of soil organic N during legume residues decomposition (Jenkinson *et al.*, 1985). Studies conducted in the mid-altitude areas of Uganda have shown that *Crotalaria ochroleuca* green manure can increase maize yield by 39% (Fischler *et al*., 1999). Other soil- related benefits attributed to cover crop legume use include breaks to crop pests and diseases during rotation and reduction in soil erosion through improved soil physical properties (Peoples and Craswell, 1992). Inclusion of legume crops as green manure or grain legume in the system has been found more beneficial than wheat-rice sequence (Singh *et al*., 2011). Legume crops fix atmospheric N, enrich soil fertility and could help to sustain the long-term productivity of cereal-based cropping systems. It has been well documented that the rice-wheat cropping system can be diversified using grain legume or *Sesbania* for green manure as a substitute crop (Bohra *et al*., 2007). Hossain *et al.* (2016) stated that, Wheat-Mungbean-Transplant Aman rice under IPNS with organic manures (CD or PM) can be practiced at farmers' level for greater productivity and profitability and improvement of soil health.

Green manuring crops are one of the effective manures for soil improvement. But the main constraint to expand the technology is intensive cropping in Bangladesh. There is a conflict between green manure crops and food and cash crops for space and time. In an intensive cropping sequence, farmers do not set apart 6-8 week exclusively for growing a green manuring crop with no direct benefit. In this situation, if green manuring crop could be fitted into the turn around period or inter cropped or relay cropped without any adverse effect on yield of main crop, it may help the farmers to grow for increasing organic matter status of the soil and productivity of the subsequent crop (Hossain and Kashem, 1997). The cost of a green manure crop in terms of labour, land and water utilization often out weighed the return, which often was less than the gain from an alternative cash crop (Rerkasem and Rerkasem, 1984). These statements shown mainly from economic analysis of current green manure use in the rice-based cropping systems. Ramteke *et al.* (1982) reported that economic analysis of cropping systems as a whole brought out the higher monetary returns from the crop sequences involving *Rabi* legumes.

Considering the above facts, the present experiment was undertaken to study the feasibility of increasing cropping intensity and productivity by growing four or three crops in a year in a same piece of land by introducing Green manure- T. Aman-Mustard cropping pattern in the existing cropping system. In Bangladesh, a few research works was done scatteredly but intensive work should be undertaken to study growth behaviour, nodulation as well as biomass yield of legume green manure crops and its effect on subsequent (T. Aman) and following crop (Mustard). The beneficial effect of several green manuring on soil N fertility and crop productivity has been adequately demonstrated. But the introducing of different type of green manure based cropping pattern is a very new practice to work because of the competition with other main crops for land.

Therefore, the study was conducted with the following objectives:

(i) to select the appropriate green manuring crops for soil quality improvement

(ii) to know the nutrient status of soil after green manuring

(iii) to find out the fertilizer economy of green manuring for subsequent rice crop

(iv) to find out the promising cropping pattern with higher monetary advantage and better soil quality concern.

CHAPTER 11

REVIEW OF LITERATURES

The research work by several workers for increasing soil organic matter as well as crop productivity through different green manures related with the topic of present investigation is reviewed and presented under suitable heads.

2 .1 Soil quality improvement through green manures

Soil quality as the balance between soil degradation and soil resilience. Soil resilience is the ability of soil to return to a dynamic equilibrium after being disturbed. The continuous depletion of nutrients due to intensive cropping system is posing a serious threat to sustainable agriculture. At the same time, the farmers cannot afford to supply all the essential nutrients through chemical fertilizers. Organic sources (green manures) of the nutrients although in small quantities, can solve the problem to some extent and help to conserve soil health in the following way:

2.1.1 Soil physical and chemical properties

Sarwar *et al*. (2017) reported that, organic matter status increased in soil after incorporation of dhaincha and succeeding crop rice intake nutrients from it.The increased of OM content in soil could also be attributed root growth and crop debris addition after crop harvest. Thus crop residual effect increased higher soil nutrients in post-harvest soil. However, OM decreased in control plot (no green manure use) due to rice crop intake nutrient from soil and soil may become exhausted. Chanda *et al*. (2017) stated that, the pH and nutrient status were improved in dhaincha incorporated soil over the control.

Chanda *et al*. (2017) reported that the sixty days old *dhaincha* crop produced up to 80 t ha^{-1} total dry mass in the monsoon season of Bangladesh whereas Khind *et al*. (1987) reported that the *Sesbania aculeata* could produce 21.1 t ha^{-1} of green biomass and accumulate about 133 kg N ha^{-1}. Thirty days old *S. aculeata* released an equivalent of 38 kg N ha^{-1}, while 45 and 60 days old plants released N equivalent to 60 kg and 120 kg N ha^{-1}, respectively.

Mzwandile *et al.* (2016) stated that, nitrogen mineralisation was significantly ($P < 0.05$) higher when sunnhemp was incorporated than when used as mulch.Green gram and black gram are also used as green manure in situ in paddy fields. After harvesting the pods, the remaining plant parts are incorporated into the soil and allowed to decompose.

Sanjoy *et al.* (2015) stated that Summer green manuring alone and in combination with nitrogenous fertilizer increased the grain yield of rice and wheat (residual) as well as N, P, K and S uptake, respectively. The highest grain yield of rice was obtained when sunnhemp grown as green manures crop incorporated along with 120kg nitrogen ha^{-1} followed by dhaincha and green gram. In case of wheat, incorporated dhaincha gave highest grain yield followed by sunnhemp and green gram. A significant increased in total uptake of N, P and K were obtained with increasing in N doses over control. The uptake of NPK by rice and wheat crops due to incorporation of green manures along with 120 kg N ha^{-1} followed by 90 kg N ha^{-1}. The increased in uptake of major nutrients may be better released of these nutrient through additional supply and prolific root system of green manuring crops resulting better absorption of water and nutrients. The integrated use of green manures in combination with fertilizer had been beneficial in the NPK uptake by rice and wheat crops.

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.

Kumar and Prasad (2008) investigated the integrated effect of mineral fertilizers and green manure on crop yield and nutrient availability under Rice-Wheat cropping system. They found that green manuring and green gram residue incorporation enhanced the uptake of N, P and K by rice and wheat. They recorded significant build up of organic carbon, available N, P and K in soil under graded levels of fertilizers and also with green manure and green gram crop incorporation after the picking of pods.

Pandey *et al*. (2008) stated that one of the most important green manure crops dhaincha (*Sesbania aculeata* L.) upon its incorporation in the soil at succulent stage adds 60- 90 kg per ha nitrogen.

Vakeshan *et al*. (2008) stated that sunn hemp (*Crotalaria juncea*) had its ability to grow fast and its efficient nitrogen fixing capacity, these plants are grown and sacrificed to improve the living condition of the main crop. Rotar and Joy (1983) reported sunhemp added 134 to 147 pounds of nitrogen per acre after 60 days of growth.

Ghosh *et al*. (2007) stated that, the cation exchange capacity (CEC) of roots of legume became approximately double compared to cereals. Relatively high CEC of legumes indicates that on soils with low levels of exchangeable K, the legumes would be deficient in K because the roots would adsorb larger amount of divalent cations. Whitbread *et al*. (1999) also reported that removal of rice stubbles resulted in negative K balance in rice.

Bah *et al.* (2006) have studied the phosphorus uptake from different green manures and phosphate fertilizers in an arid tropical soil. They reported that the green manure crops markedly increased fertilizer Phosphorus utilization in the combined treatments from 3% to 39%**.** Contribution of different green manures to Phosphorus nutrition of rice was studied by Hundal *et al.* (1992).

Eriksen (2005) stated that the application of green manures to soil is considered a good management practice in any agricultural production system because it stimulate soil microbial growth and activity, with subsequent mineralization of plant nutrients and therefore increase soil fertility and quality (Doran *et al*., 1988).

Mirza *et al.* (2005) reported that N and P utilization by rice also significantly improved with the application of green manure *Sesbania*. Nitrogen uptake by rice (grain + straw) was increased by 17.8 per cent and of P by 21.9 per cent with green manuring. The improvement attributed to the amendments in reclaiming saline-sodic soil is low but soil health and plant nutrition may be improved by introducing *Sesbania* permanently in the rotation.

Maiksteniene and Arlauskiene (2004) opined that the plant residues and green manure are not rich in K and especially P but they improve the physical characteristics and stimulate microbial activity of the soils. After decomposition, the organic phosphorous and potassium bound in the green manure crop may provide an easily accessible from of P and K to the succeeding crop.

Salim *et al*. (2003) reported that as soils in the rice tract are found slightly alkaline in nature so, the use of green manure can reduce soil pH, improves soil fertility, soil structure, porosity, water holding capacity and partially reduces the need of nitrogen fertilizer for rice crop. Besides green manuring being a part of integrated nutrient management system, would enhance the efficiency of applied fertilizer and helps in raising the organic matter contents in the soil. It also favourably improves the availability of other plant nutrients.

Cavigelli and Thien (2003) postulated that incorporating green manure crops into soil might increase P bioavailability for succeeding crops although Nakapraves *et al*. (2002) noticed a non-significant trend for green manure crops (*Sesbania, Crotalaria, Vigna* and *Canavalia* species) to increase soil pH, N, P, K, Ca, Mg and S. Sriramachandrasekharan (2001) reported that the *Sesbania* green manure increased uptake of P, K, Zn, Fe, Mn, Cu by rice plants.

Mehalatha *et al*. (2000) reported that organic matter significantly improved the soil fertility status and it was pronounced by the *dhaincha* incorporation by increasing organic carbon content, available N, P and K at post harvest stage.

Ladha *et al*. (2000) and Zia *et al*. (1992) stated that the use of *Sesbania* as green manure improves soil productivity through biological N 2 fixation. Green manures also bring about an increase in the nitrogen content of soils by encouraging the non-symbiotic or free-living bacteria, supplying them energy so they can fix nitrogen from the atmosphere in the soil. Green manures have become a vital approach particularly in the area of sustainable agriculture. The nutrients released by decomposers are incorporated into the soil which improves the status of soil fertility and recycled into the living organism.

Kanwarkamla (2000) stated that cultivation of legume crops were more soil fertility improver than as independent crops grown for their grain output. This is because legume crops are self sufficient in N supply.

Mann *et al.* (2000b) reported that organic manures increased soil organic matter content and thus total nitrogen. Increased K availability after green manuring has been reported by Kute and Mann (1969), Debnath and Hajra (1972). In contrast, Sahu and Nayak (1971) observed a slight decline of K after green manure.

Sharma and Ghosh (2000) and Palaniappan (1994) stated that the after decomposition of green manures it released nutrients and involved in recycling the nitrogen, phosphorus and potassium in integrated plant nutrients system (IPNS). Proper use of green manures leads to increased crop yields due to supply of nutrients, especially N and long term improvement of physical and chemical properties of soil (Bouldin, 1986).

Aggarwal *et al*. (1997) opined that incorporation of different organic materials before transplanting of rice, increased the total productivity of rice-wheat cropping system on an average by 2.9 to 126.2 per cent, due to improvement in soil physical properties like bulk density, penetration resistance, aggregation, hydraulic conductivity, infiltration and moisture retention and chemical properties, like organic carbon, available macro- and micro-nutrients like Zn, Cu, Mn and Fe (Bhandari *et al*., 1992; Prasad, 1994; Aggarwal *et al*., 1995 and Tiwari *et al*., 1995). Incorporation of organic manures in sodic soils, decreased pH, EC and ESP thereby increased crop yields (Kumar and Yadav, 1995).

Mansoer *et al.* (1997) stated that, as a cover crop, sunn hemp can produce 5,000-6,000 pounds of biomass per acre in southern climates in 60-90 days. It also can produce 120- 140 pounds of nitrogen in the same amount of time. It provides the benefits of a cover crop such as erosion control, soil improvement, plus resistance to root knot nematode.

Singh *et al*. (1997) reported that multiple cropping systems with legumes offer special advantage to farmer. Legumes are effective green manures as they contain high N contents and production of large quantity of biomass within a short period of time.

Bhuiyan and Zaman (1996) stated the benefits of green manuring are generally interpreted as its capacity to produce or provide nitrogen as substitute for fertilizers. Green manures have relatively more N, low C-N ratio and behave almost like chemical nitrogenous fertilizers. This helps to increase crop yields keeping the use of chemical fertilizers at low level.

Saraf and Patil (1995) stated that incorporation and decomposition of green manure had a solubilizing effect of N, P, K, and micronutrients (Zn, Fe, Mn, and Cu) in the soil and deficiency of different nutrient elements can be mitigated by way of recycling of nutrients through green manuring. Further, it also reduces the leaching and gaseous losses of N, thus increasing the efficiency of applied plant nutrients.

Bhuiya and Hossain (1994) stated that the *Sesbania rostrata* contains more nitrogen and attains more height than *Sesbania aculeata*. Inclusion of *Sesbania rostrata* as green manure in rice based cropping systems increases productivity and improves the soil organic matter.

Mureithi *et al*. (1994) stated that as *leucaena* contain (3-5) % of nitrogen, after its decomposition it has been found beneficial for meeting N requirement and improve productivity of maize and there are significant residual effects on soil fertility and productivity of the following crops.

Bandara and Sangakkara (1993) stated that, the N content of *Sesbania* biomass (both shoots and roots) was 3.12% ± 0.26%. Thus the quantum of mineral N added by 3400 and 2100 kg of *Sesbania* dry matter was equivalent to 100.3 kg and 65.5 kg Nha^{-1}. The N content supplied by *Leucaena* leaves added from external sources was also similar. Thus, the requirements of *Leucaena* leaves (3.63% N) from external sources for the two incorporations were 2765 kg and 1804 kg/ha respectively.

Ranells and Wagger (1992) opined that the green manure application had also been found to influence N cycling in soil. 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.

Oglesby and Fownes (1992) stated that the leguminous tree species with high N concentration and low lignin and phenolic compounds like *Leucaena* and *Sesbania spp* liberate more of their leaf N within two weeks of pruning.

Kalidurai and Kannaiyan (1991) stated that, among nitrogen-fixing green manures such as *S. rostrata* and *S. aculeata* yielded higher biomass than *S. speciosa* on 50th day of growth. *S. rostrata* stems produced a higher number of nodules than the root; the stem nodules had a higher nitrogenase activity than the root nodules. The nitrogen content of *S. rostrata* plant was greater than *S. aculeata* or *S. speciosa*. Micronutrient accumulation was higher in *S. rostrata*. Incorporation of *S. rostrata* and *S. aculeata* along with fertilizer nitrogen at 60 kg N ha^{-1} significantly increased the grain yield of rice.

Yadvinder *et al*. (1991) stated that leguminous green manure species differed widely in biomass production and N accumulation. The most productive green manure crops yielded about 4-5 tha^{-1} of dry biomass in 50-60 days. Clusterbean has generally been less productive than *Sesbania*, sunn hemp, and cowpea in descending order (Singh, l98l). The biomass production in *Sesbania* is mainly controlled by age factor. In Sri Lanka, Weerakoon and Gunasekera (1985) showed that about 2.5 tha^{-1} leaf dry matter of *Leucaena leucocephala* could be obtained every cropping season.

Paisancharoen *et al.* (1990) found that, cowpea (21 tha^{-1} fresh biomass) was the most promising green manure crop, followed by *Crotalaria juncea (*18 tha^{-1} fresh biomass) and pigeon pea (10 tha^{-1}fresh biomass) for improving soil fertility. This is due to the vigorous early growth of cowpea, which leads to a high amount of biomass being produced within two month before planting any crop. Furthermore, cowpea had a high nutrient content, especially nitrogen and cations such as potassium.

Yaseen *et al*. (1990) reported that the *Sesbania* can be planted in May after the wheat harvest and incorporated into the soil at the end of June, two weeks prior to rice transplanting in Bangladesh condition. As a green manure crop, it can substitute for applied fertilizer N (Raju and Reedy, 2000; Mann and Ashraf, 2000b and Subedi, 1998) in addition to supplying organic matter for the restoration of soil physical conditions.

Rupella and Saxena (1989) stated that the leguminous crops are the potential crops for their capability of nodule formation and nitrogen fixation. As for example, mungbean can fix nitrogen in the range of 30-40 kg N ha^{-1}. Soil temperature has the effect on pattern of nitrogen release during decomposition of added green manure residue in soil (Brar and Sidhu, 1997).

Bouldin (1988) opined that after green manure or legume crops residues decomposition, it released its N quickly and its organic N is transformed into available form. It is an excellent source of N for the first crop following its incorporation. It was proposed that 6.5% of the added green manure nitrogen mineralizes during 1st crop, 14% mineralizes during the second crop and so on.

MacRae and Mehuys (1988) reported that the green manure crops improved the physical, chemical and biological condition of clay soils. It is known that improvement of soils physical condition by adding green manure crops into the soil create the potential for crop growth. The long term benefit of green manure crops is to stabilize yields of subsequent crops during dry seasons.

Hoyt (1987) stated that, cowpea residue decomposition releases other plant nutrients such as phosphorous, potassium, calcium, magnesium and sulphur into the soil. When green manure is incorporated and allowed to decompose, plant nutrients become readily available in the soil for the succeeding crop resulting in improved growth and yield of the succeeding crop. This might have accounted for the higher yields of carrots from cowpea green manure compared to control.

Swarup (1987) showed in field experiments that allowing decomposition of *Sesbania* green manure for one week under flooded conditions in sodic soils significantly improved rice yields over simultaneous incorporation and transplanting of rice, possibly through improvement of physicochemical properties of sodic soils. Wen (1984) reported that it is better to turn under green manure crop about 15 days before transplanting rice seedlings so that plants do not suffer damage from the decomposition products of the green manure. To avoid losses of green manure N it was recommended to keep the fields flooded during the decomposition period before transplanting rice.

Lemare *et al*. (1987) found that green manures had no effect on the total amount of phosphate adsorbed by the soil; however, increase the proportion of added phosphate that became isotopically exchangeable. Ninety-nine per cent of the adsorbed phosphate was exchangeable in soil with green manures, but only 89% was exchangeable in soil without green manures. Easily decomposable organic material such as green manure residues made fertilizer phosphate more effective.

Onnim (1986) reported that *Sesbania* could fix up to 250 kg nitrogen in six month. Since urea fertilizer contains 46% N, this fixation is equivalent to approximately eleven 50 kg bags of urea fertilizer in six month. Dargan *et al*. (1975) also reported that, *Sesbania* can return into the soil as green manure between 80 and 120 kg N within 90 days.

Roger and Watanabe (1986) reported that N content in legumes varies from 0.2 to 0.6% (fresh weight basis). Ghai *et al*. (1985) observed that N content in *Sesbania,* sunn hemp, tops was maximum at 45 days of growth and decreased thereafter. Mukherjee and Agarwal (1950) and Ghai *et al*. (1985) reported that N content of different green manures (8 weeks old) ranged from 1.5 to 4.85%. Mukherjee and Agarwal (1950) and Ghai *et al*. (1985) reported that N content of different green manures (8 weeks old) ranged from 1.5 to 4.85%.

Roger and Watanabe (1986) stated that the green manure is an excellent natural source of N for cultivated crops. Dhaincha (*Sesbania rostrata*) is a nodulating tropical forage green manure, is considered the most promising of the green manure crop for wetland rice because of its high N_2-fixing ability in standing water. Most Asian rice-growing countries practice green manuring and, in most cases, yield and soil fertility increased because green manures added organic matter to the soil and recycle nutrients into the soil. They help prevent nutrients being washed out of the soil. The nutrients are taken up by the green manure and held inside the plant. Legumes and other nitrogen fixing plants which take nitrogen from the air to the soil are particularly beneficial.

Morris *et al*. (1986) observed that different green manures showed a linear relationship between N accumulation and dry weight irrespective of green manure species, and were affected by the age of green manure crop. It was found that green manures had maximum N content of 2.54% at 45 days and decreased to 1.88% in 60-day-old green manures.

Jones *et al.* (1985) reported that green-manure crops when incorporated into the soil promoted high biological activity making plant nutrients available for crops uptake and this improves crop yield. Frye and Blevins (1989) reported that legume green manure can replace a portion of the nitrogen fertilizer requirements for a succeeding crop.

Macrae and Mahuys (1985) stated that the application of green manures to soil is considered a good management practice in any agricultural production system because it can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical properties, by increasing soil organic matter and fertility levels (Doren and Smith, 1987), by increasing nutrient retention (Dinnes *et al*., 2002) and by reducing global warming potential.

Morris *et al*. (1985) stated that for higher crop yield, peak N releases pattern from the green manure or legume must coincides with the peak N requirement of the rice crop. Nitrogen mineralization from the green manure take place 5 days after its incorporation with a peak around 20 days, afterwards it declined to a minimum level at 45 days.

Alexander (1977) stated that the water soluble fractions of green manures get metabolized early followed by cellulose and hemi-cellulose. The lignins are the most resistant to decomposition and therefore they are more abundant in the consequently become abundant in residual decaying organic matter.

Dei and Maeda (1976) reported from a long-term (40-yr) field study that green manuring resulted in a well developed aggregate structure in the plough layer of the rice soil; a large and compact blocky soil structure was, however, developed in the field without green manure.

Dargan *et al*. (1975) reported that the green manuring had greater manurial potential when rice is planted immediately after burying the green manure. An economy of 60-80 kg N ha^{-1} can be obtained in rice-wheat rotation when dhaincha was incorporated one day prior to transplanting of rice (Meelu and Rekhi, 1983).

Allison (1973) observed that major benefit obtained from cowpea green manure was the addition of organic matter to the soil. The contribution of organic matter to the soil from the green manure is estimated to be 9 to 13 tonnes farmyard manure per hectare. Schmid and Klay (1984) stated that the most obvious direct economic benefit derived from cowpea green manure is nitrogen fertilizer saving.

Agboola and Fayemi (1972) reported that cowpea as green manure was an important source of N for many crops in the humid tropics. When properly managed, cowpea can produce 20 to 40 tonnes per hectare fresh biomass which when incorporated into the soil as green manure can add up to 45-68kg N per year (Tucker and Matlock, 1974).

Witkamp (1971) stated that a large number of soil microorganisms exist in the soil as long as there is a carbon source for energy. Soil inhabiting microorganisms are very critical for decomposing organic residues and recycling soil nutrients. The addition of green manure or other organic matter helps in the increase of microbial biomass. The process of decomposition is of great significance because unless the energy and nutrient are released through microbial activity the primary product cannot exist for long time. These microorganisms play an important role in the cycling of mineral nutrient from plants tissue bulk to plant tissue via herbivore, carnivore and saprophagous food chain.

Brown (1913) on his book Green Manuring and Soil Fertility, stated that legumes were independent of the nitrogen in the soil if their roots had so-called nodules, or swellings, which contain bacteria. These bacteria take the nitrogen from the atmosphere and supply it to the plants and thus there is no draft on the nitrogen in the soil. If the entire crop is turned under there is an addition of nitrogen to just the extent to which the nitrogen from the air is stored in the plants.

2.1.2 Effect of green manures on succeeding crop

Chanda and Sarwar (2017) stated that the incorporation of dhaincha biomass significantly influenced the yield and yield contributing characters of subsequent T. Aman rice, as compared to the control (without dhaincha incorporation).

Kalaiyarasan and Subbalakshoni (2015) opined that the effect of Dhaincha incorporation significantly affected agronomic yield in rice crop as compared to the absolute control.

Ali *et al*. (2012) stated that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to commonly practiced rice - wheat cropping pattern where *sesbania* was sown and incorporated in the soil before to rice transplanting.

Rahman *et al.* (2012) reported that the incorporation of green manuring dhaincha biomass increased rice yield 7 to 39% over control. This might be due to the fact that steady and adequate supply of nutrients by the enhanced biochemical activity of micro-organisms coupled with large photo synthesizing surface would have helped in the production of more tillers and dry matter with enhanced supply of assimilates to sink resulting in higher yield.

Talgre *et al.* (2012) reported that grain yields of three succeeding cereal crops were increased with increasing N yield of the first experimental year and the relationship between cereal yield and the amount of N in biomass was linear. The response of 1 kg of N was 8.6 kg of grains. The relationship between cereal yield and biomass N content stayed linear in the third year although the relationship was much weaker than in previous two years. The response of 100 kg N ha^{-1} added to soil in biomass (pure and undersowing), resulted in 43, 34, and 10% increase in grain yield of the first, second and third succeeding cereal respectively, compared to the unfertilized control field but the effect of N in their organic matter on yield increase was three times lower than in the first year.

Fageria (2007) reported that the total N assimilated by a subsequent cash crop (4 to 30%) could come from the mineralization of green manure crop residue. Green manure therefore has the potential for supplying some of the N requirements of cereal crops such as, maize, in low input environments where the cost of adequate use of inorganic fertilizers is beyond the means of the resource poor farmer.

Ghosh *et al*. (2007) stated that, 6-8 weeks old green manure crop of sunhemp or dhaincha accumulated about 3-4 t ha^{-1} dry matter and 100-120 kg N ha^{-1} which, when incorporated in situ, supplements up to 50% of the total N requirement of rice. Legumes with indeterminate growth are more efficient in N_2 fixation than determinate types. Fodder legumes in general are more potent in increasing the productivity of succeeding cereals. The carryover of N for succeeding crops may be 60-120 kg in berseem, 75 kg in Indian clover, 75 kg in cluster bean, 35-60 kg in fodder cowpea, 68 kg in chickpea, 55 kg in black gram, 54-58 kg in groundnut, 50-51 kg in soybean, 50 kg in Lathyrus, and 36-42 kg per ha in pigeon pea. Incorporation of whole plant of summer green gram/black gram into soil (after picking pods) before transplanting rice resulted in the economizing (40-60 kg N ha^{-1}, 30 kg P_2O_5, and 15 kg K_2O ha^{-1}) of rice in rice-wheat system. *Leucaena leucocephala* prunings provide N to the extent of 75 kg, which benefits the intercrop castor and sorghum.

Freyer (2003) reported that the nutrients were released from green manure at a slower rate; also, N from N bacteria becomes accessible over a long time span. These processes grant steady sources of N for succeeding crops.

Bokhtiar *et al*. (2003) reported that the green manures and the supplemented urea increased cane yield upto 57% along with the significant increase in organic matter, total N, available P and S of the soil.

Hemalatha *et al*. (2000) reported, that *Sesbania* increased yield of the subsequent rice crop due to high N accumulation and greater uptake; and showed a greater release of N from *Sesbania* green manure than FYM. They observed an increased availability of

N from *Sesbania* green manure during the active vegetative growth period of the rice crop. Higher availability likely resulted in greater N uptake in rice.

Mann *et al.* (2000a) stated that continued use of organic manure (preferably for 2-3 years) would accumulate modest amounts of N in the soil and thus show a considerable effect, either by rising yields of subsequent crops or by reducing fertilizer N requirement.

Kanwarkamla (2000) stated that cultivation of legume crops were viewed more soil fertility improver than independent crops grown for their grain output. This is because legume crops are self sufficient in N supply. Porpavai *et al.* (2011) also reported that legumes were potentially important to diversify cereal based mono cropping into cereal-legume sequences which had nutrient cycling advantages.

Nayyar and Chhibba (2000) stated that the increased availability of Fe and other micronutrients in soil with regular summer green manuring crops every year before transplanting of rice was responsible for higher growth and development of rice plants in the green manuring plot compared with the non-green manuring plot.

Bhuiya and Hossain (1997) observed that the incorporation of green biomass of *Sesbania rostrata* at the rate of 25 t ha^{-1} was as good as applying of 80 kg N ha^{-1} as urea for rice cultivation. Again it appeared that application of green biomass of *Sesbania rostrata* at the rate of 30 to 40 t ha^{-1} would maintain soil organic matter at a sustainable level. They also stated that *Sesbania rostrata* could be relayed with aus rice and this can be used as green manure for succeeding transplant aman rice. From the relay crop, 14.6 to 23.0 t ha^{-1} green biomass of *Sesbania* could be obtained and it was nearly sufficient to maintain soil organic matter status.

Becker *et al.* (1995) stated that although green manure was a short growth period (45–60 days) plant, green manure legumes could fix 80-100 kg N ha^{-1} of which the major portion (about 80%) is derived from biological N_2 fixation. Therefore biomass from legume green manure crops could add a huge amount of N and C to the soil, which improved soil humus characteristics. Legumes could absorb nutrients from lower soil layers, with their well developed and deep root systems and return the nutrients to upper soil layers with their biomass. The relocation of plant nutrients (especially P and K) is particularly useful in organic farming.

Sharma *et al*. (1995) observed the beneficial residual effect of *sesbania* and mungbean straw applied to rice on succeeding wheat crop. There was increase in the wheat yield by 0.6 and 0.7 t ha^{-1}, respectively as compared to the control. The *sesbania* green manure and mung straw substituted 43 and 30 kg N ha^{-1} in rice and subsequently showed beneficial effect on succeeding wheat equal to the extent of 89 and 112 kg N ha^{-1}, respectively.

Das (1995) stated that mungbean is an easily decomposable crop. It can be relayed with aus rice. Accommodating summer mungbean crop with aus rice (relayed 40 days after sowing of aus rice) produced 10-16 t ha^{-1} fresh biomasses by least hampering the rice yield. So, it may be used as green manure to raise the organic matter status of the soil.

Pervin *et al.* (1995) reported that the application of *Sesbania aculeata* along with the recommended chemical fertilizers might ensure adequate supply of nutrients especially nitrogen to the transplanted rice over the entire growing season for better plant growth with higher grain production.

Bandara and Sangarkkara (1993) stated that addition of fertilizer nitrogen with organic matter nullified the benefit and produced similar yields, which were greater than plots receiving only organic matter or fertilizer nitrogen. The use of the full complement or 50% of the rate of mineral nitrogen with *Sesbania* produced similar yields.They also stated that that the application of in situ mulch with *Sesbania* could reduce the mineral N requirement by 50%, in the Maha season in this region. As a green manure, 40–60 day old *Sesbania rostrata* can substitute for about 50-70 kg N ha^{-1} from N fertilizer for lowland rice (Kolar *et al.*, 1993). Well nodulated *Sesbania* plants may derive up to 90% N from fixation (Pareek *et al*., 1990).

Yadvinder *et al*. (1991) stated that the green manures are the crops which are returned into the soil in order to improve the growth of subsequent crops. Green manures offer considerable potential as a source of plant nutrients and organic matter. MacRae and Mehuys (1988) also stated that the long term benefit of green manure crops is to stabilize yields of subsequent crops during dry seasons.

Zaman *et al.* (1991) reported that, on a light textured soil, green manuring with 60-day-old dhaincha can completely substitute for urea-N fertilizer. The establishment of dhaincha is very difficult in a T. Aus-T. Aman cropping pattern because the farmers do not want to sacrifice any crop for green manure establishment.

Singh *et al*. (1990) reported from his studies that, *Sesbania* green manuring is very promising because of its contribution in supplementing N requirement of the following T. Aman rice and also recycling of S and P for the next crops. It has also been reported that green manuring provides a substantial amount of nutrients for the next crop (BRRI, 1998; Elahi, 1991).

Rabindra *et al*. (1989) showed that application of a part of N (30%) through green manure produced significantly more rice yield and N uptake than from 100 kg urea N/ha alone. In most of the studies, rice yield potential was high when green manure and an optimum quantity of fertilizer N were applied together.

Palm *et al*. (1988) stated that the stem and roots of green manure were generally poorer in N content and had wider C/N ratios than that of foliage portion. These parts decompose slowly and could result in immobilization of N. The net N released from green manure is the balance of all the N transformation processes occurring in the different parts of green manure. The efficiency of green manure N should depend on the extent of N losses, and the rate of N supply to the growing crops through mineralization-immobilization turnover rate.

Mahapatra *et al.* (1987) noted a significant residual effect of applied dhaincha (60 kg N ha^{-1} + 30 kg N through Azolla inoculation) to preceding rice crop resulting in increased grain yield of succeeding wheat, which was mainly attributed due to increased organic carbon and total nitrogen status of soil. Sharma *et al.* (1988) showed that nutrient from organic sources did not prove beneficial to the rice, but their residual effect in increasing the grain yield of succeeding crop was clearly evident.

Millan *et al.* (1985) reported that basal dose of nitrogen was exhausted in 45-50 days, just prior to enter initiation stage of rice. They have needed additional nitrogen for their growth and tiller development. Decomposed organic matter released nitrogen and quickly transformed into available form in soil. Crop uptake nutrients and showed a vigorous growth and as resulting increased crop yield.

Jones *et al.* (1985) reported that green-manure crops when incorporated into the soil promotes high biological activity making plant nutrients available for crops uptake and this improves crop yield. Tiwari *et al*. (1980) observed increase in grain yield of succeeding wheat crop due to residual fertility retained after harvest of rice to, which green manure was applied.

Tiwari *et al*. (1980) reported that green manure plus 40 kg fertilizer N/ha produced rice yield which was comparable with 120 kg fertilizer N/ha alone. Ishikawa (1988) reported that combining green manure and fertilizer N (56: 3g) resulted in greater rice yields than from fertilizer N alone.

2.1.3 Effect of green manure on growth of rice

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.

Vaiyapuri and Sriramachandrasekaran (2002) stated that incorporation of 12.5 t ha^{-1} of *Sesbania aculeata* recorded the highest plant height and number of tillers per hill.

Sharma and Das (1994) studied the effect of green manuring with dhaincha on growth and yield of direct-sown and transplanted rice under intermediate deepwater conditions (0–50 cm). They reported the highest yield when rice and dhaincha were grown at a 2:1 ratio in 20 cm wide rows. Increase in yield under green manuring was due to greater panicle weight, which was probably due to a continued supply of N following decomposition of organic matter added through dhaincha. They concluded that green manuring of direct-sown rice with dhaincha was beneficial for higher crop productivity under excess water conditions.

Yadvinder *et al*. (1991) stated that the supply of P through green manure appeared to be more beneficial in enhancing the yields of rice than the direct application of P to rice crop. Allowing extended periods of green manure decomposition before rice transplaiting gradually resulted in a lesser contribution to the subsequent rice irop

Balasubramaniyan and Palaniappan (1990) judged a significant effect of green manure on leaf area index and numbers of panicles as compared to control, but the filled grains per panicle was not much affected due to green manure.

Maskina *et al.* (1989) studied on the effect of integrated use of organic and inorganic sources of nitrogen on growth of rice for two years and showed that application of 120 kg N ha^{-1} was significantly superior over 60 kg N ha^{-1} in terms of dry matter accumulation and plant height.

Antil *et al.* (1988) studied that the grain and straw yield of rice were significantly higher after application of green manure of dhaincha and moong compared to fallow and maize. The beneficial effect of green manure was mainly due to steady release of nitrogen during crop season.

Kolar and Grewal (1988) examined that burying *sesbania*, cowpea and sunnhemp resulted in significant increase in grain and straw yield of rice.

Jamdade and Ramteke (1986) monitored that incorporation of dhaincha and gliricidia increased the number of tillers, dry matter accumulation, number of panicles, thousand grain weight, number of filled grains $panicle^{-1}$ as compared to no green manure, which in turn produced the highest grain yield of 52.12 and 52.09 q ha^{-1}, respectively. Jamdade (1985) viewed that application of 40 kg N ha^{-1} + green manure of *Sesbania aculeata* and *Gliricidia maculata* @ 10 t ha^{-1} was comparable with a dose of 120 kg N ha^{-1} through fertilizer alone.

Bhardwaj *et al.* (1981) showed that green manuring of sunnhemp, dhaincha and Ipomea carnea @ 15 t ha^{-1} in combination with 0, 30, 60, 90 kg N ha^{-1} increased the number of tillers m^{-2} and dry matter accumulation. They also marked that the incorporation of *Crotalaria juncea* and *Sesbania canabina* significantly increased the grain yield of rice on irrigated land. The prediction equation perceived that there was saving of 49.9 and 23.3 kg N ha^{-1} by green manure with *Crotalaria juncea* and *Sesbania canabina*, respectively.

Jha *et al.* (1980) noted that application of green manure @ 5-10 t ha^{-1} was very useful for improving the growth rate. They reported that application of green manure (*Ipomea cornea*) was very useful for improving the grain and straw yields of rice through increased number of ear bearing tillers m^{-2}. Tiwari *et al.* (1980) also opined that application of green manure was very useful for improving the grain and straw yield through increased number of ear bearing tillers.

Jaggi and Russel (1973) observed that green manure significantly influenced the number of tillers per hill and leaf area index. Chanda and Sarwar (2017) reported that 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. He also stated that due to the incorporation of dhaincha biomass in soil, the rice grain yield increased 7.82% to 33.56% over the control.

Reddi *et al*. (1972) observed that in the presence of 7.5 tha^{-1} green manure, an additional rice yield of 0.68 tha^{-1} (12.4%) was obtained at recommended fertilizer N application. The yield potential further increased to1.08 tha^{-1} when 15.0 tha^{-1} of green manure was applied.

Staker (1958) stated that the green manuring with 53-day old sunn hemp (20.6 t ha^{-1} of green matter) increased rice yield, on the average, by l.l8 t ha^{-1} over the control. In another long-term study, incorporation of 72-day-old sunn hemp green manure (15.2 tha^{-1} green matter) increased rice grain yield by 0 .7 4 tha^{-1} (19 .4%) over the control. In Cameroon, a 20-45% increase in rice yield has been obtained due to green manuring with *Sesbania* and *Crotalaria*.

2.1.4 Effect of Integrated fertilizer (green manure and inorganic fertilizer) on yield of rice

Kalaiyarasan and Subbalakshmi (2015) stated that the effect of Dhaincha incorporation significantly affected agronomic yield in rice crop as compared to the absolute control. There would have been seasonal influence on Dhaincha production and its influence on agronomic yield of direct sown rice. Increased fresh biomass of Dhaincha was distinctly seen, during summer compared to Kharif season.

Sanjoy *et al.* (2015) stated that three leguminous crops *viz*. green gram (*Phaseolus aureus* Lin.), sunnhemp (*Crotolaria juncea* L.) and dhaincha (*Sesbania aculeata* Poir.) could be grown in summer season to study the response of rice – wheat and soil characteristics in relation to grain yield and nutrient uptake by crop. Sunnhemp and dhaincha supplied treatments along with 120 kg nitrogen ha^{-1} gave maximum yield of rice and wheat.

Khatab *et al*. (2013) stated that the Plant growth is seriously hampered when lower dose of N is applied which drastically reduces the yield. However, excess amount of N-fertilizer also results in lodging of plants, prolonging growing period, delayed in maturity, increased the susceptibility to insect-pest and diseases and ultimately reduces yield (Uddin, 2003). Therefore, optimum dose of N-fertilizer application by analyzing soil fertiity and its efficient management are necessary for increasing rice yields.

Yadav and Lourduraj (2007) stated that the climatic factors during summer contributed to higher biomass yield in Dhaincha influencing on enhanced rice yield.

Singh (2006) reported that the combined use of organic and inorganic nutrients increases grain yield by 10 to 20% in rice-wheat cropping system. He also reported that amongst the organic manures the overall performance of green manure was best, followed by FYM and rice straw.

Mirza *et al.* (2005) reported that green manuring with *Sesbania* improved the paddy grain and straw yields by 15.4 and 14.5 per cent, respectively. Parihar (2004) reported that grain yields obtained with 80 kg N ha^{-1} (50% through green manure + 50%

through urea) were comparable to 80 kg N ha^{-1} (50% through FYM + 50% through urea), but both were significantly superior over 80 kg N through urea.

Singh *et al*. (2002) observed that application of 50 per cent of the recommended dose of nitrogen (RDN) through inorganic fertilizer (IF) + dhaincha (*Sesbania aculeata*) at 2.5 tonnes ha^{-1} to rice gave significantly higher mean grain yield of rice and wheat over the rest of the treatments, except for 50 percent RDN through chemical fertilizers + pressmud at 5 tonnes ha^{-1} in rice.

Singh *et al*. (2001) found that seed yield, yield attributes, siliquae per plant, 1000 grain weight and nutrient uptake of brown sarson increased significantly as result of residual effect of application of organic manure and nitrogen on preceding rice crop.

Witt *et al*. (2000) stated that organic matter content is generally lower in upland rice crop rotations. Such as rice-wheat or rice-maize cropping system. Carbon sequestration with continuous rice cropping would also be favored by the accumulation of phenolic end products that appears to occur when crop residues decomposed under anoxic condition in lowland rice (Olk *et a*l., 1996).

Bufogle *et al*. (1997) stated that nitrogen is an integral part of protoplasm, protein and chlorophyll and plays a remarkable role in increasing cell size, dry matter productions and ultimately increases rice yield.

Jaychandran and Veerabadran (1996) stated that the application of green manure i.e. *Sesbania rostrata* increased the plant height, leaf area index and total number of tillers compared to the other green manure crops such as *Sesbania aculeata* and *Crotalaria juncea*. Incorporation of gliricidia leaves @ 5 t ha^{-1} at the time of transplanting significantly increased the grain (31.43 q ha^{-1}) and straw (59.82 q ha^{-1}) yields of rice over no green manure by 8.68 and 11.21%, respectively (Turkhede *et al.*, 1996).

Prasad *et al*. (1996) opined that the available NPK status declined after 6 years by 23, 44 and 16% in those either plots, where neither manures nor inorganic fertilizers were applied. Application of 50%, 100% and 150% NPK either in presence or absence of FYM showed on an average 10 and 23% increase in available nitrogen and phosphorus, respectively after 21 years of continuous cropping as compared to 6 years of cropping. The potassium status remained unchanged. On the contrary, the balanced fertilization and integrated nutrient supply system helped to enrich the available nutrient status of soil. The highest increase was in case of available phosphate (about 330% of average value) followed by available nitrogen (16%) and available potassium (8%) as compared to their initial status.

Sriramchandrasekharan *et al*. (1996) found higher availability of NPK and organic carbon due to green manure followed by FYM, composted coir pith and paddy straw. The maximum availability of nitrogen was due to green manure treated soil due to high nitrogen content i.e. 3%, whereas low values in paddy straw treated soil was due to wide C: N ratio i.e. 60:1, which retards mineralization.

Samasundaran *et al*. (1996) observed a pronounced residual effect of green manure to the procedding crop of rice followed by the succeeding rice crop at different fertilizer levels.

Jana and Ghosh (1996) observed that grain yield of rice was higher under 100% recommended dose of NPK fertilizers supplied through either inorganic source alone or 75% through inorganic and 25% through organic in the form of FYM in rice-rice crop sequence. Similar results of saving in 25% of chemical fertilizer (NPK) through FYM in rice-based crop sequence were observed by Hedge (1996).

Tiwari *et al*. (1995) reported that the productivity of rice-wheat system increased from 62.6 q ha^{-1} without green manure to 77.7 and 76.7 q ha^{-1} with in-situ manuring of *Sesbania rostrata* and *Sesbania cannabina*, respectively.

Peeran and Ramulu (1995) found that the application of green manure with urea produced taller plant of rice, higher number of tillers per hill as compared to combined application of FYM with urea and control indicating superiority of green manure over FYM.

Gill *et al.* (1994) found that the yield obtained with 150% recommended dose of NPK was similar with green manuring + 100% recommended NPK and significantly more than all the other treatments. Matiwade and Sheelavanter (1994) reported the highest grain yield due to green manure with *Sesbania rostrata* + 100% recommended dose of fertilizer.

Prasad (1994) stated that 10 t ha^{-1} FYM + 15 kg ha^{-1} BGA could substitute 25% NPK as chemical fertilizer in rice. Further, there was residual effect equivalent to 20% of NPK as chemical fertilizers on the yield of succeeding wheat and winter maize in rice-wheat and rice-maize cropping system. Integrated use of FYM 12 tha^{-1} + 80 kg Nha^{-1} gave as much rice yield as 120 kg Nha^{-1} as fertilizer.

Deshmukh *et al*. (1994) observed that application of organic manure and fertilizer in different combinations significantly increased the grain yield over control (no fertilizer, no manure).

Pandian and Perumal (1994) observed that incorporation of green manure alone (12.5 t ha^{-1}) without mineral nitrogen recorded 11.9% more grain yield as compared to control.

Kumar and Yadav (1993) carried out long term experiment at Faizabad with rice-wheat cropping system and viewed that organic carbon increased from initial value of 0.45 to 0.50-0.54% with high fertilizer level, however, unfertilized plot showed reduction (about 50%) in organic carbon after 12 years of cropping compared with initial value. It may be attributed to very poor crop growth and naturally poor root residues.

Malik and Jaiswal (1993) noted that grain yield obtained with 87 kg N ha^{-1} was equal to that obtained with 58 kg N ha^{-1} as urea and 29 kg N ha^{-1} as FYM. This showed that half to two third of chemical nitrogen can be substituted by organic nitrogen (FYM) without any yield loss depending upon the rate of nitrogen applied to rice.

Singh *et al*. (1990) stated that if green manuring was applied along with nitrogenous fertilizer, it helps to release nutrient elements slowly during the whole period of crop growth. In another study it was found that addition of green manure in combination with chemical fertilizers produced a higher yield than did a single application of chemical fertilizer alone (Aktar *et al.*, 1993).

Balasubramanian and Palaniappan (1990) found that there was marginal increase in grain yield of about 7% due to green manured plots. Panda *et al*. (1991) recorded substantial increase in organic carbon and total nitrogen in the soil after harvest of rice due to green manure, which benefited the succeeding rice crop. The nitrogen applied through chemical fertilizers alone did not show any residual effect.

Maskina *et al*. (1989) stated that, any residual effect of green manure on succeeding wheat crop because most of the nitrogen mineralized from green manure during the rice crop season was used by rice itself. In wet land soil mineral nitrogen was almost readily lost through leaching and denitrification due to, which small amount of residual nitrogen was left after rice crop, which was beneficial to succeeding crop.

Jayaraman (1988) opined that chemical fertilizers and *Leucaena* leaf manure increased the available nitrogen, as well as organic carbon content of soil.

Gopalswamy and Vidyashekharan (1987) revealed that green leaf manure and urea were effective in increasing the yield, but only green manure was responsible for improving the soil fertility. Hussain and Jilani (1989) observed that FYM in combination with 87 kg N ha^{-1} increased plant height, number of tillers m^{-2}, grain and straw yield and nitrogen recovery in rice.

Stevenson and Kelly (1985) opined that when crop residues were not regularly incorporated in lowland and upland crop rotations, the amount of labile SOM could decrease to the point of reducing the continuous supply of available N through mineralization-immobilization turnover which could lead to lower grain yield.

Biederbeck *et al*. (1984) stated that labile SOM pools were the key supplier of nutrient to the crops whereas other SOM pools were recalcitrant in nature and would provide few nutrients but their physical and chemical properties provide stability to the soil and ultimately both increased crop yield.

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. 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.

Khind *et al.* (1982) detected that irrespective of the use of green manure crops, the combined use of 60 kg N ha^{-1} as urea and green manure gave almost equal yield of rice as obtained with 120 kg N ha^{-1} through urea alone. This suggested that all green manures were equally effective and saved 60 kg N ha^{-1} or 130 kg urea in rice.

Tiwari *et al.* (1980) stated that the addition of green manure alone coild 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.

Ghosh (1980) reported that the residual effect of green manure was double the yield of succeeding cereal crop, but there was little benefit to the leguminous crop.

2.1.5 Residual effect of plant biomass on yield of mustard

Singh *et al.* (1998) reported that use of plant biomass which contained higher amount of NPK gave significantly the highest plant height and number of primary branch.

Rajput and Warsi (1992) carried out a field experiment with different levels of inorganic and organic sources in rice nutrition and residual effect of organic sources in the following crop mustard. They found that application of 10 t plant biomass ha^{-1} saved 50 kg Nha^{-1} in grain production.

Ahmed and Rahman (1991) in a study with plant biomass and other sources of plant nutrients found significantly higher yield in the following crop musterd from the plots, which received plant biomass from previous crop.

Meelu and Morris (1987) in an experiment with rice based cropping system found increases in Mustard yield due to residual effect of plant biomass applied earlier in rice.

2.1.6 Effect of crop sequences on fertility dynamics of soil and on economics

Singh *et al.* (2002) reported that in rice-mustard cropping sequence, single super phosphate @ 250 kg ha^{-1} significantly augmented grain as well as straw yield of rice, whereas in mustard 333 kg SSP ha^{-1} significantly improved the values of yield trait and yield.

SSP application @ 333 kg ha^{-1} in rice caused the highest sulphur uptake by rice, whereas the highest sulphur uptake in mustard was associated with 333 kg SSP ha^{-1}.

Talathi *et al*. (2002) stated that amongst the two crop sequences, rice-groundnut was more remunerative than rice-maize sequence. In case of rice-groundnut sequence maximum net returns and benefit cost ratio were observed due to application of 100% RDF to both the crops. It was closely followed by application of 50% RDF + 50% N either through gliricidia or FYM to rice and 75% RDF to groundnut. Moreover, they again recorded that fertility dynamics of soil showed a deficient balance of 89.04 kg N, 10.11 kg P_2O_5, 82.51 kg K_2O ha^{-1} in control under rice-maize crop sequence, but the extent of deficit was less in rice-groundnut crop sequence (58.60 kg N, 7.72 kg P_2O_5, 79.10 kg K_2O ha^{-1}).

Gangwar and Katyal (2001) reported that stability of the system was highest (0.74) in rice-Indian mustard [*Brassica juncea* (L.) Czernj. and Cosson]-ridge gourd [*Luffa acutangula* (Roxb.) L.] sequence.

Sakal *et al*. (1999) stated that cropping systems significantly influenced the available nutrient status of soil. The maximum phosphorus and sulphur depletion was noted in rice-wheat (cereal-cereal) system whereas there was minimum depletion in rice-linseed system. In short, inclusion of oilseed in rice based system reduced the deficiency of micro-nutrients to a certain extent.

Karim (1998) found after two years cropping that soil organic matter content, total N, available P, exchangeable K and available S increased due to green manuring in the legume based rice-rice cropping patterns in both rainfed and irrigated ecosystems.

Kanwar and Sekhon (1998) concluded that rice-wheat cropping system resulted in a depletion of organic matter content that is arrested only by regular incorporation of crop residues or FYM.

Chinnusamy *et al*. (1997) revealed that the application of organic manures to rice and graded levels of NPK fertilizers to each crop in rice-soybean-sunflower and rice-gingili-maize systems exerted considerable influence on the soil fertility status. Inclusion of leguminous crop like soybean in rice-soybean-sunflower system increased the net gain of nitrogen through the addition of residue and fixation of nitrogen compared to rice-gingili-maize system. They further noted that considerable quantity of nutrients could be returned to soil if the residues are incorporated in rice based cropping systems, which are gradually available to subsequent crops on decomposition.

Setty and Gowda (1997) indicated significant increase in soil fertility status due to incorporation of green manure or legumes under rice-based cropping system in coastal Karnataka. They further observed that organic carbon status remained in the same range in rice-rice-fallow system, while significant increase was observed in rice-groundnut-cowpea system. Similarly, significant increase in available potassium content was observed in rice-groundnut-cowpea system compared to rice-rice-fallow system.

Kusinska (1993) reported that the long-term maize, rye, potato and flax monocultures showed a significant decrease of organic matter as compared to soils with crop rotations. On the other hand, in rape monoculture, an increase of organic matter in soils was found. With the flow of time, loss of organic matter in monoculture crop caused due to the new level of balance was developed between mineralization and humification.

Kurlekar *et al*. (1993) noted that the sequence of cereal-cereal-green manure (sorghum-wheat-sunnhemp) with 100% recommended dose of fertilizer was found to be comparatively more beneficial for improving the soil fertility status. This was mainly attributed to the quantity and quality of biomass of sunnhemp incorporated into the soil, which might have added sufficient mineralizable nitrogen into the soil.

Angers *et al*. (1992) stated that crop management practices influenced the amount of organic matter and the state of aggregation in soils. They monitored the effects of 1, 2, and 3 years of cropping with two crops (corn or barley), and found the decrease of the organic matter contents of the surface soil.

Loginow *et al.* (1990) found that the soil organic matter in long term continuous cereal cropping was more prone to oxidation process than one in the Norfolk rotation.

George and Prasad (1989) reported that inclusion of fodder maize in rice-wheat system on alluvial soil of Bhopal accelerated the potassium removal compared to the system involving cowpea as a pulse crop.

Singh *et al.* (1988) stated that cereal-cereal sequence (Sorghum-wheat) exhausted the soil nutrients of nitrogen and phosphorus to the maximum and cluster bean-wheat to a minimum. They further showed the maximum contribution towards soil nitrogen was by cluster bean (75-76 kg ha^{-1}) followed by black gram (63-68 kg ha^{-1}) and groundnut (54-58 kg ha^{-1}) whereas, Sorghum on an average removed 25.5 kg N ha^{-1} from the soil, which ultimately resulted in depletion of soil fertility.

Sonar and Zende (1984), Patil (1985) and Jadhav (1989) reported that inclusion of leguminous crops in sequence has improved the soil fertility status of soil after harvest. Nutrient removals by crops under different cropping sequences vary greatly, which in turn influence the fertility status of soils. Cereal crops have been reported to deplete the soil fertility to a relatively greater extent (Chakravarti, 1979). On the other hand, Nair (1977), Haines (1982) and Subbiah (1984) reported that a restorative crop of legumes enriched it to some extent.

Ramteke *et al.* (1982) reported that economic analysis of cropping systems as a whole brought out the higher monetary returns from the crop sequences involving rabi legumes. Total net profit was the highest in berseem-maize system (Rs. 11280 ha^{-1}) followed by pea-maize (Rs. 7815 ha^{1}) and lentil-maize (Rs. 6340 ha^{-1}). The maximum profit per rupee invested was obtained in berseem-maize crop sequence (1.68) followed by pea-maize (1.48) and lentil-maize system (1.32).

Rao and Sharma (1978) reported that cereal-cereal (maize-wheat) system showed a deficit balance of 53 kg N ha^{-1} while build up of 81 kg ha^{-1} was recorded under maize-potato-green gram system at the end of two years. They further noted that cropping system particularly including legumes resulted in build up the nitrogen status of soil. The beneficial effect of legumes on soil nitrogen status was also reported by Subba (1979).

Purushothaman and Palaniappan (1978) noted that available nitrogen status was slightly reduced in rice-rice-rice system at the end of two years. This might be due to continuous cropping of rice without including any legume in the rotation either as a pure or intercrop. The percentage of maximum reduction in phosphorus was in rice-rice-maize + soybean system. This could be explained by the higher demand and removal of phosphorus by maize in rotation and by higher intensity of cropping resulting in increase in dry matter accumulation and phosphorus removal by system.

Chandrashekharan (1969) stated that the legumes included in a cropping system also help to ameliorate availability of phosphorus as observed. Intensive cropping with cereals without addition of organic manures leads to reduction in organic carbon and nitrogen (Chater and Gasser, 1970).

Donald (1960) stated that it had been estimated that out of 100 M.T. of nitrogen fixed annually, the largest part comes from symbiotic sources particularly through the nodules of legume plant .

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MATERIALS AND METHODS

The overall research work was consisted of six field experiments and one laboratory based experiment that were done within the period from 2015 to 2016. The experiments were done with specific objectives and materials and those given below.

3.1 Experiment location

The experimental field was in upland soil (plot no. 46) of Sher-e-Bangla Agricultural university farm during the period from April 2015 to February 2017. The research field was located under the Agro-ecological zone of Madhupur Tract (AEZ-28) which was at $23^0$77' N latitude and $90^0$22' longitude at an elevan of 9 m above the sea level.

3.2 Soil

The soil of the experimental field was sandy loam in texture having pH 6.5. The initial soil of the experimental field (0-15 cm) was analyzed for physical and chemical properties before setting the experiment. The results are given in Appendix 1 to Appendix 6.

The initial soil sampling was collected before growing the first crop. The soil samples were also collected from each plot of all experiments after each crop grown to observed the change of chemical properties and organic matter status of the soil due to experimentation. The soil analysis was done in Soil Resource Development Institute (SRDI), Farmgate, Dhaka.

3.3 Climate

The experimental field is situated under sub-tropical climate. Usually the rainfall is heavy during *kharif* (April to September) season and scanty in *rabi* (October to March) season.

3.4 Experimentation

A number of experiments (seven) have been carried out under three broad heads– inclusion of green manuring crops (*in situ* application) in the Rice-mustard cropping pattern before rice growing and application of fertilizer from different doses (half and full recommended dose) in the rice field of Rice-Mustard cropping pattern and finally the quality performances of the collected *T. Aman* rice seeds under laboratory condition. Each set of three experiments were conducted in two consecutive years.

3.4.1 Experiment-1 and Experiment-4

Performance of different green manuring crops on biomass production and soil improvement

The experiment was undertaken during April, 2015 to June, 15 (1^{st}) and May, 16 to July, 16 (2^{nd}) to find out the following objectives:

(i) to select the appropriate green manuring crops for soil health improvement

(ii) to know the nutrient status of soil after green manuring

3.4.1.1 Species Description

Eight species viz. *Sesbania aculeata, Sesbania rostrata, Crotalaria juncea, Vigna unguiculata, Vigna mungo, Vigna radiata, Leaucena leaucocephala, Mimosa pudica* were selected as green manuring crop species. The leaves of these plants are easily decomposable and reported to contain more protein, and rich source of nitrogen and phosphorus when used as green manure. Total biomass was estimated each time before incorporation. At the age of 50 days, all green manuring plants were allowed to incorporate to the soil for decomposition.

3.4.1.2 Experimental treatments

The experimental treatments were as follows:

(i) T_0: No green manuring crop (Control)

(ii) T_1: *Sesbania aculeata*

(iii) T_2: *Sesbania rostrata*

(iv) T_3: *Crotalaria juncea*

(v) T_4: *Vigna unguiculata*

(vi) T_5: *Vigna mungo*

(vii) T_6: *Vigna radiata*

(vii) $T_{7:}$ *Leucaena leucocephala*

(ix) T_8: *Mimosa pudica*

3.4.1.3 Design and layout

The experiment was laid out in a Randomized Complete Block Design with three replications. There were eight different green manuring crops along with control with three replications. The total number of experimental units was 27 (9 x 3). The size of each plot was 17.5 m (5m x 3.5m). The replications were separated from one another by 1 m spacing. Spacing between plots was 80 cm. Plot without green manure and fertilizer were considered as control. Same plots were maintained for different green manuring crops in experiment 1 and experiment 4.

3.4.1.4 Land preparation

The land was first ploughed with a tractor drawn disc plough on 27April, 2015. Ploughed soil was brought into desirable tilth condition by three operations of ploughing and harrowing with country plough and ladder. The stubbles of the previous crops and weeds were removed.

3.4.1.5 Application of fertilizer

The experimental plots (except control) were fertilized with the recommended doses of 20-17.6-24.9 kg N, P and K ha^{-1} (BARI, 2008) from their sources of Urea, TSP and MoP. The whole amount of urea and muriate of potash, triple superphosphate were applied at the time of final land preparation and as basal dose.

3.4.1.6 Sowing of seeds and intercultural operations

The seeds of different crops were sown after final land preparation following their recommended seed rate. No intercultural operations were done except one irrigation that was given after emergence of seeds in order to maintain optimum population of each crops.

3.4. 1.7 Harvesting and decomposition

After 50days of sowing (17 June, 2015) all green manure crops were harvested, chopped into small pieces incorporated to the individual plot and allowed for decomposition for one month.

3.4.1.8 Collection of experimental data

Ten plants plot^{-1} were selected randomly for data collection. The procedures followed to determine the characters have been given below:

(i) **Plant height:** The height of the ten plants was measured from the ground level to the tip of the top most ends at 15, 30 and 45 days of sowing and finally averaged to plant^{-1} basis.

(ii) **Number of leaves plant^{-1}:** The number of leaves for each ten plant was counted at 15, 30 and 45 days after sowing and finally averaged to plant^{-1} basis.

(iii) Fresh and Dry biomass: The sample plants were uprooted at 20, 35 and 50 days of sowing and dried properly in the oven at 60^0 for 24 hours from which fresh and dry biomass was measured and converted to t ha^{-1}.

(iv) Nodule production:

Nodule number plants^{-1} was measured at 30 and 50 DAS following the standered procedure without disturbing the roots and finally averaged to plant^{-1} basis.

(v) Soil chemical properties:

Soil samples were collected before growing green manuring crops and 30 days after incorporation for both the years from which soil p^H, organic matter, N, P and K concentration were determined.

3.4.1.9 Statistical analysis

The collected data were analyzed statistically by using the STATISTIC-10 package. The mean comparision of all parameters were done with Tukey's W- procedure (Gomez and Gomez, 1984).

3.5. Experiment 2 and 5: Influence of green manuring crops on the fertilizer economy and yield of T. Aman rice

The 2nd experiment was undertaken during the period of 13 July 2015 to 22 October 2015 (2nd) and August, 15 to November, 16 (5th) with the following objectives:

(i) to find out the nitrogen economy after incorporation of green manuring crops in subsequent rice crop (2nd crop).

(ii) To find out the fertilizer (N, P and K) economy after green manures incorporation in subsequent rice crop (5th crop).

(iii) To determine the maximum yield of rice against different green manuring crops incorporation.

3.5.1 Planting material

High yielding rice varieties viz. BRRI dhan66 was used for the experiments as the test crop.

3.5.2 Description of rice varietiy

A brief description of the rice variety used in the experiment is given below:

BRRI dhan66

BRRI dhan 66, a variety of *aman* rice, was developed by the Bangladesh Rice Research Institute (BRRI). It requires about 114 days completing its life cycle. It attains a plant height of 120 cm. The grains are medium slender. It gives a grain yield of 4.6 t ha^{-1} (BRRI, 2015).

3.5.3 Experimental treatments

Two sets of treatments included in the experiment were as follows:

For 2nd experiment,

Factor A: Nitrogen dose (2):

i) 100% recommended nitrogen dose – N_1

ii) 50% recommended nitrogen dose -N_2

For 5th experiment:

Factor A: Fertilizer dose (2):

i) 100% recommended NPK fertilizer dose – F_1

ii) 50% of recommended NPK fertilizer dose-F_2

Factor B: Green manuring crops (9):

(i) T_0: No green manuring crop (Control)

(ii) T_1: *Sesbania aculeata*

(iii) T_2: *Sesbania rostrata*

(IV) T_3: *Crotalaria juncea*

(V) T_4: *Vigna unguiculata*

(VI) T_5: *Vigna mungo*

(VII) T_6: *Vigna radiata*

(viii)T_7: *Leucaena leucocephala*

(ix) T_8: *Mimosa pudica*

The recommended fertilizer used for the experiments were 200-74-100-67-10 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.

In both of experiment 2 and 5, the labour members and wages were same but the reduction of uses of 100% chemical fertilizer was the main basis of the experiments especially of using the green manuring crops for suplemeting the chemical fertilizers.

3.5.4 Experimental design and layout

The experiment was laid out in a split-plot design with three replications where fertilizer dose assigned in the main plots and green manuring crops in the sub-plots. The experimental area was divided into three blocks each representing a replication. Each block contained 9 different green manuring treatments which were then divided into two main plots having two different fertilizer doses. Therefore, the total number of plots was 54 (9 x 2 × 3). The size of unit plot was 3.5m x 2m (7.0 m^2) where block to block and plot to plot distance was 1m and 0.5 m, respectively.

3.5.5 Growing of crops

3.5.5.1 Seed collection

Healthy and vigorous seeds of BRRI dhan66 were collected from Bangladesh Rice Research Institute.

3.5.5.2 Seed sprouting

Healthy seeds were selected by specific gravity method. The selected seeds were soaked in water for 24 hours and then these were kept in gunny bags. The seed started sprouting after 48 hours and almost all seeds were sprouted after 72 hours.

3.5.5.3 Preparation of seedling nursery and seed sowing

Sprouted seeds were sown in the wet nursery bed on 13 June 2015 (for 2nd experiment) and 5 July 2016 (for 5th experiment). Proper care was taken to raise the seedlings in the nursery bed. Weeds were removed and irrigation was given in the seedbed as and when necessary.

3.5.5.4 Uprooting of seedling and transplanting

The 30 days old seedlings were uprooted carefully without causing mechanical injury to the roots and were transplanted on 13 July 2015 (for 2nd experiment) and 5 August 2016 (for 5th experiment) in 54 (3× 18) experimental plots those were puddled further with spade on the day of transplanting. Three seedlings were transplanted in each hill with 20 cm and 20 cm spacing between the rows and hills respectively.

3.5.5.5 Intercultural operations

3.5.5.5.1 Gap filling

Seedlings in some hills died off and these were replaced by gap filling after one week of transplanting with seedlings from the same source.

3.5.5.5.2 Weeding

Crops were infested with different weeds. Weeding was done twice by hand pulling before the 2nd (30 DAT) and 3rd (45 DAT) applications of urea fertilizer for both the experimens.

3.5.5.5.3 Harvesting

Plants were harvested from each experimental unit by cutting the plant close to the ground leaving the boarder lines. Threashing, drying and cleaning were done properly and finally converted into t ha^{-1} basis.

3.5.5.5.4 Soil Sampling

After harvesting, soil samples were collected from each plot at 0-15cm depth and dried for analysis purpose. The collected soil was analysed from Soil Resource and Development Institute (SRDI).

3.5.6 Procedure of plant sampling

Five hills were randomly selected soon after transplanting and marked with bamboo sticks in each plot excluding border rows to record the data on plant height and number of tillers $hill^{-1}$ at 15 day intervals beginning 30 DAT up to harvesting.

3.5.7 Growth and yield components

The following data on growth and yield components of rice were recorded:

i. Plant height (cm)

ii. Number of tillers $hill^{-1}$

iii. Panicle length (cm)

iv. Panicle weight (gm)

v. Number of rachis $panicle^{-1}$

vi. SPAD value

vii. Dry matter weight (g)

viii. Number of effective tillers $hill^{-1}$

viii. Number of non-effective tillers $hill^{-1}$

ix. Number of filled grains $panicle^{-1}$

x. Number of unfilled grains $panicle^{-1}$

xi. Weight of 1000 grains (g)

xii. Grain yield (t $ha^{-1)}$

xiii. Straw yield (t ha^{-1})

xiv. Grain protein content (%)

xv. Soil properties

Data on individual plant parameters were recorded from five randomly selected hills of each unit plot and those on seed moisture percentage, grain yield, straw yield, biological yield and harvest index were recorded from the whole plot at harvest.

3.5.8 Procedure of data collection

i) **Plant height**

Plant height (selected five hills) was measured from the ground level to the tip of the longest panicle and finally averaged to plant^{-1} basis.

ii) Number of tillers hill^{-1}

Tillers which had at least one leaf visible were counted. It included both productive and nonbearing tillers. Total number of five selected plants were counted and averaged to hill^{-1} basis.

iii) Panicle length

Panicle length was recorded from the neck node to the apex of each panicle. The length of ten randomly selected panicles from each plot were measured and averaged.

iv) Panicle weight

Ten panicles were randomly collected at the harvesting stage (HD) from each plot to measure panicle weight from neck node to the apex of each panicle and averaged.

v. Number of rachis panicle^{-1}

Number of rachis panicle^{-1} was recorded from 10 randomly selected panicles in each unit plot after harvest and averaged.

vi) SPAD (Soil Plant Analysis Development) value

The greenness of the five flag leaves from five hill of each plot was measured by SPAD meter (model-SPAD-502 PLUS, Japan) and finally averaged.

vii) Dry matter weight

In order to collect samples, five sample plants were uprooted from each plot at 15 days intervals up to 85 DAT and were cleaned, de-rooted and leaves were separated from the culms. Collected samples were dried in an electric oven for 72 hours maintaining a constant temperature of 60° C. After drying, weight of each sample was recorded.

viii) Number of effective tillers hill^{-1}

Tillers having panicles which had at least one grain were considered as effective tillers. Effective tillers from five randomly selected hills were counted and averaged.

ix) Number of non-effective tillers hill^{-1}

The tillers which had no panicle were regarded as non-effective tillers. Non effective tillers from five randomly selected hills were counted and averaged.

x) Filled grains panicle^{-1}

Presence of any food material in the spikelet was considered as filled grain and numbers of filled grains present in ten randomly selected panicles were counted and averaged.

xi) Number of unfilled grains panicle^{-1}

Lack of any food materials inside the rachis were considered as unfilled grains, such grains present on randomly selected ten panicles were counted and averaged.

xii) Weight of 1000 grains

One thousand clean dried grains from the seed lot of each plot were counted separately and weighed by an electrical balance.

xiii) Grain yield

Grain yield was determined from the central lines leaving the boarder rows. Grains were threshed from the plants, cleaned, dried and then weighed carefully. Dry weight of grains of each plot was converted into grain yield (t ha^{-1}). Final grain weight was adjusted to 14% moisture content by using the following formula:

Moisture (%) = Fresh weight-Oven dry weight/Fresh weight x100

xiv) Straw yield

Straws obtained from each plot were sun dried and weighed to record the straw yield $plot^{-1}$ and finally converted to ton per hectare.

3.5.9 Statistical analysis

Data recorded for growth, yield and yield contributing characters were compiled and tabulated in proper form for statistical analyses.The collected data were analyzed statistically by using the Statistic-10 computer package. The mean comparision of all parameters were done with Tukey's W- procedure (Gomez and Gomez, 1984).

3.6 Expeiment 3 and 6:
Effect of previous land condition on yield of Mustard

The experiment was undertaken during the period of 25 November 2015 (for the 1st year) to 04 February 2016 (for the 2nd year) with the following objectives:

i) to find out the growth, yield attributes and yield of mustard in different cropping pattern

ii) to find out the rice equivalent yield

iii) to determined the changes of soil properties with different copping pattern

3.6.1 Planting material

High yielding rape seed variey *viz*. BARI Sarisha -14 was used for the experiment as the test crop for the first year and BARI Sarisha-15 for second year.

3.6.2 Description of variety

A brief description of the rice variety used in the experiment is given below:

BARI Sarisha 14 (1st year) and BARI Sarisha 15 (2nd year)

BARI Sarisha -14 (1st year) and BARI Sarisha 15 (2nd year) variety of sarisha, was developed by the Bangladesh Agricultural Research Institute (BARI). The varieties require about 75 days completing their life cycle. The varieties attain a plant height of 90 cm. The grains are medium slender. It gives a grain yield of 1.20 t ha^{-1} (Mondal. *et al.,* 2011).

3.6.3 Experimental treatments

The previous land condition of rice experiments was used for growing mustard to evaluate the crop response, changes of soil properties and pattern performances. Hence no additional treatment was assigned for the mustard experiment. The crop was grown following the recommended management practices of mustard cultivation.

3.6.4 Application of fertilizer

The crop was fertilized with 83-30-57-21-2 kg N, P, K, S and Zn ha^{-1} from their source of urea, triple super phosphate, murate of potash, gypsum and zinc sulphate respectively. The One half of whole amount of urea, triple superphosphate and full amount of muriate of potash, gypsum and zinc were applied at the time of final land preparation. The rest one-half of urea was top dressed after 30 days of sowing.

3.6.5 Sowing of seeds

The seeds at the rate of 7 kg ha^{-1} was sown after final land preparation. Line sowing (row to row distance 30 cm and in row seeds were sown manually) procedure was used. Plant populations were kept 55-60 per square meter.

3.6.6 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done on 05 February, 2016 for the 1st year and 17 February, 2017 for the 2nd year. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks.

3.6.7 Collection of experimental data

Ten plants $plot^{-1}$ were selected randomly for data collection. The sample plants were uprooted prior to harvest and dried properly in the sun. The seed yield and stover yield $plot^{-1}$ were recorded after cleaning and drying those properly in the sun. The procedures followed to determine the characters have been given below:

3.6.7.1 Plant height

The height of the randomly selected ten plants was measured from the ground level to the tip of the plant and finally averaged.

3.6.7.2 Number of Siliquae plant^{-1}

The number of siliquae for each plant from randomly selected ten plants was counted and finally averaged to plant^{-1} basis.

3.6.7.3 Length of siliqua

The length of each siliquae was measured from the randomly selected ten siliquae and averaged.

3.6.7.4 Seeds Siliqua^{-1}

Seeds were collected by splitting randomly selected ten siliquae from each plant out of ten plants and then counted the seed and averaged.

3.6.7.5 Weight of 1000 seeds

Thousand seeds of each plot were counted and weighed with a fine electric balance.

3.6.7.6 Seed yield

The mature plants were harvested leaving the boarder rows. By threshing the plants of each plot, the seed weight was taken and converted the yield into kg ha^{-1} basis.

3.6.7.7 Stover yield

Plants that contain grain or plants that left in a field after harvest is called stover.Weight of the plants containing grains was taken by subtracting the grain weight from the total weight, the stover weights were calculated.

3.6.8 Statistical analysis

The collected data were analyzed statistically by using the Statistic-10 computer package. The mean comparision of all parameters were done with Tukeys W-procedure (Gomez and Gomez, 1984).

3.7 Soil Chemical analysis

3.7.1 Soil sample collection

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

I. Pre-sowing

II. After decomposition of green manure (1^{st} year and 2^{nd} year)

III. Post harvest of Aman rice (1^{st} year and 2^{nd} year) and

IV. post-harvest of mustard (1^{st} year and 2^{nd} year)

All collected samples were sun dried and sieved through a 2mm sieve. The soil samples were analyzed for $P^{H,}$ organic matter, total nitrogen, available phosphorus and exchangeable potassium following standard methods as described below:

Initial soil samples were collected before planting the first crop. Then soil samples were collected from each unit plot of each experiment after harvesting of each crop. The soil samples were analyzed for p^H, N, P, K and organic matter (Appendix 1 to Appendix 6). The following methods were followed for aforesaid analyses.

3.7.2 Determination Methods

pH: 1:1.25 soil water ratio using glass electrode (Black *et al*., 1965).

Organic carbon: Walkley and Black method: through oxidation of organic matter with potassium dichromate and titration with ferrous sulphate using barium diphenylamine sulphate indicator (Black *et al*., 1965).

Total N: Micro-Kjeldahl method following H_2SO_4 digestion and steam distillation with NaOH. Ammonia was collected in boric acid indicator and then titrated with 0.01 NH_2SO_4 (Black *et al*., 1965).

Available P: Extraction was done with 0.5 N $NaHCO_3$ solution. Blue colour was developed by $SnCl_2$ reduction and then measured the colour colorimetrically (Black *et al*., 1965).

Exchangeable K: Extraction was made by neutral ammonium acetate and then determined directly by Flame Photometer (Black *et al*., 1965).

3.8 Experiment 7

Performances of grown T. Aman seed on laboratory condition

3.8.1 Location

The experiment was conducted during the period of 14 March 2017 to 22 March 2017 to observe the quality of post-harvest seed.

3.8.2 Experimental materials

Seed physiological parameters were examined by using BRRI dhan66 variety. Seeds were collected from experiment 5. Twenty seeds of each treatment were placed on petridish having moistened germination paper and from which different quality parameters were observed. The total sets of treatments were replicated thrice.

3.8.3 Seed sprouting

The selected twenty seeds were soaked in water and then these were placed in 11 mm size blotting paper for germination. The seed started sprouting after 24 hours and almost all seeds were sprouted after 72 hours.

3.8.4 Experimental data collection:

3.8.4.1 Germination percentage

Three replication of twenty seeds each was planted between moistened germination paper and observed its sprouting. Seeds with .5cm radical and plumule were considered as germinated (ISTA, 1993).

3.8.4.2 Germination energy

The germination energy was calculated as the total number of germinated seeds divided by total number of seed placed for germination.

3.8.4.3 Cotyledon length

After five days of germination, cotyledon length of 54 petridish were start to measured for two days interval.

3.8.4.4 Radicle length

After five days of germination, radicle length of 54 petridish were start to measure for two days interval.

3.8.4.5 Fresh weight of seedling

After five days of germination, fresh weight of germinated seeds of 54 petridish were start to measure for two days interval.

3.8.4.6 Dry weight of seedling

After five days of germination, dry weight of germinated seeds of 54 petridish was starting to measure for two days interval.

3.8.5 Statistical analysis

The collected data were analyzed statistically by using the STATISTIC-10 package. The mean comparision of all parameters were done with Tukey's W- procedure (Gomez and Gomez, 1984).

CHAPTER 1V

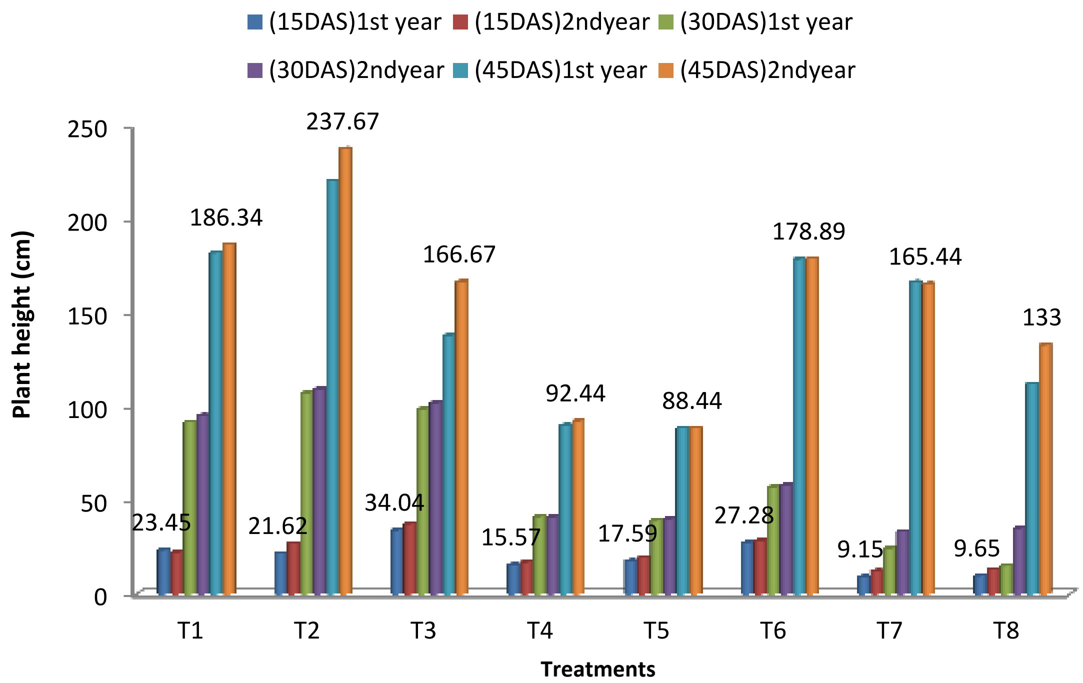
RESULTS AND DISCUSSIONS

Seven sets of experiments have been arranged under two broad heads – effect of green manures (in situ) on soil improvement and fertilizer economy in the GM-Rice-Mustard cropping patterns. Seven experiments have been discussed under different general and yield contributing heading.

4. 1 Experiment 1 and 4: Performance of different green manuring crops on biomass production and soil improvement

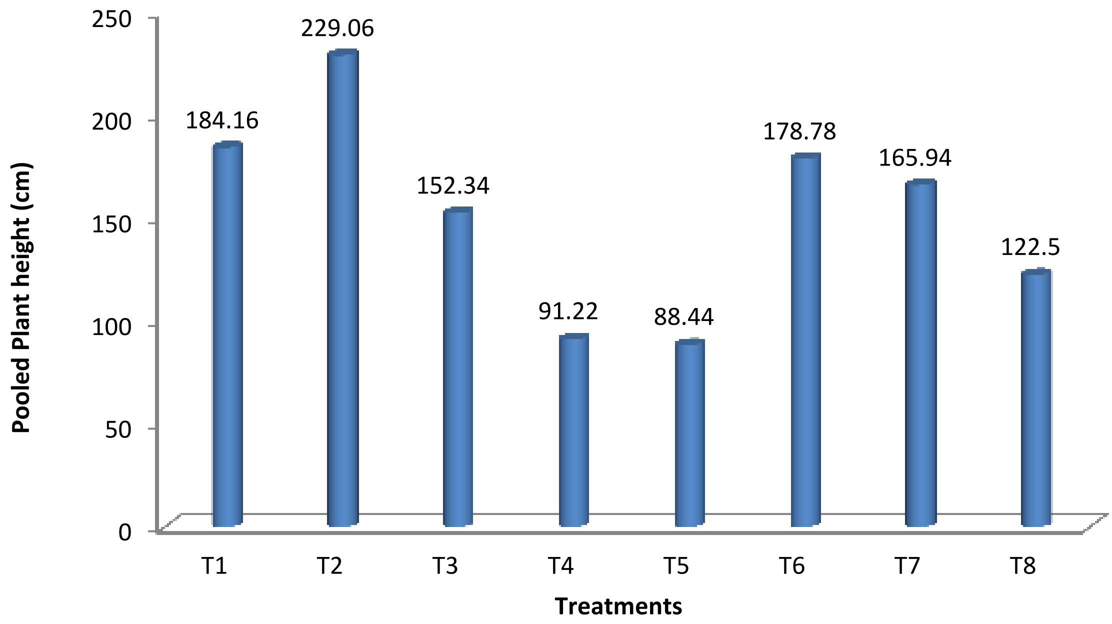
4.1.1 Plant height of green manuring crops

There was significant difference observed in plant height among the green manure crops throughout the growth period in two years (Figure. 1). At 15 DAS (both year), *C. juncea* (34.04 cm and 37.28 cm for 1^{st} and 2^{nd} year respectively) produced the tallest plant which was statistically similar with *V.unguiculata* and was followed by *S. aculeata* and *S. rostrata* along with *V. mungo* for the second year, those were at par for both the years. *Leucaena leucocephala* showed the shortest plant height at 15 DAS (9.15 cm for the first year and 12.33 cm for the second year) which was similar with *Mimosa pudica* for the first year and *Mimosa pudica,Vigna radiata, Vigna mungo and Sesbania aculeata* for the second year. At 30 DAS, *S. rostrata* (107.18 cm and 109.28 cm for 1^{st} and 2^{nd} year) and *C. juncea* showed the highest plant height for both the years that were followed by *S.aculeata* and *Vigna unguiculata* (both year) .The lowest plant height (15.01cm) for first year was shown by *Mimosa pudica* whereas *Leucaena leucocephala* (33.33cm) for the second year. At 45 DAS, *Sesbania rostrata* showed the highest plant height for both the years (220.44 cm for the first and 237.67 cm for the second year) followed by *Sesbania aculeata* and *V. unguiculata* in this respect. The lowest plant height for both the years was given by *Vigna radiata* (90 cm and 92.44 cm for 1^{st} and 2^{nd} year) and *Vigna mungo*. The plant height of *Sesbania rostrata* at 45 DAS was 149.25% and 16.74% higher than that of *Vigna mungo* for the first year and second year respectively. The pooled plant height at 45 DAS for the two years showed the highest result for *Sesbania rostrata* that followed by *Sesbania aculeata* and *Vigna unguiculata* (Figure. 2). Pramanik *et al.* (2009) also obtained the similar result, reporting higher plant height in *Sesbania* among evaluating different green manureing crops and stated that, *S. rostrata* gave the highest height followed by S. *aculeata* and *C. juncea.* It was observed that plant height increased progressively with the age of the plants up to 45 DAS. *S. rostrata* showed slow growth rate at early stage but at the later stages it superseded all others at 45 DAS. *C. juncea* showed reverse behaviour as was observed with *S. rostrata.* Variation of plant height over the growth period occurred probably due to individual genetic makeup of the green manure crops. Romulo *et al.* (2013) studied with different green manuring crops and found that *C. juncea* had the longer height than the other ones. The superiority of *C. juncea* was expected in that study since it was a short-day and fast growing plant compared to others. 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 45DAS.



Here, T$_1$=*S. aculeata*, T$_2$=*S. rostrata*,T$_3$= *C. juncea*,T$_4$=*V. radiata*,T$_5$=*V. mungo*,T$_6$=*V. unguiculata*,T$_7$=*L. leucocephala*,T$_8$=*M. pudica*

Figure. 1. Plant height of different green manuring crops at different days after sowing (DAS) in two year (SE (±) = 2.25 and 2.75 for 15 DAS, 4.08 and 4.47 for 30 DAS and 19.83 and 16.54 for 45 DAS at 2015 and 2016 respectively).



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

Figure. 2. Pooled plant height (cm) of green manuring crops at 45 DAS.

4.1.2 Number of leaves plant^{-1}

There was significant difference in leaves number was observed among the different green manure crops throughout the growth period (Table 1). In both year, at 15 DAS, *Leucaena leucocephala* and *Mimosa pudica,* produced the highest number of leaves followed by *S. aculeata* and *S. rostrata*. The *V. mungo* gave the lowest number of leaves plant^{-1} for both the year which was similar to *Vigna radiata*. At 30 DAS, *S. rostrata* produced the highest number of leaves plant^{-1} for both the year followed by *Sesbania aculeata*. Again *V. radiata*, *L. leucocephala* and *M. pudica* exhibited lower but similar performance in this regard. But *V. mungo* and *V. unguiculata* gave the lowest performance. At 45 DAS, the trend was as follows (highest to lowest) *S. rostrata* > *S. aculeata* >*V. radiata* >*L. leucocephala* >*M. pudica*>*V. unguiculata* > *V. radiata*. The *Sesbania rostrata* showed slow growth rate at early stage but at the later stages it superseded all others at 45 DAS. With the time of maturity *Sesbania* species contained lots of branch in comparision to others. *Crotalaria. juncea* showed reverse behaviour as was observed in *S. rostrata.* Variation of leaves number over the growth period occurred probably due to individual genetic makeup of the green manure crops.

Table 1. Number of leaves of green manuring crops at different days after sowing (DAS) in two Years

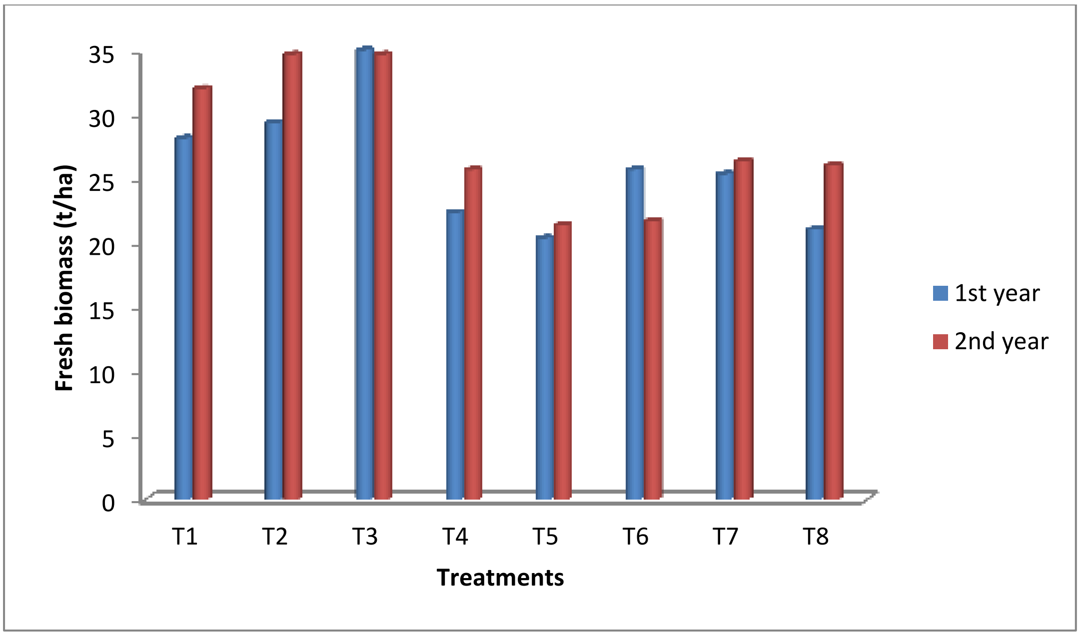
Treatments	Leaves number plant^{-1} at					
	15 DAS		30 DAS		45 DAS	
	1st year	2ndyear	1st year	2ndyear	1st year	2ndyear
T_1	36.12bc	41.11c	1005.3b	1086.10b	1054.00b	1131.50b
T_2	42.38b	52.05b	1168.00a	1301.30a	1204.70a	1324.70a
T_3	14.44bc	17.44de	45.90e	49.20e	59.50e	59.50e
T_4	12.57bc	13.57e	469.00c	525.70c	515.70c	549.00c
T_5	11.190c	11.86e	40.70e	50.70e	59.70e	63.00e
T_6	22.70bc	24.37d	56.70e	56.70e	58.70e	65.30e
T_7	148.00a	171.33a	315.00d	355.00d	326.30d	379.70cd
T_8	150.00a	163.33a	320.00d	344.00d	333.00d	376.30d
SE (±)	**8.45**	**2.80**	**35.70**	**38.94**	**39.46**	**48.85**
CV(%)	**18.93**	**5.54**	**10.22**	**10.12**	**10.71**	**12.12**

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

4.1.3 Biomass production of green manure crops

4.1.3.1 Fresh biomass

Fresh biomass was significantly varied among different green manure crops (Figure. 3). The fresh biomass of green manure crops ranged from 20.33 to 35.00 t ha^{-1} in 2015 (1st year) and 21.33 t ha^{-1} to 34.66 tha^{-1} in 2016 (2nd year). *Crotalaria juncea* produced significantly higher fresh biomass (35.00 t ha^{-1}) in 2015 that followed by *Sesbania rostrata* (29.33 t ha^{-1}) and *Sesbania aculeata* (28.12 t ha^{-1}) whereas *Sesbania rostrata* (34.66 t ha^{-1}), *Crotalaria juncea* (34.66 t ha^{-1}) and *Sesbania aculeata* all produced the highest fresh biomass in the second year. The minimum fresh biomass was noted in *Vigna mungo* (20.33 t ha^{-1} in 2015 and 21.33 t ha^{-1} in 2016). It was observed that, *Sesbania rostrata* and *C. juncea* recorded significantly higher fresh biomass compared with *S. aculeata* during two year. Again *S. aculeata* recorded significantly higher fresh biomass over *Vigna unguiculata*, *Mimosa pudica* and *Leucaena leucocephala*. Singh and Shivay (2014) stated that the increased of biomass accumulation of *Sesbania* might be due to its fast and determinate growth habit leading to enhanced biomass incorporation/addition and nutrient availability in soil. Khind *et al.* (1987) opined that, *Sesbania aculeata* could produce 21.1 t ha^{-1} of green biomass and accumulate about 133 kg N ha^{-1}. Sanjay *et al*. (2015) reported that among the summer green manuring crops, dhaincha recorded significantly higher total fresh and dry matter accumulation compared with sunhemp and cowpea in their two consecutive researches. Further, sunhemp recorded significantly higher fresh and dry matter over cowpea, but was significantly lower than dhaincha during both the years.



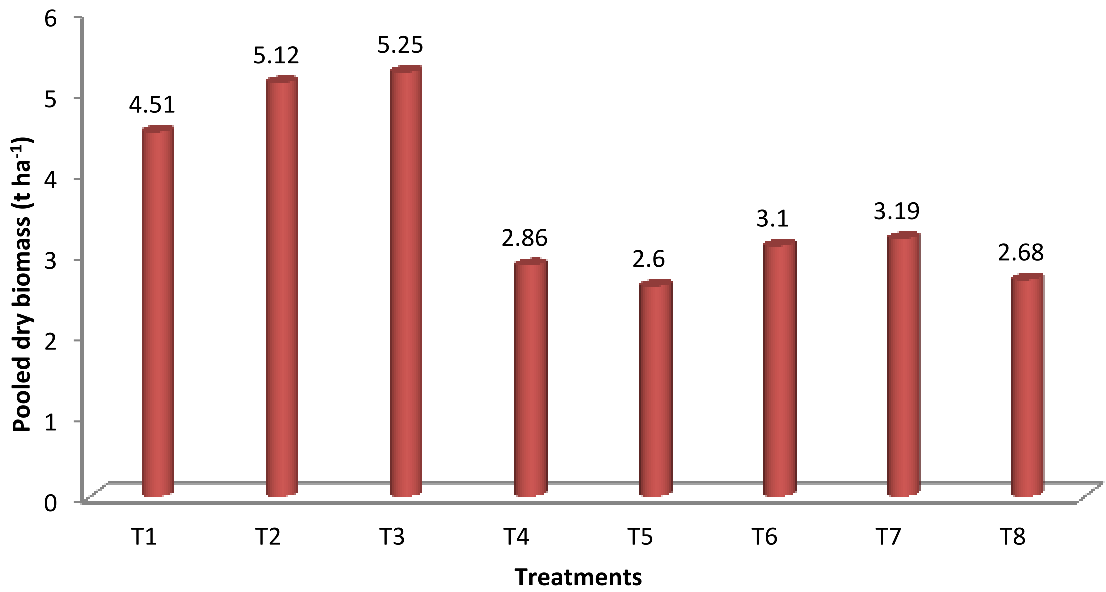
Here, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*, T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 3. Fresh biomass of different green manuring crops in two years (SE (±) = 0.90 and 2.21 in 2015 and 2016 year respectively).

4.1.3.2 Dry biomass

The dry biomass of green manuring crops varied significantly in two consecutive years. In 1^{st} year (2015), the highest dry matter (DM) biomass was obtained from *Crotalaria juncea* (5.30t ha^{-1}) followed by *Sesbania rostrata* (5.03 t ha^{-1}) (Figure. 4). The significantly lowest biomass (2.66 t ha^{-1}) was recorded in *Vigna radiata* and *Vigna mungo*. However, differences in dry biomass between these treatments were statistically significant ($P< 0.01$) in both years. In the following year (2016), the maximum dry biomass of 5.20 t ha^{-1} was obtained for *Sesbania rostrata* and C. juncea which was at par with that obtained for *Sesbania aculeata* (4.66 tha^{-1}) whereas the significantly lowest biomass of 2.33 t ha^{-1} was recorded for *V. unguiculata*. Becker *et al*. (1995) found that the growth of *S. rotrasta* was more vigorous in the wet season (long day period) than in the dry season. Singh (1981) also agreed with the findings and reported that, the most productive green manure crops yielded about 4-5 tha^{-1} of dry biomass in 50-60 days and clusterbean has generally been less productive than *Sesbania*, sunnhemp, 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.

It was observed that in case of *S. rostrata*, *S. aculeata* and *C. juncea* dry biomass yield increased rapidly apparently with the age of plant compared to other green manuring crops. This variation of dry biomass yield may be due to individual genetic makeup of the green manure crop. The highest dry biomass at 50 DAS for two pooled year was given by *Crotalaria juncea* that followed by *Sesbania rostrata* and *Sesbania aculeata*.



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*

Figure. 4. Dry biomass of different green manuring crops in two pooled year (SE (±) = 0.20 and 0.24 at 1st year and 2nd year respectively).

4.1.4 Dry matter production pattern

The pattern of dry matter production of different green manuring crops was studied at 20, 35 and 50 DAS for both the years (Table 2). At 20 DAS (both year), *Vigna unguiculata* produced the highest dry matter (2.20 g plant^{-1} and 2.70 g plant^{-1} in 1st and 2nd year) that similar to *Sesbania rostrata* (1.50 g plant^{-1} and 2.66g plant^{-1} in 1st and 2nd year) and *Crotalaria juncea*. The lowest dry matter was recorded in *Leucaena leucocephala* and *Mimosa pudica*. At 35 DAS, the highest dry matter in 1st year (2015) was given by *Sesbania spp* that similar to the other crops except *Leucaena leucocephala* and *Mimosa pudica* but in 2nd year (2016), *Sesbana aculeata* produced the highest dry matter plant^{-1} (8.08 g) that similar to the all other studied crops (Table 2). At 50 DAS, both the *Sesbania spp* along with *Crotalaria juncea* produced the highest dry matter plant^{-1} whereas the lowest was produced by *Mimosa pudica* in 1st year and and *Vigna radiata i*n 2nd year. Paisancharoen *et al.* (1990) found that, cowpea was the most promising green manure crop, followed by *Crotalaria juncea* and pigeon pea for biomass production. This is due to the vigorous early growth of cowpea, which leads to a high amount of biomass being produced within two month before planting any crop.

Table 2. Dry matter production of different green manuring crops in 2015 and 2016

Treatments	Dry matter (g plant^{-1}) at					
	20 DAS		35 DAS		50 DAS	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
T_1	0.89bc	1.79	7.11a	8.08a	9.61ab	13.06ab
T_2	1.50ab	2.66	7.06a	7.76ab	10.87a	14.00a
T_3	0.99ab	2.20	5.38ab	7.36ab	7.33cd	11.33a-c
T_4	0.94ab	1.93	5.47ab	6.53ab	6.23de	7.80c
T_5	0.71b	2.03	4.66ab	5.93ab	6.00e	9.00bc
T_6	2.20a	2.70	6.44a	6.56ab	8.33bc	9.03bc
T_7	0.230b	1.40	3.33b	5.80ab	6.60de	9.00bc
T_8	0.250b	1.40	3.40b	5.10ab	5.86e	8.36bc
SE (±)	**0.37**	**NS**	**0.76**	**0.77**	**0.37**	**1.22**
CV(%)	**46.85**	**27.98**	**17.46**	**14.24**	**6.03**	**14.67**

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

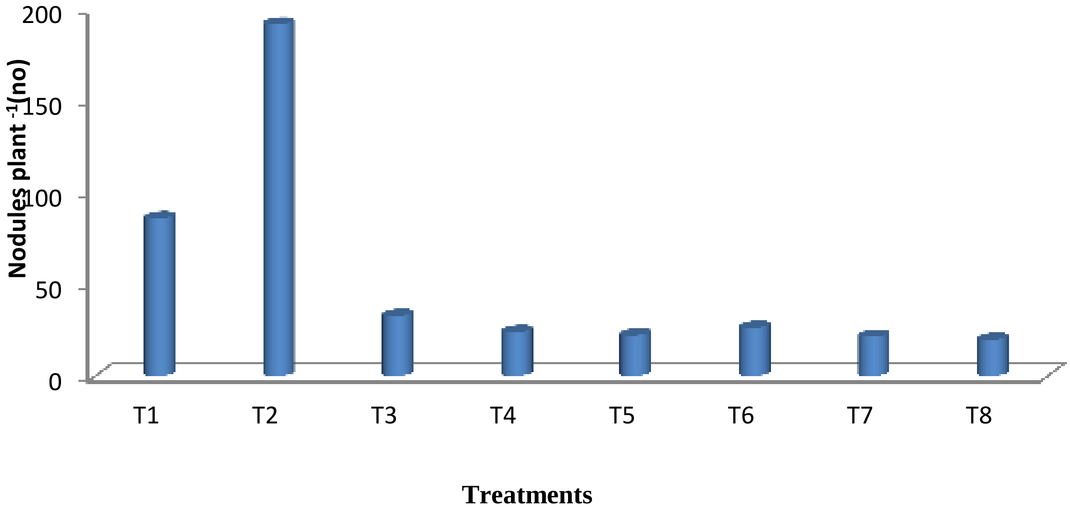
4.1.5 Nodule production

There was significant variation on nodule production plant^{-1} among green manuring crops up to 50 DAS (Table 3). At 30 DAS, the highest number of nodules plant^{-1} was observed in *S. rostrata* followed by *S. aculeata*, *V.unguiculata,* and *Vigna radiata* for the first year and *Sesbania rostrata* for the second year. The lowest number of nodules plant^{-1} was observed in *Leucaena leucocephala and Crotalaria juncea*. At 50 DAS, the highest number of nodules plant^{-1} was observed in *S. rostrata* and *S. aculeata* for both the year *C. juncea* and *V. unguiculata* exhibited similar performance and occupied the second highest position. The lowest number of nodules plant^{-1} was observed in *Mimosa pudica* for both the years. The results was almost similar to the findings of Pramanik *et al*. (2009) who found , the highest number of nodules plant^{-1} from *S. aculeata*. *C. juncea* and *S. rostrata*. Variation of number of nodules plant^{-1} might be due to the individual genetic characteristics of green manure crops. The pooled data of nodules plant^{-1} for two years showed the highest number in *Sesbania rostrata* that followed by *Sesbania aculeata* (Figure. 5).

Table 3. Number of nodules plant^{-1} of different green manure crops at different days after sowing (DAS)

Treatments	Number of nodules plant^{-1} at			
	30 DAS		50 DAS	
	1st year	2nd year	1st year	2nd year
T_1	18.06bc	29.oob	67.78b	103.76b
T_2	36.53a	46.00a	158.33a	224.00a
T_3	11.66bc	10.66c	32.67b	32.67c
T_4	15.33bc	15.33c	23.33b	24.33c
T_5	12.66c	13.33c	23.00b	21.33c
T_6	23.33b	12.00c	32.33b	20.00c
T_7	11.00c	10.66c	21.67b	21.00c
T_8	12.00c	12.00c	19.33b	20.00c
SE (±)	**2.45**	**2.35**	**20.46**	**15.82**
CV(%)	**17.14**	**15.36**	**3.62**	**33.19**

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



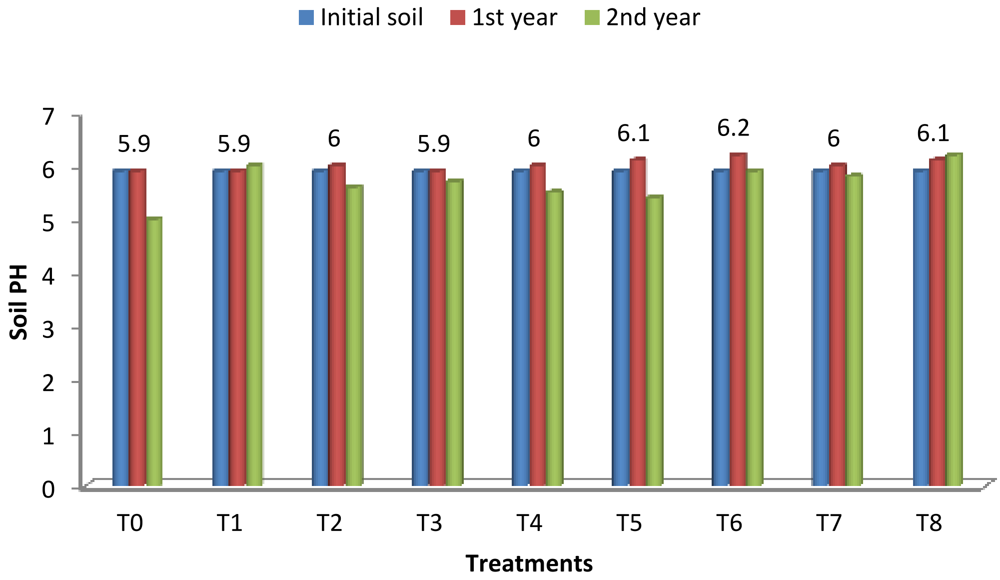
Here, T_1=*S. aculeata*, T_2=*S.rostrata*, T_3= *C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*,T_6=*V.unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 5. Pooled data of Number of nodule plant^{-1} of different green manure crops at 50 days after sowing.

4.1.6. Effect of green manures on chemical properties of soil after incorporation

4.1.6.1 Soil pH

After green manure incorporation, the highest soil pH (6.2) from initial (5.9) was observed in the trend of $T_6>T_5>T_8>T_2>T_4>T_7$ at 1st year (2015) and $T_8>T_1$ in 2nd year (2016) (Figure. 6 and Appendix 2). In second year, green manures status showed decreasing trend compared to initial soil except *Mimosa pudica* and *Sesbania rostrata*. The decreased may be attributed to the higher production of CO_2 and organic acids during decomposition of incorporated green manure crops, but a slight increase of soil pH in some cases may be due to increase base saturation from the applied treatments. This reduction in P^H occurred possibly due to the production of organic acids from the decomposition of biomass of herbaceous legumes (mungbean and blackgram) as reported by Chandha *et al*. (2009). Salahin *et al*. (2013) also reported decreased soil P^H from the application of green manure in soils. Swarup (1991) also observed that decrease in soil pH resulted from the application of green manure in soil. Atiwag and Edward (1987) reported that *ipil-ipil* incorporated into soil significantly (p^H= 0.05) increased the soil p^H of ionic strength reaching maximum at 4 weeks of equilibrium in the glass house and then gradually decreased with time.

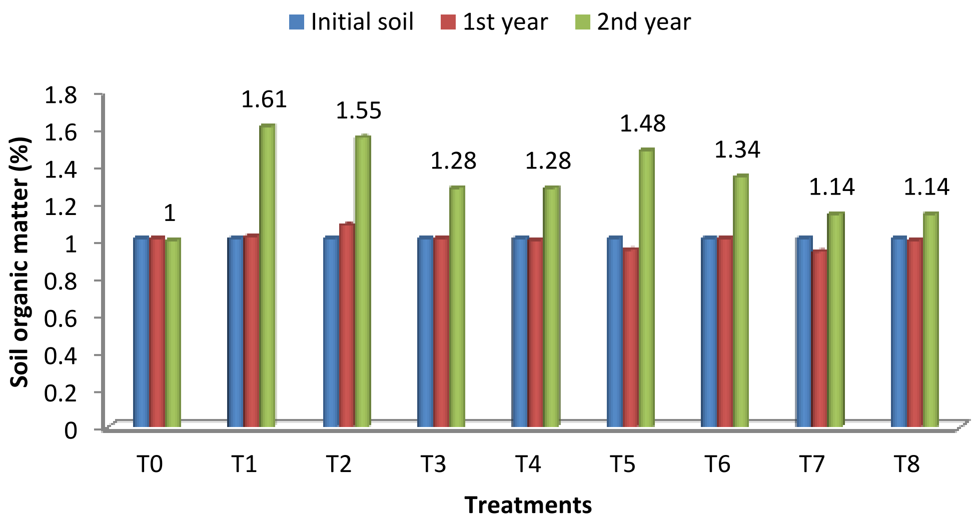


Here, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 6. Influence of different green manuring crops on soil pH.

4.1.6.2. Soil organic matter

Incorporation of eight different green manures, some of them increased the soil organic matter from 1.01% (initial) level to 1.08% in 1st year and up to 1.61% in 2nd year (2016) (Appendix 3). The highest organic matter (1.08%) was found in T_2 (*S. rostrata*) from 2015. In 2016, the higher organic matter (1.61%, 1.61% and 1.55%) was recorded from T_7 (*L. leucocephala* with 100% NPK), T_1 (*S. aculeata* with 50% NPK) and T_2 (*S. rostrata* with 50% NPK) that followed by *Sesbania aculeata* (1.02%) in 1st year (2015). In 2nd year (2016), all of the green manuring crops showed increasing trend of organic matter content compared to 1st year (2015) as well as initial soil and the trend was T_1>T_2>T_5>T_6>T_3>T_4>T_7>T_8 with 50% NPK (Appendix. 3 and Figure.7). Soil organic matter decreased in control plot due to lack of legumes and increased in plots where green manure was added. *Sesbania aculeata*, *Sesbania rostata* and *Leucaena leucocephala* incorporation in soil increased 60% organic matter compared to control in second year. The cumulative effect of organic matter and legume residue resulted in more positive gains of total nitrogen. Higher organic matter and N contents were present because of incorporation of green manures (Biswas and Mukherjee, 1991). Similar results were also observed by Mondal *et al.* (2003). Rahman *et al*. (2013) stated that, after incorporation of dhaincha, the organic matter status of the soils were found slight increased compared to control (organic matter and total N status of soil from dhaincha ranged from 1.42 to 1.58%). Sarwar *et al*. (2017) reported that, both the organic matter content and total nitrogen (%) were increased due to dhaincha incorporation in soil and the amount of organic matter (%) varied from 1.582 to 2.133 before incorporation and 1.995 to 2.271 after incorporation of dhaincha biomass in soil. Mann *et al.* (2000a) reported that after continous green manuring of three years, the soil organic matter increased up to 1.09%. Ali *et al.* (2012) found that among green manures, *Sesbania* incorporated plot increased soil organic matter (0.79%) from its initial soil (0.67). It indicated that *Sesbania rostrata* is much more beneficial to soil health than any other green manures.

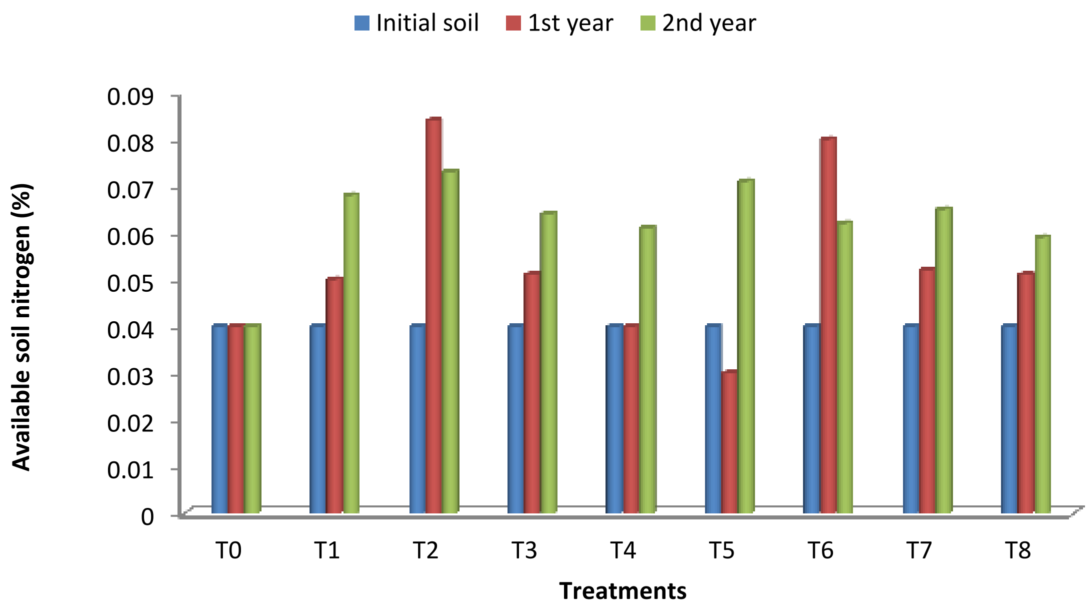


Here, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 7. Effect of different green manuring crops on organic matter (%).

4.1.6.3. Total N

Total N status of soil ranged from 0.04% to 0.084% for the first year and 0.081% for the second year (initial level 0.04%). The results pertaining to total nutrients in soil of legumes treated plot is presented in Figure. 8 and Appendix 4. In 1st year (2015), the highest N content of 0.08% was found in T_2 (*Sesbania rostrata)* followed by T_6 (*Vigna unguiculata*).The lowest N content of 0.03% was obtained for T_5 (*Vigna mungo),* which was much lower than its initial soil. The other green manures showed very little increased of total available N in soil. The increasing trend was T_2> T_6>T_7>T_8>T_3>T_1 at 1st year and T_1>T_2>T_5>T_7>T_6>T_8>T_3 (with 100% NPK which was at par with 50% NPK) in 2nd year (Appendix 4). In 2nd year (2016), the maximum N content of (0.07% and .08% with 100% and 50% NPK) was recorded for *Sesbnia rostrata* and *Sesbania aculeata* followed by *Vigna mungo* and *L. leucocephala*. The significantly lowest N content of 0.041% was obtained from control plot. *S. rostrata* increased 166% and 75% total nitrogen in comparision to *V. mungo* and control in 1st and 2nd year (with 100% N and 100% NPK) whereas it is increased 100% with 50% NPK in 2nd year. These results suggested that green manuring of *Sesbania* would have increased N fertility of soil because of greatest N contents in their biomass. The increase in total N content of soil due to application of organic manure may be attributed to the mineralization of N by organic manure in soil and greater multiplication of soil microbes, which could convert organically bound N to inorganic form. Actually plant materials used as a green manure differed in their chemical composition, rate of decomposition and nutrient element released to the soil.Thats why different type of plant added different amount of nutrients to the soil. Other studies have also reported that green manure legumes contain substantial amount of N and other nutrients. Rinaudo *et al*. (1983) reported that N_2 fixed by *Sesbania rostrata* was about 267 kg N ha^{-1}, one third was transferred to the crop and two third to soil. Mann *et al*. (2000a) reported that *Sesbania* incorporated plot increased soil N (0.60%) from initial soil (0.48%). Onim (1986) reported that *sesbania* can fixed upto 250 kg N ha^{-1} in six month. Palaniappan (1990) also reported that at 45 days *Sesbania aculeata* and *Sesbania rostrata* accumulated 185 and 219 kg N ha^{-1} respectively. 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



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

Figure. 8. Effect of different green manuring crops on soil total nitrogen (%).

4.1.6.4 Other nutrients (K and P)

Among other nutrients K showed slightly increasing trends (0.22meq/100g) from initial soil (0.18meq/100g) after incorporation of green manures. In first year, the highest K content (0.22meq/100g) was found from T_1 (*S. aculeata*) and T_2 (*S. rostrata*) followed by T_3 (0.21meq /100g) and T_4 (0.20 meq/100g) that was superior to initial soils (Table 4). In second year, there was declining trend showed in K status in soil with 100% and 50% NPK compared to initial soil but was superior from control (Appendix. 5). 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) but was superior from control soil in 2^{nd} year (Appendix.6). It may be lost through leatching. Losses of phosphorous are normally thought to be mainly by surface run off and erosion but sometimes it can be lost through leatching also. 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 may be due to the low pH and P fixation in soil.

Table 4. Changes of soil fertility status of P and K for the incorporation of different green manuring crops for two year

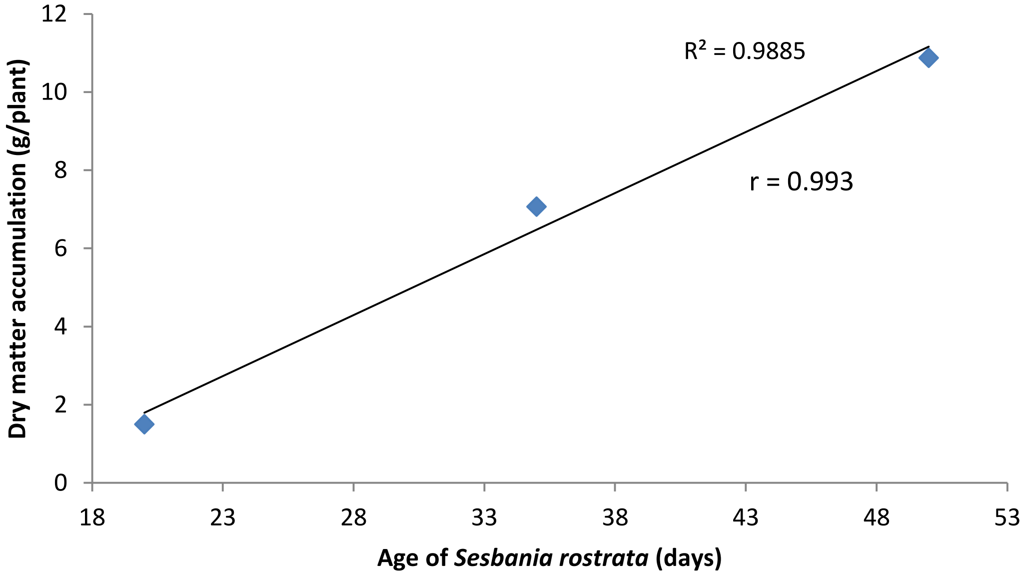
Treatments	P (ppm)			K(meq $100g^{-1}$)		
	Initial soil	1st year	2nd year (100%NPK)	Mother soil	1st year	2nd year (100%NPK)
T_0	15.83	15.83	8.62	0.18	0.18	0.06
T_1	15.83	12.22	12.51	0.18	0.22	0.12
T_2	15.83	15.00	12.61	0.18	0.22	0.10
T_3	15.83	14.9	12.33	0.18	0.21	0.10
T_4	15.83	11.45	12.31	0.18	0.20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

Here, T1=*S. aculeata*, T2=*S. rostrata*,T3= *C. juncea*,T4=*V. radiata*,T5=*V. mungo*,T6=*V. unguiculata*,T7=*L. leucocephala*,T8=*M. pudica*

4.1.7. Relationship between age of *Sesbania* and biomass production of green manuring crops

Relationship between age of *Sesbania rostrata* and biomass production or dry matter accumulation of green manuring crops are important characteristics responsible for higher grain yield for succeeding crop. Relationships of age of *Sesbania rostrata* and biomass production of green manuring crops were found strong positively correlated (r = 0.993 and r = 0.997 for age of *Sesbania* at 2015 and 2016 respectively) (Figure. 9 and Figure. 10). This means an increase in age of *sesbania rostrata* will result in corresponding increase in dry matter accumulation of green manuring crops. Morris *et al*. (1986) observed that different green manures showed a linear relationship between N accumulation and dry weight irrespective of green manure species, and were affected by the age of green manure crop.

Figure. 9. Relationship between age of *S. rostrata* and dry matter accumulation of green manuring crops in 1st year (2015).



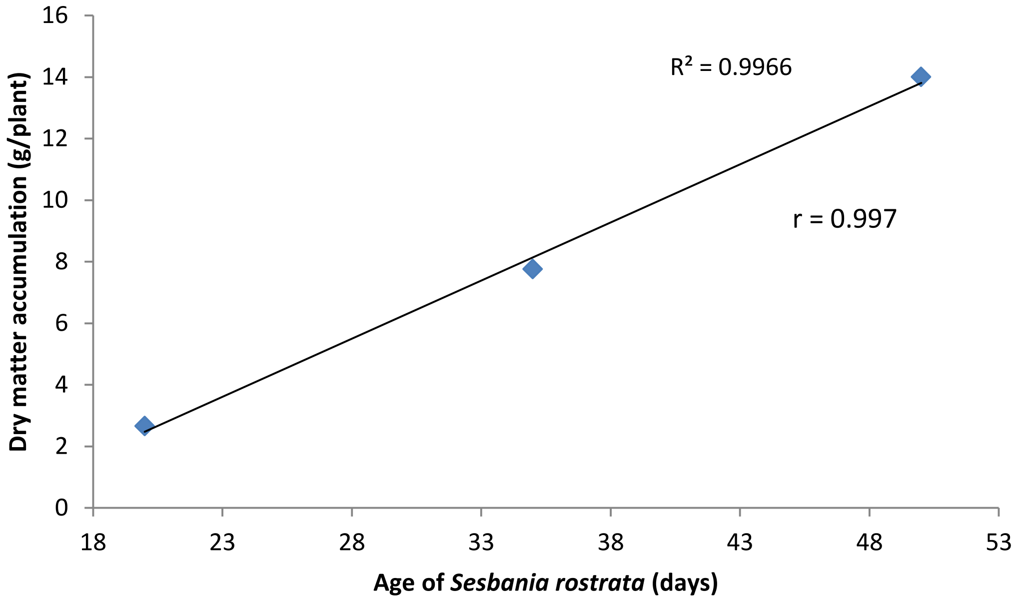


Figure. 10. Relationship between age of *S. rostrata* and dry matter accumulation of green manuring crops at 2nd year (2016).

4.1.8. Relationship between biomass production and soil organic matter content of green manuring crops

Relationship between biomass production and soil organic matter (%) of green manuring crops are important characteristics responsible for higher grain yield through the betterment of soil quality. Relationships of biomass production and soil organic matter (%) of green manuring crops were found significantly and positively correlated (r = 0.574 and r = 0.512 for biomass prduction at 2015 and 2016 respectively) (Figure. 11 and Figure. 12). This means an increase in biomass production will result in corresponding increase in soil organic matter.

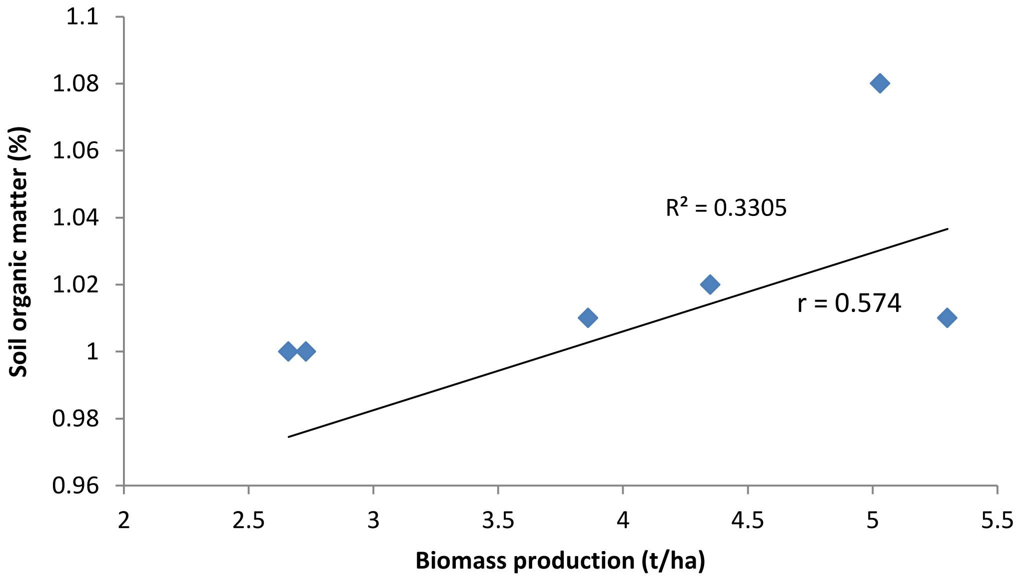


Figure. 11. Relationship between biomass production (green manure) and soil organic matter at 1st year (2015).

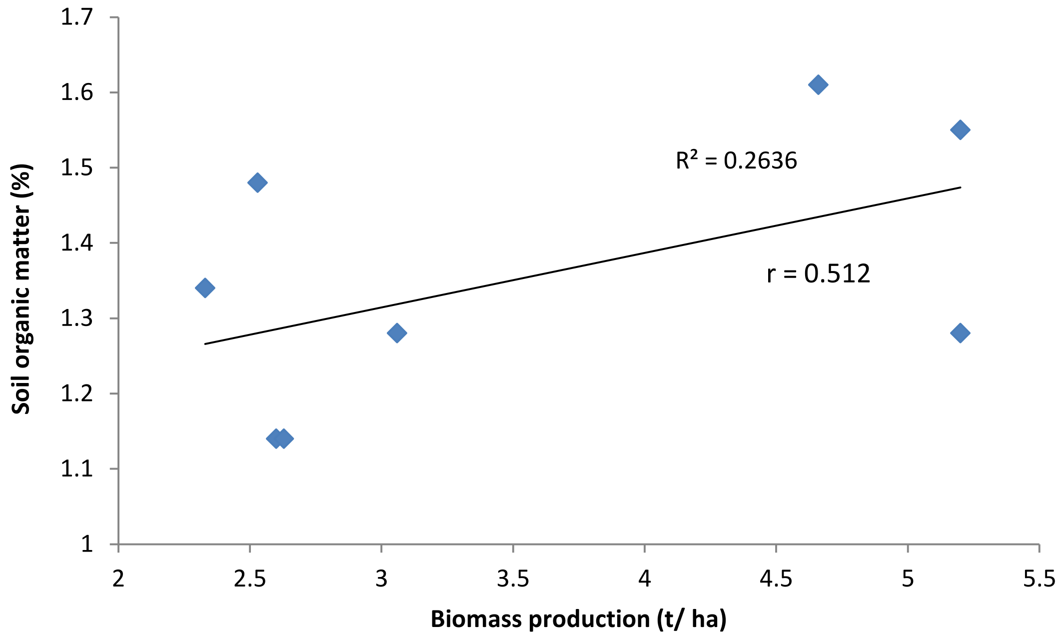


Figure. 12. Relationship between biomass production (green manure) and soil organic matter in 2nd year (2016).

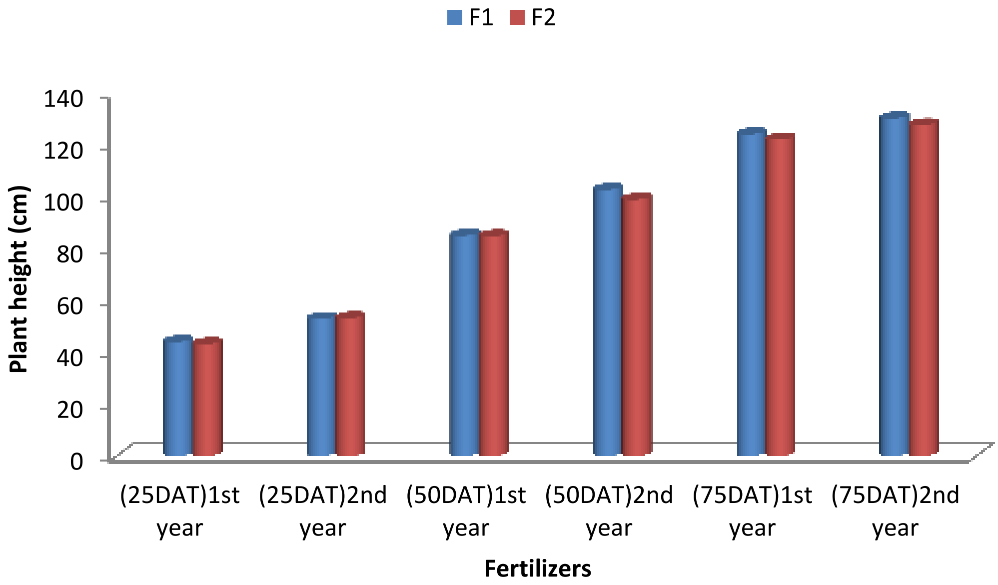
4.2 Experiment 2 and 5: Influence of green manuring crops incorporation on the fertilizer economy and yield of T. Aman rice

Results obtained from the present study regarding the influence of green manures and two levels of N (half and full recommended doses in 1st year) and two levels of NPK (half and full recommended doses in 2nd year) on growth, yield and yield contributing characters of transplant aman rice were studied and presented and discussed in this chapter. The results have been presented in Table 5 through Table 19 and Figure 13 to Figure 38. The growth parameters and grain yield with yield contributing characters of the rice varieties have been presented and discussed under separate heads and sub–heads as follows:

4.2. 1 Plant height

4.2.1.1 Effect of different levels of N and NPK fertilizers

Plant height did not vary significantly due to different nitrogen levels at all the data recording stages of 25, 50 and 75 DAT (Fig 13). In 1st year, among the N levels, the taller plant (44.08, 84.91 and 124.02 cm) was obtained with higher (100% N ha^{-1}) doses of N followed by 50% N ha^{-1} (43.20, 84.65 and 121.96 cm). Similar results were found in 2nd year with little increase of height in both half (NPK) and full fertilized dosed plot. Green manures residues decomposition added more nitrogen to the soil, through which soil enriched and showed similar results at par to full dose. These result revealed that the plant height of rice progressively increased with every increased level of nitrogen. Such effect of increased level of nitrogen on plant height may be associated with the stimulating effect of nitrogen on various physiological processes including cell division and cell elongation of the plant. According to Biswas *et al.* (1996), incorporation of green manuring crop to the soil reduced 50 percent of recommended N-levels of rice. Dargan *et al*. (1975) also reported that *Sesbania* as a green manure can return into the soil 80-120 kg N within 90 days. Schmid and Klay (1984) stated that the most obvious direct economic benefit derived from cowpea green manure is nitrogen fertilizer saving.



Here, F_1 = 100% Nitrogen in 2015 and NPK in 2016, F_2 = 50% Nitrogen in 2015 and NPK in 2016

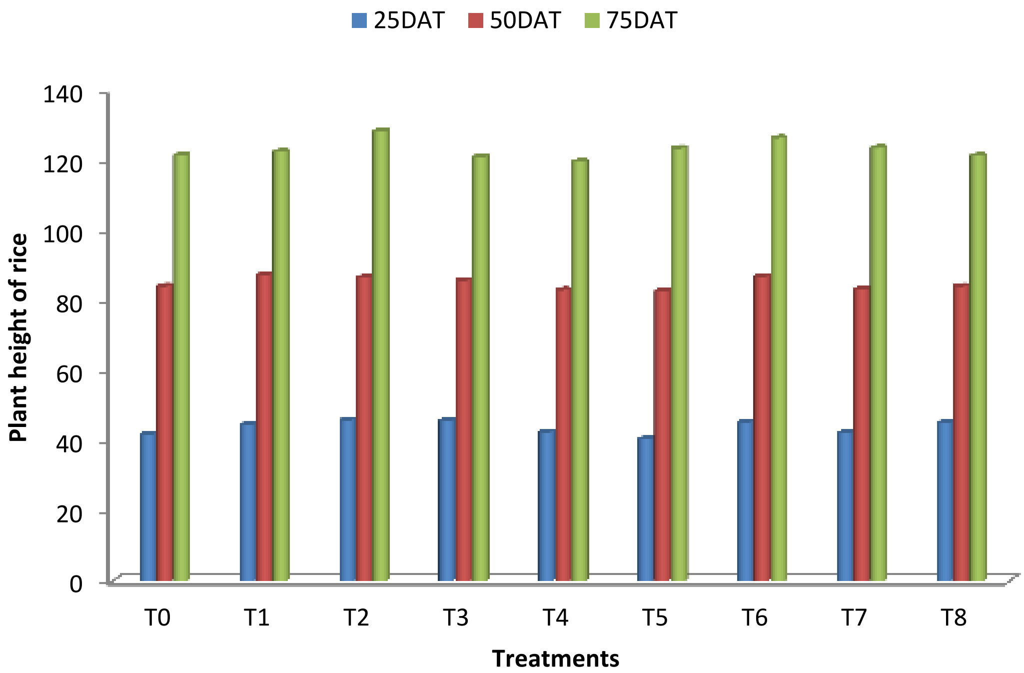
Figure. 13. Effect of fertilizers on plant height of T. aman rice at different days after transplanting in two years.

4.2.1.2 Effect of green manure

Plant height was recorded at 25, 50 and 75 DAT in this study. Plant height of transplant aman rice was significantly influenced by incorporation of green manures at 75 DAT in 1st year (2015) and 25 DAT and 75 DAT in 2nd year (2016) (Appendix 13). At 75 DAT, the highest (128.13 cm and 134.67 cm in 2015 and 2016 respectively) plant height was obtained with the incorporation of T_2 (*Sesbania rostrata*) in both year. The T_6 (*V. unguiculata*) occupied second position in 1st year (2015) and T_1 (*S. aculeata*) in 2nd year (2016) and that of the lowest with *V. radiata* (119.47cm) and control (123.8 cm) at 75 DAT in 2015 and 2016 respectively (Figure. 14 and Figure. 15). It may be due to the genetic variation among the treatments (green manures) regarding plant height. Because the green manures increased the soil organic matter and improved the soil physical properties which resulted into improved vegetative growth of the plant. Similar result was obtained by Pramanik *et al*. (2004) who stated that, soil incorporation of green manuring specially *Sesbania rostrata* crops had significant influence on plant height. Sarwar *et al*. (2017) also reported that *dhaincha* incorporation gave taller plant height over no manuring. Millan *et al*. (1985)

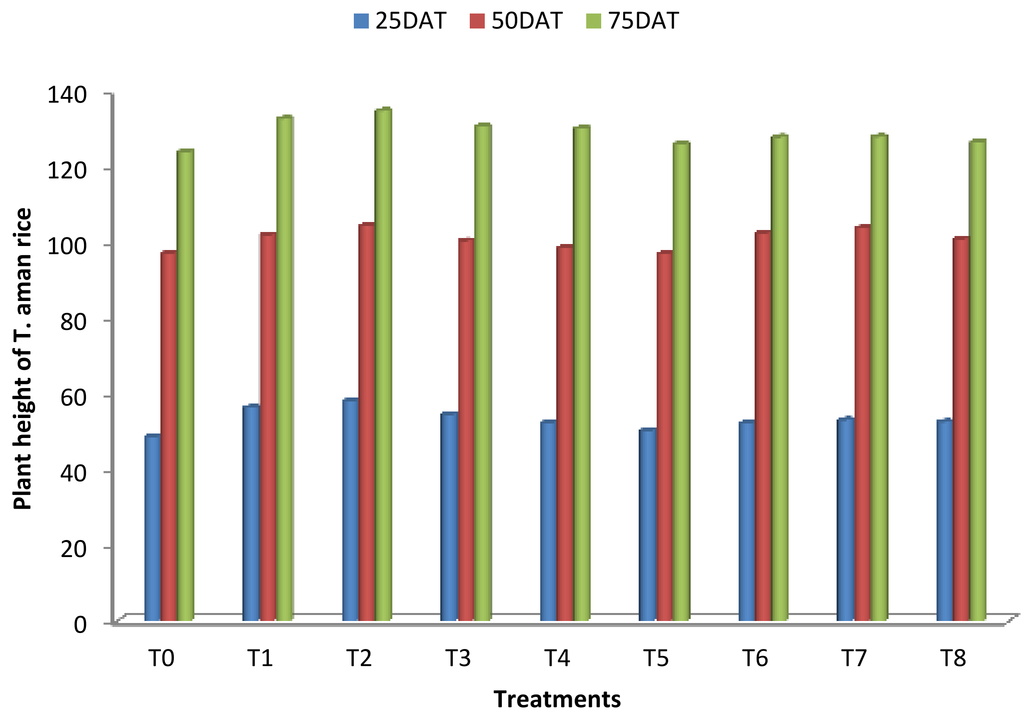
opined that basal dose of N had been exhausted within 45-50 days just prior to panicle initiation stage. The incorporation of *Sesbania spp* in soil influenced plant growth, yield and yield contributing parameters of rice.

Abdallahi and N'Dayegamiye (2000) reported that, plant growth generally depends on optimal soil physical and biological properties. Therefore, cropping practices such as regular green manure applications increased total soil C and N, therefore, improved plant growth and yields. Allison (1973) observed that major benefit obtained from cowpea green manure was added as organic matter to the soil.



Here, T_0 = Control, T1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 14. Effect of green manuring crops on plant height of transplant aman rice in 1st Year (SE(±) = 2.40 at harvesting).



Here, T_0 = Control, T1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 15. Effect of green manuring crops on plant height of transplant aman rice in 2nd year (SE (±) = 1.64 and 2.83 at 25 DAT and 75 DAT respectively).

Table 5. Interaction effect of fertilizer levels and green manuring crops on plant height of rice in two years

Interactions	Plant height (cm) at					
	25 DAT		50 DAT		75 DAT	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$F_1 T_0$	41.00	46.15c	81.00	98.66	118.90ab	125.40
$F_1 T_1$	44.20	57.10ab	88.80	100.53	123.30ab	134.97
$F_1 T_2$	44.30	56.76ab	86.20	105.37	124.70ab	136.00
$F_1 T_3$	47.30	53.23a-c	86.60	101.03	125.40ab	130.00
$F_1 T_4$	45.10	52.66a-c	83.80	101.77	121.60ab	129.97
$F_1 T_5$	40.20	50.20a-c	81.40	101.00	125.00ab	129.97
$F_1 T_6$	44.20	52.90a-c	89.20	105.77	121.30ab	131.53
$F_1 T_7$	43.40	53.73a-c	82.80	105.27	122.90ab	125.97
F_1T_8	43.80	53.60a-c	83.50	103.33	121.50ab	124.20
F_2T_0	43.00	51.07a-c	88.60	95.33	126.10ab	122.34
$F_2 T_1$	44.70	55.46ab	85.60	103.20	131.50a	130.20
$F_2 T_2$	44.30	59.23a	86.60	103.20	126.60ab	133.33
$F_2 T_3$	44.00	55.66a-c	84.80	99.67	116.20b	131.13
$F_2 T_4$	39.60	51.81a-c	82.00	95.20	117.20b	126.77
$F_2 T_5$	40.70	50.20bc	83.80	92.73	120.60ab	121.87
F_2T_6	46.10	51.43a-c	84.40	98.97	125.80ab	124.00
$F_2 T_7$	40.80	52.33a-c	83.40	102.10	123.90ab	129.63
F_2T_8	46.10	51.43a-c	84.50	98.33	120.80ab	128.67
SE(±)	NS	2.15	NS	NS	3.24	NS
CV(%)	7.20	5.38	4.56	3.87	3.39	3.87

Here, F1= 100% Nitrogen in 2015 and NPK in 2016 , F2= 50% Nitrogen 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*, NS = Not Significant

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

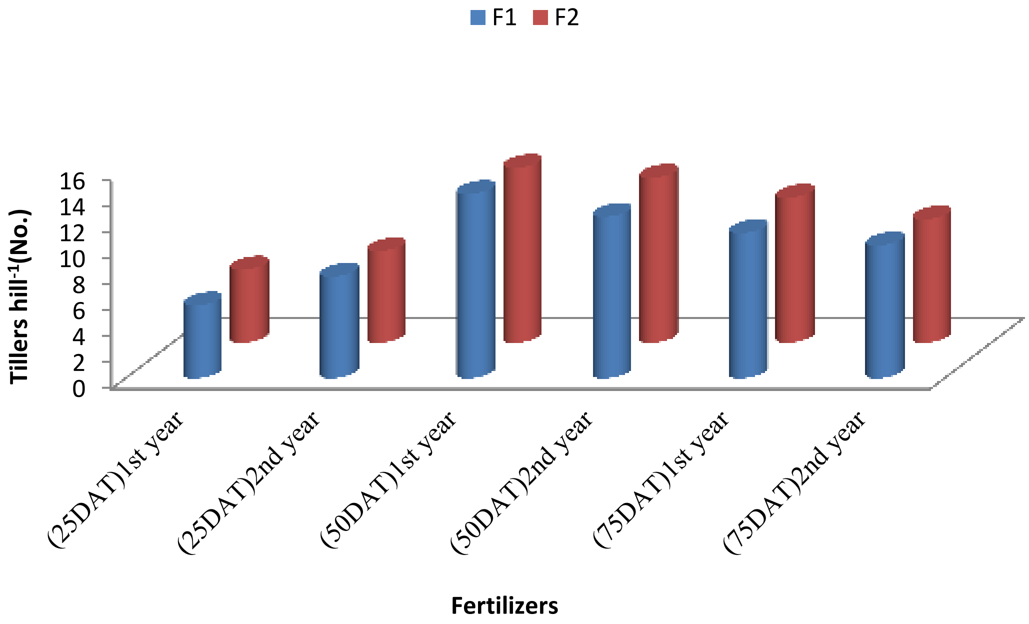
4.2.1.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Plant height did not vary significantiy at all the data recording stages except 75 DAT in 1^{st} experiment and 25DAT in second experiment (Table 5). However, a regular trend of increased in the plant height was observed with the increasing level of nitrogen regarding each green manure crops and also the advancement of the study period. At 75 DAT, significantly the tallest plant (136.00cm) was obtained from the treatment combination of *S. rostrata* and 100% Nha^{-1} followed by *S. aculeata* (136 cm) with 100% NPK which was at par with 50% N and NPK at both years. The lowest plant height was observed from control along with *V. radiata* and *V. mungo* with 50% N ha^{-1}. It indicate that half dose of N is similar to half dosed of fertilizer and full dose of fertilizer as well.

4.2.2. Number of tillers $hill^{-1}$

4.2.2.1 Effect of different levels of N and NPK fertilizers

Number of total tillers $hill^{-1}$ was not influenced significantly due to various levels of nitrogen and NPK at different days after transplanting in both years. In experiment, the maximum number of total tillers $hill^{-1}$ (5.58, 14.18 and 11.18 in 1^{st} year and 7.80, 12.43 and 10.23 in 2^{nd} year) with 100% N ha^{-1} and 100% NPK ha^{-1}which was statistically similar with 50% N ha^{-1} and 50% NPK ha^{-1}(5.61, 13.46 and 11.17 in 1^{st} year and 7.05, 12.70 and 9.51 in 2^{nd} year) at 25, 50 and 75 DAT (Figure. 16). Inspite of half of fertilizer applied, similar findings were recorded in second year as well with little increase of tillers $hill^{-1}$. The number of total tillers $hill^{-1}$ increased progressively due to application of higher level of nitrogen up to 50 DAT while at 75 DAT, it was decreased at 100 kg N ha^{-1}. The result indicated that the tiller production progressively increased at 50 DAT and decreased at harvest in the present study which may be due to the possibility of mortality for its maturity.

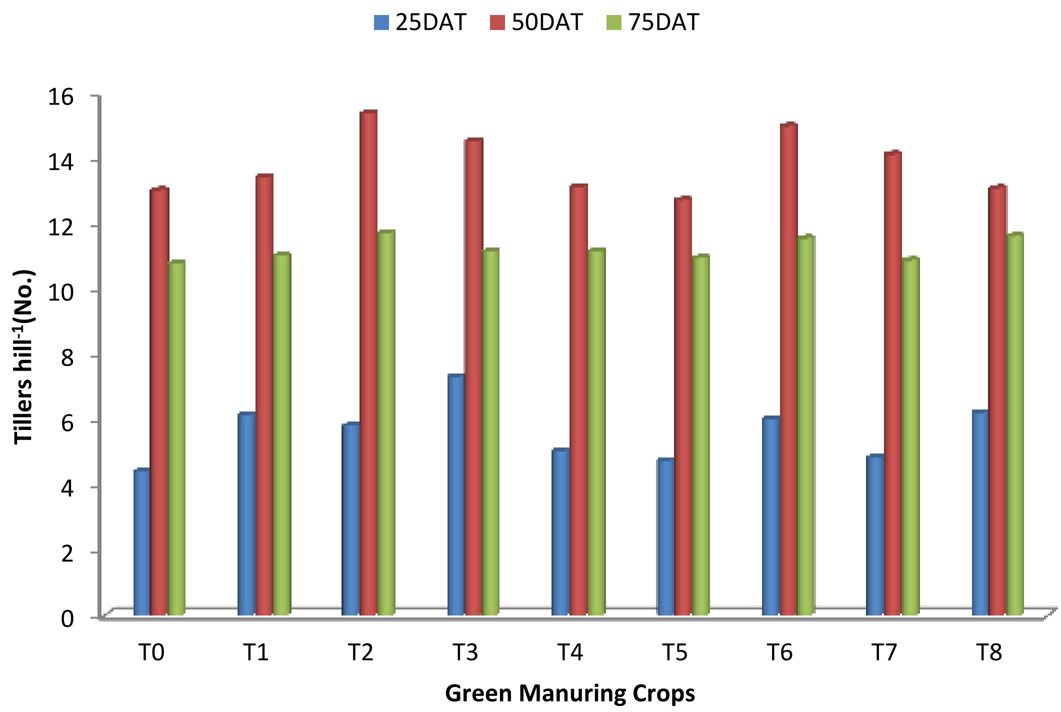


Here, F1 = 100% Nitrogen in 2015 and NPK in 2016, F2= 50% Nitrogen in 2015 and NPK in 2016

Figure. 16. Effect of fertilizers on tillers hill^{-1} of T. aman rice at different days after transplanting in two years.

4.2.2.2 Effect of green manuring crops

Number of total tillers hill^{-1} was significantly influenced in 2nd year but not in 1st year except 25 DAS (Figure. 17 and Figure. 18 and Appendix 14). The maximum number of total tillers hill^{-1} was found from the treatment *S. rostrata* (15.35 and 11.70 in 1st year*)* followed by *Vigna unguiculata* (14.96 and 11.53 in 1st year) and the lowest was from control (13 and 10.76 in 1st year) at 50 and 75 DAT. Whereas in second year, the higher number of tiller hill^{-1} were recored from *S. rostrata* (17.66 and 13.83 in 2nd year) followed by *S. aculeata* (14.50 and 11.27 in 2nd year) at 50 and 75 DAT. These results revealed that, tiller production significantly increased up to 50 DAT and there after declined at harvest due to its different types of tiller mortality at harvest. Similar results were found by Chanda and Sarwar (2017). Bisht *et al*. (2006) reported that this higher result could be attributed to the higher supply of N and other micronutrient cations through the incorporation of green manures into soil.



Here, T $_0$ = Control, T1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 17. Effect of green manuring crops on tillers hill^1 of transplant aman rice in 1st year (SE (±) $_=$ 0.525 at 25DAT).

Here, T_0 = Control, T1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 18. Effect of green manuring crops on tillers hill^{-1} of transplant aman rice in 2nd year (SE (±) = 0.892, 1.13 and 0.986 at 25, 50 75DATrespectively).

4.2.2.3 Interaction effect of green manures and fertilizer (N, NPK) levels

Interaction effect between fertilizer doses and green manuring crops had significant influence on tiller production hill^{-1} at different days after transplanting (Table 6 and Appendix 14). In first year, the numerically maximum number of total tillers hill^{-1} was obtained from the variety *S. rostrata* (6.1, 15.7 and 11.4) followed by *C. juncea* (7.3, 14.8 and 11.4) at 25, 50 and 75 DAT when N was applied @ 100% ha^{-1} that similar to other interactions with 50% Nha^{-1}. But in second year, the highest tiller hill^{-1} was found from *S. rostrata* (19.0 and 13.6 for 100% NPK and 14.9 and 12.0 for 50% NPK ha $^{-1}$) followed by *S. aculeata* (14.3 and 14.6 at 50% and 100% NPK/ha respectively) at 50 and 75 DAT. The minimum tillers hill^{-1} (4.2, 12.46 and 10.6) was found from the control in 100% N ha^{-1} which was statistically similar to the 100% N ha^{-1} at 25, 50 and 75DAT in first year. But in second year, minimum tillers hill^{-1} was found from control plot with50% NPK ha^{-1}. Pramanik *et al*. (2004) stated that, increasing trend of tillers hill^{-1} was observed from green manuring crops in combination with higher levels of nitrogen

Table 6. Interaction effect of fertilizer levels and green manuring crops on the tillers hills^{-1} of rice

Treatments	Tiller hills^{-1} (No.) at					
	25 DAT		50 DAT		75 DAT	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$F_1 T_0$	4.2c	6.3	12.46	11.0bc	10.6	9.6abc
$F_1 T_1$	5.9a-c	9.3	13.5	14.6abc	11.5	11.4abc
$F_1 T_2$	6.1a-c	8.4	15.7	16.3ab	11.4	14.0a
$F_1 T_3$	7.3a	7.0	14.8	14.0abc	11.4	12.1abc
$F_1 T_4$	5.8c	7.5	14.1	10.9bc	10.9	8.8abc
$F_1 T_5$	4.2a-c	9.0	14.0	11.6bc	11.0	8.8abc
$F_1 T_6$	5.6a-c	8.8	15.5	12.7bc	11.2	10.6abc
$F_1 T_7$	4.9a-c	8.0	13.4	11.8bc	10.6	8.2bc
F_1T_8	6.0a-c	5.7	14	8.6c	11.6	8.1bc
F_2T_0	4.8bc	5.6	14a	8.9c	10.9a	6.4c
$F_2 T_1$	6.3a-c	8.4	13.2	14.3abc	10.4a	11.1abc
$F_2 T_2$	5.4a-c	7.3	14.9	19.0a	12.0	13.6ab
$F_2 T_3$	7.2ab	6.8	14.2	13.0abc	10.8	10.3abc
$F_2 T_4$	4.2c	7.3	14.1	12.6bc	11.3	8.1c
$F_2 T_5$	5.2a-c	7.0	11.4	12.33bc	10.8	9.5abc
F_2T_6	6.4a-c	7.6	14.4	11.6bc	11.8	7.7c
$F_2 T_7$	4.7a-c	7.1	14.7	11.7bc	10.9	9.54abc
F_2T_8	6.3a-c	6.0	12.1	8.6bc	11.5	9.1abc
SE (±)	**0.988**	**NS**	**NS**	**1.44**	**NS**	**1.27**
CV(%)	**16.24**	**20.37**	**10.45**	**15.86**	**11.82**	**17.31**

Here, F1= 100% Fertilizer for 2015 and NPK for 2016, F2= 50% Nitrogen for 2015 and NPK for 2016
T 0= 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.

4.2.3. Panicle length

4.2.3.1 Effect of different levels of N and NPK fertilizers

There was no significant difference observed between two treatments. In both year, the maximum result was observed from F_1 (100% fertilizer) followed by F_2 (50% Fertilizer dose) (Table 7).

Table 7. Effect of fertilizer levels on panicle length, spikelet panicle $^{-1}$, panicle Weight of transplant aman rice in 2015 and 2016

Fertilizer levels	Panicle length(cm)		spikelet panicle^{-1}		Panicle weight (g)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
F_1	25.43	22.54	12.33	16.15	2.65	2.78
F_2	24.68	22.21	12.50	15.25	2.66	2.82
SE (±)	NS	NS	NS	NS	NS	NS
CV(%)	5.67	5.12	5.01	15.48	5.94	5.55

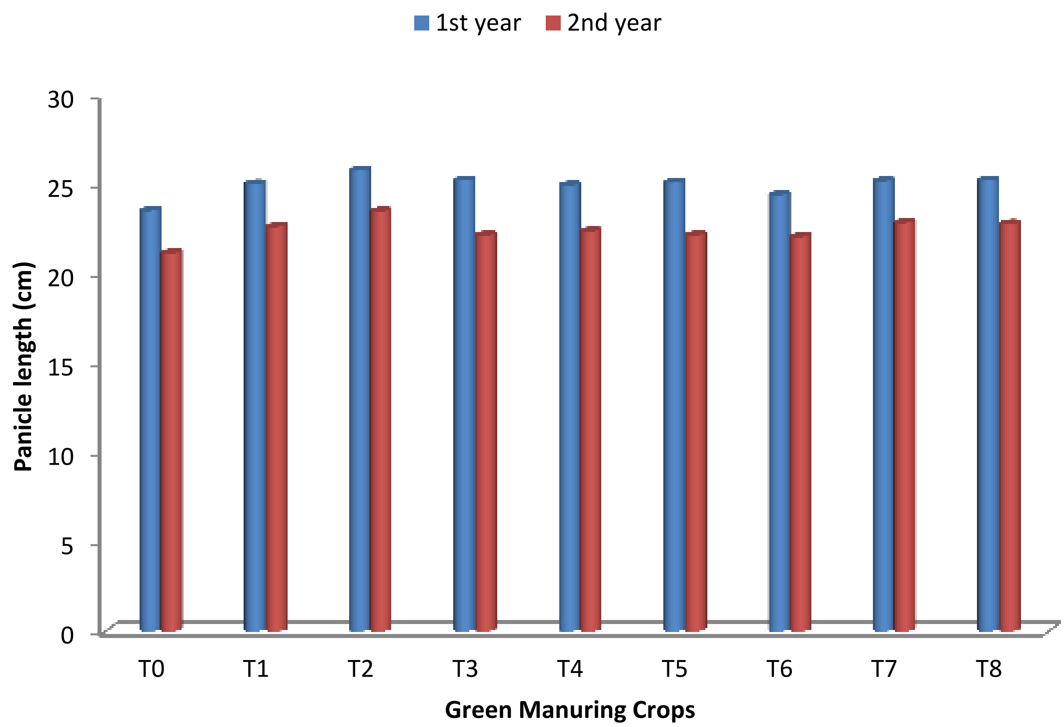
Here, F1= 100% Fertilizer dose in 2015 and NPK in 2016, F2= 50% Fertilizer dose in 2015 and NPK in 2016 ,
NS= Not Significant

4.2.3.2. Effect of green manuring crops

Panicle length was significantly influenced during 2nd year (2016) but not in 1st year (2015) (Figure.19). In both years, the highest panicle length was recorded from *S. rostrata* (25.74 cm and 23.46 cm in 1st and 2nd year) followed by *C. juncea* (25.20 cm in 1st year) and *L leucocephala* (25.15 cm and 22.82 cm in 1st and 2nd year). Panicle length was found to be decreased in next year (2016) in comparision to 2015 year.The lowest length was observed from control plot in both years. The result was similar to Singh (2014) findings who stated that the incorporation of summer green manuring crops residue and various Zn fertilization treatments significantly influenced the panicle length and also found the highest panicle length from *S. aculeata* followed by *C. juncea*.

4.2.3.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Interaction between nitrogen/NPK levels and green manuring crops were not significantly differed in two consecutive years (Table 8). The maximum panicle length (25.80 cm) was observed from T_3 (*C. juncea*) with full N dose which was very close (25.76 cm) to T_2 (*S. rostrata*) with half of recommended N dose in 2015 year whereas T_2 (*S. rostrata*) showed the highest panicle length (23.76 cm and 23.16 cm) with half and full recommended dose of fertilizer in second year.



Here, T_0 = Control, T1=*S. aculeata*, T_2=*S .rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 19. Effect of green manuring crops on panicle length (cm) of T. aman rice at two years (SE (±) = 0.66 at 2nd year).

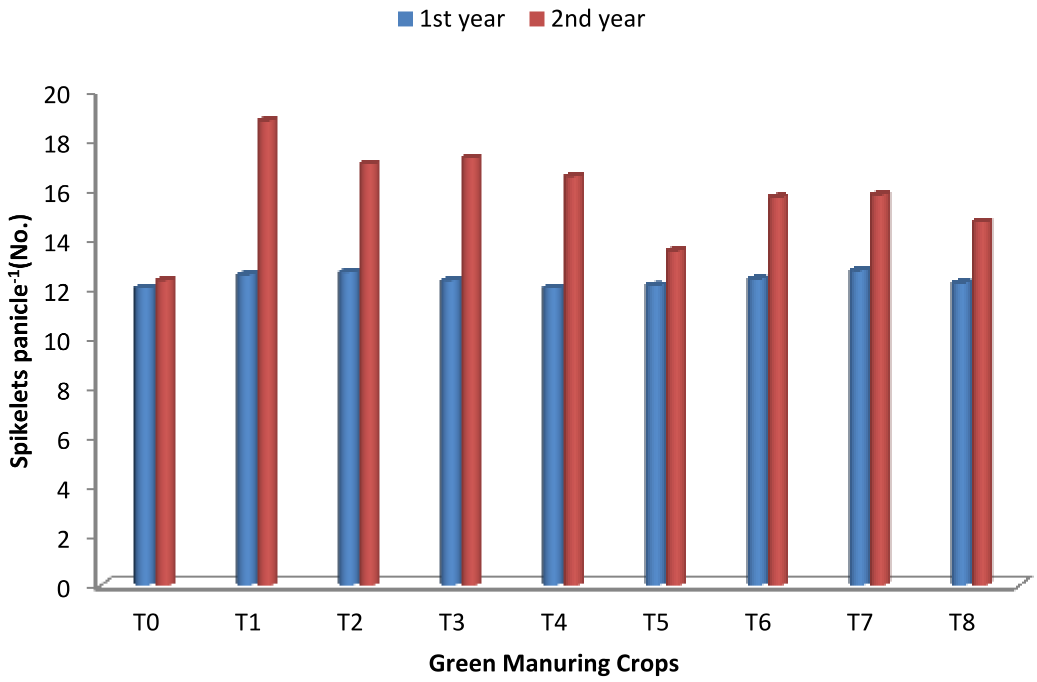
4.2.4 Number of rachis panicle^{-1}

4.2.4.1 Effect of different levels of N and NPK fertilizers

There was no significant difference observed between two treatments. In both year, the numerically maximum number of rachis panicle^{-1} was observed from F_2 (50% Nitrogen) in 1st year and F_1 (100% NPK) in 2nd year respectively (Table 7).

4.2.4.2 Effect of green manuring crops

The number of rachis per panicle was significantly influenced in 2nd year (2016) but not in 1st year (Figure. 20 and Appendix 16). The highest number of rachis panicle^{-1} was recorded from *S. aculeata* (18.75) followed by *S. rostrata* (17.00) *and C. juncea* (17.25) during 2nd year. The lowest number (12.00 and 12.30 in 1st and 2nd years) of rachis panicle^{-1} was observed from control plot in both years respectively. Kamiji *et al*. (2011) stated that variation of spikelet number was caused mainly by plant nitrogen status at the late spikelet differentiation stages. The effects of nitrogen fertilizer on panicle branching may be mediated by CKs, in which accumulation in the inflorescence meristem can regulate panicle development, resulting in increased numbers of flowers and branches. These results suggest that nitrogen fertilizer enhances local CKs synthesis to increase flower numbers in the panicles of rice (Chengqiang *et al*., 2014).



Here, T_0 = Control,T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V.mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 20. Effect of green manuring crops on rachis panicle^{-1} of T. aman rice at two years (SE (±) = 1.40 at 2nd year).

4.2.4.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Interaction between nitrogen/NPK levels and green manuring crops were significantly differed in 2nd year (Table 8) instead of 1st year. In both years, the highest number (12.40 and 19.66 in 1st and 2nd year) was observed in T_1 (*S. aculeata*) and (12.80 and 19.33 in 1st and 2nd year) T_2 (*S. rostrata*) plot with full nitrogen and NPK dose which was very close to T_1 (*S. aculeata*) and T_3 (*C. juncea*) with half of recommended nitrogen and NPK dose. Whereas T_0 (*control*) showed the lowest rachis panicle^{-1} with half of recommended dose of fertilizer in both years.

4.2.5 Panicle weight (g)

4.2.5.1 Effect of different levels of N and NPK fertilizers

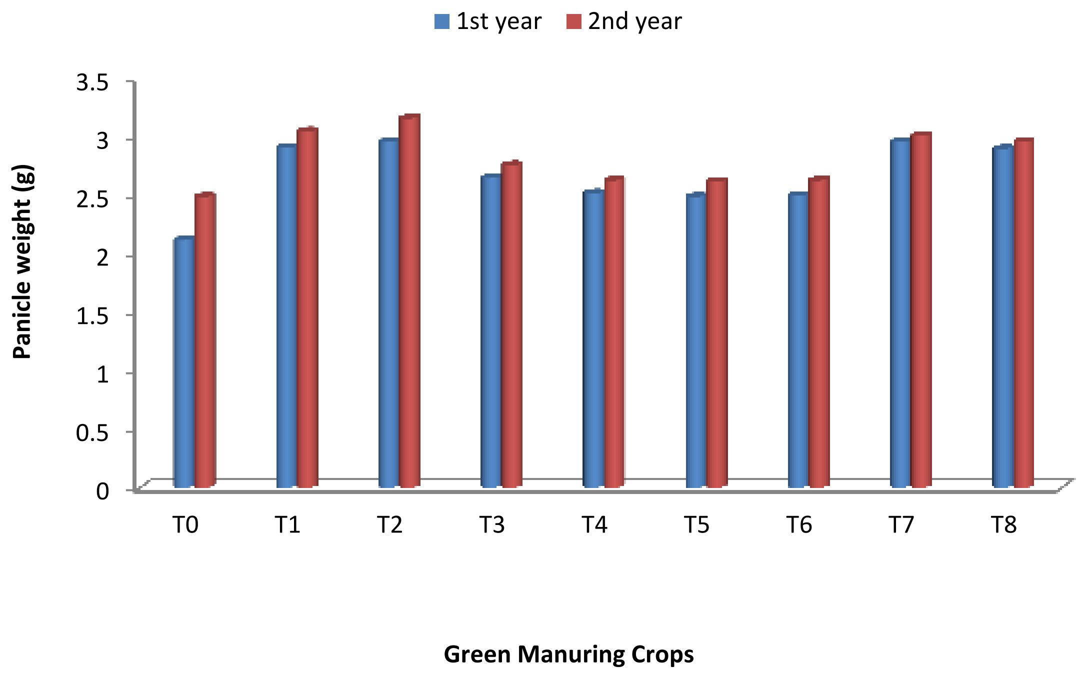
There was no significant difference observed between two treatments. In both year, the higher weight (2.66 g and 2.82 g in 1st year and 2nd year) was observed from F_2 (50% fertilizer) followed by F_1 (100% fertilizer dose) (Table 7).

4.2.5.2 Effect of green manuring crops

Panicle weight was significantly influenced during both year (2015 and 2016). The highest panicle weight was recorded from *S. rostrata* (2.95 g and 3.15 g in 1st year and 2nd year) and *L. leucocephala* (2.95 g and 3.00 g in 1st year and 2nd year) that was followed by *S. aculeata* (2.90 g and 3.04 g in 1st year and 2nd year) and *M. pudica* during both years (Fig 21 and Appendix 15). The lowest weight (2.1 g and 2.48 g in 1st year and 2nd year) was observed from control plot. Singh and Shivay (2014) stated that the incorporation of summer green manuring crop residue and various Zn fertilization treatments significantly influenced the panicle weight and he also found the highest panicle length from *S. aculeata* followed by *C. juncea*. Sharma and Ghosh (2000) reported that the panicle number was lower but the panicle weight was higher with dhaincha green manuring.

4.2.5.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Interaction between nitrogen/NPK levels and green manuring crops were significantly differed in two consecutive years (Table 8). The highest (2.96 g and 3.11 g in 1st year and 2nd year) panicle weight was observed from T_2 (*S. rostrata*) followed by T_7 (*L. leucocephala*) plot with full nitrogen and NPK dose which was at par to T_2 (*S. rostrata*) and T_7 with half of recommended nitrogen and NPK dose in 2015 and 2016 year whereas T_0 showed the lowest (2.09 g and 2.33 g in 1st and 2nd year) with half of recommended dose of N and NPKfertilizer in both years.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C.juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 21. Effect of green manuring crops on panicle weight (g) of T. aman rice at two years (SE (±) = 0 .091 and 0.08 at 1st and 2nd year respectively).

Table 8. Interaction effect of fertilizer levels and green manuring crops on the panicle length , rachis panicle^{-1} and panicle weight of rice in 2015 and 2016

Interactions	Panicle length (cm)		Rachis panicle $^{-1}$(No.)		Panicle weight (g)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
F_1 T_0	22.53	21.07	12.00	11.83b	2.09d	2.33d
F_1 T_1	24.65	22.52	12.40	19.66a	2.92ab	3.04a-c
F_1 T_2	25.73	23.76	12.80	19.33a	2.96a	3.11ab
F_1 T_3	25.80	22.11	12.40	17.16ab	2.64abc	2.73a-d
F_1 T_4	25.64	22.61	12.00	17.66ab	2.46b-d	2.62cd
F_1 T_5	25.21	21.91	11.93	12.66ab	2.47b-d	2.63b-d
F_1 T_6	24.87	22.93	12.26	15.66ab	2.51a-d	2.65b-d
F_1 T_7	25.78	23.11	12.26	16.83ab	2.95ab	2.99a-c
F_1T_8	25.24	22.83	12.13	14.66ab	2.92ab	2.97a-c
F_2T_0	24.45	21.18	12.00	12.77ab	2.13cd	2.63b-d
F_2 T_1	25.32	22.66	12.66	17.83ab	2.89ab	3.03a-c
F_2 T_2	25.76	23.16	12.46	14.66ab	2.95ab	3.19a
F_2 T_3	24.60	22.13	12.20	17.33ab	2.65a-c	2.77a-d
F_2 T_4	24.17	22.08	12.00	15.33ab	2.57a-d	2.62b-d
F_2 T_5	24.93	22.33	12.26	14.33ab	2.49a-d	2.59cd
F_2T_6	23.88	21.13	12.46	15.66ab	2.48a-d	2.59cd
F_2 T_7	24.52	22.53	13.13	14.70ab	2.95ab	3.01a-c
F_2T_8	25.16	22.70	12.26	14.66ab	2.86ab	2.92a-c
SE (±)	NS	NS	NS	1.85	0.116	0.114
CV(%)	5.67	5.12	5.01	15.48	5.94	5.55

NS = Not Significant Here, F_1= Recommended dose of nitrogen, F_2 = Half of recommended dose of nitrogen ,
Here,T_0=Control,T_1=*S.Saculeata*,T_2=*S.rostrata*,T_3=*C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*,T_6=*V.unguiculata*,T_7=*Leucaena leucocephala*,T_8=*Mimosa pudica*
In a column, figure(s) followed by same letter do not differ significantly at 5% level.

4.2.6 Total dry matter weight of shoot

4.2.6.1 Effect of different levels of N and NPK fertilizers

Total dry matter weight of shoot did not vary significantly due to fertilizer levels at all the data recording stages in 2015 and 2016 year. The maximum shoot DM was found from F_1 (100% fertilizer) which was insignificant to F_2 (50% fertilizer) in 2nd year (Table 9). At 90 DAT, the highest (22.73 g) shoot dry matter was obtained from F_2 followed by F_1 (21.94 g). Zaman *et al.* (1991) reported that, on a light textured soil, green manuring with 60-day-old *dhaincha* can completely substitute for urea-N fertilizer. Pramanik *et al.* (2004) also found from his experiment on green manure and stated that highest dry matter was obtained when crop was fertilized with 80 kg N ha^{-1} followed by 60, 40 and 20 kg N ha^{-1}.

4.2.6.2 Effect of green manuring crops

Total dry matter (TDM) of shoot was significantly influenced by different treatments of green manures at different data recording stages in both experimentation years (Figure. 22 and Figure. 23). It was found that dry matter production of shoot increased with age of rice plant up to harvest. In both years, among the treatments, T_2 (*S. rostrata*) showed the highest TDM hill^{-1} (1.91 g, 7.15 g and 27.25 g in 1st year and 5.78 g, 29.91 g and 33.16 g in 2nd year) at 30, 60 and 90 DAT of shoot respectively followed by T_6 (*V. unguiculata*) but in second year dry matter accumulation was found higher than first year. The lowest (1.24 g, 3.60 g and 16.58 g in 1st year and 4.48g, 19.03g and 21.29g in 2nd year) TDM of shoot was found from control plot where green manure was absent. The result was totally supported by Pramanik *et al.* (2004) who found the highest TDM in *S. rostrata* followed by *S. aculeata* and also stated that TDM increased with increasing plant age up to physiological maturity and high yielding varieties always maintained higher TDM.

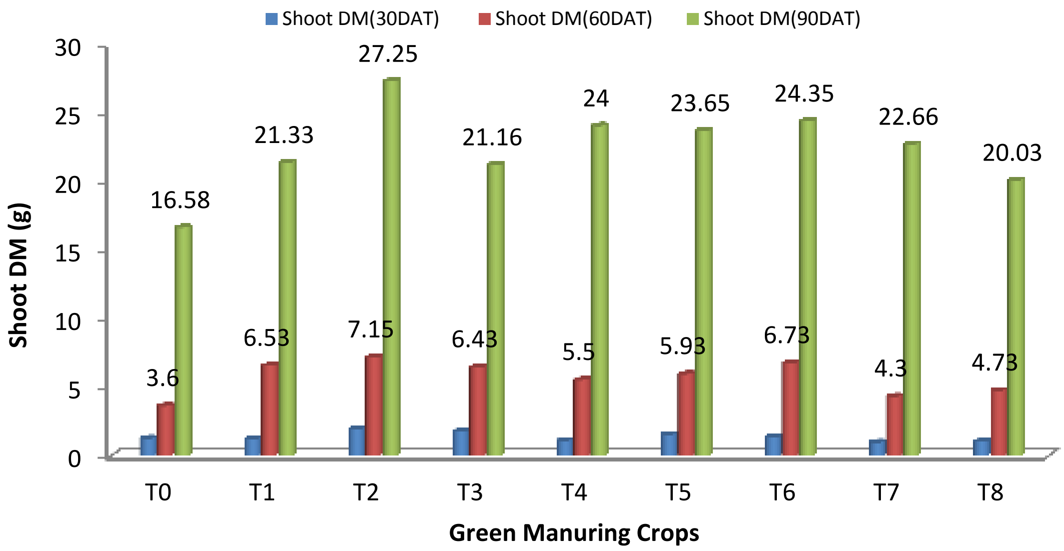
Table 9. Effect of fertilizer levels on shoot dry matter and root dry matter of transplant aman rice at different days after transplanting in 2015 and 2016. (Lanscape page have to check)

Fertilizer Levels	At 30 DAT(DM)				At 60 DAT (DM)				At 90 DAT (DM)			
	Shoot wt		Root wt		Shoot wt		Root wt		Shoot wt		Root wt	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
F1	1.41	4.75	0.78	1.44	5.48	24.42	2.89	3.69	21.94	28.55	5.51	4.36
F2	1.25	4.65	0.84	1.46	5.47	24.69	2.96	3.30	22.73	27.47	5.47	3.88
$LSD_{(0.05)}$	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV(%)	**40.21**	**19.06**	**45.37**	**34.17**	**19.75**	**17.23**	**21.51**	**26.69**	**15.95**	**15.15**	**17.00**	**32.38**

Here, F1= 100% Fertilizer dose in 2015 and NPK in 2016, F2= 50% Fertilizer dose in 2015 and NPK in 2016 ,
NS= non significant

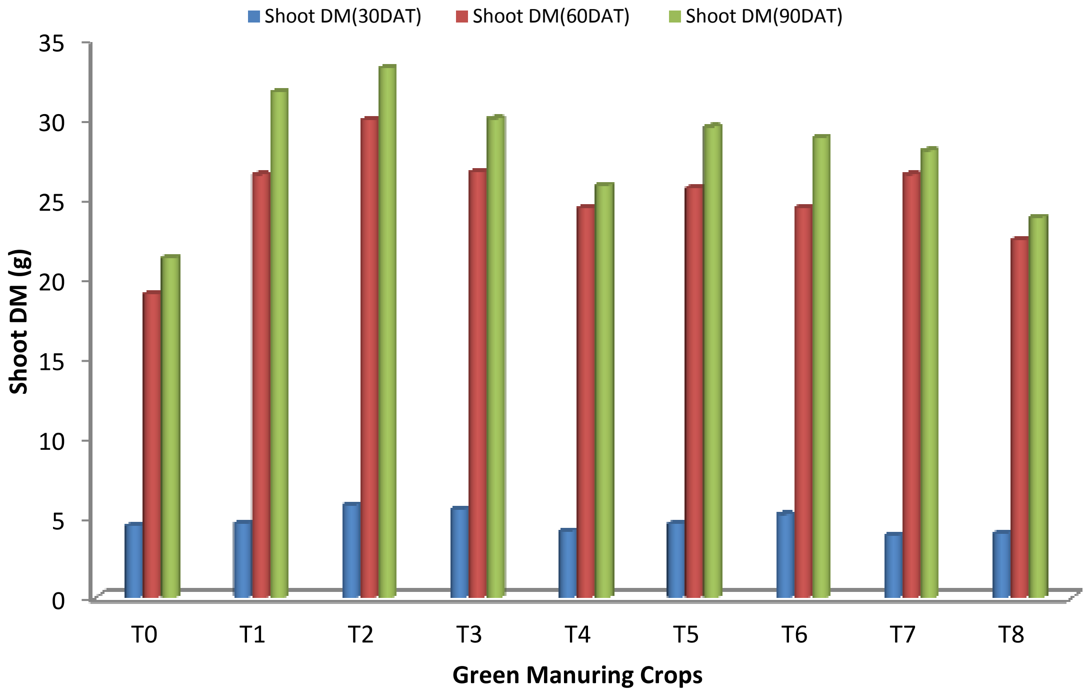
4.2.6.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Dry matter of shoot production of transplant aman rice was significantly influenced by the interaction of fertilizer levels and green manures at all the data recording stages (Table 10) Among the interactions, the *S. rostrata* registered the higher TDM of shoot (2, 6.80 and 29.33g hill^{-1}) in 50% N ha^{-1} at 30, 60 and 90 DAT which was at par of with 100% N ha^{-1} , while lower TDM of shoot (1.05, 3.58 and 17.33 g hill^{-1}) was observed from the control in both 50% Nha^{-1} and 100% Nha^{-1} in 1st year. Whereas in 2nd year, TDM of shoot was found increased compared to 1st year and *S. rostrata* showed the highest (6.37, 31.33 1nd 33.66) followed by *C. juncea* at 30 DAT with 100% N ha^{-1}, *V. mungo* at 60 DAT with 50% NPK fertilizer.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S.rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 22. Effect of green manuring crops on total dry matter of shoot hill^{-1} (g) in 1st year (SE (±)= 0.883 and 0.823 at 60, 90 DAT respectively).



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 23. Effect of green manuring crops on total dry matter of shoot hill^{-1} (g) in 2nd year (SE (±) = 0.517, 0.249 and 2.45 at 30, 60, 90DAT).

4.2.7 Total dry matter weight of root

4.2.7.1 Effect of different levels of N and NPK fertilizers

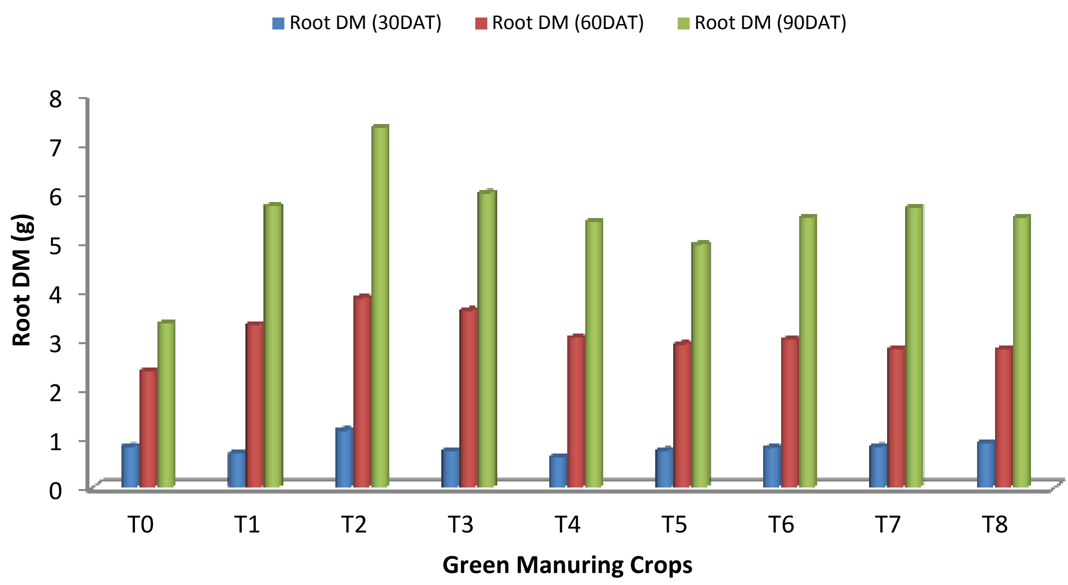
Total dry matter weight of roots did not vary significantly due to N and fertilizer levels at all the data recording stages (Table 9).

4.2.7.2 Effect of green manuring crops

Total dry matter of root was significantly influenced by different treatments at different data recording stages during two uninterrupted year except 30 DAT (Figure. 24 and Figure. 25). It was found that dry matter production of root increased with age of rice plant. In 1^{st} year, among the treatments T_2 (*S. rostrata*) showed the highest TDM of roots $hill^{-1}$ (1.16 g, 3.85g and 7.33 g) at 30, 60 and 90 DAT followed by T_3 (*C. juncea*). In second year, *S.rostrata* (2.08 g, 4.90 g) showed the highest root weight except 90 DAT followed by T_1 (*S. aculeata)* and T_3 (*C. juncea)*. Incorporation of *S. rostrata* residue resulted into 120% and 33% increased in dry matter of transplant aman rice over fallow at 90 DAT in 2015 and 2016, respectively. The lowest TDM of root was found from control plot where green manure was absent. Variation in TDM of roots might be due to higher nutrient availability and better physicochemical soil properties under green manures incorporated plots. Mondal *et al*. (2003) reported that root length density and yield of rice were higher in green manure plots than in fallow both in rice and as well as in succeeding wheat crop.

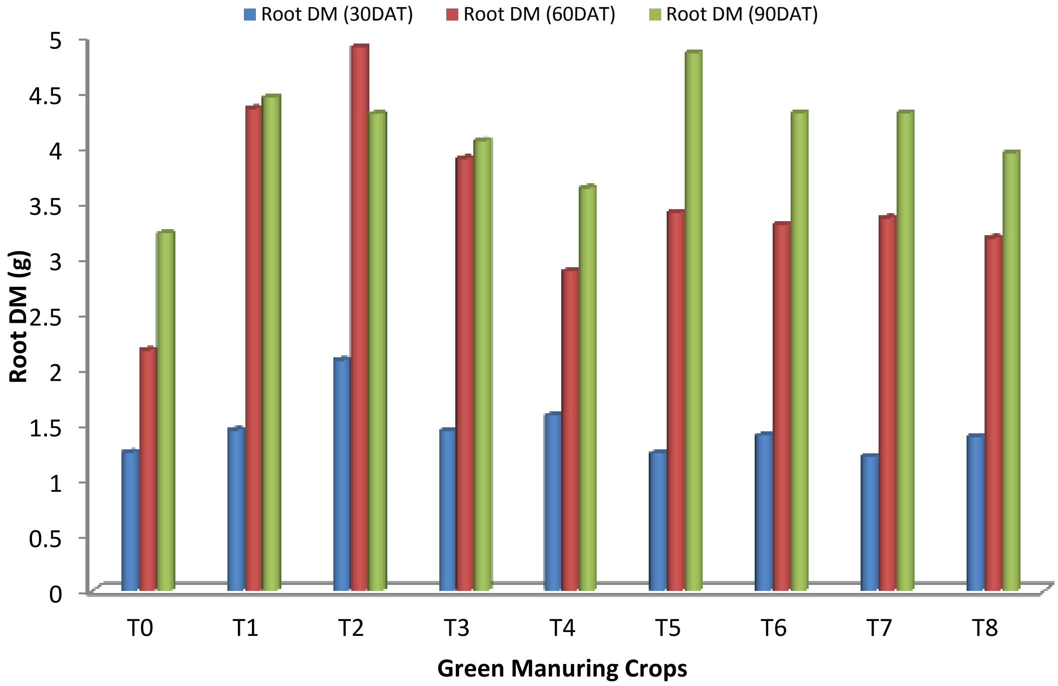
4.2.7.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

A significant variation was found due to interaction effect between N /NPK levels and green manuring crops in respect of TDM of root in first experiment at all the data recording stages but in second experiment significant difference was found only 60 DAT of root and 90 DAT (1^{st} year) (Table 10). Among the interactions, the variety of *S.rostrata* registered the higher TDM of root (1.16, 4.00 and 7.33g $hill^{-1}$) in 50% N ha^{-1} at 30, 60 and 90 DAT while lower TDM of root (0.66, 1.45 and 3.33 g $hill^{-1}$) was observed from the control in both 100kg Nha^{-1} and 100% Nha^{-1} in 1^{st} year. In 2^{nd} year, the higher result was found both from half and full fertilizer doses with *S. rostrata* and *C. juncea* at 30 and 60 and 90 DAT.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 24. Effect of green manuring crops on total dry matter of root hill^{-1} (g) at different days in 1st year (SE (±) = 0.228 and 0.823 at 60, 90DAT respectively).



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 25. Effect of green manuring crops on total dry matter of root hill^{-1} (g) at different days in 2nd year (SE (±) = 0.538 at 60 respectively).

LANSCAPE OF INTERACTION

4.2.8 Number of effective tillers $hill^{-1}$

4.2.8.2 Effect of different levels of N and NPK fertilizers

The levels of nitrogen did not significantly influence on number of effective tillers $hill^{-1}$ (Table 11). In both years, the maximum number of effective tillers $hill^{-1}$ was recorded in 100% N and NPK ha^{-1} which was similar to 50% N and NPK ha^{-1}. The results were in conformity with the findings of Biswas *et al*. (1996) who stated that the effective tillers $hill^{-1}$ increased with higher nitrogen doses but was similar with 40 kg and 80 kg Nha^{-1}. Additional N was added to the soil through green manureing which help to make similar yield from both the fertilizer doses.

Table 11. Effect of fertilizer levels on number of effective tiller $hill^{-1}$ and no. of non effective tillers $hill^{-1}$, the number of fiiled grains, unfilled grains panicle of transplant aman rice in 2015 and 2016

Fertilizer levels	No. of effective tillers $hill^{-1}$		No. of non-effective tillers $hill^{-1}$		No of filled grains $panicle^{-1}$		No of unfilled grains $panicle^{-1}$	
	1st year	2nd year	1st year	2nd year	1st year	2nd year	1st year	2nd year
F_1	8.64	9.84	1.97	0.48	155.01	171.00	12.63	21.67
F_2	8.56	9.65	1.82	0.43	140.03	168.08	13.13	17.16
SE (±)	NS	NS	NS	NS	NS	NS	NS	NS
CV(%)	16.34	13.44	43.61	71.85	10.97	4.98	47.30	37.57

NS = Not Significant, Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016

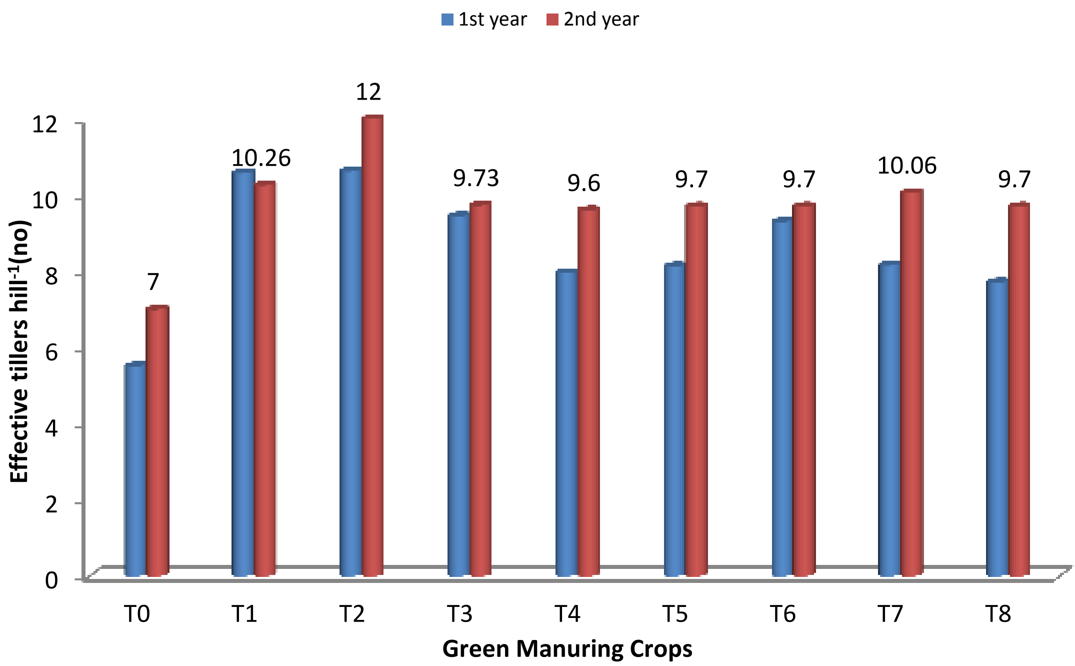
4.2.8.2 Effect of green manures

Number of effective tillers $hill^{-1}$ had shown significant difference among the green manures in both the years (Figure. 26 and Appendix 15). In both years, the highest number of effective tillers $hill^{-1}$ (10.63 and 12.00 in 1st year and 2nd year) was recorded inT_2 (*Sesbania rostrata)* plot followed by T_1 (10.58 and 10.26 in 1st and 2nd year) and the minimum value were found from control plot (T_0). The T_3 (*C. juncea*) and T_7 (*L. leucocephala*) occupied third position in 2015 and 2016 respectively. As nitrogen encouraged tiller production, so the number of effective tillers $hill^{-1}$ increased with the increased in N fertiltzation. T_2 (*S. rostrata*), T_1 (*S. aculeata*) and T_6 (*V.*

unguiculata) increased soil N through biological N fixation higher than the other green manures.This observations were in aggrement with the findings of Saha *et al*. (2007) in rice. Similar findings were reported by Pramanik *et al*. (2004) who stated that, number of effective tillers hill^{-1} were obtained from the incorporation of *S. rostrata* and *S. aculeata* .The result were in consequence with the findinds of Chanda and Sarwar (2017) who stated that number of effective tillers hill^{-1} significantly and positively differed after biomass incorporation of Dhaincha.

4.2.8.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

The effect of interaction between N/NPK levels and green manuring crops was significant in respect of number of effective tillers hill^{-1} throughout the growth period of the crop (Table 12). In 1st year, the maximum number of effective tillers hill^{-1} was produced by the treatment combination of the *S. aculeata* (10.90 and 10.26) with 50% N ha^{-1} and 100% N ha^{-1} which were at par with *S. rostrata* (10.86 and 10.40) with 50%N and 100% N dose. Similar results were found in 2nd year experimentation. The minimum number of effective tillers hill^{-1} was produced in the treatment combination of the control with 50% N ha^{-1} which was statistically similar to 100% Nha^{-1}.



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V .radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 26. Effect of green manuring crops on effective tillers hill^{-1} at two year (SE (±) = 0.812 and 0.678 at 1st year and 2nd year respectively).

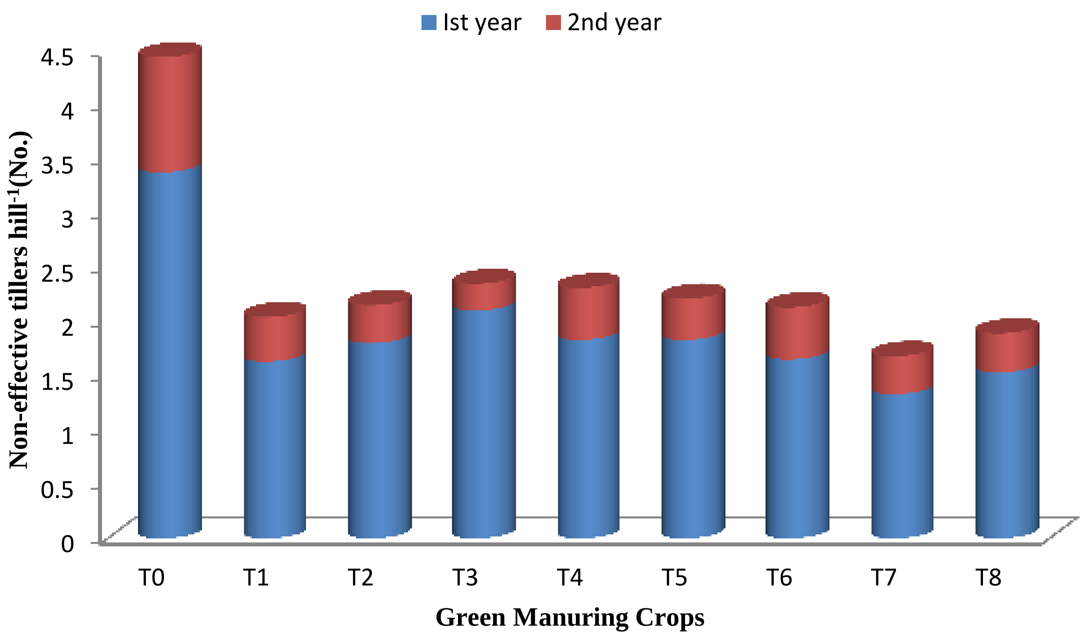
4.2.9 Number of non-effective tillers hill^{-1}

4.2.9.1 Effect of different levels of N and NPK fertilizers

In both experimentation year, the number of non–effective tillers hill^{-1} was not influenced significantly by different nitrogen levels (Table 11).The maximum number of non–effective tillers hill^{-1} (1.97) was obtained from 100% Nha^{-1} applied which was statistically similar to 50% N ha^{-1}. Addition of fertilizer nitrogen with organic matter nullifies this benefit, and produces similar yields, which are greater than plots receiving only organic matter or fertilizer nitrogen. The use of the full complement or 50% of the rate of mineral nitrogen with *Sesbania* produced similar yields.

4.2.9.2 Effect of green manuring crops

Number of non–effective tillers hill^{-1} was differed significantly in both the years (Figure. 27). In 1st year, the maximum number of non–effective tillers hill^{-1} (3.38) was obtained in control or without green manure treated plot. The minimum number of non–effective tillers hill^{-1} (1.33) was observed in *L. leucocephala* treated plot. In 2nd year, non-effective tiller was found minimum than 1st year and T_3 (*C. juncea*) (0.25) followed by T_2 (*S. rostrata*) (0.35) showed the lowest ones. Rahman and Buhiya (2009) reported that the mnnimum number of non-effective tillers hill^{-1} was recorded from the incorporation of *Mimosa* with recommended fertilizer (NPK) doses. Green mauring with *Mimosa* may save a substantial amount of nitrogen.



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 27. Effect of green manuring crops on non-effective tillers hill^{-1} at two years (SE (±) = 0.478 and 0.191 at 1st year and 2nd year respectively).

4.2.9.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

Non–effective tillers hill^{-1} was not significantly affected by the interaction between nitrogen and NPK levels and green manuring crops in both years (Table 12). The control treatment produced the maximum number of non–effective tillers hill^{-1} (3.43) in 50% N ha^{-1}. Similarly, the minimum number of non–effective tillers hill^{-1}(1.20) was obtained from the Mimosa pudica in 50% N ha^{-1} but in second experiment, *S. aculeata* produced less non-effective tillers.

Table 12. Interaction effect of fertilizer levels and green manurings crops on the effective tillers hill^{-1} and non effective tillers hill^{-1} of rice

Interactions	Effective tillers hill^{-1}		Non effective tillers hill^{-1}	
	1st year	2nd year	1st year	2nd year
$F_1 T_0$	5.40c	7.50b	3.34	1.12
$F_1 T_1$	10.26ab	9.40ab	1.93	0.20
$F_1 T_2$	10.40ab	11.13ab	1.80	0.30
$F_1 T_3$	9.66ab	10.26ab	2.13	0.40
$F_1 T_4$	7.96a-c	9.80ab	1.73	0.53
$F_1 T_5$	8.40a-c	9.93ab	2.20	0.66
$F_1 T_6$	9.40a-c	9.20ab	1.50	0.53
$F_1 T_7$	8.56a-c	9.80ab	1.46	0.40
F_1T_8	7.76a-c	10.46ab	1.33	0.20
F_2T_0	5.62bc	6.50b	3.43	1.00
$F_2 T_1$	10.90a	12.26a	1.33	0.63
$F_2 T_2$	10.86a	11..73a	1.80	0.40
$F_2 T_3$	9.23a-c	9.20ab	2.06	0.10
$F_2 T_4$	7.96a-c	9.40ab	1.93	0.43
$F_2 T_5$	7.86a-c	9.46ab	1.50	0.10
F_2T_6	9.20a-c	10.20ab	1.20	0.43
$F_2 T_7$	7.76	10.33ab	1.73	0.30
F_2T_8	7.66abc	8.93ab	1.73	0 .53
SE (±)	**1.08**	**0.973**	**NS**	**NS**
CV(%)	**16.34**	**14.44**	**43.61**	**71.85**

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016 T_0=Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*, T_4=*V. radiata*, T_5=*V. mungo*, T_6=*V. unguiculata*, T_7=*L. leucocephala*, T_8=*M. pudica*, NS = Not Significant
In a column, figure(s) followed by same letter do not differ significantly at 5% level.

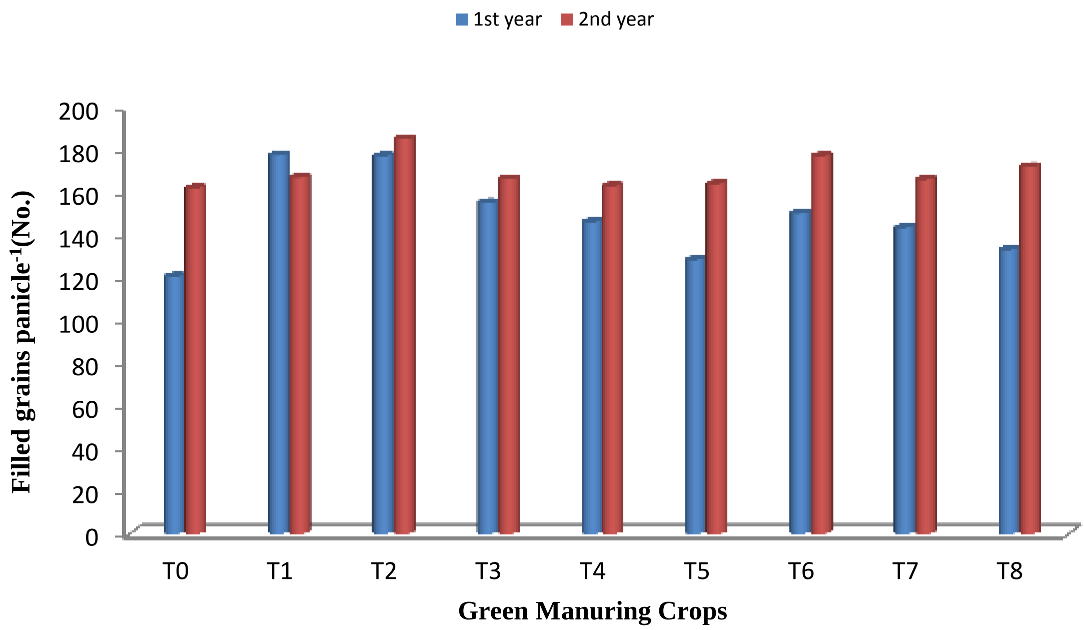
4.2.10 Number of filled grains panicle^{-1}

4.2.10.1 Effect of different levels of N and NPK fertilizers

Number of grains panicle^{-1} did not vary significantly due to nitrogen levels in 1st year and fertilizer levels in 2nd year (Table 11). Number of grains panicle^{-1} increased with increased levels of N up to 50% to 100% Nha^{-1}. The maximum number of grains panicle^{-1} in first and second year (155.00 and 171.00 respectively) was recorded in 100% N and 100% NPK ha^{-1} which was statistically similar with 50%N and 50% NPK ha^{-1} (140.03 and 168.06). Biswas *et al.* (1996) reported a similar finding with the present study where they found that application of 80 kg Nha^{-1} produced the highest filled grains panicle^{-1} but it was similar with 40 kg Nha^{-1}. Similarly increases of grains panicle^{-1} with increasing nitrogen doses was also repored by Halepyati and Sheelavantar (1990).

4.2.10.2 Effect of green manuring crops

Number of filled grains panicle^{-1} influenced significantly among the green manure treated plots in both experimentation years (Figure. 28). In 1st year, maximum number of grains panicle^{-1} (177.33) was obtained fromT_1 (*S. aculeata*) followed by T_2 (177) and minimum (120.69) from control but in 2nd year, the maximum number of grains panicle^{-1} (185.00) was found from the T_2 biomass (*S. rostrata*) incorporated plot followed by T_6 (*V. unguiculata*).The variation in filled grains panicle^{-1} production among green manures incorporated plot may be due to their genetic makeup. Rahman *et al*. (2012) reported the similar findings with the present study where they found that the number of filled grain panicle^{-1} obtained from green manuring plot was higher and the lowest from control. The increase in grains panicle^{-1} under green manure might be under additional supply of N in the soil through green manuring. Pramanik (2006) found higher numbers of grains panicle when *S. rostrata* was incorporated in the soil. These results were also in agreement with the findings of some other authors (Hossain *et al.*, 1995; Bhander *et al*., 1998).



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 28. Effect of green manuring crops on filled grains panicle^{-1} at two years (SE (±) = 9.33 and 4.88 at 1st year and 2nd year respectively).

4.2.10.3 Interaction effect between fertilizer (N, NPK) levels and green manuring crops

Number of grains panicle^{-1} was significantly influenced by the interaction of nitrogen and NPK levels and green manuring crops in 1st year and 2nd year as well (Table 13). The maximum number of grains panicle^{-1} in both years obtained from the incorporation of *S. rostrata* (184) with 100% Nha^{-1} which was statistically at par with the *Sesbania aculeata* in both 50% and 100% NPK ha^{-1}. The minimum number of grains panicle^{-1} in both years was obtained from the control where green manure was absent.

Table 13. Interaction effect of fertilizer levels and green manurings crops on the number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} of rice in 2015 and 2016

Interactions	No of filled grains panicle^{-1}		No of unfilled grains panicle^{-1}	
	1st year	2nd year	1st year	2nd year
$F_1 T_0$	117.80c	151.56b	17.69	21.35
$F_1 T_1$	182.33ab	167.00b	6.28	18.46
$F_1 T_2$	184.00a	198.00a	13.44	18.53
$F_1 T_3$	171.33ab	164.00b	12.29	13.33
$F_1 T_4$	155.00a-c	162.00b	14.77	24.33
$F_1 T_5$	134.33a-c	166.00b	12.67	18.60
$F_1 T_6$	150.00-bc	182.00ab	9.95	21.13
$F_1 T_7$	154.33a-c	164.00b	9.44	21.40
F_1T_8	146.00a-c	172.00ab	16.29	25.60
F_2T_0	123.58-bc	151.00b	17.13	20.92
$F_2 T_1$	164.33a-c	168.00b	9.46	17.00
$F_2 T_2$	170.00a-c	173.00ab	12.21	16.80
$F_2 T_3$	139.00a-c	168.00b	13.55	15.33
$F_2 T_4$	137.33a-c	164.00b	11.99	21.53
$F_2 T_5$	122.67a-c	163.00b	19.86	17.00
F_2T_6	150.00a-c	173a.00b	9.17	18.33
$F_2 T_7$	132.67a-c	167.00b	13.10	15.20
F_2T_8	120.33bc	172.00ab	11.72	16.60
SE (±)	12.50	6.22	NS	NS
CV(%)	10.97	4.58	47.30	19.54

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016, NS = Not Significant.

T_0=Control,T_1=*S.aculeata*,T_2=*S.rostrata*,T_3=*C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*,T_6=*V.unguiculata*,T_7= *L. leucocephala*,T_8=*M. pudica*

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

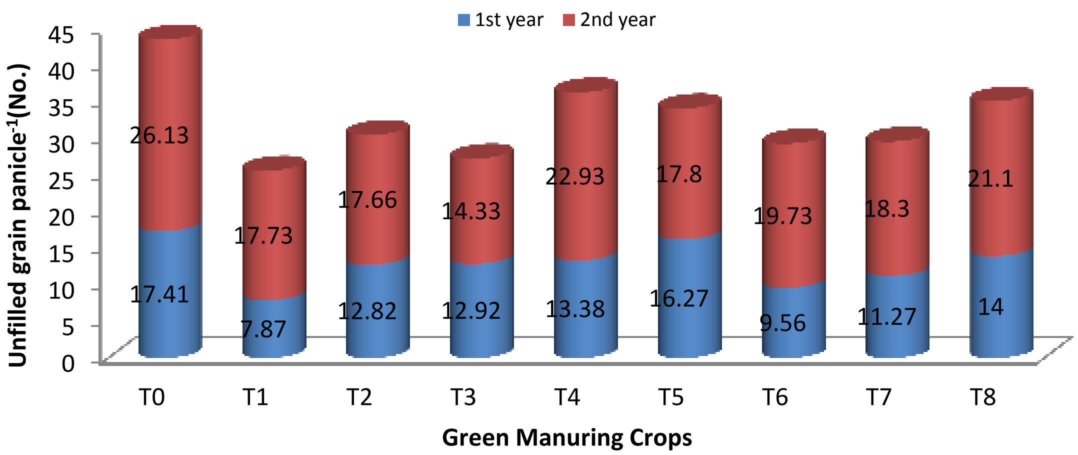
4.2.11 Number of unfilled grains panicle^{-1}

4.2.11.1 Effect of different levels of N and NPK fertilizers

The effect of different levels of fertilizer on the number of unfilled grains panicle^{-1} was not significant in both experimentation years (Table 11)). In both years, the higher result was (13.13 and 21.67) found with 50% Nha^{-1} and 100% NPKha^{-1} which had no statistical difference to 100% Nha^{-1} and 50% NPK ha^{-1}.

4.2.1.2 Effect of green manuring crops

The number of unfilled grains panicle^{-1} did not vary significantly among the treatments which indicated that all the green manures incorporated plot were produced numerically similar unfilled grains panicle^{-1} in this study (Figure. 29). The maximum unfilled grains found from T_0 (control) plot in both year which was (17.41 and 26.13 in 2015 and 2016 respectively), the minimum unfilled grains panicle^{-1} (7.87 and 17.73 in 2015 and 2016 respectively) was found T_1 (*S. aculeata*). The higher unfilled grains panicle^{-1} was found highest in 2nd year than 1st year.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C.juncea*, T_4=*V. radiata*, T_5=*V. mungo*, T_6=*V. unguiculata*, T_7=*L. leucocephala*, T_8=*M. pudica*

Figure. 29. Effect of green manuring crops on unfilled grain panicle^{-1} at two years.

4.2.11.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

The number of unfilled grains panicle^{-1} was not significantly influenced by the interaction of nitrogen and NPK and green manuring crops levels (Table 13). The maximum number of unfilled grains panicle^{-1} (17.69 and 21.35 in 2015 and 2016 respectively) was produced from the control plot with combination of 100% N ha^{-1} and 100% NPKha^{-1}. The minimum number of unfilled grains panicle^{-1} (6.28 and 13.33) was produced from the T_1 (*Sesbania aculeata)* and T_2 (*S. rostrata*) with 100% N ha^{-1} in 2015 and T_3 (*Crotalaria juncea*) with 100% NPK ha^{-1} in 2016 respectively.

4.2.12 1000–grain weight

4.2.12.1 Effect of different levels of N and NPK fertilizers

In both years, nitrogen levels had no significant effect on 1000–grain weight (Table 14). The maximum 1000–grain weight (23.06 g) was found from 100% Nha^{-1} in 1st year but 2nd year the maximim was found from 50% NPKha^{-1}.The numerically minimum 1000-grain weight was observed from 50% N/NPK application through it was statistically similar with 100% N/NPKha^{-1}.

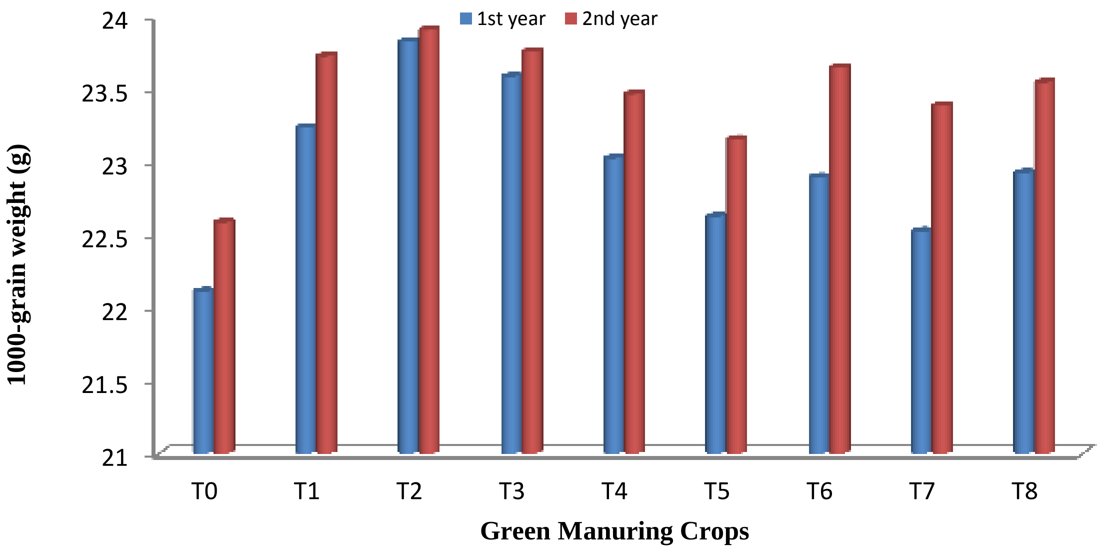
Table 14. Effect of fertilizer levels on1000-grain weight, grain yield and straw yield of transplant aman rice in two years.

Fertilizer leves	1000 seed wt (g)		Grain yield (t ha^{-1})		Straw yield (tha^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
F_1	23.06	23.45	4.30	4.85	6.17	7.00
F_2	22.88	23.47	4.40	4.66	5.99	7.05
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV(%)	**3.63**	**1.96**	**8.87**	**8.06**	**14.91**	**8.06**

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016, NS = Not Significant

4.2.15.2 Effect of green manuring crops

Thousand grains weight had vary significantly among all green manuring treatments (Figure. 30 and Appendix 17) where, T_2 (*S. rostrata*) showed the highest 1000–grain weight (23.82 and 23.90 g in 2015 and 2016 respectively) that similar to all other treatments except control plots both the year.The T_0 (control) showed the lowest 1000–grain weight (22.11g and 22.58 g in 2015 and 2016 respectively). But there were no significant variations found among green manuring crops for 1000-grain weight.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 30. Effect of green manuring crops on 1000-grain weight at two years (SE (±)= 0.484 and 0.265 at 1st and 2nd year respectively).

4.2.15.3 Interaction effect of fertilizer (N, NPK) levels and green manuring crops

The 1000- grain weight was significantly influenced by interaction effect between nitrogen and NPK levels and green manuring crops in both years (Table 15). In both year, the highest weight (23.94 g and 24.11g) was obtained from the treatment combination of the variety *S. rostrata* and 100% N ha^{-1} and 100% NPK ha^{-1} which was statistically similar to the same treatments under the 50% N and 50% NPK ha^{-1} levels (23.87g and 23.54 g in 2015 and 2016 rspectively). On the other hand, the lowest one (22.08 g and 21.36 g) was obtained by the interaction of the control plot and 100% N ha^{-1} and 100% NPK level.

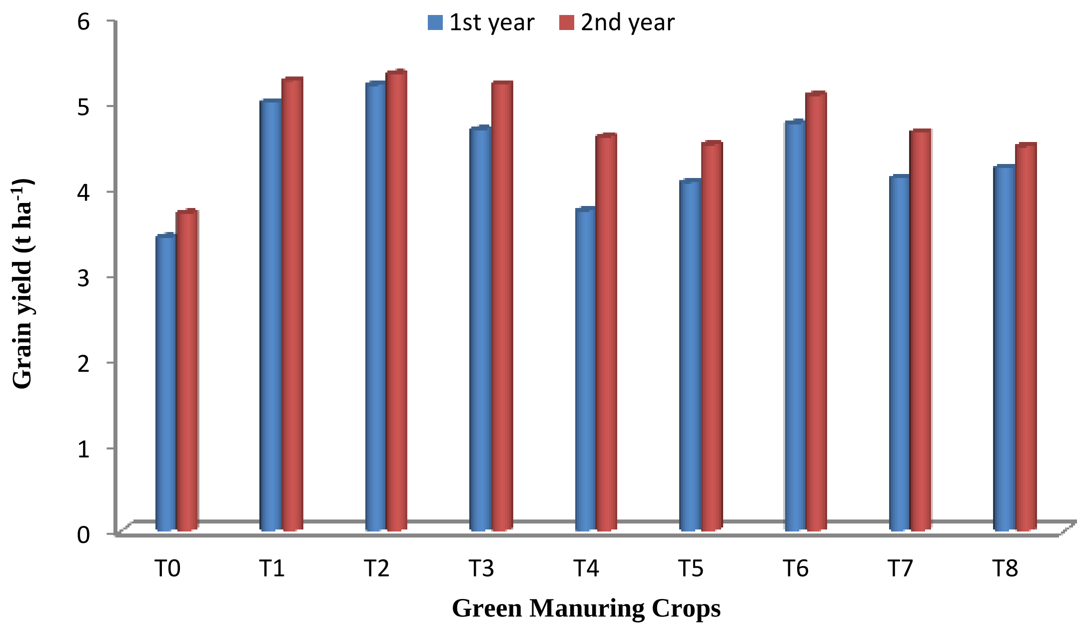
4.2.13 Grain yield

4.2.13.1 Effect of different levels of N and NPK fertilizers

Nitrogen levels did not vary significantly the grain yield (Table 14). The maximum yield of grain (4.40 t ha^{-1} and 4.85 tha^{-1}) was obtained from 50% N ha^{-1} and 100% $NPKha^{-1}$ and the minimum yield of grain (4.30 t ha^{-1} and 4.66 tha^{-1}) was noted in 100% Nha^{-1} and 50% $NPKha^{-1}$ in two consecutive years. This might be due to the efficient and adequate nutrients supply from dhaincha biomass decomposition and released nutrients for the crop. Again, Bandara and Sangakkara (1993) found that the use of the full complement or 50% of the rate of mineral nitrogen with *Sesbania* produced similar yields. This suggests that the application of in situ mulch with *Sesbania* could reduce the mineral N requirement by 50%, produce rice yields similar to that obtained with the full complement of fertilizers. Beri and Meelu (l98l) also have reported that green manure plus 50% of the recommended fertilizer N resulted in higher rice yields than when recommended N rates were applied.

4.2.13.2 Effect of green manuring crops

Incorporation of green manures had significant influences on grain yield (Figure. 31 and Appendix 17). The highest grain yield was obtained with the incorporation of T_2 (*Sesbania rostrata*) (5.02th^{-1} and 5.33 tha $^{-1}$) followed in order by T_1 (*S. aculeata)* (5.00 $th^{-1}$and 5.25 th^{-1}) in 2015 and 2016. The T_6 (*V. unguiculata*) and T_3 (*C. juncea*) also produced higher grain yield of rice in both years. *S. rostrata* increased 52% and 44% grain yield compared to control in 1st year and 2nd year respectively.The increased grain yield may be due to more availability of nitrogen and other nutrients to rice crop released by incorporation of green manure and due to other beneficial effects of green manure.These variations in grain yield, due to incorporation of same dhaincha in two consecutive years, may be due to differences in prevailing weather condition during the growing periods. The lowest amount (3.42 tha^{-1} and 3.70 tha^{-1}) of grain yield was obtained without green manure treated plot in 2015 and 2016 respectively. This result supported by Ehsan *et al.* (2014) who stated that, the rice grain yield increased 32% to 77% over control due to green manure (*dhaincha*) incorporation with different doses of NPK fertilizers application. Pramanik *et al*. (2004) stated that the highest grain yield was found with the incorporation of *S. rostrata* followed by *S. aculeata* and *Crotalaria juncea.* He also stated that *Sesbania spp* showed better performances compared to *Crotalaria juncea* in respect of growth attributes and yield of transplant aman rice. Ashrafuzzaman *et al*. (2009) reported that the varieties which produced higher number of effective tillers $hill^{-1}$ and higher number of grains $panicle^{-1}$ showed higher grain yield ha^{-1}. Rahman *et al.* (2012) reported that the incorporation of green manure *dhaincha* biomass increase rice yield 7 to 39% over control. This might be due to the fact that steady and adequate supply of nutrients by the enhanced biochemical activity of micro-organisms coupled with large photo synthesizing surface would have helped in the production of more tillers and dry matter with enhanced supply of assimilates to sink resulting in higher yield. Kalaiyarasan and Subbalakahshmi (2015) opined that the effect of *dhaincha* incorporation significantly affected agronomic yield in rice crop as compared to the absolute control. Hoyt (1987) stated that when green manure is incorporated and allowed to decompose, plant nutrients become readily available in the soil for the succeeding crop resulting in improved growth and yield of the succeeding crop. Millan *et al*. (1985) opined that basal dose of N had been exhausted within 45-50 days and at that time, panicle initiation stage started. They had needed additional nitrogen for their growth and tiller development.The incorporation of *Sesbania* spp. decomposed and supply extra nutrient to plants which influenced plant growth, yield and yield contributing parameters of rice.



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 31. Effect of green manuring crops on grain yield at two years (SE (±) = 0.223 and 0 .221 at 1st and 2nd year respectively).

4.2.13.3 Interaction effect between fertilizers (N/NPK) levels and green man crops

The combined effect of nitrogen and NPK levels and green manuring crops had a significant influence on grain yield (Table 15). In 2015, some green manures (*S. rostrata, S. aculeata, C. juncea, V. mungo* and *V. unguiculata)* in combination with 100% N dose and rest green manures (*V. radiata, L. leucocephala* and *M. pudica*) with 50% N gave better yield over control. Whereas, in 2016, all green manures showed equal performance in combination with 100% fertilizer dose over 50% fertilizer dose. The highest grain yield (5.23 t ha^{-1} and 5.56 tha^{-1}) was obtained from the treatment combination of the T_2 (*Sesbania rostrata)* followed by T_1 (*Sesbania aculeata*) (5.13 t ha^{-1} and 5.3 tha^{-1}) with 100% N ha^{-1} and 100% NPK fertilizer which was statistically similar to the combination of 50% N and 50% NPK fertilizer in 2015 and 2016 respectively. On the other hand, the lowest one (3.10 t ha^{-1} and 3.43 tha^{-1}) was obtained by the interaction of the control (absent of green manure) and with application of 100% and 50% N ha^{-1}. Similar results were found by Hiremath and Patel (1998) reported that nitrogen fertilizer application could be reduced to 50% of the recommended dose due to green manuring. The highest grain yield was recorded in the plot treated with 75% recommended dose of nitrogen and green manure incorporated at 50 DAS (Islam *et al*., 2014). Dekamedhi and Medhi (2000) reported that grain yield of rice was significantly increased due to application of green manure in combination with fertilizer.

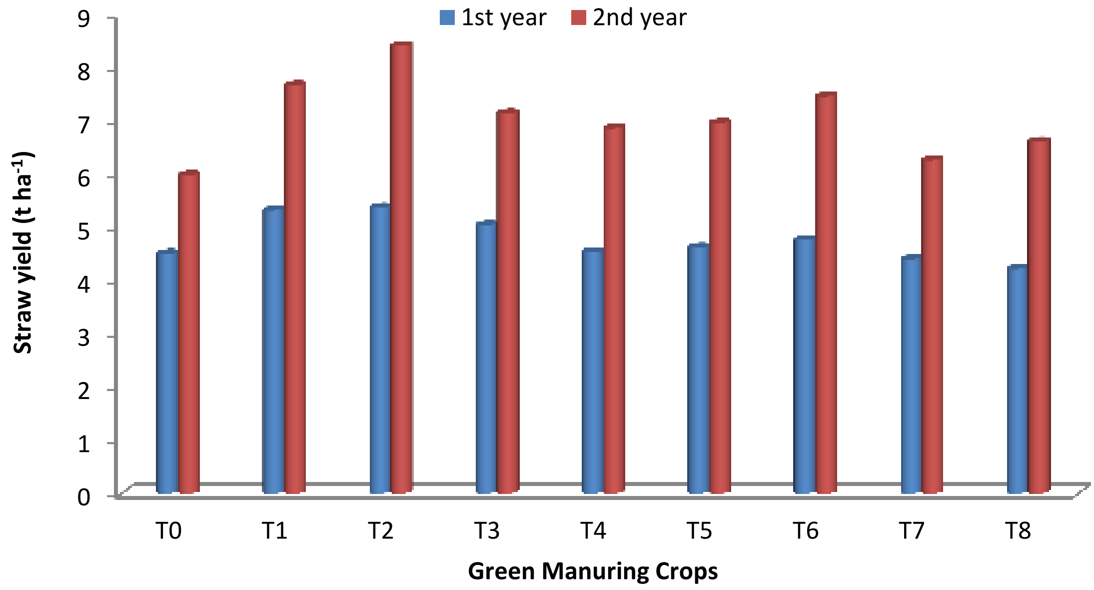
4.2.14 Straw yield

4. 2.14.1 Effect of different levels of N and NPK fertilizers

Straw yield was not significantly influenced by nitrogen levels (Table 14). The maximum straw yield (7.05 t ha^{-1} and 6.17 t ha^{-1}) was produced at 50% NPK ha^{-1} and 100% Nha^{-1} in 2016 and 2015 respectively. The minimum straw yield (5.99 tha^{-1} and 7.00 tha^{-1}) was found in 50% N ha^{-1} in 2015 and 100% NPK ha-^{1} in 2016 respectively. The tallest plant and maximum total tillers may be due to higher straw yield of rice.

4. 2.14. 2 Effect of green manuring crops

Green manure had significant effect on straw yield of aman rice (Figure. 32 and Apendix 17). The highest straw yield were obtained with the incorporation of T_2 (*S. rostrata)* (8.40 tha^{-1} and 5.36 tha^{-1}) in 2016 and 2015 respectively. In both year T_1 (*S.aculeata*) (7.66 tha^{-1} and 5.31 t ha^{-1}) exhibited similar behavior as that of T_2 (*S. rostrata*) in terms of aforesaid parameters. The lowest straw yield was obtained from control (5.97 tha^{-1} and 4.50 tha^{-1} for 2015 and 2016 respctively) where no green manure was applied. Same findings were reported by Pramanik *et al.* (2004). Dekamedhi and Medhi (2000) found that straw yield of rice increased with the addition of green manure and urea. Rahman *et al.* (2012) reported that the slow released nitrogen remains available throughout the growth period of rice. That's why the maximum straw yield of T.Aman obtained from dhaincha green manuring treatments over the control. Similar findings are reported by Bridgit *et al*. (1996). This may be due to the fact that adequate biomass production and better nutrient uptake which might have resulted in higher straw yield in these treatments. This was in accordance with the results obtained by Yadav and Lourduraj (2007).



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 32. Effect of green manuring crops on straw yield at two years (SE (±) =0.327 at 2nd year).

4. 2.14.3 Interaction effect between fertilizer (N, NPK) levels and green manuring crops

The interaction effect between studied nitrogen and NPK levels and green manuring crops had significant effect on straw yield in second year except 1st year (Table 15). The highest straw yield (8.66 t ha^{-1} and 5.70 tha^{-1}) was produced by the interaction of the T_2 *(S. rostrata*) in combination of 50% NPK ha^{-1} in 2016 and 100% N ha-^{1} in 2015 which was statistically similar to the interaction effect between T_1 (*S. aculeata*) with 50% NPK ha^{-1} (7.7 t ha^{-1}) and 100% NPK (5.66 tha^{-1}) in 2016 and 2015 year respectively. The lowest yield of straw (5.67t ha^{-1}) and (4.25 t ha^{-1}) was produced by the interaction of the control and 50% NPK ha^{-1} in 2016 and 100% N ha^{-1} in 2015 respectively. According to Islam *et al.* (2015) 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 fellow with lower nitrogen produced lower straw yield.

Table 15. Interaction effect of fertilizer levels and different green manuriing crops on grain yield, straw yield and 1000-grain weight of transplant aman rice in two years

Interactions	Grain yield (tha^{-1})		Straw yield (tha^{-1})		1000-grain wt. (g)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$F_1 T_0$	3.10f	3.43b	4.25	6.27cd	21.36b	22.08b
$F_1 T_1$	5.13a-c	5.20a	5.66	7.67a-d	23.38ab	23.91a
$F_1 T_2$	5.23a	5.56a	5.70	8.13ab	24.11a	23.94
$F_1 T_3$	4.93a-d	5.30a	4.90	7.30a-d	23.56ab	23.69a
$F_1 T_4$	3.56f	4.73a	4.30	7.10a-d	22.78ab	23.41ab
$F_1 T_5$	4.20a-f	4.73a	4.70	6.93a-d	22.59ab	22.92ab
$F_1 T_6$	4.76a-d	5.13a	4.83	7.06a-d	23.08ab	23.85a
$F_1 T_7$	3.96b-f	4.76a	4.10	6.10cd	23.23ab	23.50ab
F_1T_8	3.80d-f	4.83a	4.01	6.50b-d	23.50ab	23.75a
F_2T_0	3.68d-f	3.97ab	4.76	5.67d	22.86ab	23.07ab
$F_2 T_1$	4.86a-d	5.30a	4.96	7.7b-d	23.07ab	23.53a
$F_2 T_2$	5.16ab	5.11a	5.03	8.66a	23.54ab	23.87a
$F_2 T_3$	4.43a-e	5.13a	5.16	6.96a-d	23.60ab	23.80a
$F_2 T_4$	3.90d-f	4.45ab	4.76	6.60b-d	23.26ab	23.51a
$F_2 T_5$	3.93d-f	4.26ab	4.53	6.96a-d	22.73ab	23.39ab
F_2T_6	4.73a-e	5.03a	4.66	7.83a-c	21.71ab	23.44ab
$F_2 T_7$	4.26a-f	4.53ab	4.70	6.40cd	21.88ab	23.26ab
F_2T_8	4.66a-e	4.13ab	4.43	6.70b-d	23.33ab	23.33ab
(SE (±)	**0.283**	**0.296**	**NS**	**0.427**	**0.663**	**0.340**
CV(%)	**8.87**	**8.06**	**14.91**	**8.06**	**3.63**	**1.96**

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016

Here,T_0=Control,T_1=*S.aculeata*,T_2=*S.rostrata*,T_3=*C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*,T_6=*V.unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*, NS = Not Significant

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

4.2.15 SPAD value

4.2.1.1 Effect of different levels of N and NPK fertilizers

The SPAD value both in first and second year did not varied significantly due to fertilizer levels at all the data recording stages. The numerically maximum (42.30% and 36.61%) SPAD value was recorded from 50% Nha^{-1} and 50% NPK ha^{-1} which was similar (42.20% and 37.62%) to 100% Nha^{-1} and 100% NPK N ha^{-1} in both years (Table 16).

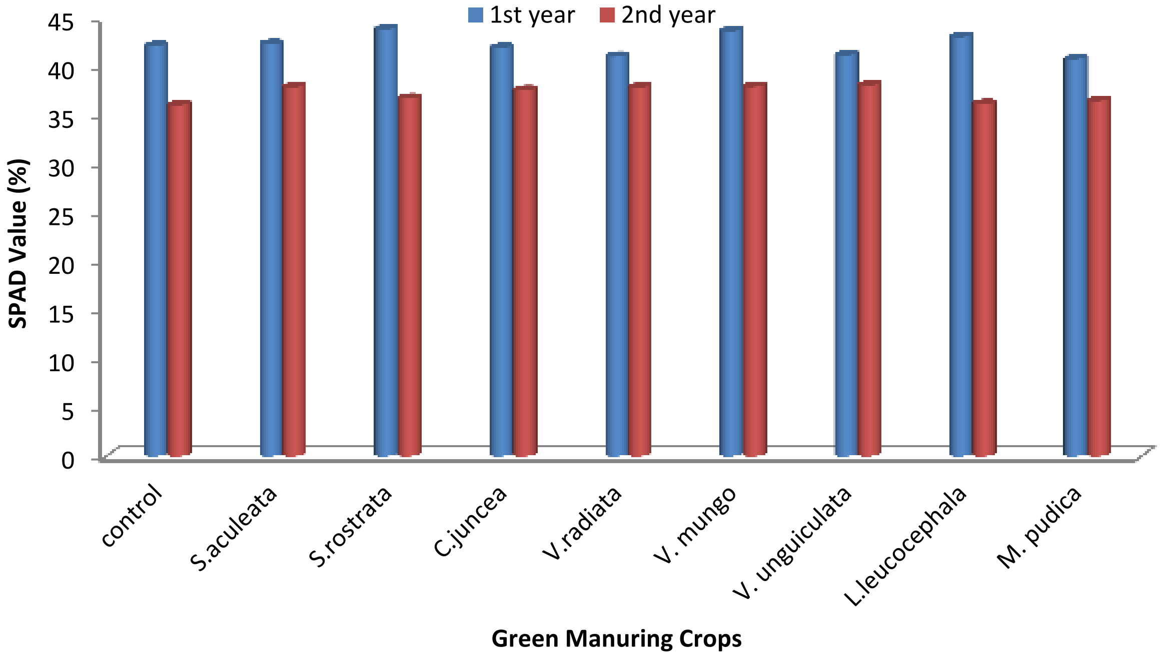
Table 16. Effect of fertilizer levels on the SPAD value and protein content (%) of aman rice

Fertilizer levels	SPAD value (%)		Protein content (%)
	1st year	2nd year	2nd year
F_1	42.20	37.62	8.15
F_2	42.30	36.61	8.11
SE (±)	NS	NS	NS
CV(%)	6.37	5.64	1.99

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NP in 2016. NS= Not Significant

4.2.15. 2 Effect of green manuring crops

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 has been well recognized as a mean of determining the one set of senescence process in a leaf (Rajcan *et al*., 1999). The sharp decrease of SPAD value indicates the senescence of leaf. In the present experiment, there was no significantly difference observed among green manure crops. The SPAD value was recorded from the upper two fully expanded leaves of the main tiller and the average value was recorded. The SPAD value recorded was highest at T_2 (*S. rostrata*) (43.77) followed by T_5 (*V. mungo*) (43.57) whereas in second experiment, the highest SPAD value was recorded from T_6 (*V. unguiculata*) (38.07) followed by *V. mungo* (37.83) . The lowest value was recorded from T_8 (*M. pudica*) (40.72) in 1st year and from *L. leucocephala* in 2nd year but there were no statistical difference observed between them (Figure. 33).



Here, T_{0} = Control, T_1=*S. aculeata*, T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 33. SPAD value of T. aman rice under different green manuring treated Plots.

4.2.15.3 Interaction effect of fertilizers N/NPK levels and green manuring crops

There was no significant difference found due to interaction effect between N and NPK levels and green manures in respect of SPAD value at data recording stages. Among the interactions, the treatment of T_2 (*S. rostrata*) registered the higher SPAD value (44.47) in 50% N ha^{-1} followed by T_1 (*42.28*) at 100% Nha^{-1} while lower value was found from T_4 (*V. radiata*) (39.37) with 100% Nha^{-1}. But in second experiment, minimum value was found from *L. leucocephala* with 100% NPK ha^{-1} and maximum found from T_1 (*S. aculeata*) with 100% NPK ha^{-1} (Table 17).

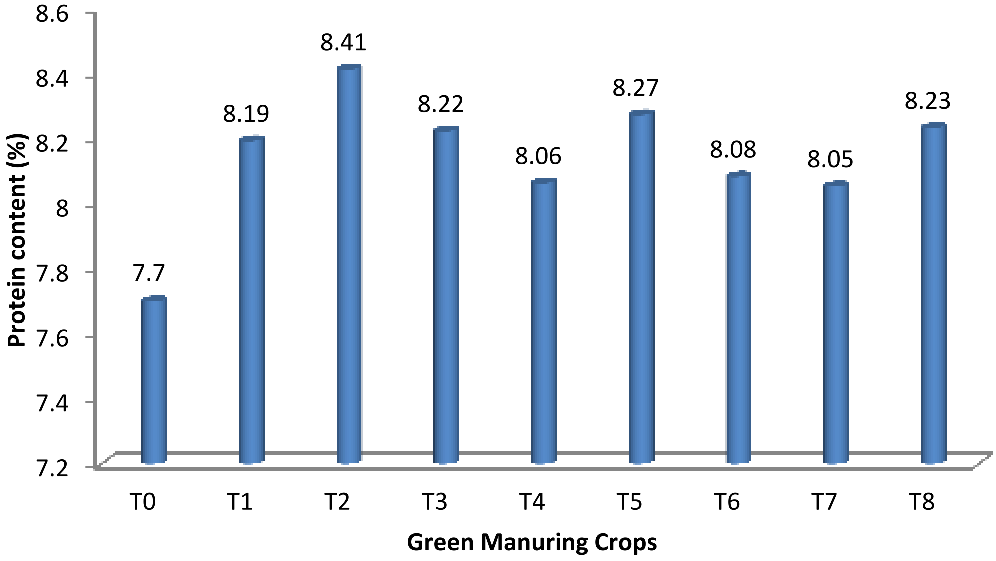
4. 2.16 Grain protein content

4. 2.15.1 Effect of different levels of N and NPK fertilizers

Nitrogen had no significant effect on grain protein content. The 8.15% grain protein was obtained from 100% $NPKha^{-1}$ which was statistically similar (8.11%) with 50% $NPKha^{-1}$ in 2016 (Table 16).

4.2.16.2 Effect of green manuring crops

The variation in grain protein content was significant in 2^{nd} year which ranged from 7.70% to 8.41% (Figure. 34 and Appendix 17). In 2^{nd} year, the highest grain protein content was recorded in T_2 (*S. rostrata)* (8.41%) followed by T_5 (*V. mungo*) and (8.23%). The lowest result was found in seasonal fallow (no green manures) i.e., control plot (7.70%). 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. Singh *et al*. (1996) opined that N contributed through green manuring might be the reason for increased nitrogen uptake by grain and straw in rice. Pramanik (2006) also reported that higher nitrogen uptake by grain and straw was found with the incorporation of all green manure crops compared to fallow. Pareek *et al.* (1990) reported that well nodulated *Sesbania* plants may derive up to 90% N from fixation and therefore contribute N to rice. That means the increase in N content was directly related to biological nitrogen fixation and organic matter addition to the soil.



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*, T_4=*V. radiata*, T_5=*V. mungo*, T_6=*V. unguiculata*, T_7=*L. leucocephala*, T_8=*M. pudica*

Figure. 34. Grain protein content (%) of T. aman rice under different green manuring crops (2nd year) (SE (±) = 0.0420).

4. 2.16.3 Interaction effect between fertilizer (N, NPK) levels and green manuring crops

There were significant effect on the interaction of nitrogen and NPK doses and green manuring crops on grain protein content (Table 17). The highest grain protein (8.54%) was in *S. rostrata* with 50% NPKha^{-1} followed by *C. juncea* (8.22%) however the value was statistically similar with other crops when subjected to different NPK levels. The lowest one was recorded in control (7.54%) plot with 50% NPKha^{-1}.

Table 17. Interaction effect of fertilizer levels and green manuring crops on the SPAD value and protein content (%) of T. aman rice

Interactions	SPAD value (%)		Protein content (%)
	1st year	2nd year	2nd year
$F_1 T_0$	43.83	36.71	7.85cd
$F_1 T_1$	42.28	39.05	8.17a
$F_1 T_2$	43.07	36.76	8.28a
$F_1 T_3$	40.35	38.70	8.23a
$F_1 T_4$	39.37	38.93	8.04a
$F_1 T_5$	44.40	38.43	8.40ab
$F_1 T_6$	42.58	38.36	8.10a-c
$F_1 T_7$	42.94	36.10	8.09a-c
F_1T_8	40.93	36.53	8.26a-c
F_2T_0	40.28	37.65	7.54d
$F_2 T_1$	42.21	36.60	8.21a-c
$F_2 T_2$	44.47	36.60	8.54a
$F_2 T_3$	43.40	36.33	8.22a-c
$F_2 T_4$	42.57	36.66	8.04a-d
$F_2 T_5$	42.74	37.33	8.15a-c
F_2T_6	41.64	37.66	8.06a-d
$F_2 T_7$	43.00	36.33	8.01b-d
F_2T_8	40.52	36.33	8.20a-c
SE (±)	NS	NS	0.056
CV(%)	6.37	5.64	1.99

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016. NS = Not Significant

T_0=Control,T_1=*S.aculeata*,T_2=*S.rostrata*,T_3=*C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*,T_6=*V.unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

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

4.2.17 Relationship between effective tillers and grain yield of transplant aman rice at two years

In the experiment, the relationship between effective tillers and grain yield was estimated and it was found significantly and positively correlated (r = 0.947 and r = 0.833 for effective tiller at 2015 and 2016 respectively) (Figure. 35 and Figure. 36). This means an increase in effective tillers will result in corresponding increase in grain yield of this variety of rice.

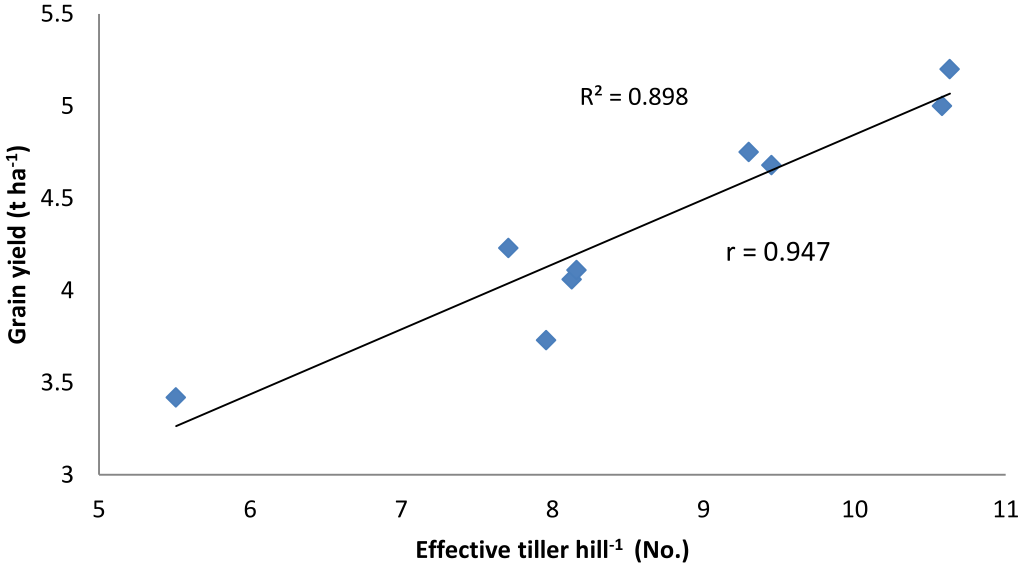


Figure. 35. Relationship between effective tiller and grain yield of transplant aman rice at 1st year (2015)

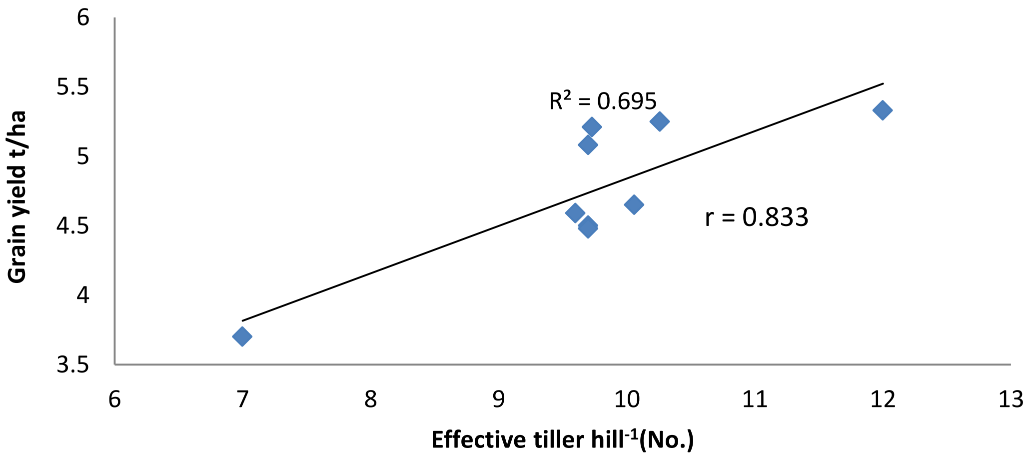


Figure. 36. Relationship between effective tiller and grain yield of transplant aman rice at 2nd year (2016).

4.2.18 Relationship between total dry matter (shoot and root) and grain yield of transplant aman rice at two years

Total dry matter (shoot weight and root weight) are important characteristics responsible for higher grain yield. Relationships of total dry matter of shoot weight and root weight with grain yield was found significantly and positively correlated **(** r = 0.894 and r = 0.586 for shoot weight and root weight at 60DAT respectively) (Figure. 37 and Figure. 38). This means an increase in total dry matter will result in corresponding increase in grain yield of this variety of rice.Dry matter weight gradually increased the yield of rice.When the dry matter content remain higher the translocation of assimilates towards grain remains higher.

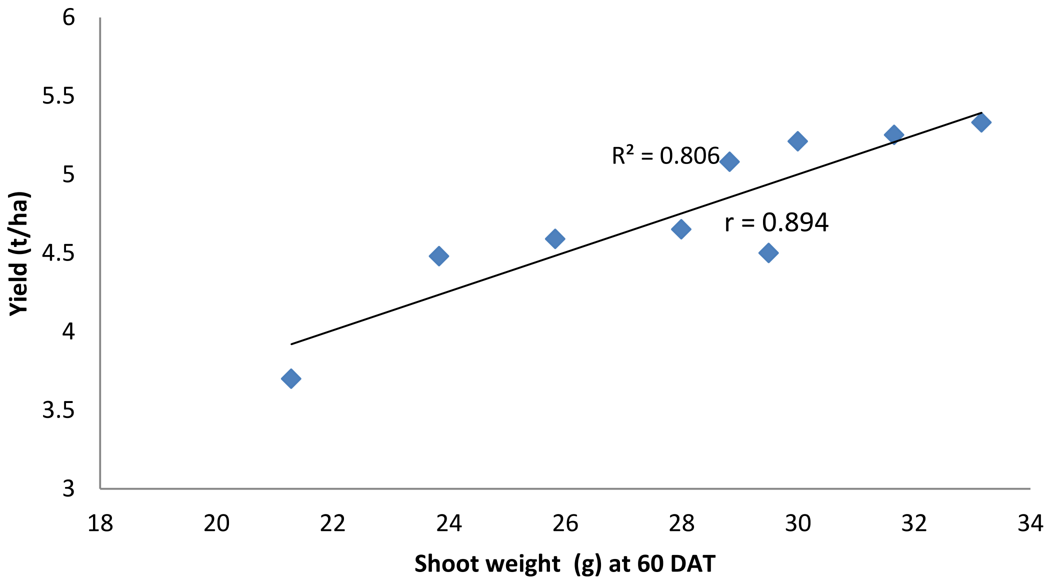


Figure. 37. Relationship between shoot weight and grain yield of transplant aman rice at 60 DAT in 2016.

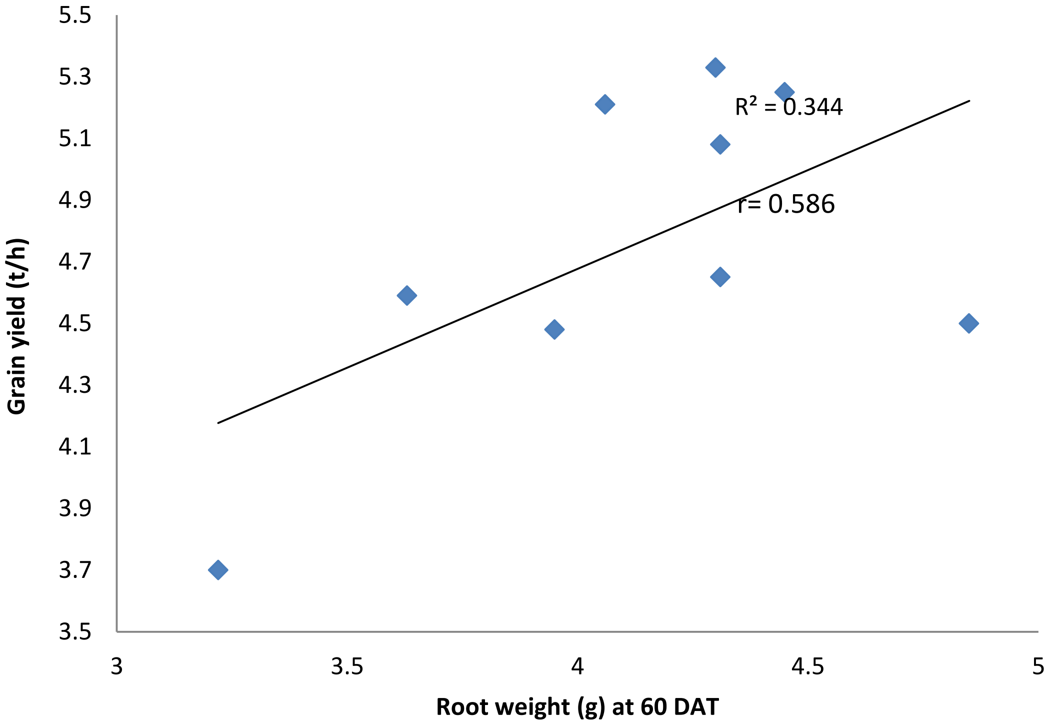


Figure. 38. Relationship between root weight and grain yield of transplant aman rice at 60 DAT in 2016.

4.2.19 Changes of soil properties after harvesting of T. Aman rice

4.2.19.1 Soil pH

After harvest of rice, the soil analysis results revealed that little increased (6.4 and 7.1 in 1st and 2nd year) of soil P^H compared to initial soil (5.9) in both year (Table 18) where higher soil pH was found from *S. rostrata* (6.4) that similar to *V. mungo* (6.4) in combination with 50% Nha^{-1} in first year. Eventually in second year, the soil pH was found highest from *S. rostrata* (7.1) followed by *S. aculeata* (6.7) in combination with 100% $NPKha^{-1}$. Yamane (1978), Ponnamperuma (1978) and Safiqual *et al*. (2015) reported the same findings that, numerically increasing trend in soil p^H was found with higher levels of nitrogen with green maanuring crops. Chanda and Sarwar (2017) agreed with that results and stated that soil pH value ranges from 6.05 to 6.63 (initial) and 5.93 to 6.63 (post-harvest). He also reported that the pH value changes could be due to the incorporation of dhaincha crop in soil. Nierves and Salas (2015) explained that the decomposed organic matter producing humic acid, nitric acid and sulfuric acid those increase the H^+ ion in the soil. Rainfall which causes leaching that tends to wash away the basic cations *viz*., K^+, Mg^+ and Ca^+ those are replaced by acidic cations like H^+ making soil acidic. However, microbial activity and root respiration release CO2, which is slightly acidic as a result enhance the acidity of the soil.

4.2.19.2 Soil organic matter

The organic matter status of soils in the treatments comprises control, *V. radiata* (50% N). *V. mungo* (50% N), *V. unguiculata* (100% NPK), *L. leucocephala* (both doses) and *M. pudica* (both doses) treated plot showed a decreasing trend in 1st year compared to that of initial soil (1.01%) while *Sesbania rostrata* (1.02% and 1.14%) , *S. aculeata* (1.21% and 1.41%) and *C. juncea* (1.02% and 1.14%) showed increased trend in both fertilizer doses (Table 18). Average soil organic matter was 19% and 73% increased from *S. aculeata* and *Vigna mungo* with combination of 100% Nha^{-1} in 1st year compared to control (1.01%). But in 2nd year, the organic matter increased from *S. aculeata* (1.97% and 1.72%) and *S. rostrata* (2.01% and 1.77%) followed by rest of green manuring crops with combination of 100% and 50% $NPKha^{-1}$ in comparison to control. 63% and 60% soil organic matter increased through *S. rostrata* and *S. aculeata* in compared to control in 2nd year. Ali *et al*. (2012) and Mehalatha *et al*. (2000) agreed with the findings and stated that, the higher contents of organic matter 0.79%, N 0.65%, available P (8.2 ppm) and available K (198 ppm) were found in case of *Sesbania* was incorporated into the soil as green manuring crop which indicated that *Sesbania* is much more beneficial to soil health than any other legume crop. Results were also in conformity with those of Sharma *et al*. (2001) and Karim (1998). Chanda and Sarwar (2017) stated that the soil OM varied from 2.30% to 2.95% at initial stage and 2.71% to 2.98% at postharvest stage. Sarwar *et al*. (2017) stated that organic matter status increased may be incorporation of dhaincha in soil and succeeding crop rice intake nutrients from it. The increase of OM content in soil could also be attributed root growth and crop debris addition after crop harvest. However, OM decreased in control plot (no green manure use) due to rice crop intake nutrient from soil and soil may become exhausted. Quayyum (1994) and Rahman *et al*. (2012) reported that organic matter content of the soil increased in Legume-T. aman rice and maize-dhaincha-rice cropping sequence but decreased in Aus rice-T. aman rice sequence.

4.2.19.3 Total Soil nitrogen

Total soil nitrogen was increased from 0.04 (initial) to 0.09% at 1st year and 0.11% at 2nd year (Table 18). The higher soil nitrogen was found from *Vigna mungo* (0.09%) followed by S. *rostrata* (0.08%) in combination with 100% Nha^{-1} applied in 1st year. But in 2nd year, the soil nitrogen showed little bit increased compared to first year and highest was found from the following trend $T_2>T_3>T_7>T_8>T_1>T_5$. 100% and 120% total soil nitrogen was increased from *S. rostrata* comparision to control at 2015 and 2016 respectively.The increase in total N content of soil due to application of organic manure may be attributed to the mineralization of N by organic manure in 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%). Nitrogen mineralization from the green manure take place 5 days after its incorporation with a peak around 20 days, afterwards it declined to a minimum level at 45 days (Morris *et al*.,1985). Bhardwaj and Dev (1985) reported a slightly build up of N in soil following rice harvest in a Rice-Wheat cropping system. It was also reported that continued use of green manure would likely to have a measurable effect because of accumulation of modest amounts of organic N (Faassen and Smilde, 1985). Sharma and Gosh (2000) reported that the *Sesbania* green manuring and mungbean residue incorporation interacted positively with inorganic fertilizers in building up soil total N. Chanda *et al.* (2017) reported that the total N status ranged from 0.13 to 0.17 at the initial soil and 0.16 to 0.17 at the post-harvest soil. The increase in total N content of soil may be the effect of incorporation of dhaincha in soil. Islam (2006) reported that nitrogen content increased in dhaincha incorporated plot, but static in unincorporated plot.

4.2.19.4 Soil potassium

After harvest of rice, little decreased trend of soil K were found from both the year from initial soil (0.18 meq100g^{-1}) and the ranged varied from 0.07 to 0.11 meq 100g^{-1} in both year (Table 19). The higher uptake of K than its addition indicates K mining from soils. Similar results was found by Rahman *et al*. (2013) who stated that, exchangeable K level varied from 0.060 to 0.070 me 100 g^{-1} (initial level 0.082 me 100 g^{-1}). K mining from soil also reported by Zaman (2002). Sahu and Nayak (1971) observed a slight decline of K after green manuring.

4.2.19.5 Soil phosphorous

After harvesting of rice, soil phosphorous was found decreased than the initial level (15.83 ppm) in first year. But in second year, drastically increasing trend (T_2>T_1>T_3>T_5>T_4>T_8>T_6) was observed among all green manures with two doses of fertilizer. 66% and 46% increased total soil P was found from *S. rostrata* and *S.aculeata* compared to control in 2nd year. *C. juncea* occupied third position in P accumulation (Table 19). The increase in available P content of soil may be due to greater mobilization of native soil P by vigorous root proliferation and contribution through biomass. Results were in conformity with those of Raju and Reddy (2000) and Mehalatha *et al*. (2000). They observed that green manuring significantly improved the fertility status of soil and it was pronounced by the Dhaincha incorporation by increasing available P at post harvest soil. Green manure increases availability of P through the mechanisms of reduction, chelation, and favorable changes in soil pH (Hundal *et al*., 1987). The form and availability of phosphorus in soil is highly depending on soil pH (McKenzie, 2003). In pH values less than 6 create a chemical bond between aluminum (Al) and phosphate; on the other hand, in higher values of soil pH (6-8), adsorption of phosphate ions occur on solid Al or Fe hydroxide (Georgantas and Grigoropoulou, 2006). The P value decrease may be due to the low pH and P fixation in soil. Nierves and Salas (2015) reported that cycling of organic matter is slower due to acidic soil (low soil pH) and the amount of major elements, viz. N, P and S, is reduced. Moreover, decomposed organic matter releases organic molecules, which form complex compound with Fe and Al ions and those are also responsible for P fixation (Ghosal *et al.*, 2011). Rahman *et al.* (2012) also obtained similar result in maize-dhaincha- T. aman cropping system in Bangladesh condition.

Table 18. Changes in post-harvest soil nutrient status (p^H, OM and total N) as affected by green manures and nitrogen levels

Treatments	N levels (kgha-[1])	Soil pH		Soil organic matter (%)		Total N(%)	
		2015	2016	2015	2016	2015	2016
Control	F_1	6.0	6.0	1.01	1.23	0.04	0.05
	F_2	6.2	5.9	0.54	1.31	0.05	0.07
S. aculeata	F_1	6.2	6.7	1.21	1.97	0.06	0.09
	F_2	6.1	6.3	1.41	1.72	0.05	0.10
S. rostrata	F_1	6.1	7.1	1.02	2.01	0.08	0.11
	F_2	6.4	6.4	1.14	1.77	0.07	0.10
C. juncea	F_1	6.2	6.2	1.14	1.80	0.06	0.11
	F_2	6.2	5.8	1.03	1.77	0.08	0.10
V. radiata	F_1	6.2	6.2	1.08	1.80	0.05	0.10
	F_2	6.2	5.9	0.81	1.72	0.05	0.10
V. mungo	F_1	6.1	6.6	1.75	1.56	0.09	0.09
	F_2	6.4	6.4	0.87	1.72	0.05	0.10
V. unguiculata	F_1	6.1	6.2	0.87	1.72	0.05	0.10
	F_2	6.2	6.3	1.21	1.56	0.04	0.09
L. leucocephala	F_1	6.0	6.5	0.94	1.76	0.05	0.11
	F_2	6.0	6	0.94	1.77	0.05	0.10
M .pudica	F_1	6.3	6.7	0.94	1.23	0.05	0.11
	F_2	6.1	6.0	0.87	1.51	0.06	0.08

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016

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

Table 19. Changes in post-harvest soil nutrient status (K and P) as affected by green manures and nitrogen levels

Treatments	N levels (kg/ha)	Soil K (meq 100g^{-1})		Available P (ppm)	
		2015	2016	2015	2016
Control	F_1	0.09	0.10	3.00	23.40
	F_2	0.09	0.09	3.06	21.86
S. aculeata	F_1	0.10	0.079	4.33	31.20
	F_2	0.10	0.10	3.67	33.17
S. rostrata	F_1	0.11	0.16	4.71	39.00
	F_2	0.09	0.10	3.92	33.00
C. juncea	F_1	0.10	0.10	4.59	28.00
	F_2	0.10	0.10	3.91	31.51
V. radiata	F_1	0.10	0.11	4.14	27.97
	F_2	0.09	0.10	3.27	27.04
V. mungo	F_1	0.10	0.06	3.89	30.77
	F_2	0.10	0.10	3.06	27.70
V. unguiculata	F_1	0.10	0.07	3.91	26.00
	F_2	0.09	0.09	3.27	23.00
L.leucocephala	F_1	0.10	0.09	4.22	24.00
	F_2	0.11	0.10	3.44	22.44
M. pudica	F_1	0.10	0.10	4.11	27.38
	F_2	0.12	0.08	3.72	22.00

Here, F_1= Recommended dose for N in 2015 and NPK in 2016, F_2= Half of recommended dose for N in 2015 and NPK in 2016

4.3 Expeiment 3 and 6: Effect of previous land condition on the performance of Mustard

In the present experiment, different yield and yield components of mustard (BARI Sarisha-14 and BARI Sarisha-15) varieties were studied to find out the effect of green manures biomass and fertilizer on the yield contributing character of (as a following crop) mustard. This experiment was described under two sub headings.

4.3.1 Plant height

4.3.1. 1 Effect of different levels of N and NPK fertilizers

Application of different levels of fertilizers on rice did not have any significant affect on subsequent mustard crop numerically (Table 20). The taller plant of 90.65 cm in 1st year by 50% recommended fertilizer and 72.30 cm in 2nd year by 100% recommended N was produced but it was not statistically similar. Asaduzzaman and Shamsuddin (1986) have reported that different levels of fertilizer doses significantly effect on plant height.

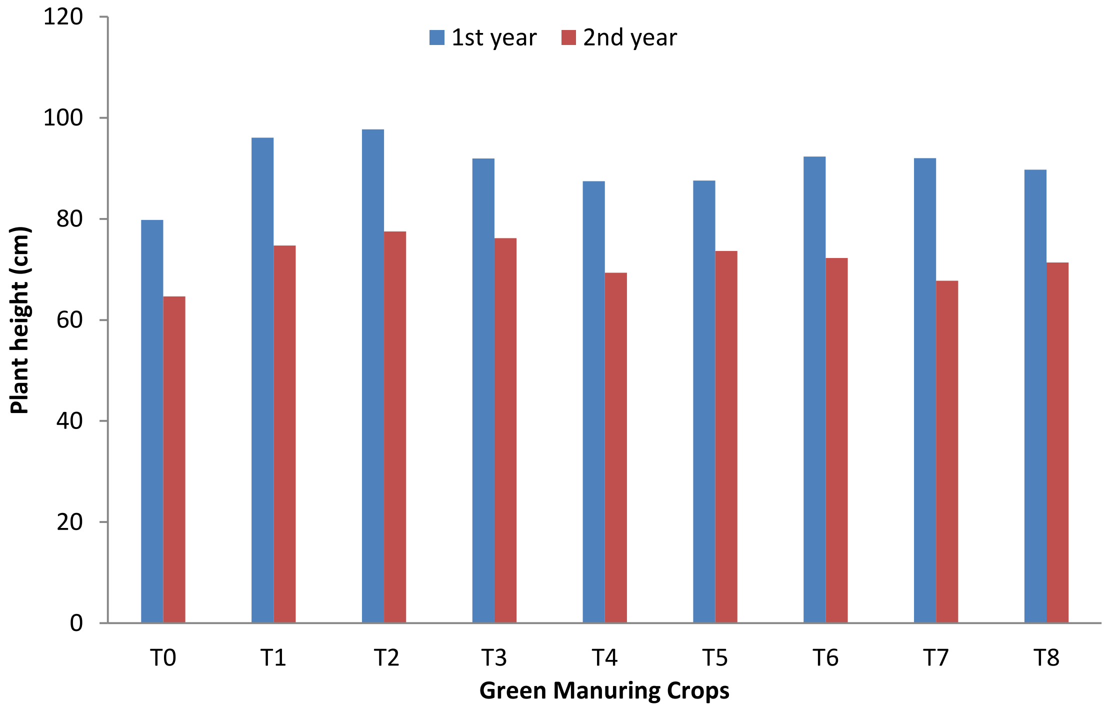
Table 20. Effect of fertilizer levels on physiological characteristics of mustard

Fertilizer levels	Plant height (cm)		Siliquae plant^{-1}(No.)		Siliquae length (cm)	
	1st year	1st year	1st year	2nd year	1st year	2nd year
F_1	90.35	72.30	27.58	35.26	4.75	4.87
F_2	90.65	71.58	25.77	35.35	4.63	4.81
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV(%)	**7.72**	**7.53**	**13.42**	**31.16**	**5.85**	**7.17**

F_1= 100% recommended fertilizer, F_2= 50% recommended fertilizer. NS = Not Significant

4.3.1.2 Effect of green manuring crops

Plant height was significantly affected by residual plant biomass in both years. The taller plant height (97.70 cm and 77.50 cm in 1st year and 2nd year) was produced by the treatment of T_2 (*S. rostrata*) and the shortest plant height (79.76 cm and 64.68 cm in 1st year and 2nd year) was obtained from T_0 (control) (Figure. 39 and Appendix 18). It was observed that plant height increased gradually with the increment of nutrient availability from previous crop. This may be due to higher availability and uptake of nutrients that progressively enhanced the vegetative growth of the plant. Rich nutrient content (NPK) of the plots with *S. rostrata* might have positive effect on plant height. Singh *et al.* (1998) studied direct and residual effect of nutrient management practices of mustard. They reported that use of plant biomass which contained higher amount of NPK gave significantly highest plant height.



Here, T_0 = Control, T_1=*S. aculeata*,T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 39. Effect of green manuring crops on plant height of mustard at two consecutive years (SE (±) =3.12 and 4.03 at 1st year and 2nd year respectively).

4.3.1.3 Interaction effect of previous fertilizers and green manuring crops

The plant height was not significantly affected due to the interaction of fertilizer dose and green manuring crops in both years (Table 21). The 100% and 50% recommended fertilizer dose in rice plant with different green manuring crops produced similar plant height to those of other interactions.Hence it was observed from the result that 100% and 50% recommended fertilizers applied in rice plants with different green manures showed similar plant height in subsequent mustard crop. This might be the residual effect of previous crops.

4.3.2 Number of siliquae plant^{-1}

4.3.2.1 Effect of different levels of N and NPK fertilizers

Fertilizer dose did not significantly influence the number of siliquae plant^{-1} (Table 20). The maximum number of siliquae plant^{-1} (35.35 and 27.58) was produced by 100% recommended fertilizer dose in 2nd year and by100% N fertilizer dose in 1st year. Grewal and Kolar (1990) recorded maximum number of siliquae plant^{-1} when N was applied at 100% recommended fertilizer dose which promoted higher seed yield of *B. juncea*. These results indicated that higher dose of fertilizer up to a certain level favored for higher number of siliquae formation.

4.3.2.2 Effect of green manuring crops

Plant biomass had significant effect on number of silquae plant^{-1} in both the year (Fig 40 and Appendix 18). The highest number of siliquae plant^{-1} (33.83) was found from *Sesbania rostrata* plots that similar with *Crotalaria juncea* (32.16) plot in 2015 but in 2016, *V. unguiculata* (43.84) along with *C. juncea* (40.91) exhibited similar number of siliquae plant^{-1} except control plots that showed the lowest number of siliquae plant^{-1} (15.98). Number of siliquae plant^{-1} is a genetically control trait but it can be changed by using different green manures through which mustard soil performed better with increased in organic matter and available nitrogen .

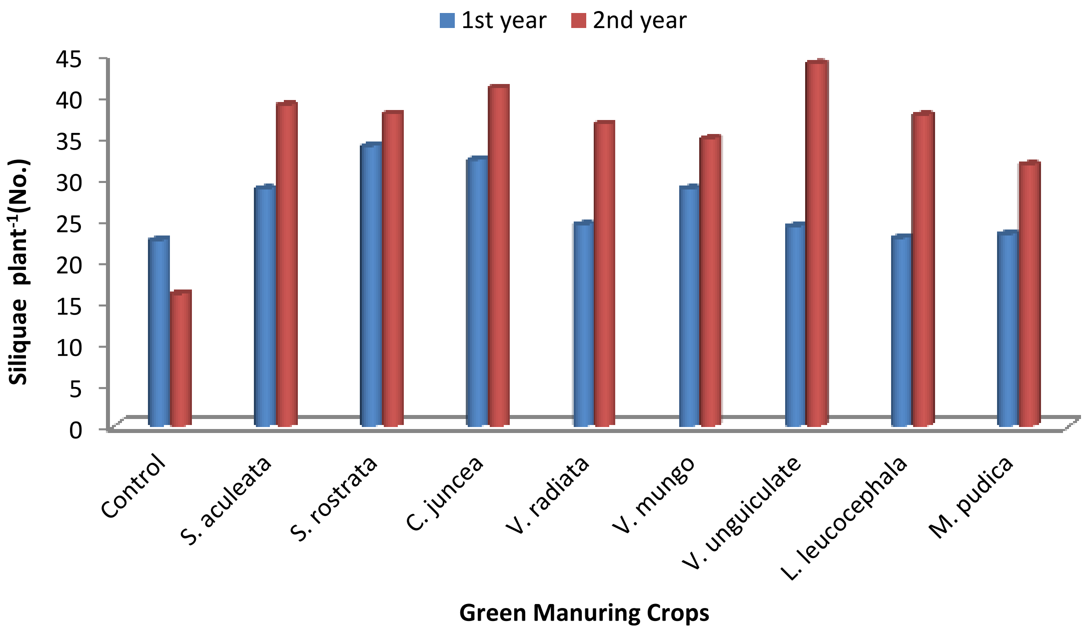


Figure. 40. Effect of green manuring crops on siliqua plant $^{-1}$ of mustard at two consecutive years (SE (±) = 2.06 and 6.35 at 1st year and 2nd year respectively).

4.3.2.3 Interaction effect of previous fertilizers and green manuring crops

There was significant difference observed in the 2nd year instead of 1st year, F_1 T_2 (100% recommended fertilizers with *Sesbania rostrata*) showed the highest number of siliquae plant^{-1} (37.00) that similar to F_1T_1, F_2T_1, F_2T_2, F_1 T_3, F_2 T_3, F_1 T_5, F_2 T_5 and F_1 T_6 interactions in 2nd year (Table 21). The interaction of F_2 T_6 (50% recommended fertilizer with *Vigna unguiculata*) plots showed the lowest number of siliquae plant^{-1} that similar with F_2 T_0 plots.

Table 21. Interaction effect of previous fertilizer levels and green manuring crops on phenological characteristics of mustard

Interactions	Plant height (cm)		Siliquae plant^{-1} (No.)		Siliqua length (cm)	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$F_1 T_0$	80.82	62.85	23.75bc	16.01	3.74cd	4.26ab
$F_1 T_1$	100.9	73.20	29.66a-c	45.31	4.93a	4.01ab
$F_1 T_2$	95.77	77.33	37.00a	41.86	4.63ab	5.14a
$F_1 T_3$	88.67	76.20	32.00a-c	37.10	5.26ab	5.03ab
$F_1 T_4$	88.60	70.77	24.66bc	32.20	4.63ab	4.93ab
$F_1 T_5$	89.63	71.20	27.33a-c	34.56	4.66ab	4.81ab
$F_1 T_6$	92.67	77.54	27.22a-c	44.53	5.43ab	4.98ab
$F_1 T_7$	89.00	68.44	22.33bc	33.03	4.80ab	4.72ab
F_1T_8	87.10	73.10	24.33bc	32.73	4.66ab	5.04ab
F_2T_0	78.44	66.52	21.16bc	15.94	2.96d	3.85b
$F_2 T_1$	91.10	76.22	27.66a-c	32.33	4.70ab	5.33a
$F_2 T_2$	99.63	77.66	30.66a-c	33.63	4.80ab	5.08ab
$F_2 T_3$	95.27	76.20	32.33ab	44.73	5.00ab	5.03ab
$F_2 T_4$	86.33	67.88	24.00bc	40.93	4.43bc	4.66ab
$F_2 T_5$	85.53	76.10	30.00a-c	34.90	4.63a-c	4.67ab
F_2T_6	92.00	66.86	21.00c	43.15	5.23ab	4.87ab
$F_2 T_7$	95.17	67.11	23.10bc	42.20	4.90ab	4.97ab
F_2T_8	92.40	69.64	22.00bc	30.40	5.03ab	4.79ab
(SE (±)	**NS**	**NS**	**2.66**	**NS**	**0.206**	**0.265**
CV(%)	**7.72**	**7.53**	**13.42**	**31.16**	**5.85**	**7.17**

Here, T_0 = Control, T_1=*S . aculeata*,T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica.* NS = Not Significant
In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly.

4.3.3 Siliqua length

4.3.3.1 Effect of different levels of N and NPK fertilizers

There was no significant variations of siliquae number plant^{-1} observed due to the different interactions through application of 100% recommended fertilizer dose in previous rice crop that produced the maximum number of siliquae (4.75 and 4.87) in 2015 and 2016, respectively followed by 50% of recommended fertilizer dose (Table 20). Similarly that number of siliquae might be due to the residual effect of different fertilizers dose in different green manuring crops.

4.3.3.2 Effect of green manuring crops

It was observed that incorporation of different green manuring crops in previous rice crop significantly affect the siliquae length for both years. In first year, longest siliqua (5.33 cm) was found from T_6 (*Vigna unguiculata*) that similar with T_3 (5.16 cm), T_7 (4.85 cm*)*, T_8 *(*4.85) and T_1 (4.81). The lowest siliquae length was found from control plots. In 2016, all the green manuring incorporated plots statistically superior and similar length of siliquae compared to that of no green manuring incorporated plots (Figure. 41 and Appendix 18).

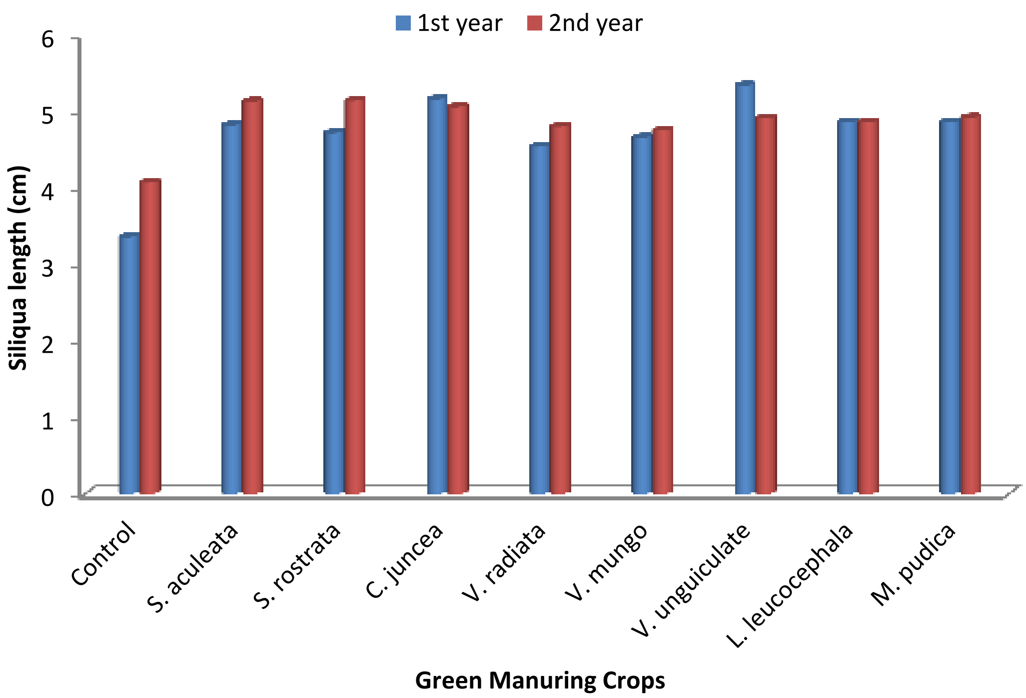


Figure. 41. Effect of green manuring crops on siliqua length of mustard at two consecutive years (SE (±) = 0.158 and 0.200 at 1st year and 2nd year respectively).

4.3.3.3 Interaction of fertilizer and green manuring crops

There was significant variation of siliqua length observed for different interactions in both the years where all the green manuring incorporated plots irrespective of their fertilizer dose showed the higher length of siliquae except control (3.85 cm) that exhibited lowest siliqua length (Table 21).

4.3.4 Seeds siliqua^{-1}

4.3.4.1 Effect of different levels of N and NPK fertilizers

Different doses fertilizer did not significantly influenced the number of seeds per siliqua (Table 22). It was observed that numerically the number of seeds siliqua^{-1} increased with the increasing rates of fertilizer in 2015 but the trend was reverse in 2016 where 50% or recommended fertilizer showed higher number of seeds siliquae^{-1}. The maximum number of seeds siliqua^{-1} (29.68 and 22.12) was obtained with the application of 100% and 50% of recommended fertilizer dose in first and second year, respectively.

Table 22. Effect of fertilizers level on number of seeds silliqua^{-1}, 1000 seed wt, seed yield and stover yield of mustard

Fertilizer levels	Seeds siliquae^{-1}(No.)		1000 seed wt. (g)		Stover yield (kg ha^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
F_1	29.68	21.74	2.51	2.35	2199	2566
F_2	29.37	22.12	2.46	2.32	2216	2532
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
$CV_{(\%)}$	**6.7**	**8.61**	**16.95**	**4.05**	**7.89**	**33.14**

F_1= 100% Recommended dose, F_2= 50% of recommended dose. NS = Not Significant

4.3.4.2 Effect of green manuring crops

Different treatments significantly influenced seeds siliquae^{-1} in both the year. The number of seeds siliqua^{-1} produced by the treatments T_6 (*V. unguiculata*) was significantly higher followed by T_1 (*Sesbania aculeata*) and the lower from T_0 (control) plots in first year (Figure. 42), whereas in second year, *S. rostrata* gave the highest result that similar to all other green manurings treated plots and the lowest number of seed siliquae^{-1} (19.62) was found in T_0 (control) plots.

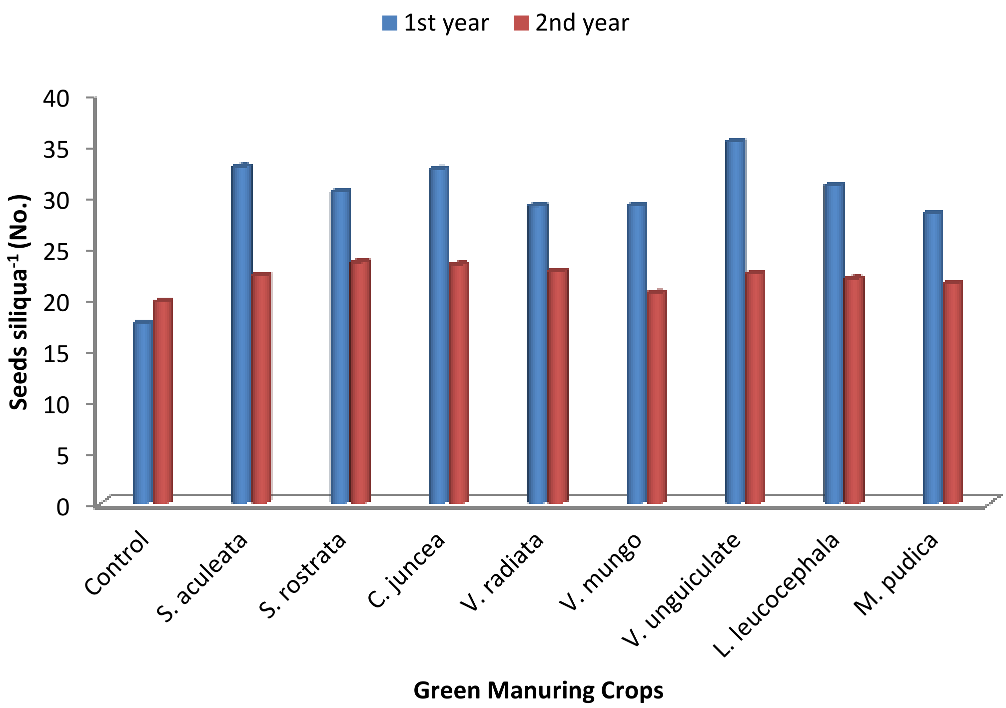


Figure. 42. Effect of green manuring crops on seeds siliqua^{-1} of mustard at two Consecutive years (SE (±) = 2.01 and 1.09 at 1st year and 2nd year respectively).

4.3.4.3 Interaction effect of fertilizer dose and green manuring crops

Interaction of fertilizer dose and green manuring crops was significant in respect of number of seeds siliqua^{-1} in first year (2015). The highest number of seeds siliqua^{-1} was obtained in all green manuring treated plots irrespective of fertilizer dose except *V. mungo* and control plots having 50% recommended doses of fertilizer but the lowest number of seeds siliqua^{-1} (15.51) was showed in control plots with 50% recommended fertilizer dose (Table 23).

4.3.5 Weight of 1000- seed

4.3.5.1 Effect of different levels of N and NPK fertilizers

Thousand seed weight of mustard was not significantly affected by different rates of fertilizer dose applied in previous rice crop (Table 22). The maximum (2.51g and 2.35g in 2015 and 2016 respectively) 1000 seed weight was found in 100% recommended fertilizer dose followed by 50% recommended dose which was at par in 100% N and 50% NPK dose.

4.3.5.2 Effect of green manuring crops

Thousand seed weight of mustard was significantly affected by incorporation of different green manuring crops in previous rice crop (Figure. 43). The treatments *S. rostrata* (2.91 g and 2.60 g in 1st and 2nd year) followed by *V. unguiculata* (2.84 g and 2.36 g in 1st and 2nd year) produced the heavier seed and it was significantly higher than control in both years. Mondal and Wahab (2001) described that, weight of 1000 seeds varied from variety to variety and species to species.

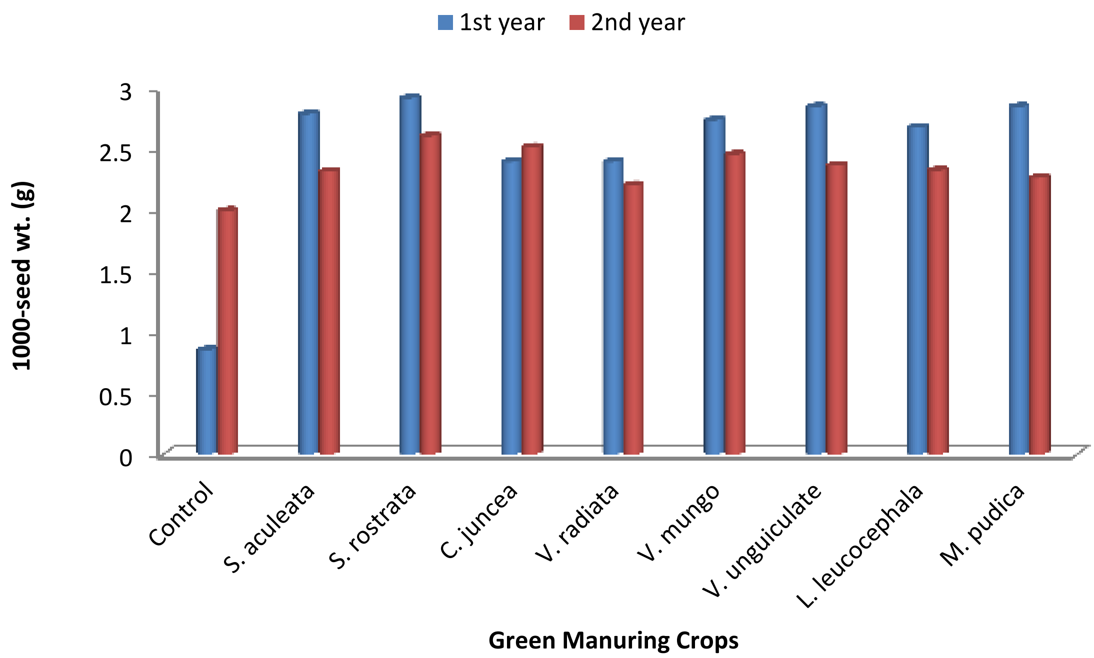


Figure. 43. Effect of green manuring crops on 1000- seed weight of mustard at two consecutive years (SE (±) = 0.244 and 0.05 at 1st year and 2nd year respectively).

4.3.5.3 Interaction effect of fertilizer and green manuring crops

Interaction of fertilizers and green manuring crops also differed significantly for 1000-seed weight in both the years. In 1st year, the highest weight of 1000-seed was found in the interaction of 50% recommended N dose with *Mimosa pudica* (2.96 g) followed by *Sesbania rostrata* (2.90 g) with 100% N ((Table 23). In 2nd year, *S. rostrata* (2.64 g and 2.57 g) showed highest 1000-grain weight with 100% and 50% NPK.

4.3.6 Seed yield

4.3.6.1 Effect of different levels of N and NPK fertilizers

Fertilizer dose had significant effect on seed yield (Figure. 44). The numerically maximum seed yield (1209.9 kg ha^{-1} and 879 kg ha^{-1}) was produced by 100% recommended fertilizer dose followed by 50% dose in first year and second year respectively. The cause of yield increment might be due to higher nitrogen consumption and favorable effect of yield contributing characters of mustard.

These results are in conformity with that of Mondal and affar (1983) who have observed increased seed yield of mustard by increasing rate of nitrogen.

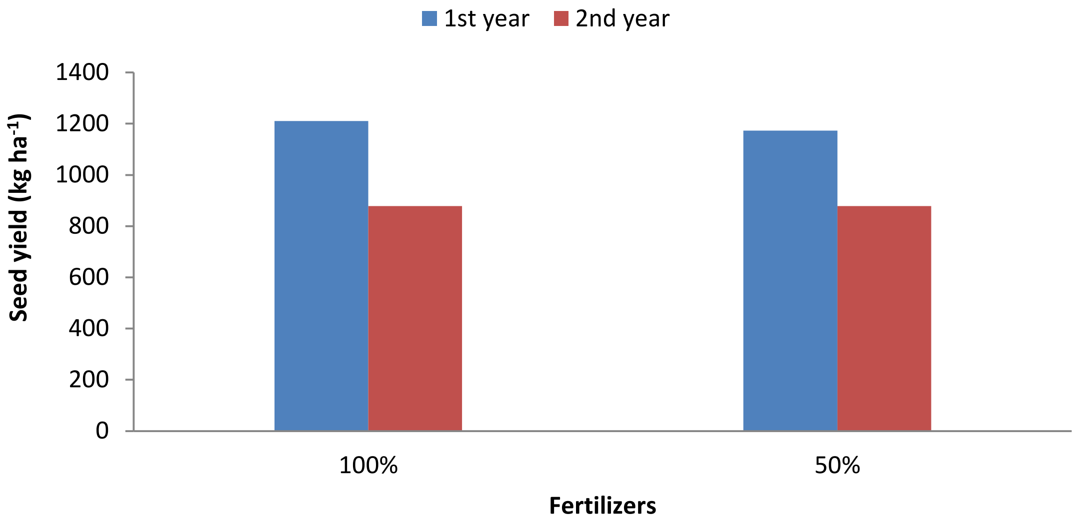


Fig 44. Effect of fertilizer levels on seed yield of mustard in two consecutive years.

4.3.6.2 Effect of green manuring crops

Green manuring crops had significant effect on seed yield. Incorporation of T_2 (*S. rostrata)* to the previous rice crop produced higher seed yield of subsequent mustard crop (1594 kg ha^{-1} and 1104.00 kg ha^{-1} for 2015 and 2016 respectively) and lower yield (837.70 kg ha^{-1} and 658 kg ha^{-1}) was produced in control in first year and second year respectively (Figure. 45). Production of higher seed yield by the treatments of T_2 (*S. rostrata*) may be due to the contribution of the cumulative favorable effects of the crop characters *viz*- number of siliquae $plant^{-1}$, seeds $siliqua^{-1}$, weight of 1000-seeds. From the experiment it was observed that 1^{st} year trial gave maximum yield compare to 2^{nd} year.This may be due to the residual effect of green manures that provide organic matter after decomposition to the mustard. This organic matter helps in increasing adsorptive power of the soils for cations and anions. These adsorbed nutrients are released slowly for the benefits of succeeding crop. Aulakh and Pasricha (1998) stated that, the effect of green manuring on enhancing the yield potential of mustard beyond N supply.

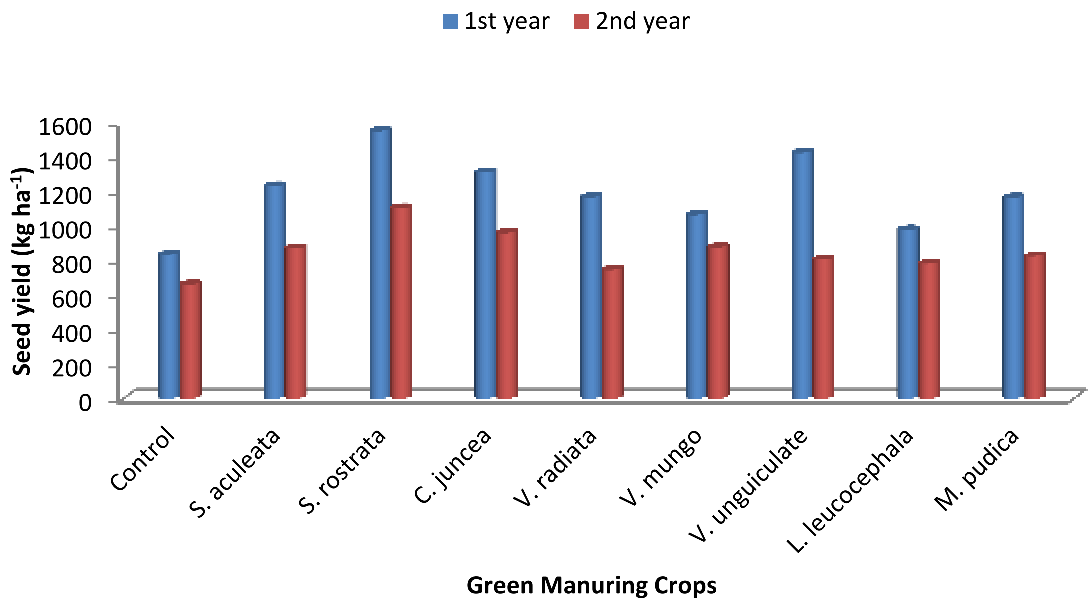
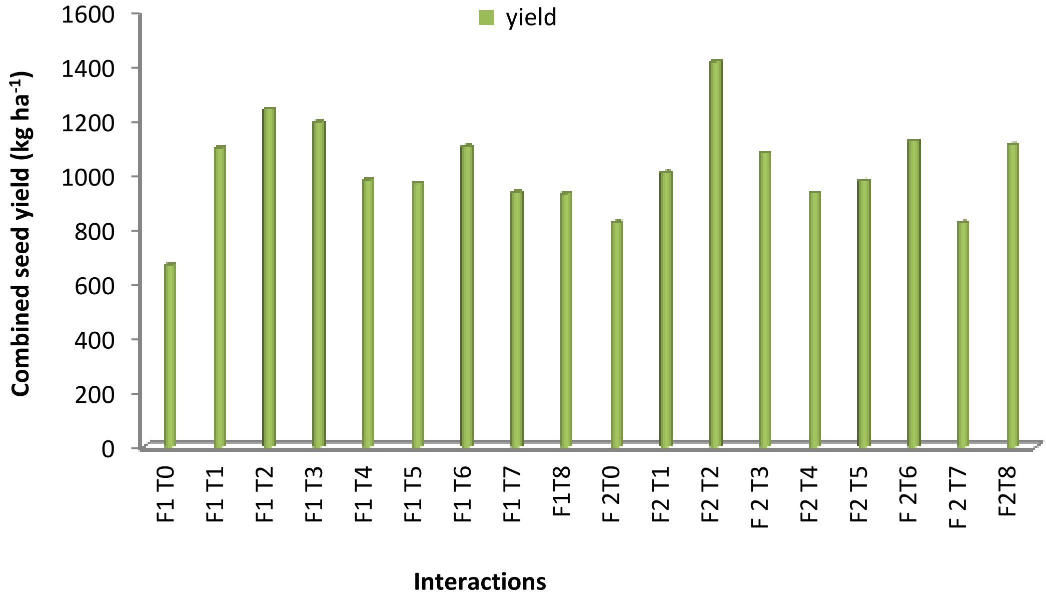


Figure. 45. Effect of green manuring crops on seed yield of mustard at two consecutive years (SE (±) = 131.69 and 121.23 at 1st year and 2nd year respectively).

4.3.6.3 Interaction effect of fertilizer and green manuring crops

The highest seed yield (1592.3 kg ha^{-1}) by *Sesbania rostrata* with 100% fertilizer dose and 952.0kg ha^{-1} with *Sesbania aculeata* by 50% fertilizer dose was found in 2015 and 2016 year respectively. The lowest seed yield was obtained from no green manuring treated plots.The highest combined yield of mustard was found in *Sesbania rostrata* with 50% fertilizer that followed by *Vigna unguiculata* (Figure.46) and *M. pudica* and the trend $T_2 > T_3 > T_1 > T_6$ with 100% fertilizer dose. The lowest combined mustard yield was given by control plots.



Here, T_0 = Control, T_1=*S. aculeata*,T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 46. Interaction effect of pervious fertilizer levels and green manuring crops on seed yield of mustard in two pooled years

4.3.7 Stover yield

4.3.7.1 Effect of different levels of N and NPK fertilizers

Stover yield was not significantly influenced by different levels of fertilizer (Table 22). Application of 50% recommended fertilizer dose produced the maximum stover yield (2216.0 kg ha^{-1}) in first year and 2566 kg h^{-1} in second year with 100% fertilizer dose.

4.3.7.2 Effect of green manuring crops

Stover yield was significantly influenced by different green manuring crops in first year (Figure. 47). T_1 (*S. aculeata*) produced the significant higher stover weight (2517.0 kg ha^{-1}) followed by T_2 (*Sesbania rostrata*) which were significantly different than that of control. In second year, T_3 (*Crotalaria juncea*) produced higher (2955.50 kg ha^{-1}) stover yield followed by T_1 (*Sesbania aculeata*) and lower obtained from control.

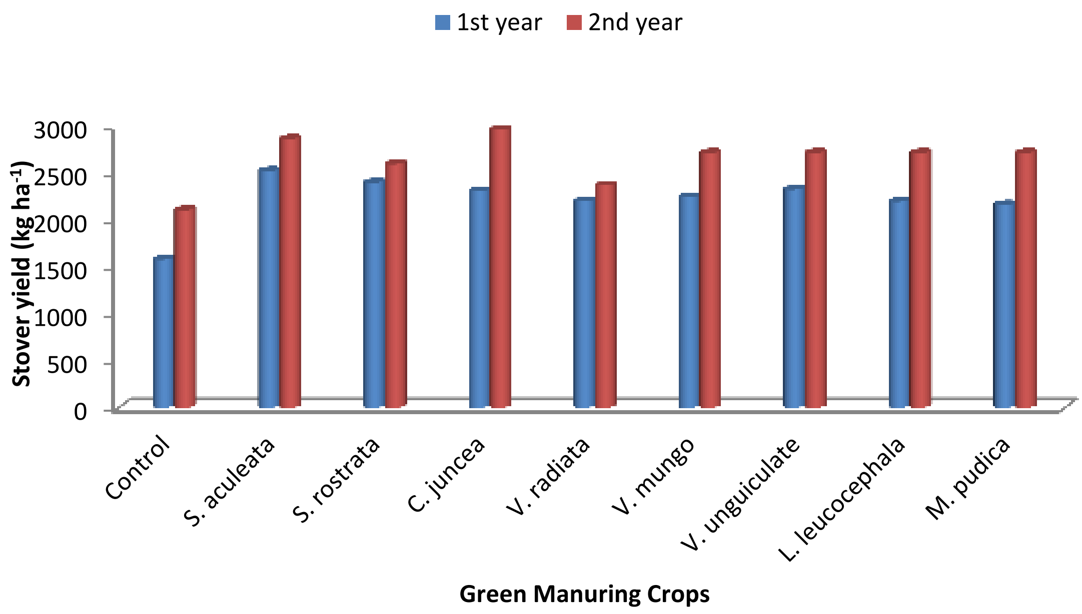


Figure. 47. Effect of green manuring crops on stover yield of mustard at two consecutive years (SE (±) = 100.52 at 1st year).

4.3.7.3 Interaction effect of fertilizer dose and green manuring crops:

Significant interaction was found from stover yield in first year. The highest stover yield (2539.0 kg ha^{-1}) was obtained from *S. aculeata* with 50% fertilizer dose that followed by other green manuring crops irrespective of fertilizer dose but the lowest stover yield (1448.0 kg ha^{-1}) was found from control plots with 100% recommended fertilizer which was similar with the control having 50% recommended fertilizer dose (Table 23).

Table 23. Interaction effect of previous fertilizer levels and green manuring crops on number of seeds silliqua^{-1}, 1000-seed wt, seed yield and stover yield of mustard

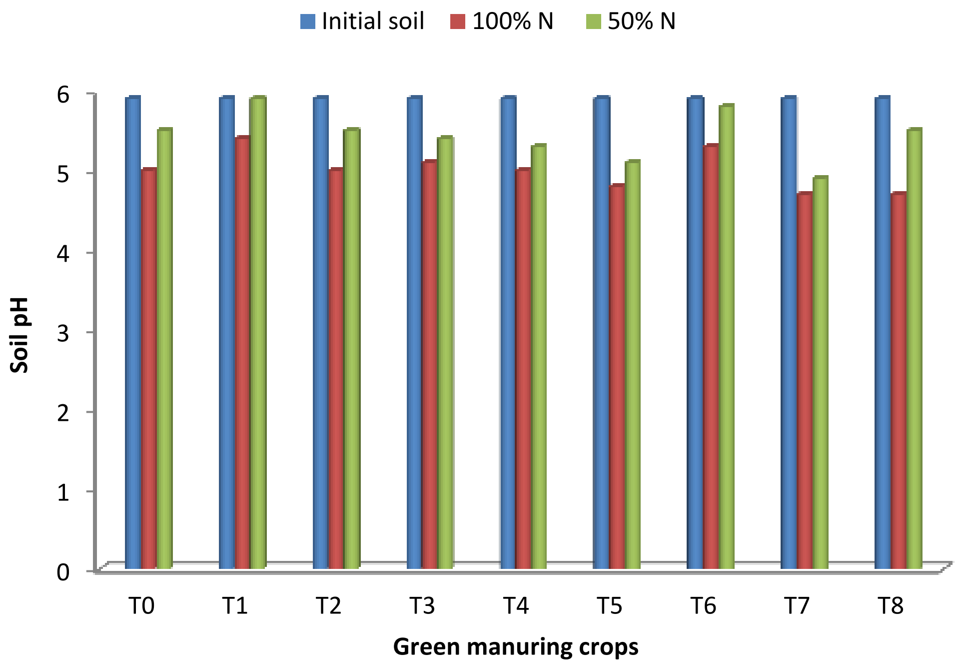
Interactions	Seeds siliqua^{-1}(No.)		1000- seed wt. (g)		Stover yield (kg ha^{-1})	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
$F_1 T_0$	19.55bc	18.05	0.83c	1.99f	1448.00c	2202.00
$F_1 T_1$	33.40a	22.20	2.71a	2.33b-d	2495.00ab	2980.70
$F_1 T_2$	30.00a	23.22	2.90a	2.64a	2383.00ab	2621.00
$F_1 T_3$	32.96a	23.10	2.58a	2.53ab	2359.30ab	3037.70
$F_1 T_4$	28.06ab	21.88	2.49a	2.16d-f	2133.30ab	2354.30
$F_1 T_5$	28.06ab	22.22	2.63a	2.30b-e	2229.70ab	2742.70
$F_1 T_6$	35.66a	23.32	2.85a	2.41a-d	2300.00ab	2011.00
$F_1 T_7$	30.30a	21.53	2.69a	2.34b-d	2175.00ab	2668.00
F_1T_8	29.13ab	21.10	2.96a	2.33b-d	2272.00ab	2474.70
F_2T_0	15.51c	21.20	0.86bc	1.99f	1700.00bc	1994.70
$F_2 T_1$	32.20a	22.22	2.85a	2.30b-e	2539.00a	2735.70
$F_2 T_2$	30.73a	23.77	2.92a	2.57ab	2405.00ab	2561.30
$F_2 T_3$	32.20a	23.41	2.21a	2.50a-c	2240.00ab	2873.30
$F_2 T_4$	29.90a	23.33	2.30a	2.24c-f	2252.00ab	2366.30
$F_2 T_5$	29.93a	19.75	2.83a	2.50a-c	2238.00ab	2676.00
F_2T_6	34.86a	21.42	2.83a	2.30b-e	2333.00ab	2331.00
$F_2 T_7$	31.66a	22.22	2.65a	2.31b-e	2202.00ab	2337.70
F_2T_8	27.36a-c	21.77	2.73a	2.20d-f	2038abc	2918.3
SE (±)	**2.52**	**NS**	**0.316**	**0.069**	**135.64**	**NS**
CV(%)	**6.7**	**8.61**	**16.95**	**4.05**	**7.89**	**33.14**

F1= 100% recommended dose, F2= 50% of recommended dose. NS = Not Significant T_0 = Control, T_1=*S. aculeata*,T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudic* In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly

4.3.8. Residual effect of plant biomass as supplement of chemical fertilizer on soil

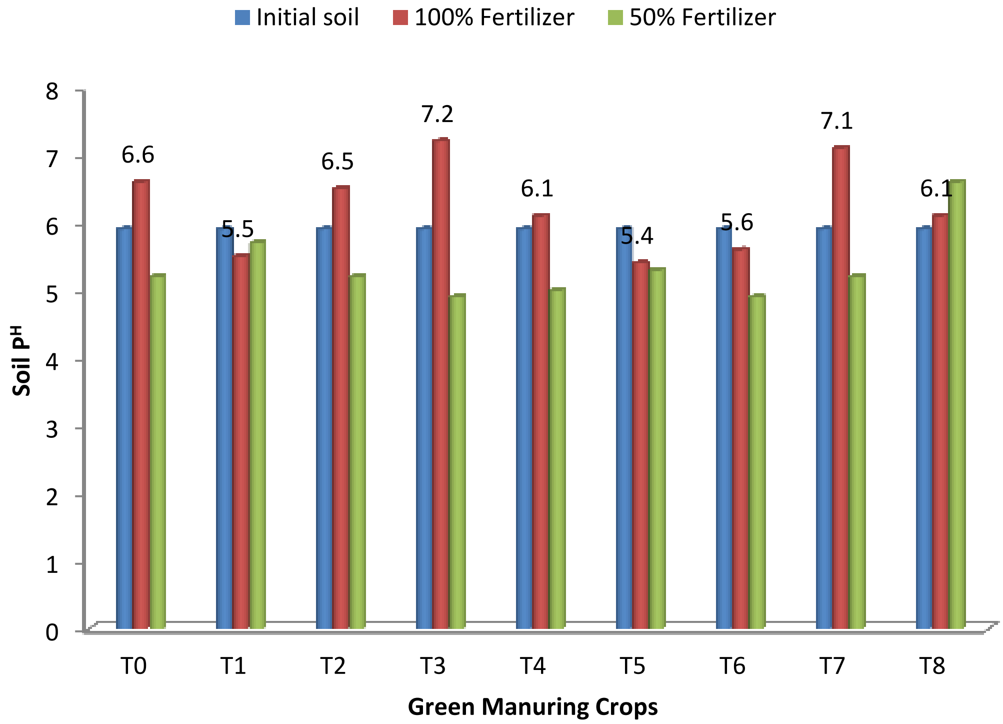
4.3.8.1 Soil pH

After harvesting of mustard, all green manuring crops showed decreasing trend of soil pH at 1st year compared to initial (5.9) soil. Only *S. aculeata* showed slight inreased trend with 50% N dose in 1st year (Figure. 48 and Appendix 2). Whereas, in 2nd year, *C. juncea* (7.2) and *L. leucocephala* (7.1) with 100% fertilizer and *M. pudica* (6.6) with 50% fertilizer showed increased trend compared to initial soil (Figure.49).



Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S.rostrata*, T_3= *C.juncea*, T_4=*V. radiata*, T_5=*V. mungo*, T_6=*V. unguiculata*, T_7=*L. leucocephala*, T_8=*M. pudica*

Figure. 48. Residual effect of previous plant biomass on soil pH in 1st year.

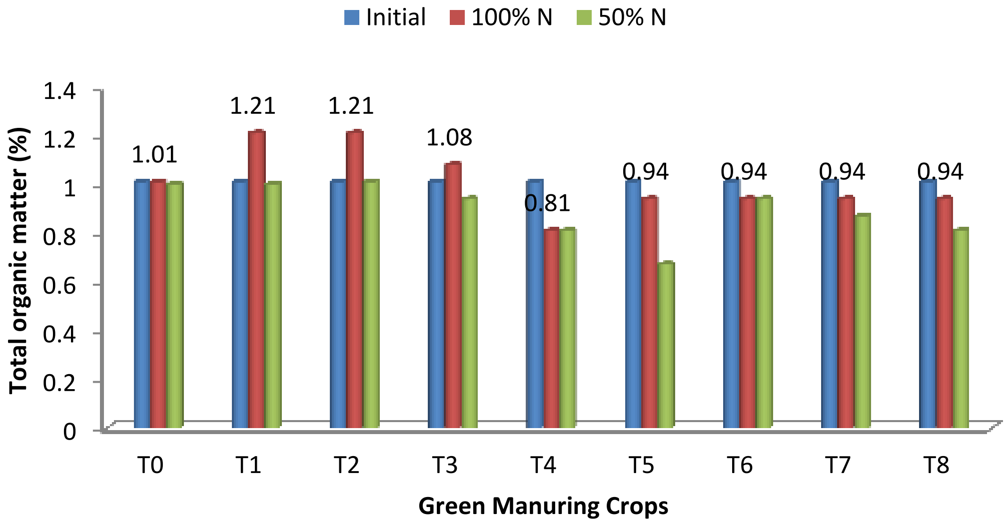


Here, T_0 = Control, T_1 = *S. aculeata*,T_2 = *S. rostrata*,T_3 = *C. juncea*,T_4= *V. radiata*,T_5= *V. mungo*, T_6 = *V. unguiculata*,T_7 = *L. leucocephala*,T_8 = *M. pudica*

Figure. 49. Residual effect of previous plant biomass on soil pH in 2nd year

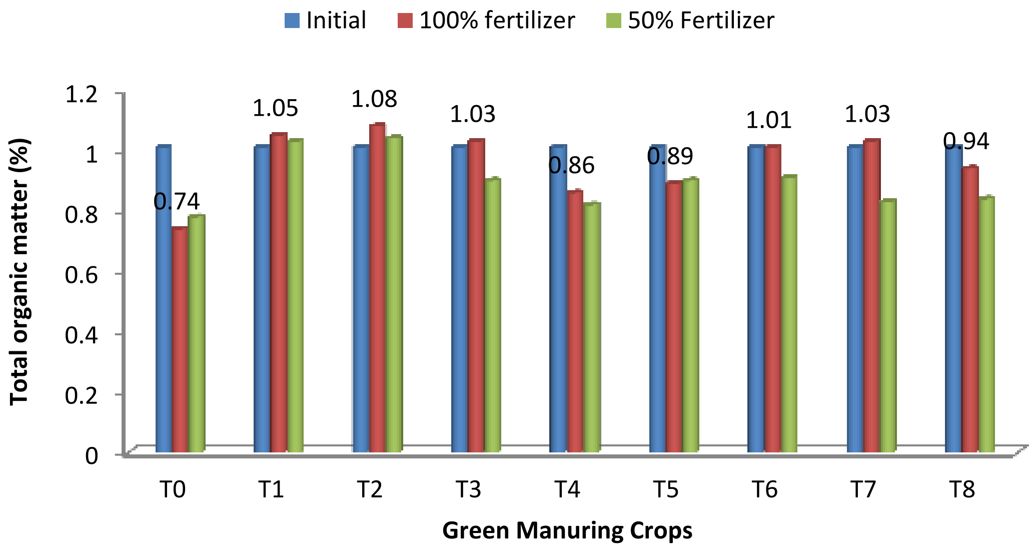
4.3.8.2 Total soil organic matter

It was observed that *S. rostrata* and *S. aculeata* (1.21%) followed by *C. juncea* (1.08) showed the highest organic matter content with 100% recommended nitrogen compared to initial (1.01%) soil in 1st year, where as the lowest value obtained from *V. radiata* with 100% fertilizer and *V. mungo* with 50% nitrogen. During 2nd year, *S. rostrata* > *S. aculeata* > *L. leucocephala* > *C. juncea* showed the highest organic matter under both 100% and 50% fertilizer doses and the lowest obtained from control plot (Figure. 50 and Figure. 51 and Appendix 3). Higher level of organic matter increased in *S. rostrata* (19% and 45% at 1st and 2nd year) followed by *S. aculeata* (19% and 41% at 1st and 2nd year) in comparision to control.



Here, T $_0$ = Control ,T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 50. Residual effect of plant biomass on total organic matter content of soils in 1st year.



Here, T $_0$ = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 51. Residual effect of plant biomass on total organic matter content of soils in 2nd year.

4.3.8. Total nitrogen content of soil

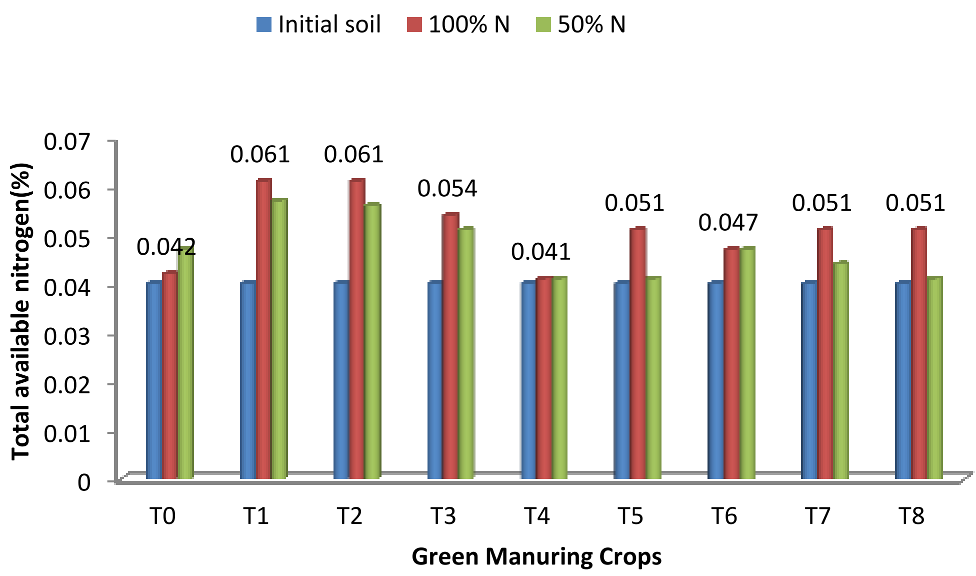
Residual effect of green manuring crops was performed better in N content. The N content of all post harvest soil was found to be increased compared to initial soil (0.04%). After harvest of mustard, soil nitrogen was increased from 0.041 to 0.61% at 1^{st} year and 0.094% at 2^{nd} year, where initial soil analysis showed 0.04% (Figure. 52 and Figure. 53). In 1^{st} year, the highest N content was obtained from *S.rostrata* (0.61%) and *S.aculeata* with 100% N dose over control and the minimum from T_4 (*V. radiata*) and T_5 (*V. mungo*) from 50% N dose. Whereas in 2^{nd} year, the highest available nitrogen was found from *L. leucocephala >S. rostrata >S. aculeata > M. pudica* both 100% and 50% fertilizer and lowest found from control. 50% increased total soil nitrogen was found from *S. rostrata* at 1^{st} and 2^{nd} year.The increasing trend of soil N was observed in all treatments and this may be the decomposition of organic matter.

4.3.8.3. Available potassium in the soil

The result revealed from experiment that after harvest of mustard, soil K status showed a increased trend from initial (0.18 meq 100g) to 0.69 meq 100g with two fertilizer doses in 2^{nd} year but decreased trend $T_2>T_1>T_3>T_4>T_5>T_6>T_7>T_8$ were found with 100% N and $T_8>T_7>T_3>T_1$ with 50% N in first year. *M. pudica* (0.69 meq/100g) and *V. unguiculata* (0.59meq/100g) and *S. aculeata* (0.50meq/100g) bomass showed the highest K content in soil in 2^{nd} year (Figure. 54). The 109% available K increased from *M. pudica* in comparision to control in 2^{nd} year.The exchangeable K in soil gradually increased over time due to combined use of green manure and chemical fertilizer. Integrated use of organic and inorganic fertilizers also increased exchangeable K in soil (Rahman, 1999 and Islam, 2000). Prasad *et al*. (1991) reported that K availability increased significantly by the incorporation of organic wastes. The amount of K mineralized increased significantly and raised the available K pool in soil due to relase of more organically bound potassium in course of decomposition of organic wastes.

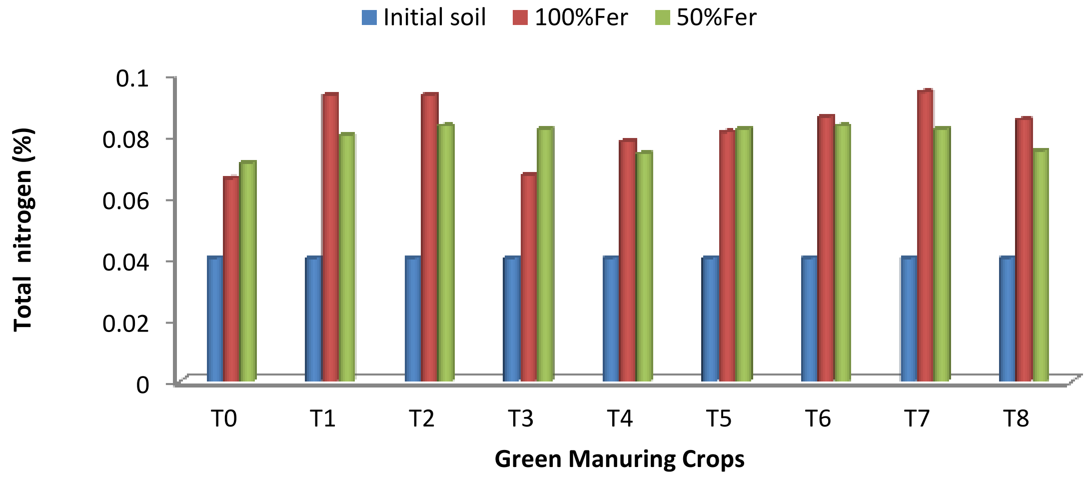
4.3.8.4 Available phosphorous in the soil

The result indicated that among residual effect of green manuring crops, all plot showed decreased trend of soil P in compared to initial (15.83 ppm) soil with 100% and 50% of N fertilizer in 1st year (Figure. 55). But in 2nd year, available soil P was drastically increased in the following trend $T_3>T_7>T_2>T1$ with 100% fertilizer compared to 50% fertilizer. *C. juncea* (31.30 ppm) showed the higher performance followed by *L. leucocephala* (26.20 ppm), *S. rostrata* (20.90 ppm) and *S. aculeata* (18.00 ppm) with 100% fertilizer over control in 2nd year. Singh *et al*. (1998) found that the amount of litter fall and the soil composition, organic carbon as well as available P increased by application of plant biomass.



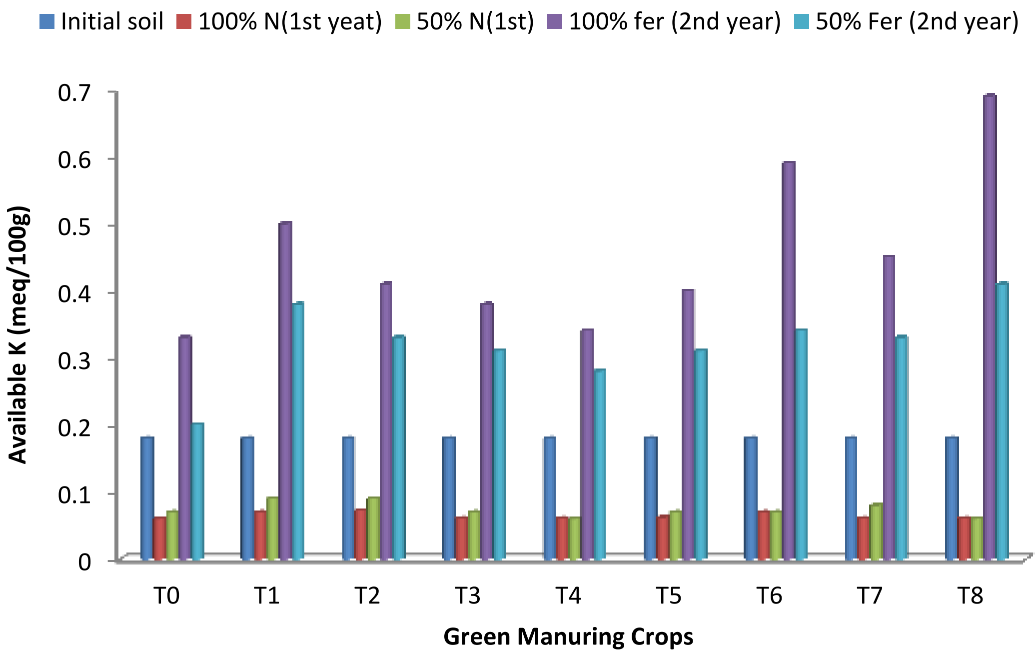
Here, Here, T_0 = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*, T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*, T_7 =*L leucocephala*,T_8=*M. pudica*

Figure. 52. Residual effect of plant biomass on total nitrogen content in soils in 1st Year.



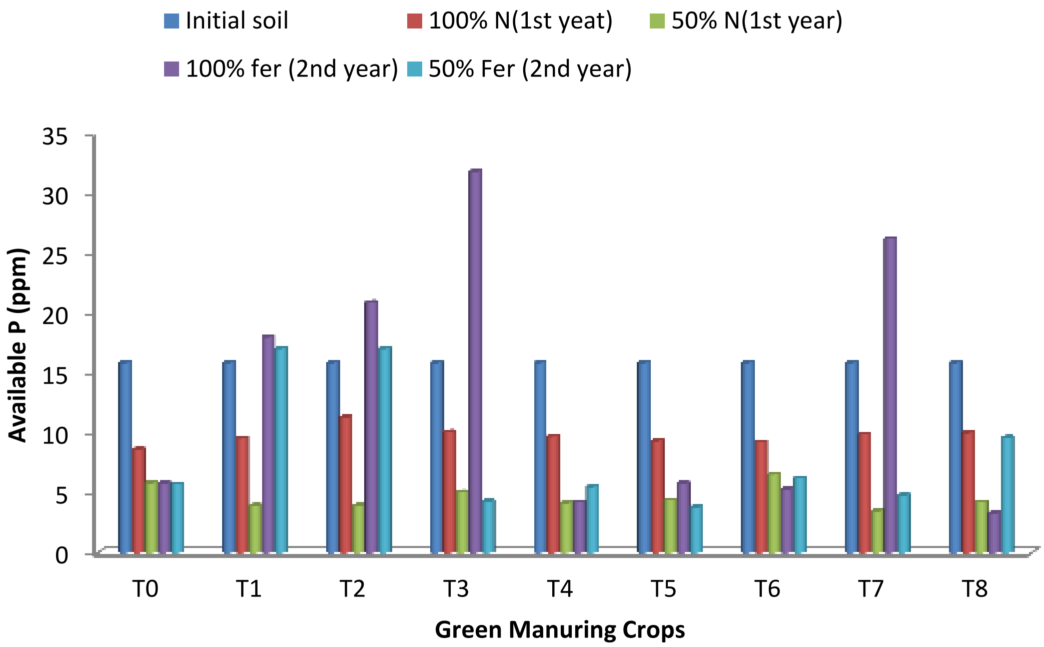
Here, Here, T $_0$ = Control,T$_1$=*S. aculeata*, T$_2$=*S. rostrata*, T$_3$= *C. juncea*,T$_4$=*V. radiata*,T$_5$=*V. mungo*,T$_6$=*V. unguiculata*,T$_7$=*L. leucocephala*,T$_8$=*M. pudica*

Fig 53. Residual effect of plant biomass on total nitrogen content in soils in 2nd Year.



Here, Here, T $_0$ = Control,T$_1$=*S. aculeata*, T$_2$=*S. rostr ata*, T$_3$= *C. juncea*,T$_4$=*V. radiata*,T$_5$=*V. mungo*,T$_6$=*V. unguiculata*,T$_7$=*L. leucocephala*,T$_8$=*M. pudica*

Figure. 54. Residual effect of previous plant biomass on exchangeable potassium content in soils in two consecutive year.



Here, Here, T $_0$ = Control, T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C.juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

Figure. 55. Residual effect of previous plant biomass on available phosphorous content of soils in two consecutive year.

4.3.9 Cropping pattern performance

Total productivity of different cropping pattern was evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of rice combined with yield of mustard (rice equivalent yield). Rice equivalent yields were varied due to different cropping patterns (Table 24). The highest REY (9.60 t ha^{-1} in 1st year) and (11.49 t ha^{-1} in 2nd year) was recorded from the cropping pattern; *S. rostrata* – T.aman – Mustard respectively that followed by *C. juncea* – T.aman – Mustard , *S. aculeata* – T.aman – Mustard, in 2015 but in 2016, *V. unguiculata* based pattern showed second highest rice equivalent yield. The lowest REY (6.02 t ha^{-1} in 1st year) and (6.98 t ha^{-1} in 2nd year) was obtained from the cropping pattern; Fallow-T. Aman – Mustard. Inclusion of mustard during rabi season in *S. rostrata* (59.47% and 64.61% in 2015 and 2016 respectively) and *C. juncea* (41.47% and 49.14% in 2015 and 2016 respectively) increased REY compared to Fallow-T. Aman-Mustard cropping pattern that followed by *V. unguiculata* (45.70% and 54.15% in 2015 and 2016 respectively) and *S. aculeata* (40.86% and 32.0% for 2015 and 2016 respectively). It is noted that inclusion of crops likes *S. rostrata*, *C. juncea*, *S. aculeata* and *V. unguiculata* showed higher REY than other crops as GM in GM-T. Aman-Mustard cropping pattern. The cost of production in situ green manure was lower than addition of similar quantities from external sources. This again signifies the usefulness of in situ green manuring, especially for a rice crop, at a time when the fields are idle, rather than importing organic matter. This would also reduce the N requirement by 50% to obtain similar yields.

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Table 24. Rice equivalent yield of different cropping patterns in 2015 and 2016

Cropping patterns	1st year				2nd year				Average rice equivelent yield (t ha^{-1})
	Rice yield (t ha^{-1})	Mustard yield (t ha^{-1})	Rice equivalent yield (t ha^{-1})	Net income	Rice yield (t ha^{-1})	Mustard yield (t ha^{-1})	Rice equivalent yield (t ha^{-1})	Net income	
Fellow-Rice-Mustard	3.42	0.65	6.02	120400	3.70	0.82	6.98	139600	6.50
S.aculeata-Rice-Mustard	5.00	0.87	8.48	169600	5.25	1.23	10.17	203400	9.33
S. rostrata-Rice-Mustard	5.20	1.10	9.60	192000	5.33	1.54	11.49	229800	10.55
C. juncea-Rice-Mustard	4.68	0.96	8.52	170400	5.21	1.30	10.41	208200	9.47
V. radiata-Rice-Mustard	3.73	0.74	6.69	133800	4.59	1.16	9.23	184600	7.96
V. mungo-Rice-Mustard	4.06	0.87	7.54	150800	4.50	1.13	9.02	180400	8.28
V. unguiculata-Rice-Mustard	4.75	0.80	7.95	159000	5.08	1.42	10.76	215200	9.36
L.leucocephala-Rice-Mustard	4.11	0.77	7.19	143800	4.65	1.16	9.29	185800	8.24
M.pudica-Rice-Mustard	4.23	0.82	7.51	150200	4.48	1.21	9.32	186400	8.42

Price : Rice = TK. 20 kg^{-1}, Mustard = TK. 80 kg^{-1}

4.4. Experiment 7. Performances of grown T. Aman seed on laboratory condition

In the present study, the experiment was conducted in a laboratory to observe the effect of fertilizer doses and green manures applied in previous rice crop from where seeds were collected on the post storage seed quality.

4.4.1 Germination percentage and germination energy percentage

4.4.1.1 Effect of fertilizer on germination percentage and germination energy percentage

The effect of fertilizer dose on germination (six months of storaged seeds) was not significant (Fig: 56). Fertilizer treatments both recommended and half of recommended NPK chemical fertilizer dose maintained an acceptable level of germination percentage (>80%). The highest germination of seed was obtained from both fertilizer doses.

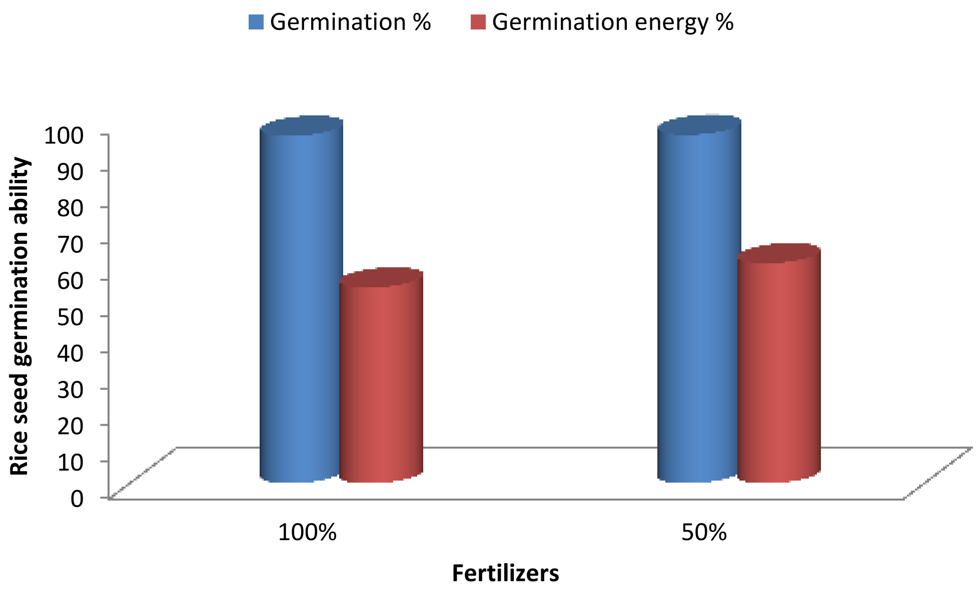
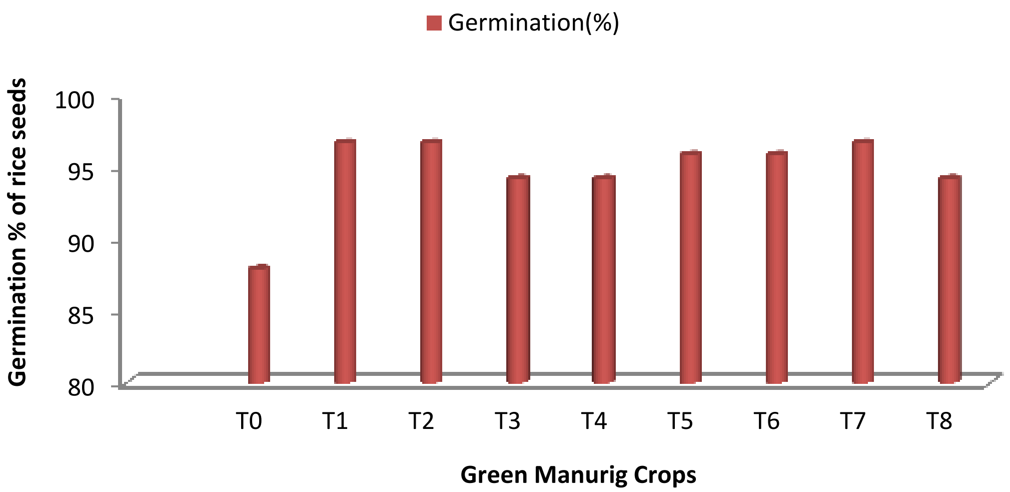


Figure. 56. Post- harvest effect of fertilizers on seed germination and seed germination energy of rice under laboratory condition

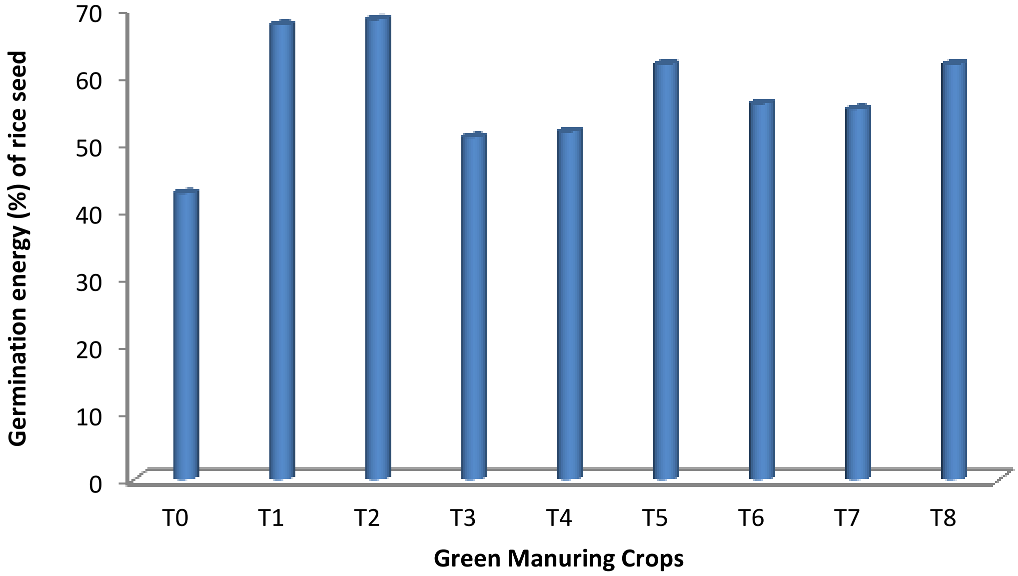
4.4.1.2 Effect of green manuring crops

The residual effect of green manuring crops on germination of stored rice seeds were not significant (Figure. 57 and Figure. 58). Result showed that *S rostrata, S. aculeata* and *L.leucocephala* had maximum germination percentage (96.6%), where as minimum germination percentage (87.91%) was found from control. Germination energy of rice seeds also found significant with each other. *S. rostrata* (68.33%) and *S. aculeata* (67.5%) showed the highest germination energy followed by *V. mungo* and *M. pudica*. On the other hand, the lowest was observed from control (42.50%) seeds. Control seeds were found susceptible to infection than other seeds. Hossain (2014) found from his study and stated that recommended NPKSZn chemical fertilizer dose kept an acceptable level of germination percentage (>80%) but without fertilizer treatment showed better performance in respect of viability, germination and seedling length in BRRI dhan37. He also showed that fertilizer along with green manure produced second highest germination percentage.



Here, T_0 = Control,T_1=*S. aculeata*,T_2=*S.rostrata*,T_3= *C .juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M.. pudica*

Figure. 57. Post- harvest effect of different green manuring crops on rice seed germination (%) under laboratory condition.



Here, T_0 = Control, T_1=*S. aculeata*,T_2 = *S. rostrata*,T_3= *C. juncea*,T_4 = *V. radiata*,T_5 = *V. mungo*,T_6 = *V. unguiculata*,T_7= *L. leucocephala*,T_8 = *M.. pudica*

Figure. 58. Post- harvest effect of different green manuring crops on rice seed germination energy (%) of rice seed under laboratory condition (SE (±) = 6.92).

4.4.1.3 Interaction effect of fertilizer doses and green manuring crops

Seed germination parameters eg. germination percentage and germination energy percentage did not varied significantly due to interaction of fertilizer and green manuring crops (Table 26).The highest germination percentage was found from *V. radiata* (100%) with 50% fertilizer dose that followed by *S. aculeata, V. mungo and V. unguiculata* and *S. rostrata* with 100% fertilizer dose. On the other hand the highest germination energy was found from *S. rostrata* (80%) and *S. aculeata* (70%). The lowest germination percentage and germination energy was observed from control plot seed.

4.4.2 Cotyledon length

4.4.2.1 Effect of fertilizer on cotyledon length of seedling:

The effect of fertilizer on cotyledon length of seedling (six months of storage seeds) was not significant (Table 25). Fertilizer treatments both recommended and half of recommended NPK chemical fertilizer dose maintained an acceptable level of cotyledon length from 9 days after germination to 15 days after germination (4.25 to 5.90 cm).

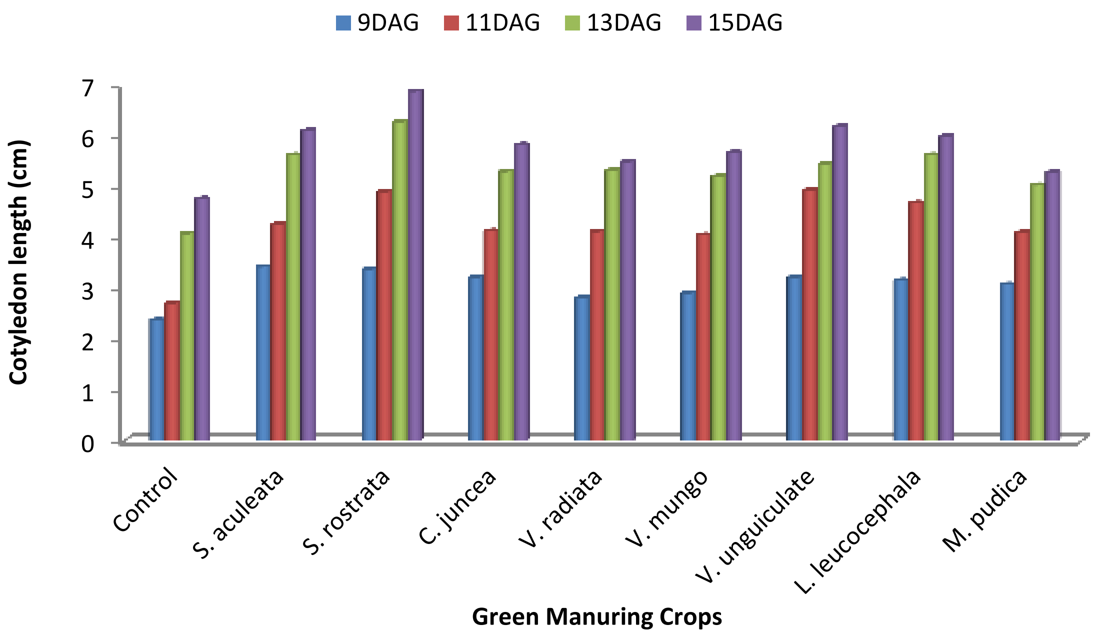
Table 25. Effect of fertilizers level on seed quality characters (Cotyledon and radical length) of Rice in laboratory

Fertilizer levels	Cotyledon length (cm)				Radicle length (cm)			
	9 DAG	11 DAG	13 DAG	15 DAG	9 DAG	11 DAG	13 DAG	15 DAG
F_1	2.93	4.25	5.44	5.90	5.43	6.59	6.90	7.36
F_2	3.17	4.14	5.20	5.68	5.50	6.54	6.72	7.12
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV(%)	**19.69**	**11.41**	**15.98**	**18.15**	**16.12**	**9.70**	**12.86**	**21.17**

Here, DAG= Days after germination, F_1=100% recommended fertilizer doses, F_2= 50% recommended fertilizer doses. NS= Not Significant

4.4.2.2 Effect of green manuring crops

Seed vigor as expressed in terms of seedling length was significantly affected by different fertilizer treatments (Figure. 59). Cotyledon length of rice seeds was shown significant difference with each other. Cotyledon lengths were taken after two days interval from germination. At the 9 DAG (Days after germination), the highest length was found from *S. aculeata* (3.41 cm) followed by *S. rostrata* (3.36 cm) and *L. leucephala*. At 11DAG (Dys after germination), the highest cotyledon length was found from *V. unguiculata* (4.92 cm) and *S. rostrata* followed by *L. leucocephala*. At 13 DAG (Days after germination), *S.rostrata* (6.26 cm) showed the highest length followed by *S. aculeata* and *L. leucocephala*. At 15DAG (Days after germination), *S. rostrata* (6.86 cm) showed the highest performance followed by *S. aculeata* and *V. unguiculata*. Whereas control showed the lowest performances. 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). In mungbean, without fertilizer treatment had higher vigor than when fertilized (Aquino and Fernandez, 2001). The better filling of seeds, which indicates the better food reserves in the seeds treatments, might have resulted in better quality parameter (Krishna *et al.*, 2008; Nandisha and Mahadevappa, 1984; Udaykumar, 2005). 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).



Here, Here, T_0 = Control,T_1=*S. aculeata*, T_2=*S. rostrata*, T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V .mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*
DAG = Days After Germination

Figure. 59. Post-harvest effect of green manuring crops on cotyledon length of rice seed at different days under laboratory condition (SE (±) = 0.240, 0.436, 0.562 and 0.479 at 9, 11, 13 and 15DAG).

4.4.2.3 Interaction effect of fertilizer doses and green manuring crop

Cotyledon length had significant at 11 DAG and 13DAG but not at 9DAG and 15DAG. At 9DAG, the highest length was found from *S. aculeata* and *V. unguiculata* followed by *S. aculeata* with 50% fertilizer dose. At 11DAG, the highest cotyledon length was found from *S. rostrata* followed by *S. aculeata* with 50% and 100% fertilizer dose respectively (Table 26). At 13 DAG to 15 DAG, *S.rostrata* showed the highest performances followed by *S. aculeata* and *L. leucocephala.*

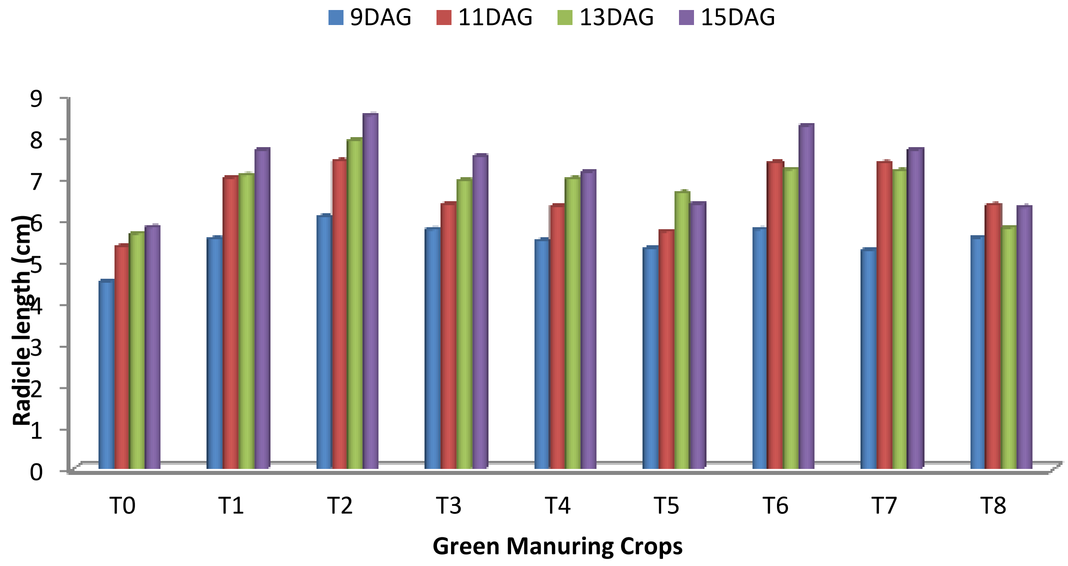
4.4.3 Radicle length

4.4.3.1 Effect of fertilizer on radicl length of seedling:

The effect of fertilizer dose on radicle length of seedling (six months of storaged seed) was not significant (Table 25). Fertilizer treatments both recommended and half of recommended NPK chemical fertilizer dose maintained an acceptable level of cotyledon length from 9 days after germination to 15 days after germination (5.43 to 7.36 cm).

4.4.3.2 Effect of green amnuring crops

Radicle length of rice seeds were shown significant difference with each other among different days after germination for the effect of different green manuring crops. Among the different days after germination, *S. rostrata* showed the highest radical length followed by *V. unguiculata, S. aculeata* and *L.leucocephala* whereas control plot showed the lowest length on its growth (Figure. 60).



Here, T_0 Control, T_1=*S. aculeata*,T_2=*S. rostrata*,T_3=*C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*
DAG = Days After Germination

Figure. 60. Post-harvest effect of green manuring crops on radicle length of rice seed at different days under laboratory condition (SE (±) = 0.295, 0.368 at 9 DAG, 11DAG in 2nd year).

4.4.3.2 Interaction effect of fertilizer and green manuring crops

Interaction effect did not shown significant difference with each other except 11 days after germination. *S. rostrata* treated seed plot gave the highest data in all days after germination followed by *S. aculeata* whereas control treated plot seed gave the lowest performances in that aspect. (Table 26).

Table 26. Interaction effect of fertilizer levels and green manuring crops on seed quality characteristics of rice seed (LANDSCAPE)

Interactions	Germination %	Germination energy (%)	cotyledon length(cm)				Radicle length(cm)			
			9DAG	11DAG	13DAG	15DAG	9DAG	11DAG	13DAG	15DAG
$F_1 T_0$	86.67	40.00	2.30	2.61c	4.05b	5.30	5.01	5.74bcd	5.63	5.78
$F_1 T_1$	98.33	55.00	3.20	3.86a-.c	4.62ab	5.28	5.40	6.30a-d	6.46	8.00
$F_1 T_2$	96.70	66.66	3.20	4.88ab	7.16a	7.63	6.13	7.56a-c	8.00	9.13
$F_1 T_3$	91.67	48.33	3.03	4.05a-c	5.63ab	5.98	5.55	6.36a-d	7.53	8.06
$F_1 T_4$	88.33	45.00	2.51	4.53a-c	5.98ab	6.06	5.56	7.10a-d	7.46	7.93
$F_1 T_5$	98.33	66.66	3.10	4.70ab	5.61ab	6.05	5.66	6.32a-d	6.73	6.57
$F_1 T_6$	98.33	48.33	2.80	4.56a-c	5.42ab	5.90	4.97	6.60a-d	7.46	7.23
$F_1 T_7$	95.00	58.33	2.96	4.70ab	5.30ab	5.67	4.86	7.13a-d	6.83	7.26
F_1T_8	88.33	56.66	3.26	4.36a-c	5.17ab	5.20	5.76	6.17a-d	6.00	6.30
F_2T_0	89.17	45.00	2.42	2.76bc	4.10ab	4.20	3.96	4.94d	5.69	5.84
$F_2 T_1$	95.00	80.00	3.63	4.63ab	6.56ab	6.90	5.67	7.70ab	7.66	7.33
$F_2 T_2$	96.67	70.00	3.53	4.90ab	5.56ab	6.10	5.98	7.23abc	7.80	7.86
$F_2 T_3$	96.67	53.33	3.37	4.18a-c	5.95ab	5.69	5.97	6.35a-d	6.33	6.95
$F_2 T_4$	100.00	58.33	3.10	3.68a-c	4.64ab	4.90	5.40	5.53cd	6.48	6.36
$F_2 T_5$	93.33	56.66	2.69	3.39a-c	4.76ab	5.26	4.94	5.10d	6.54	6.17
F_2T_6	93.33	63.33	3.61	5.27a	5.44ab	6.45	6.55	6.17a-d	6.93	9.26
$F_2 T_7$	98.33	51.66	3.32	4.64ab	5.92ab	6.28	5.66	6.52a-d	7.50	8.07
F_2T_8	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

F_1 = 100% Recommended fertilizer dose, F_2= 50% Fertilizer dose

Here,T_0 = Control,T_1=*S.aculeata*,T_2=*S.rostrata*,T_3=*C.juncea*,T_4=*V.radiata*,T_5=*V.mungo*, T_6=*V.unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica*

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

4.4.4 Fresh weight of seedling

4.4.4.1 Effect of fertilizer

The effect of fertilizer dose on fresh weight of seedling (six months of storage seeds) was not significant (Table 27). Fertilizer treatments both recommended and half of recommended NPK chemical fertilizer dose maintained an acceptable level of cotyledon length from 9 days after germination to 15 days after germination (0.169 to 0.290 gm).

TABLE 27. Effect of fertilizers level on fresh and dry weight of seed quality of Rice

Fertilizer levels	Fresh wt. (g)				Dry wt. (g)			
	9 DAG	11 DAG	13 DAG	15 DAG	9 DAG	11 DAG	13 DAG	15 DAG
F_1	0.169	0.20	0.24	0.28	0.05	0.05	0.05	0.06
F_2	0.180	0.20	0.24	0.29	0.05	0.05	0.05	0.06
SE (±)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV(%)	**17.65**	**16.31**	**18.26**	**26.74**	**8.25**	**11.37**	**10.94**	**9.55**

F_1 = 100% Recommended fertilizer dose, F_2= 50% Fertilizer dose. NS= Not Significant

4.4.4.2 Effect of green manuring crops

Fresh weight of rice seeds was shown significant difference with each other only at 9 DAG. At the 9 DAG to 11 DAG, the higher fresh weight was found from *S. aculeata* followed by *S. rostrata* and *L. leucocephala*. At 15 DAG, *S. rostrata* and *V. radiata* showed the higher followed by *S. aculeata* and *L. leucocephala*. The lower was found from rice seed of control plots (Table 28).

Table 28. Effect of green manuring crops on seed quality characters (fresh weight) of Rice seed

Green Manuring Crops	Fresh wt. seedling^{-1}(g)			
	9 DAG	**11 DAG**	**13 DAG**	**15 DAG**
T_0	0.11b	0.17	0.20	0.25
T_1	0.17ab	0.20	0.25	0.27
T_2	0.21a	0.23	0.28	0.33
T_3	0.19a	0.20	0.22	0.28
T_4	0.18a	0.20	0.25	0.31
T_5	0.16ab	0.10	0.25	0.28
T_6	0.18a	0.21	0.24	0.29
T_7	0.16ab	0.22	0.27	0.30
T_8	0.16ab	0.17	0.23	0.25
SE (±)	**0.0178**	**NS**	**NS**	**NS**
CV(%)	**17.65**	**16.31**	**18.26**	**26.74**

Here,T_0 = Control,T_1= *S. aculeata*,T_2 = *S. rostrata*,T_3 = *C. juncea*,T_4 = *V. radiata*,T_5 = *V. mungo*, T_6= *V. unguiculata*,T_7 = *L. leucocephala*,T_8 = *M. pudica*, NS = Not Significant
In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly

4.4.4.3 Interaction effect of fertilizer and green manuring crops

Interaction effect of fresh weight of seedling did not show significant difference except 9 day after germination. The highest weight was found from *S. rostrata* followed by *V. radiata* with 50% fertilizer dose from 11 to upto 15 days after germination (Table 30).

4.4.5 Dry weight of seedlings

4.4.5.1 Effect of fertilizer

The effect of fertilizer dose on dry weight of seedling (six months of storage seed) was not significant (Table 27). Fertilizer treatments both recommended and half of recommended NPK chemical fertilizer dose maintained an acceptable level of cotyledon length from 9 days after germination to 15 days after germination (0.050 to 0.061 gm). The highest germination of seed was obtained from both fertilizer doses.

4.4.5.2 Effect of green manuring crops

Dry weight of rice seeds was shown significant difference with each other only at different days after ransplanting. At 9 DAG to 15DAG, the highest fresh weight was found from *S. rostrata* followed by *S. aculeata*. The lowest dry weight was found from control plot seed (Table 29). Mishara and Salokhi (2008) stated that in unfertilized seedbeds, seedlings allocate more dry matter to the roots for better nutrient uptake

Table 29. Effect of green manuring crops on seed quality characters (dry weight) of rice seed

Green Manuring Crops	Dry wt. seedling^{-1} (g)			
	9 DAG	11 DAG	13 DAG	15 DAG
T_0	0.03b	0.04b	0.05b	0.05b
T_1	0.05a	0.06ab	0.06ab	0.06ab
T_2	0.05a	0.06a	0.07a	0.07a
T_3	0.05a	0.05ab	0.06ab	0.06ab
T_4	0.05a	0.05ab	0.06ab	0.06ab
T_5	0.05a	0.05ab	0.06ab	0.06ab
T_6	0.05a	0.05ab	0.05b	0.05b
T_7	0.05a	0.05ab	0.06ab	0.06b
T_8	0.05a	0.06ab	0.06ab	0.059b
SE (±)	**2.40E-03**	**1.889E-03**	**3.744E-03**	**3.391E-03**
CV(%)	**8.25**	**11.37**	**10.94**	**9.55**

Here,Control, T_1= *S. aculeata*,T_2= *S. rostrata*,T_3= *C. juncea*,T_4= *V. radiata*,T_5= *V .mungo*, T_6= *V. unguiculata*, T_7= *L. leucocephala*,T_8= *M. pudica*, NS = Not Significant
In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly

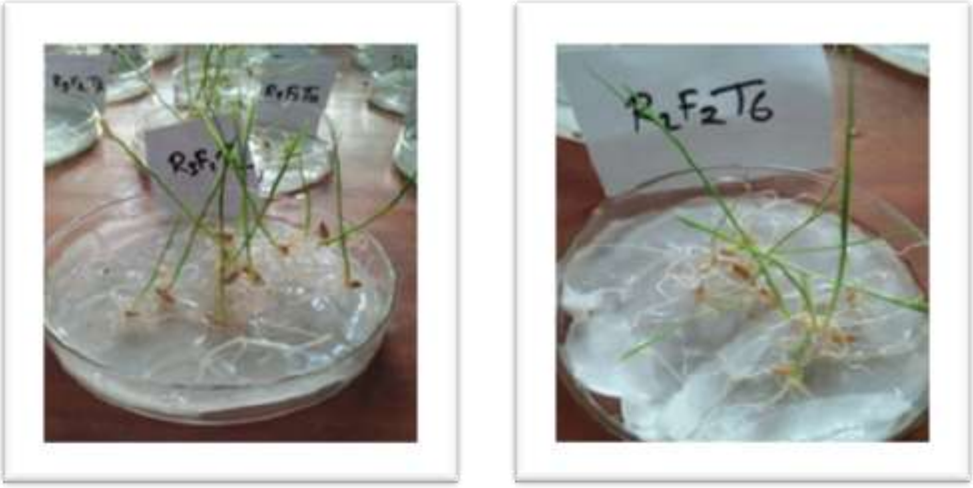
4.4.5.3 Interaction effect of fertilizer and green manuring crops

Interaction effect of dry weight of seedling did not show significant difference except 11 and 15 day after germination. The highest weight was found from *S. rostrata* followed by *V. radiata* with 50% fertilizer dose from 11 to upto 15 days after germination. On the other hand, control plot seed gave the the lowest result compared to other plots (Table 30).

Table 30. Interaction effect of fertilizer levels and green manuring crops on seed quality (fresh weight and dry weight) of rice seed

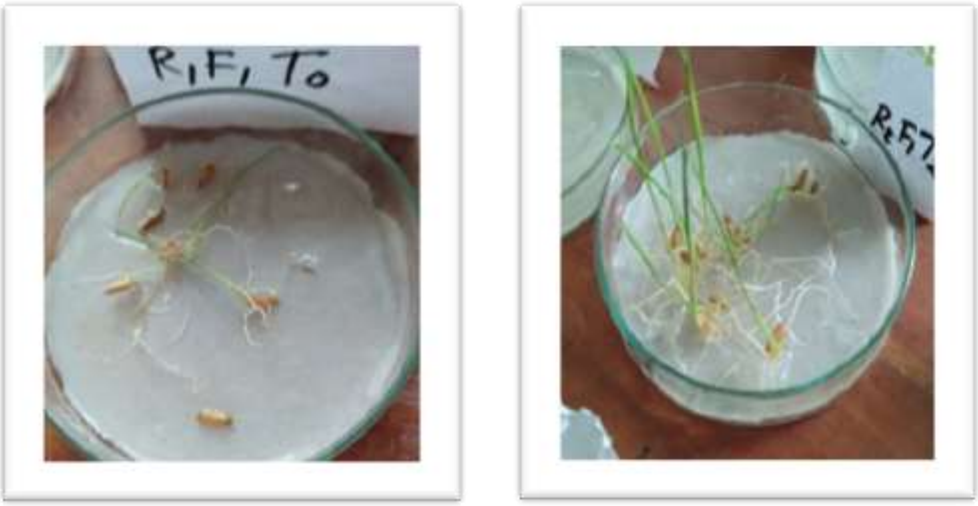
Interactions	Fresh wt. (g)				Dry wt (g)			
	9 DAG	11DAG	13DAG	15DAG	9DAG	11DAG	13DAG	15DAG
$F_1 T_0$	0.11b	0.175	0.20	0.21	0.03c	0.05	0.05ab	0.05b
$F_1 T_1$	0.15ab	0.19	0.23	0.27	0.05a-c	0.05	0.05ab	0.06ab
$F_1 T_2$	0.21a	0.24	0.29	0.42	0.05a	0.06	0.06ab	0.06ab
$F_1 T_3$	0.16ab	0.19	0.21	0.27	0.04a-c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

F_1 = 100% Recommended fertilizer dose, F_2= 50% Fertilizer dose, NS= Non Significant, Here, T_0 = Control, T_1=*S. aculeata*,T_2=*S. rostrata*,T_3= *C. juncea*,T_4=*V. radiata*,T_5=*V. mungo*,T_6=*V. unguiculata*,T_7=*L. leucocephala*,T_8=*M. pudica* In a column, figures having similar letter(s) do not differ significantly whereas figures bearing dissimilar letter differ significantly



Sesbania rostrata *Vigna unguiculata*

Figure. 61. Vigorous growth of *Sesbania rostrata* and *Vigna unguiculata* treated rice seeds unde laboratory condition



Control ***S. rostrata***

Figure. 62. Comparision between control and *Sesbania rostrata* treated rice seeds under laboratory condition

Figure. 63. Performances of infested control rice seeds ($R_3F_1T_0$) under laboratory condition

CHAPTER V

SUMMARY AND CONCLUSION

Eight species *viz. Sesbania aculeata, Sesbania rostrata, Crotalaria juncea, Vigna unguiculata, Vigna mungo, Vigna radiata, Leaucena leauccephala, Mimosa pudica* were selected as green manure crops to study the effect of green manures (*in situ*) on soil improvement and fertilizer economy in the GM-Rice-Mustard cropping patterns in two consecutive years 2015 and 2016. The influenced of green manures and two levels of N (half and full recommended dose) on growth, yield and yield contributing characters of transplant aman rice were studied in first year and two levels of NPK fertilizer (half and full recommended dose) along with different green manures on T-Aman were studied in second year. No significant differences were observed in 100% and 50% doses of N and NPK fertilizer as well on rice.Yield contributing character of mustard were studied in two years and mustard yield were converted to rice equivalent yield to find out the monetary advantages in a cropping pattern basis. Finally seed quality of different green manures and fertilizer treated rice seed was analyzed in laboratory to find out germination ability and healthy seed. The soil samples which were collected from each unit plot of each experiment after harvesting of each crop including initial soil were analyzed for p^H, OM, N, P and K for ensuring soil quality. All data were analyzed through STATIC-10 package.

Four green manures *viz. S. rostrata, S. aculeata, C. juncea* and *V. unguiculata* were found to be effective green manures in terms of biomass, nodulation, nitrogen contribution. These green manures can tremendously benefit nutrient exhaustive different cropping pattern through nitrogen as well as NPK fertilizer saving, increase the crop yields and higher income per unit area as these crop increase the soil fertility. Significant difference observed in plant height among the green manure crops throughout the growth period in two consecutive years. It was observed that, spontaneous vegetation of S*esbania rostrata* and *C. juncea* recorded significantly higher fresh and dry biomass compared with *S. aculeata* during two years. Again *S. aculeata* recorded significantly higher fresh biomass over *V. unguiculata, M. pudica* and *L. leucocephala*.The highest number of nodules plant^{-1} was observed in *S.*

rostrata. S. aculeata and *V. unguiculata* followed by *V. radiata.* The lowest number of nodules plant^{-1} was observed in *L. leucocephala and C. juncea*.

After incorporation of green biomass the highest organic matter (1.08% and 1.55% in 1st year and 2nd year) were found in T_2 (*S. rostrata*) and was followed by T_1 (*S. aculeata*) (1.02% and 1.61% in 1st and 2nd year). The increasing trend of organic matter was T_1> T_2>>T_5>T_6>T_3>T_4>T_8>T_7 from half of recommended fertilized plots in 2016. It seemed that the plot which did not get green manures was automatically occupied lowest position (T_0). The increase of organic matter in green manure treated plots might be due to addition of more biomass. The increasing trend of available N was T_2>T_6>T_7>T_8>T_3>T_1 in 1st year. In 2016, the maximum N content of 0.08% was recorded in *Sesbnia rostrata*, and *Sesbania aculeata* (0.81%) followed by *V. mungo* (0.07%) from half recommended fertilized plot which was at par with full recommended fertilizer dose. The significantly lowest N content of 0.041% was obtained from control plot and the highest K (0.22meqv 100g^{-1}) was found from T_1 (*S. aculeata*) which was similar to T_2 (*S. rostrata*) and followed by *Crotalaria juncea* and *Vigna radiata* that was superior to mother soils (0.18).

Different parameters of T. Aman rice did not vary significantly due to different nitrogen levels at all the data recording stage in both the years. Because incorporation of different green manuring crops to the soil reduced 50% of recommended N levels of rice.

Different green manuring crops had significant influence on different parameter of T.Aman rice at all data recording stages. Plant height of transplant aman rice was significantly influenced by incorporation of green manures and different levels of nitrogen. At 75 DAT, the highest (128.13 cm and 134.67 cm in 2015 and 2016 respectively) plant height was obtained with the incorporation of T_2 (*Sesbania rostrata*) in both year. The T_6 (*V. unguiculata*) occupied second position in 1st year (2015) and T_1 (*S. aculeata*) in 2nd year (2016) and that of the lowest with *V. radiata* (119.47cm) and control (123.8 cm) at 75 DAT in 2015 and 2016 respectively. Number of total tillers hill^{-1} was significantly influenced at 2nd year but not 1st year except 25 DAT. The maximum total tillers hill^{-1} was found from the treatment *S. rostrata (15.35)* followed by *Vigna unguiculata* (14.96) and the lowest were found from control (12.26) in both years.

Panicle length and spikelet panicle $^{-1}$ was significantly influenced during second year (2016). The highest panicle length was recorded from *S. rostrata* followed by *C. juncea* during first year which was ultimately decreased in length in next year (2016). The highest number of spikelet panicle^{-1} was recorded from *S. aculeata* followed by *S. rostrata and C. juncea* during 2nd year. The highest panicle weight was found from *S. rostrata* and *L. leucocephala* during both years. Dry matter production of shoot and root increased with the age of rice plant up to harvest. Among the biomass, *S. rostrata* showed the highest TDM hill^{-1} at 30, 60 and 90 TDM of shoot and root respectively followed by T_1 (*S. aculeata*) but in second year dry matter accumulation was found little higher than first year.The lowest TDM of shoot and root was found from control plot where green manure was absent.The SPAD value recorded was highest at *S. rostrata* (43.77) followed by *Vigna mungo* (43.57) where as in second experiment, highest SPAD value was recorded from T_6 (*Vigna unguiculata*) (38.07) followed by *Vigna mungo* (37.83). The highest number of effective tillers hill^{-1} (12.00) was recorded in *Sesbania rostrata* incorporated plot followed by *Sesbania aculeata* (10.26) and the minimum value were found from no green manuring treated plot (T_0) in 2nd year. The *V. unguiculata* and *C. juncea* occupied third position in 2015 and 2016 respectively. As nitrogen encouraged tiller production, so the number of effective tillers hill^{-1} increased with the higher N fertiltzation. The maximum number of filled grains panicle^{-1} was obtained from *S. aculeata* from 1st year and *S. rostrata* from 2nd year. This may be additional supply of N through green manuring. Maximun unfilled grain panicle^{-1} was obtained from control plot in both years. Thousand grain weight, grain yield and straw yield was found highest from *S. rostrata* followed by *S. aculeata* in both years and lowest found from control. This may be steady and adequate supply of nutrients through plant nutrients. Plant nutrient become readily available for succeeding crop resulting improved yield of succeeding (T. Aman rice) and following crop (mustard). The variation in grain protein content was significant in 2nd year which ranged from 7.70% to 8.41% .The highest grain protein content was recorded in *S. rostrata* (8.41%) followed by *M. pudica* and (8.23%). The lowest result was found in control plot.

Interaction effect between green manuring crops and fertilizer doses had significant influence on plant height and tiller production at 75 DAS for both years. In 1st year, the maximum number of total tillers hill^{-1} was obtained from the variety *Vigna* *unguiculata* (15.5) and *S. rostrata* (15.7) at 50 DAT with 100% ha^{-1} N and *S. rostrata* (19.00) followed by *S. aculeata* (1.66) at 50% and 100% $NPKha^{-1}$ respectively. The number of highest rachis $panicle^{-1}$ were found from *S. rostrata* with 50% N fertilizer in 1st year and 100% NPK dose in 2nd year.The highest panicle length was observed from *S. rostrata* followed by *L. leucocephala* with 100% N dose in 1st year but 50% NPK dose in 2nd year. Dry matter of shoot and root production of transplant aman rice was significantly influenced by the interaction between green manures and fertilizer. The higher TDM of shoot was found from *S. rostrata* (2.0, 6.80 and 29.33g $hill^{-1}$) with 50% N ha^{-1} in 2015 which was at par with 100% NPK at 2nd year at 30, 60 and 90 DAT while lower TDM of shoot (1.05, 3.58 and 17.33 g $hill^{-1}$) was observed from the control in both 50% N ha^{-1} and 100% N ha^{-1}.Where, in case of root, 50% $NPKha^{-1}$ showed the highest result with *S. rostrata.* The effect of interaction between nitrogen and NPK levels and green manure crops were significant in respect of number of effective tillers $hill^{-1}$ throughout the growth period of the crop. In first year, the maximum number of effective tillers $hill^{-1}$ was produced by the treatment combination of the *S.aculeata* with 50% N ha^{-1} which was statistically similar to the 100% N ha^{-1}. Similar results were found in second year. Number of grains $panicle^{-1}$ was significantly influenced by the interaction between N and NPK and green manuring crops levels. The maximum number of grains $panicle^{-1}$ in both years were obtained from the incorporation of *S. rostrata* with 100% N ha^{-1} which was statistically at par with the *Sesbania aculeata* in both 100% and 50% N ha^{-1}. In both years, the highest 1000-grain weight (23.94g and 24.11g) was obtained from the treatment combination of the *S. rostrata* with 100% NPK and 100% N ha^{-1} which was statistically similar to the same variety under the 50% NPK and 50% N ha^{-1} levels (23.87g and 23.54g). The combined effect of green manures and nitrogen levels had a significant influence on grain yield. It was observed that in 2015 year, some green manures (*S. rostrata, S. aculeata,, C. juncea, V. mungo and V. unguiculata)* in combination with 100% fertilizer dose and rest green manures (*V. radiata*, *L. leucocephala* and *M. pudica*) with 50% N dose gave better yield over control. Whereas, in 2016, all green manures except *S. aculeata* showed the best performance in combination with 100% fertilizer dose over 50% fertilizer dose. The significant highest grain protein content from *S.rostrata* with 100 kg NPK ha^{-1} followed by *Vigna mungo*, however the value was statistically similar with other varieties when subjected to the highest doses of N fertilizer. The lowest one was recorded in control plot with

100 kg N ha^{-1}. Highest mustard yield also obtained from *S. rostrata* treated plot followed by *S. aculeata*. Germination%, germination energy, seedling length also found highest from *S. rostata* and *S. aculeata* under laboratory condition. After harvest of rice, soil organic matter was increase 73% and 19% from *Vigna mungo* and *S. aculeata* respectively with the combination of 100% N ha^{-1} in first year over control. In 2nd year, *S. rostrata* (63%) and *S. aculeata* (60%) increased organic matter with 100% NPK ha^{-1}. Soil nitrogen was increased from 0.04 to 0 .08% over initial soil (0.04%).The higher soil nitrogen was showed from *Vigna mungo* followed by S. *rostrata* in combination with 100% N ha^{-1} applied in first year. But in second year, the soil nitrogen showed little bit increased compared to first year and the highest was found from *S. rostrata* followed by *Crotalaria juncea* with 100% NPK ha^{-1}. K showed decreased trend in both year but P just reverse trend in second year both 50% NPKha^{-1} and 100% NPKha^{-1} with *S. rostrata*.

After mustard harvest, *S. rostrata* and *S. aculeata* showed higher accumulation (20%) of soil organic matter with 100% N compared to control in 1st year. Soil nitrogen was found 50% increased in both *S. rostrata* and *S. aculeata* with 100% N at both year.Soil K and P was found decreased trend in 1st year with 100% and 50% fertilizer. But in 2nd year *M. pudica* showed 109% increased soil K and *C. juncea* showed 44% increased soil P compared to control with 100% N.

CONCLUSION

Considering the above statement, it is concluded that four green manures *viz*. *S. rostrata, S. aculeata, C. juncea* and *V. unguiculata* were found to be effective green manures in terms of biomass, nodulation, nitrogen contribution and specially its incorporation into soil revealed the significant and positive effect of succeeding crop in the cropping pattern and soil quality as well.

The increased rice grain yields (52% and 42% in 1st and 2nd year) were obtained due to growing and incorporation of *Sesbania rostrata* followed by *S. aculeata* (46% and 41% in 1st and 2nd year) prior to T. aman rice in both years. This crops when incorporated into soil with 50% N or 50% NPK; produced higher and satisfactory yield of T. aman rice compared to that of 100% N and 100% NPK. Residual effect of *S. rostrata* and *S. aculeata* had also positive impact on the following crop mustard. Inclusion of *S. rostrata* in cropping pattern gave 59% and 64% yield increase over fallow pattern as well as monetary advantages (1,92,000 Tk ha^{-1} and 2,29,800 Tk ha^{-1}

in 1st and 2nd year) in two consecutive years. After two years of study, soil fertility levels i.e., N (125% and 100%), P (32 ppm and 7.93 ppm), K (127 meq/100g and 134 meq/100g), and organic matter (7% and 3%) were found increased with 100% fertilizer and 50% fertilizers due to *in situ* application of *S. rostrata* biomass. It was also observed that addition of biomass through *S. rostrata* grown before rice cultivation (succeeding crop) and Mustard (following crop) enriched the organic matter content of the soil very much. *S. rostrata* – T. aman – Mustard cropping pattern gave the highest rice equivalent yield as well as improved soil fertility followed by *C. juncea* – T.aman – Mustard, *S. aculeata* – T. aman – Mustard and *V. unguiculata*- T. aman- Mustard cropping pattern, so it may recommended for farmers for their betterment of soil as well as crop productivity.

RECOMMENDATION

For betterment of soil and higher monetary advantages, GM – T. aman – Mustard cropping pattern can be practiced instead of Fallow – T. aman – Mustard cropping pattern. The 50% reduction of chemical fertilizer can be recommended for succeeding T. aman rice from followed by growing *Sesbania rostrata, Sesbania aculeata, Crotalaria juncea* or *Vigna unguiculata* as a preceeding green manuring crop. As the 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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APPENDICES

Appendix 1. Initial soil data before crop planting

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

Appendix 2. Soil P^H data in of the experimental field GM-T-Aman-Mustard cropping pattern (two consecutive year)(LANDSCAPE 2-6)

Treatments	**1^{st} year**					**2^{nd} year**		
	Mother soil	After GM decomposition		After rice harvesting	After mustard harvesting	After GM decomposition (2^{nd})	After rice harvesting (2^{nd})	After mustard
T0	5.9	0	F1	6.0	5.0	5.0	6.0	6.6
T1		5.9		6.2	5.4	6.0	6.7	5.5
T2		6		6.1	5.0	5.6	7.1	6.5
T3		5.9		6.2	5.1	5.7	6.2	7.2
T4		6.0		6.2	5.0	5.5	6.2	6.1
T5		6.1		6.1	4.8	5.4	6.6	5.4
T6		6.2		6.1	5.3	5.9	6.2	5.6
T7		6.0		6.0	4.7	5.8	6.5	7.1
T8		6.1		6.3	4.7	6.2	6.7	6.1
T0			F2	6.2	5.5	5.5	5.9	5.2
T1				6.1	5.9	5.5	6.3	5.7
T2				6.4	5.5	5.7	6.4	5.2
T3				6.2	5.4	5.6	5.8	4.9
T4				6.2	5.3	5.6	5.9	5.0
T5				6.4	5.1	5.6	6.4	5.3
T6				6.2	5.8	5.7	6.3	4.9
T7				6.0	4.9	5.4	6.0	5.2
T8				6.1	5.5	5.7	6.0	6.6

Appendix 3. Soil organic matter data of the experiment field in GM-T-Aman-Mustard cropping pattern (two consecutive year)

Treatments	1st year				2nd year		
	Mother soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition(2nd)	After rice harvesting(2nd)	After mustard
T_0	1.01	1.01	1.01	1.01	1.01	1.23	.74
T_1		1.02	1.21	1.21	1.1	1.97	1.05
T_2		1.08	1.02	1.21	1.14	2.01	1.08
T_3		1.01	1.14	1.08	1.14	1.80	1.03
T_4		1.00	1.08	0.81	1.14	1.80	.86
T_5		0.95	1.75	0.94	1.34	1.56	.89
T_6		1.01	0.87	0.94	1.08	1.72	1.01
T_7		0.94	0.94	0.94	1.61	1.76	1.03
T_8		1.00	0.87	0.94	1.28	1.23	.94
T_0			0.54	1.00	1	1.31	.78
T_1			1.41	1.00	1.61	1.72	1.03
T_2			1.14	1.01	1.55	1.77	1.04
T_3			1.03	0.94	1.28	1.77	.90
T_4			0.81	0.81	1.28	1.72	.82
T_5			0.87	0.67	1.48	1.72	.90
T_6			1.21	0.94	1.34	1.56	.91
T_7			0.94	0.87	1.14	1.77	.83
T_8			0.87	0.81	1.14	1.51	.84

Appendix 4. Soil available nitrogen data of the experimental field in GM-T-Aman- Mustard cropping pattern (two consecutive year)

Treatments	1st year				2nd year		
	Mother soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition(2nd)	After rice harvesting(2nd)	After musterd
T_0	0.04	0.05	0.04	0.042	0.042	0.05	0.066
T_1		0.05	0.061	0.061	0.068	0.09	0.093
T_2		0.08	0.08	0.061	0.073	0.11	0.093
T_3		0.05	0.056	0.054	0.064	0.11	0.067
T_4		0.04	0.054	0.041	0.061	0.10	0.078
T_5		0.03	0.09	0.051	0.071	0.09	0.081
T_6		0.08	0.05	0.047	0.062	0.10	0.086
T_7		0.05	0.05	0.051	0.065	0.11	0.094
T_8		0.05	0.05	0.051	0.059	0.11	0.085
T_0			0.05	0.047	0.047	0.07	0.071
T_1			0.05	0.057	0.081	0.10	0.080
T_2			0.07	0.056	0.081	0.10	0.083
T_3			0.08	0.051	0.064	0.10	0.082
T_4			0.05	0.041	0.064	0.10	0.074
T_5			0.05	0.041	0.074	0.10	0.082
T_6			0.04	0.047	0.067	0.09	0.083
T_7			0.05	0.044	0.057	0.10	0.082
T_8			0.061	0.041	0.057	0.08	0.075

Appendix 5. Available soil K data of the experimental field in GM-T-Aman-Mustard cropping pattern (two consecutive year)

Treatments	1st year				2nd year		
	Mother soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition(2nd)	After rice harvesting(2nd)	After mustard
T_0	0.18	0.18	0.09	0.06	0.06	0.100	0.33
T_1		0.22	0.106	0.07	0.12	0.079	0.50
T_2		0.22	0.113	0.072	0.10	0.016	0.41
T_3		0.21	0.103	0.061	0.10	0.10	0.38
T_4		0.2	0.103	0.061	0.11	0.11	0.34
T_5		0.18	0.103	0.062	0.10	0.06	0.40
T_6		0.18	0.103	0.07	0.09	0.07	0.59
T_7		0.19	0.103	0.061	0.16	0.09	0.45
T_8		0.2	0.100	0.061	0.18	0.10	0.69
T_0		0	0.09	0.07	0.07	0.09	0.20
T_1			0.10	0.09	0.12	0.10	0.38
T_2			0.09	0.09	0.11	0.10	0.33
T_3			0.10	0.07	0.11	0.10	0.31
T_4			0.09	0.06	0.13	0.10	0.28
T_5			0.10	0.07	0.10	0.10	0.31
T_6			0.09	0.07	0.11	0.09	0.34
T_7			0.11	0.08	0.11	0.10	0.33
T_8			00.12	0.06	00.08	00.08	0.41

Appendix 6. Available soil P data of the experimentation in GM-T-Aman-Mastard cropping pattern (two consecutive year)

Treatments	1st year				2nd year		
	Mother soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition (2^{nd})	After rice harvesting(2^{nd})	After mustard
T_0	15.83	15.83	3.00	8.62	8.62	23.40	5.80
T_1		12.22	4.33	9.52	12.51	31.20	18.00
T_2		15.00	4.71	11.30	12.61	39.00	20.90
T_3		14.90	4.59	10.07	12.33	28.00	31.80
T_4		11.45	4.14	9.68	12.31	27.97	4.20
T_5		12.09	3.89	9.33	12.60	30.77	5.80
T_6		11.86	3.91	9.20	12.31	22.37	5.30
T_7		12.01	4.22	9.88	12.64	21.46	26.20
T_8		13.54	4.11	10.00	12.44	27.38	3.30
T_0		11.00	3.06	5.83	3.06	22.00	5.70
T_1		12.00	3.67	3.94	12.97	33.17	17.0
T_2		13.00	3.67	3.94	12.22	33.00	17.0
T_3		14.00	3.91	5.07	12.31	31.51	4.30
T_4		12.00	3.27	4.15	12.33	27.04	5.50
T_5		12.00	3.06	4.38	12.41	27.70	3.80
T_6		11.00	3.27	6.52	12.82	20.56	6.20
T_7		11.32	3.44	3.48	12.71	22.44	4.80
T_8		11.90	3.72	4.21	12.78	21.86	9.60

Appendix 7. Mean square values for plant height of Green manuring crops at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing					
		15		30		45	
		1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year
Replication	2	4.60	10.23	28.41	101.35	1020.17	1356.81
Green manuring crops	7	219.95**	216.19**	3731.61**	3119.18**	6804.94**	7445.04**
Error	14	7.63	11.39	24.99	29.97	590.16	410.69

**1% level of significance

Appendix 8.Mean square values for number of leaves of Green manuring crops at different days after Sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing					
		15		30		45	
		1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year
Replication	2	0.118	47.20	56.98	1571	100.23	2337
Green manuring crops	7	30.08**	13278.30**	516.05**	683423**	918.50**	707198**
Error	14	1.61	11.8	42.21	2275	44.49	3580

**1% level of significance

Appendix 9.Mean square values for dry matter plant^{-1} of Green manuring crops at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing					
		20		30		50	
		1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year
Replication	2	0.27	0.21	0.54	1.64	0.49	2.72
Green manuring crops	7	1.34*	0.07	6.58*	3.12*	10.04**	15.68*
Error	14	0.21	0.31	0.87	0.89	0.21	2.23

*5% level of significance

**1% level of significance

Appendix 10. Mean square values for number of nodule plant $^{-1}$ of Green manuring crops at different days after sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing			
		30		50	
		1st year	2nd year	1st year	2nd year
Replication	2	43.33	40.81	1.50	405
Green manuring crops	7	227.62**	486.94**	8.56**	15793.20**
Error	14	9.07	8.31	0.28	375.50

**1% level of significance

Appendix 11. Mean square values for fresh biomass and dry biomass of Green manuring crops at harvesting

Sources of variation	Degrees of freedom	Mean square values at harvesting			
		Fresh Biomass		Dry Biomass	
		1st year	2nd year	1st year	2nd year
Replication	2	60.76	5.51	0.39	.0009
Green manuring crops	7	164.85*	85.64**	3.74**	4.84**
Error	14	28.03	7.35	0.06	0.08

*5% level of significance

**1% level of significance

Appendix 12. Mean square values for plant height of T. aman rice at different days after Sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing					
		25		50		75	
		1st year	2nd year	1st year	2nd year	1st year	2nd year
Replication	2	5.68	6.77	3.02	135.39	6.00	27.04
Fertilizers	1	10.48	0.86	0.85	189.20	77.77	89.54
Error (a)	2	41.58	5.80	20.73	20.33	2.98	39.78
Green manure(GM)	8	23.53	47.72**	19.01	43.08	45.65*	67.57*
Fertilizer x GM	8	11.34	8.38*	13.41	16.69	22.50*	33.39
Error (b)	32	9.86	8.15	14.97	20.86	17.38	24.14

*5% level of significance

**1% level of significance

Appendix 13. Mean square values for tillers hill^{-1} of T. aman rice at different days after Sowing

Sources of variation	Degrees of freedom	Mean square values at different days after sowing					
		25		50		75	
		1st year	2nd year	1st year	2nd year	1st year	2nd year
Replication	2	0.09	2.30	7.68.	24.19	1.94	5.59
Fertilizers	1	0.006	7.91	8.24	0.16	0.009	6.86
Error (a)	2	6.56	6.89	1.50	2.88	0.64	1.57
GM	8	5.12**	5.83*	5.53	25.83**	0.68	20.75**
Fertilizer x GM	8	0.87*	0.70	2.65	2.39*	0.50	3.92*
Error (b)	32	.827	2.38	2.07	3.14	1.74	2.91

*5% level of significance

**1% level of significance

Appendix 1. Initial soil data before crop planting

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

Appendix 2. Soil P^H data in of the experimental field GM-T.aman-Mustard cropping pattern (twoconsecutive year)

Treatments	1st year					2nd year		
	Initial soil	After GM decomposition		After rice harvesting	After mustard harvesting	After GM decomposition(2nd)	After rice harvesting (2nd)	After mustard
T0	5.9	5.9	F1	6.0	5.0	5.0	6.0	6.6
T1		5.9		6.2	5.4	6.0	6.7	5.5
T2		6		6.1	5.0	5.6	7.1	6.5
T3		5.9		6.2	5.1	5.7	6.2	7.2
T4		6.0		6.2	5.0	5.5	6.2	6.1
T5		6.1		6.1	4.8	5.4	6.6	5.4
T6		6.2		6.1	5.3	5.9	6.2	5.6
T7		6.0		6.0	4.7	5.8	6.5	7.1
T8		6.1		6.3	4.7	6.2	6.7	6.1
T0			F2	6.2	5.5	5.5	5.9	5.2
T1				6.1	5.9	5.5	6.3	5.7
T2				6.4	5.5	5.7	6.4	5.2
T3				6.2	5.4	5.6	5.8	4.9
T4				6.2	5.3	5.6	5.9	5.0
T5				6.4	5.1	5.6	6.4	5.3
T6				6.2	5.8	5.7	6.3	4.9
T7				6.0	4.9	5.4	6.0	5.2
T8				6.1	5.5	5.7	6.0	6.6

Appendix 3. Soil organic matter (%)data of the experiment field in GM-T. aman-Mustard cropping pattern(two consecutive year)

Treatments	**1st year**				**2nd year**		
	Initial soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition(2nd)	After rice harvesting (2nd)	After mustard harvest
T_0	1.01	1.01	1.01	1.01	1.01	1.23	.74
T_1		1.02	1.21	1.21	1.1	1.97	1.05
T_2		1.08	1.02	1.21	1.14	2.01	1.08
T_3		1.01	1.14	1.08	1.14	1.80	1.03
T_4		1.00	1.08	0.81	1.14	1.80	.86
T_5		0.95	1.75	0.94	1.34	1.56	.89
T_6		1.01	0.87	0.94	1.08	1.72	1.01
T_7		0.94	0.94	0.94	1.61	1.76	1.03
T_8		1.00	0.87	0.94	1.28	1.23	.94
T_0			0.54	1.00	1	1.31	.78
T_1			1.41	1.00	1.61	1.72	1.03
T_2			1.14	1.01	1.55	1.77	1.04
T_3			1.03	0.94	1.28	1.77	.90
T_4			0.81	0.81	1.28	1.72	.82
T_5			0.87	0.67	1.48	1.72	.90
T_6			1.21	0.94	1.34	1.56	.91
T_7			0.94	0.87	1.14	1.77	.83
T_8			0.87	0.81	1.14	1.51	.84

Appendix 4.Soil totalnitrogen (%) data of the experimental field in GM-T.aman- Mustard cropping pattern (twoconsecutive year)

Treatments	1st year				2nd year		
	Initial soil	After GM decomposition (1st year)	After rice harvesting (1st year)	After mustard harvesting (1st year)	After GM decomposition (2nd year)	After rice harvesting (2nd year)	After mustard (2nd year)
T_0	0.04	0.04	0.04	0.042	0.042	0.05	0.066
T_1		0.05	0.061	0.061	0.068	0.09	0.093
T_2		0.08	0.08	0.061	0.073	0.11	0.093
T_3		0.05	0.056	0.054	0.064	0.11	0.067
T_4		0.04	0.054	0.041	0.061	0.10	0.078
T_5		0.03	0.09	0.051	0.071	0.09	0.081
T_6		0.08	0.05	0.047	0.062	0.10	0.086
T_7		0.05	0.05	0.051	0.065	0.11	0.094
T_8		0.05	0.05	0.051	0.059	0.11	0.085
T_0			0.05	0.047	0.047	0.07	0.071
T_1			0.05	0.057	0.081	0.10	0.080
T_2			0.07	0.056	0.081	0.10	0.083
T_3			0.08	0.051	0.064	0.10	0.082
T_4			0.05	0.041	0.064	0.10	0.074
T_5			0.05	0.041	0.074	0.10	0.082
T_6			0.04	0.047	0.067	0.09	0.083
T_7			0.05	0.044	0.057	0.10	0.082
T_8			0.061	0.041	0.057	0.08	0.075

Appendix 5. Available soil K(meq/100g) data of the experimental field in GM-T. aman-Mustard cropping pattern (twoconsecutive year)

Treatments	1st year				2nd year		
	Initial soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition	After rice harvesting	After mustard
T_0	0.18	0.18	0.09	0.06	0.06	0.100	0.33
T_1		0.22	0.106	0.07	0.12	0.079	0.50
T_2		0.22	0.113	0.072	0.10	0.016	0.41
T_3		0.21	0.103	0.061	0.10	0.10	0.38
T_4		0.2	0.103	0.061	0.11	0.11	0.34
T_5		0.18	0.103	0.062	0.10	0.06	0.40
T_6		0.18	0.103	0.07	0.09	0.07	0.59
T_7		0.19	0.103	0.061	0.16	0.09	0.45
T_8		0.2	0.100	0.061	0.18	0.10	0.69
T_0		0	0.09	0.07	0.07	0.09	0.20
T_1			0.10	0.09	0.12	0.10	0.38
T_2			0.09	0.09	0.11	0.10	0.33
T_3			0.10	0.07	0.11	0.10	0.31
T_4			0.09	0.06	0.13	0.10	0.28
T_5			0.10	0.07	0.10	0.10	0.31
T_6			0.09	0.07	0.11	0.09	0.34
T_7			0.11	0.08	0.11	0.10	0.33
T_8			00.12	0.06	00.08	00.08	0.41

Appendix 6. Available soil P(ppm) data of the experimentation in GM-T.aman- Mustard cropping pattern (two consecutive year)

Treatments	1st year				2nd year		
	Initial soil	After GM decomposition	After rice harvesting	After mustard harvesting	After GM decomposition	After rice harvesting	After mustard
T_0	15.83	15.83	3.00	8.62	8.62	23.40	5.80
T_1		12.22	4.33	9.52	12.51	31.20	18.00
T_2		15.00	4.71	11.30	12.61	39.00	20.90
T_3		14.90	4.59	10.07	12.33	28.00	31.80
T_4		11.45	4.14	9.68	12.31	27.97	4.20
T_5		12.09	3.89	9.33	12.60	30.77	5.80
T_6		11.86	3.91	9.20	12.31	22.37	5.30
T_7		12.01	4.22	9.88	12.64	21.46	26.20
T_8		13.54	4.11	10.00	12.44	27.38	3.30
T_0			3.06	5.83	3.06	22.00	5.70
T_1			3.67	3.94	12.97	33.17	17.0
T_2			3.67	3.94	12.22	33.00	17.0
T_3			3.91	5.07	12.31	31.51	4.30
T_4			3.27	4.15	12.33	27.04	5.50
T_5			3.06	4.38	12.41	27.70	3.80
T_6			3.27	6.52	12.82	20.56	6.20
T_7			3.44	3.48	12.71	22.44	4.80
T_8			3.72	4.21	12.78	21.86	9.60

Appendix 14: Summary of analysis of variance for yield and yield contributing component of T. aman rice atharvest

Source of variation	Degrees of freedom	Panicle length		Panicle weight		Effective tillers hill^{-1}		Non effective tillers hill^{-1}		Filled grain panicle^{-1}		Unfilled grain panicle^{-1}	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Replication	2	2.45	1.32	2.45	0.03	6.03	3.58	0.44	0.21	115.93	14.54	7.10	62.46
Fertilizers	1	1.17	1.43	1.17	0.01	0.09	0.47	0.32	0.02	2978.29	152.47	4.72	189.55
Error (a)	2	2.34	0.20	2.34	0.008	2.32	1.38	1.17	0.24	299.14	22.61	74.90	23.14
GM	8	2.22	2.38*	2.22*	0.32**	14.25**	8.94*	1.91*	0.29*	2103.04**	350.49**	51.92	67.31
Fertilizer x GM	8	1.67	0.64	1.67*	0.016*	0.32*	1.66*	0.23*	0.13	204.87*	123.64*	19.59	22.61
Error (b)	32	1.99	1.31	1.99	0.02	1.97	1.71	0.68	0.10	261.69	71.46	36.86	53.82

*5% level of significance

**1% level of significance

Appendix 15: Summary of analysis of variance for crop characters, yield and yield contributing component of T. aman rice at harvest

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Source of variation	Degrees of freedom	30				60				90				Spikelets panicle^{-1}	
		Shoot wt.		Root wt.		Shoot wt.		Root wt.		Shoot wt.		Root wt.			
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Replication	2	0.23	1.79	0.04	0.11	3.60	121.42	4.29	12.38	55.70	55.11	14.11	32.74	2.63	5.50
Fertilizers	1	0.37	0.13	0.04	0.003	0.50	6.93	1.10	2.02	51.60	15.19	.02	2.99	0.00	10.97
Error (a)	2	0.00	0.18	0.11	0.69	4.59	37.37	1.17	0.12	23.17	5.10	1.18	4.94	0.44	5.28
GM	8	0.66	2.62*	0.14	0.41	7.10*	52.22*	0.83*	3.67**	8.07*	80.74*	6.01*	1.27	1.87	22.36*
Fertilizer x GM	8	0.47	0.54*	0.07	0.43	1.84*	22.56	0.49*	0.50*	48.47	2.55*	2.03*	0.96	0.44	5.79*
Error (b)	32	0.28	0.80	0.13	0.24	2.25	18.64	0.65	0.87	12.68	18.01	0.87	1.78	0.30	5.91

*5% level of significance

**1% level of significance

Appendix 16: Summary of analysis of variance for crop characters, yield and yield contributing component of T. aman rice at harvest

Source of variation	Degrees of freedom	1000-grain wt		Grain yield		Straw yield		SPAD value		Protein content
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	2nd
Replication	2	0.03	0.22	0.36	1.00	8.54	4.59	2.57	23.97	0.01
Fertilizers	1	0.42	0.004	0.13	0.50	0.05	0.03	6.55	13.51	0.02
Error (a)	2	1.17	0.07	0.03	0.16	0.30	0.22	6.54	2.32	0.001
GM	8	1.55*	0.86**	2.00**	1.52**	0.97*	3.18**	0.18	6.71	0.21**
Fertilizer x GM	8	1.03*	0.30*	0.28*	0.18*	0.37	0.30*	7.13	1.94	0.04*
Error (b)	32	0.69	0.21	0.14	0.14	0.50	0.32	7.18	4.37	0.02

*5% level of significance

**1% level of significance

Appendix 17: Summary of analysis of variance for crop characters, yield and yield contributing component of Mustardat harvest

Source of variation	Degrees of freedom	Plant height		Siliquae plant^{-1}		Siliqua length		Seeds siliquae^{-1}	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Replication	2	123.20	151.94	27.14	1451.91	0.20	0.611	246.18	2.13
Fertilizers	1	6.99	1.14	1.26	0.13	0.17	0.040	43.82	1.94
Error (a)	2	99.13	80.32	0.33	315.50	0.04	0.114	6.46	7.61
GM	8	96.99**	157.56**	136**	348.18*	1.68**	0.566**	108.46**	8.88*
Fertilizer x GM	8	33.27	46.55	5.35*	86.65	0.14*	0.097*	13.76	3.12*
Error (b)	32	29.34	48.85	12.20	121.03	0.07	0.12	12.82	3.56

*5% level of significance

**1% level of significance

Appendix 18: Summary of analysis of variance for crop characters, yield and yield contributing component of Mustardat harvest

Source of variation	Degrees of freedom	1000-seed yield		Seed yield		Stover yield	
		1^{st} year	2^{nd} year	1^{st} year	2^{nd} year	1^{st} year	2^{nd} year
Replication	2	0.34	0.000	558302	96844	18429	72531
Fertilizers	1	0.034	.008	18305	55601	3818	14613
Error (a)	2	0.10	.001	33895	118669	39212	600301
GM	8	2.19^{**}	0.182^{**}	277426^{*}	97258^{*}	373885^{**}	504706
Fertilizer x GM	8	0.04^{*}	0.009^{*}	38214	63327^{*}	26363^{*}	97400
Error (b)	32	0.17	0.008	52024	44094	30316	713635

*5% level of significance

**1% level of significance

APPENDIX 15: Landscape

Plate 1. A view of 50-days older plots with different green manure

(a) **(b)**

Plate 2. View of 50-days older *S. rostrata* (a-retained nodule both in stem and root) and *S. aculeata* (b-retained nodule only in root)

Plate 3: Panicle initiation stage (a) and harvesting stages (b) of T. Aman plot (subsequent crop)

Plate 4: Mustard plot as a following crop

Plate 5. Residual effect of green manuring crops to mustard

Plate 6. Different green manure crops incorporated T. Aman seed sprouting under laboratory condition (Replication 1, Replication 2 and Replication 3)