INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
19–0754/2019/22–5–1043–1049
DOI: 10.17957/IJAB/15.1167
http://www.fspublishers.org

Full Length Article

Sesbania Green Manuring Improved Soil Health and Productivity of Autumn Maize under Varying Nitrogen Rates

Muhammad Atif Shabir[1*], Haroon Zaman Khan[1*], Muhammad Farrukh Saleem[1] and Muhammad Anwar Ul Haq[2]
[1]*Department of Agronomy, University of Agriculture, Faisalabad, Pakistan*
[2]*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan*
[*]For correspondence: haroon679@hotmail.com; aatif.shabir@yahoo.com

Abstract

Integrated soil fertility management not only helps to prevent soil degradation but also ensures food security. The present study was conducted to assess the impact of sesbania green manuring (GM) and different nitrogen (N) application levels on soil properties and maize productivity. Maize was grown using six nitrogen levels *i.e*., 0. 50, 100, 150, 200 and 250 kg ha^{-1} along with sesbania GM and without GM. The GM improved grain yield (+21%, +37%) due to significant increase in number of grains/cob (+13%, +29%) and 1000-grain weight (+14%, +38%) during autumn 2016 and 2017 respectively. Likewise, GM also resulted in substantial increase in organic matter (OM) (+40%, +88%), organic carbon (OC) (+39%, +88%), available nitrogen (N) (+55%, +210%), total phosphorus (P) (+14%, +112%), and potassium (K) (+11.6%, +19%) as compared with no GM. Similarly, application of N at 250 kg ha^{-1} observed higher number of grains/cob, 1000-grain weight, biological and grain yield compared with control and other N levels. However, interactive effect of GM and N showed that application of N at 150 kg ha^{-1} along with GM, outperformed in improving number of grains per cob, 1000-grain weight, maize productivity and agronomic N efficiency. In conclusion, sesbania GM improved the soil OM, OC and total soil N compared with no GM. Moreover, GM along with N application at 150 kg ha^{-1} harvested higher maize grain yield, agronomic N efficiency and saved 40% N compared with no GM where N at 250 kg ha^{-1} harvested higher grain yield.

Keywords: Food security; Green manuring; Nitrogen; Productivity; Soil properties

Introduction

Farmers generally apply excessive doses of macro nutrients like nitrogen (N) and phosphorus (P) to get higher crop yield. However, the expected yields cannot be achieved instead of increased doses of these nutrients (Vitousek *et al.,* 2009; Chen *et al.,* 2011). The average ratio of farmer's yield over potential yield is 0.41 (Meng *et al.,* 2013), which indicates a huge yield gap for maize (*Zea mays* L.). Significant amount of applied N fertilizer is lost into the environment (Ju *et al.,* 2009), through nitrates leaching to groundwater (Zhou *et al.,* 2016) and greenhouse gas emissions (Zheng *et al.,* 2004). Nonetheless, increasing food demand due to ever rising population and rising environmental problems necessitates improving crop yield and efficiency of applied nutrients (Chen *et al*., 2014; Yu *et al*., 2015). Therefore, it is direly needed to get more grain yield with eco-friendly approach, *e.g*., reduced nutrient losses (Vitousek *et al.,* 2009; Chen *et al*., 2011).

Replacement of artificial nutrient by green manuring (GM) can significantly reduce the use of chemical fertilizers in agriculture (Xie *et al.,* 2016). Green manuring is the promising strategy to improve nutrient utilization efficiencies and therefore, prevents the loss of nutrients (Elfstrand *et al.,* 2007; Yasmeen *et al.,* 2018). Moreover, GM improves water holding capacity, porosity, soil fertility, soil structure and decreased the soil pH. It has central role in integrated nutrient management; as it markedly increases the efficiency of applied fertilizers and increased OM contents which leads to increase in availability of other nutrients (N, P, K) and overall soil fertility (Salim *et al.,* 2003).

More nutrient utilization and crop growth by the application of GM are linked with the improved physicochemical properties of soil (carbon and N contents, bulk density and water conductivity) (Mandal *et al.,* 2003; Wasaya *et al.*, 2018). Nitrogen provided by GM can be available for plants over a long time when it is co-applied with synthetic N (Yang *et al.,* 2015). The co-application of inorganic fertilizers and GM restores degraded soils and improves the nutrient use efficiency than sole utilization of synthetic fertilizers (Monedero *et al.,* 2004). With the addition of GM the availability of N to the next crop plants increased (Ashraf *et al.,* 2004). Nutrients from organic sources are released slowly and they are available for longer time for microbial activities which in turns increases their availability and thereby crop yield (Talgre *et al.,* 2012).

To cite this paper: Shabir, M.A., H.Z. Khan, M.F. Saleem and M.A.U. Haq, 2019. Sesbania green manuring improved soil health and productivity of autumn maize under varying nitrogen rates. *Intl. J. Agric. Biol*., 22: 1043–1049

Organic matter level in soil is a key indicator for the efficiency of green manure incorporation. For the sustenance of agricultural productivity, OM is important as it provides different basic nutrient to the plants. Intensive agriculture has degraded the soil and yield owing to reduction in OM (Lal, 1996). Under low input situations, the application of GM enhanced the soil OM level. In earlier studies, Nkonya *et al.* (2005) and Marin *et al.* (2007) found that combination of mineral and organic fertilization showed significant improvement in the soil N and soil OM contents. Moreover, the type of GM and its decomposition determined the quantity of OM accumulation in the soils.

Some earlier studies unveiled that GM improved the maize yield up to 44% and restores soil fertility (Mureithi *et al.*, 2002; Odhiambo *et al.*, 2010). Moreover, GM can also reduce the dependence on the application of inorganic N. Therefore, this two-year field study was designed with the hypothesis that GM has the potential to improve soil health and crop yield along with sizable reduction in N requirement of maize crop.

Materials and Methods

Experimental Site, Soil and Climate

This study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan during autumn 2016 and 2017. Before sowing and after harvesting, soil samples were taken from each experimental plot from 0–30 cm depth using auger to determine soil physiochemical properties given in Table 1. The study site comes under sub-tropical regions and weather data during the crop growing season of both years is given as Table 2.

Treatment Description and Experimental Design

Maize was grown using six N levels *i.e.*, 0, 50, 100, 150, 200 and 250 kg ha^{-1} with GM and without GM. Sesbania was sown on 28th and 26th May by broadcasting the seed in field during 2016 and 2017 respectively and was incorporated into the soil at the blooming stage (45 days after sowing) as GM while fallow was taken as without GM. The maize crop was sown on July 28 and July 24 in 2016 and 2017, respectively. The experiment was laid out following randomized complete block design (RCBD) with split plot arrangement keeping GM in main plots and N levels in sub-plots. The experiment was replicated three times in both years with net plot size of 5 m × 3 m.

Crop Husbandry

Seedbed was prepared by two ploughing followed by one planking. Pioneer 30Y87 single cross maize hybrid was sown by dibbling method on a well prepared seed bed in both years. The crop was sown in 75 cm apart rows with 25 cm plant to plant distance using seed rate of 25 kg ha^{-1}. First irrigation was applied post 25 days after sowing, whilst remaining irrigations were applied; after an interval of 15 days until the crop reached to flowering, after that, irrigation was applied after every 7 day until the seed formation. Other than N, both P and K were applied at; 125 kg ha^{-1} using single super phosphate (SSP) and sulphate of potash (SOP). Complete P, K and half of N was applied using urea as a source for N at sowing and remaining half N was applied with first irrigation.

Observations

Yield and Related Traits

Ten cobs from each plot were selected and total number of grains were counted and averaged to record number of grains per cob and weighed to determine the 1000-grain weight. Crop from each plot was harvested at maturity and sun dried separately. The cobs along with stalks were weighed on digital balance to determine biological yield which was converted into t ha^{-1}. After shelling, grain weight of each plot was recorded and converted into t ha^{-1} following Mehboob *et al*. (2018).

Agronomic Nitrogen Efficiency (kg kg^{-1})

Agronomic efficiency of N was calculated as:

$$\text{Agronomic N efficiency} \quad \frac{\text{Grain yield of N fertilized plot- Grain yield of unfertilized plot}}{\text{Quantity of N applied}}$$

Soil Properties

Using the standard modified methodology of Walkley-Black method, OM and OC were determined (Moodie *et al.*, 1959). For the determination of N, P and K, Kjeldhal (VELP scientifica, UDK, 126 D) (1883), Olsen (1954) and Hanway and Heidel (1952) methods were used respectively.

Statistical Analysis

Collected data were statistically analyzed by analysis of variance technique by using MSTAT-C and difference amid treatments was compared by using least-significant difference test at 5% probability (Steel *et al.*, 1997).

Results

The application of N at different levels and GM had significant effect on number of grains per cob, 100-grain weight, grain yield and biological yield during both years of study. Moreover, the interaction of GM × N significantly affected the number of grains per cob and grain yield during both years of study while 100-grain weight during 2nd year of study only (Table 3).

Green manuring compared with no GM, and higher levels of N application compared with control and lower N

Table 1: Physico-chemical analysis of soil

	2016		2017	
	No green manuring	Green manuring	No green manuring	Green manuring
Organic matter (%)	0.58	0.72	0.56	0.93
Organic carbon (%)	0.44	0.54	0.42	0.70
Total soil nitrogen (%)	0.065	0.07	0.054	0.10
Available phosphorus (mg kg^{-1})	4.96	5.00	4.61	6.97
Available potassium (mg kg^{-1})	169.39	179.09	171.36	193.14

Table 2: Weather conditions during both growth seasons

Months	Maximum mean temperature(^{0}C)		Monthly total rainfall (mm)	
	2016	2017	2016	2017
July	32.2	33.5	193.4	160.9
August	31.1	33.2	47.9	66.3
September	31.0	30.5	12.0	35.6
October	26.7	27.1	22.2	0.0
November	20.1	18.0	0.0	1.5

Source: Meteorological Observatory, Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan

Table 3: Effect of green manuring and different nitrogen rates on yield and related traits of autumn sown maize

Treatments	Number of grains/cob		1000-grain weight (g)		Grain yield (t ha^{-1})		Biological yield (t ha^{-1})	
	2016	2017	2016	2017	2016	2017	2016	2017
No green manuring	296 B	290 B	249 B	249 B	3.42 B	3.34 B	11.2 B	11.4 B
Green manuring	336 A	376 A	284 A	345 A	4.15 A	4.58 A	13.3 A	13.9 A
LSD value at 5%	6.57	46.7	19.6	24.7	0.06	0.14	0.20	2.16
Nitrogen levels (kg ha^{-1})								
0	216 F	223 D	163 E	224 C	2.31 F	2.42 E	8.8 D	9.02 B
50	252 E	247 D	200 D	247 BC	2.79 E	2.81 D	9.2 CD	9.83 B
100	308 D	317 C	255 C	272 B	3.38 D	3.42 B	11.0 C	11.4 B
150	348 C	385 B	268 C	346 A	4.14 C	4.80 B	12.8 B	14.6 A
200	374 B	399 B	330 B	340 A	4.63 B	4.95 B	14.3 B	15.1 A
250	401 A	429 A	381 A	356 A	5.46 A	5.37 A	17.5 A	15.8 A
LSD value at 5%	12.3	290 B	22.3	37.9	0.24	0.19	1.77	2.47
GM×NL	*	*	NS	*	*	*	NS	NS

Means sharing different letters within a column differ from each other at $P \leq 0.05$
NS = non-significant; * = Significant at $P \leq 0.05$

levels significantly improved number of grains/cob, 1000-grain weight, grain and biological yields of autumn sown maize in both years of study (Table 3). Maximum 1000-grain weight was recorded when N was applied at 250 kg ha^{-1} during first year while biological yield during both years of study (Table 3). However, during autumn 2017, maximum 1000-grain weight was recorded by application of N at 250 kg ha^{-1} along with GM which was statistically similar with N application at 150 and 200 kg ha^{-1} (Fig. 2).

Likewise, maximum number of grains per cob were recorded where GM was practiced along with application of N at 250 kg ha^{-1} during both years of experimentation but was statistically at par with N application at 150 and 200 kg ha^{-1} during second year of study (Fig. 1). Moreover, maximum grain yield was noticed where GM was done along with N application at 250 kg N ha^{-1} during first year, and during 2nd year maximum was with GM and N application at 150 kg N ha^{-1} which was statistically similar with 200 and 250 kg N ha^{-1} (Fig. 3).

Soil Properties

GM application had significant effect on all soil characters while N application had non-significant effect on the all soil characteristics except total N. Likewise, interaction of GM and N rates was also non-significant for all the parameters except total N (Table 5).

Maximum OM and OC was recorded with GM and minimum OM and OC was by no GM (Table 5). Likewise, maximum total N, available P and available K was noted in GM plots, whereas the minimum total N, available P and available K was recorded from plots where no GM was done (Table 4). Similarly, interactive effect of GM and N rates improved the total soil N during second year of study (Fig. 4).

Agronomic Nitrogen Efficiency

Agronomic N efficiency was also improved by the application of GM and different N rates. In 2016, maximum agronomic N efficiency was recorded with GM as compared with no GM (Table 4). In case N application, maximum agronomic N efficiency was recorded with application of N at 150 kg ha^{-1} during first year (Table 4). During second year, the maximum agronomic N efficiency was recorded with GM along with N application at 150 kg ha^{-1} (Fig. 5).

Table 4: Effect of green manuring and different nitrogen rates on soil properties of autumn sown maize

Treatments	Organic matter (%)		Organic carbon (%)		Total soil nitrogen (%)		Available phosphorus (ppm)		Available potassium (ppm)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
No green manuring	0.55 B	0.53 B	0.41 B	0.40 B	0.06 B	0.05 B	4.77 B	4.49 B	165 B	169 B
Green manuring	0.77 A	1.00 A	0.57 A	0.75 A	0.09 A	0.15 A	5.48 A	9.56 A	1846 A	201 A
LSD value at 5%	0.10	0.07	0.07	0.05	0.03	2.90	0.44	0.21	17.6	14.3
Nitrogen levels (kg ha^{-1})										
0	0.62	0.72	0.47	0.54	0.06 D	0.08 E	5.05	6.83	172	183
50	0.63	0.74	0.47	0.56	0.07 CD	0.09 D	5.08	7.01	173	184
100	0.64	0.76	0.48	0.57	0.07 C	0.09 CD	5.12	7.04	174	185
150	0.67	0.78	0.50	0.58	0.08 BC	0.10 C	5.14	7.04	175	186
200	0.68	0.79	0.51	0.59	0.08 B	0.11 B	5.15	7.10	176	186
250	0.70	0.81	0.52	0.61	0.09 A	0.13 A	5.19	7.13	179	188
LSD value at 5%	NS	NS	NS	NS	0.01	0.01	NS	NS	NS	NS
GM×NL	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

Means sharing different letters within a column differ from each other at $P \leq 0.05$
NS = non-significant; * = Significant at $P \leq 0.05$

Table 5: Effect of green manuring and different nitrogen rates on agronomic nitrogen efficiency of autumn sown maize

Sources	Agronomic nitrogen efficiency (kg kg^{-1})	
	2016	2017
No green manuring	10.5 B	9.02 B
Green manuring	12.2 A	14.3 A
LSD value at 5%	0.69	1.69
Nitrogen levels (kg ha^{-1})		
0	_	_
50	9.63 C	7.90 D
100	10.7 BC	9.98 C
150	12.2 A	15.9 A
200	11.4 AB	12.7 B
250	12.6 A	11.8 B
LSD value at 5%	1.43	1.42
GM×NL	NS	*

Means sharing different letters within a column differ from each other at $P \leq 0.05$
NS = non-significant; * = Significant at $P \leq 0.05$

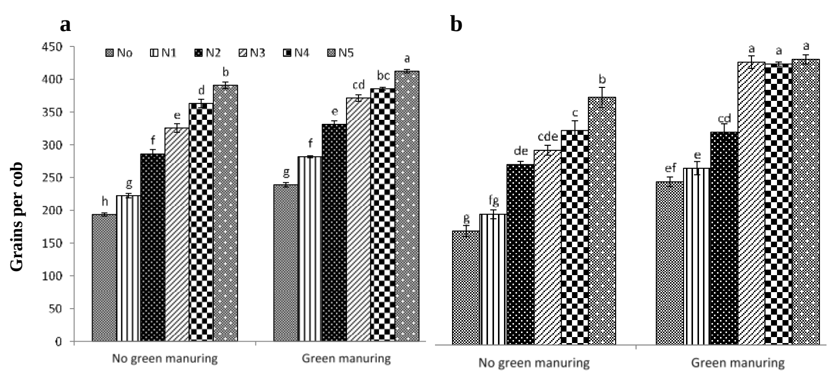

Fig. 1: Interactive effect of green manuring and nitrogen levels on number of grains per cob in autumn 2016 (**a**) and autumn 2017 (**b**). N_0=0 kg N ha^{-1}: N_1=50 kg N ha^{-1}: N_2=100 kg N ha^{-1}: N_3=150 kg N ha^{-1}: N_4=200 kg N ha^{-1}: N_5=250 kg N ha^{-1}

Discussion

Results of this two-year field study indicated that GM and different N application levels significantly improved the soil properties and maize productivity. Higher grain yield was due to increase in number of grains per cob and 100-grain weight with the application of N and GM (Table 3); as the number of grains per cob and 1000-grain weight are key yield attributes of maize (Shah *et al.,* 2009). In this studies, the increase in number of grains per cob and 1000-grain weight were due to improved soil fertility as evident from higher soil OM, soil OC and rhizosphere nutrient pool (N, P, K) which lead to healthier plant with better photosynthesis and assimilates formation and translocation towards developing grains (Aziz *et al.*, 2010; Laekemariam and Gidago, 2012). In addition, the soil receiving organic amendment and adequate N supply also had significant enhancement in number of grains per cob and 1000-grain weight (Shah and Ahmad, 2006; Shah *et al.,* 2009; Odhiambo *et al.,* 2010; Nielsen, 2013).

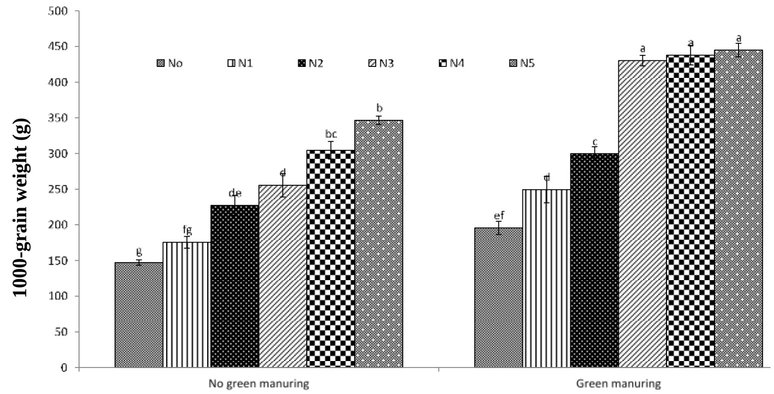

Fig. 2: Interactive effect of green manuring and nitrogen levels on 1000-grain weight in autumn 2017. N_0=0 kg N ha^{-1}: N_1=50 kg N ha^{-1}: N_2=100 kg N ha^{-1}: N_3=150 kg N ha^{-1}: N_4=200 kg N ha^{-1}: N_5=250 kg N ha^{-1}

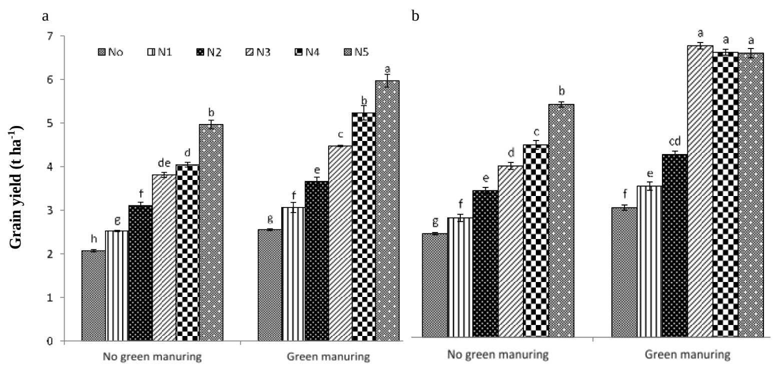

Fig. 3: Interactive effect of green manuring and nitrogen levels on grain yield (t ha^{-1}) in autumn 2016 (**a**) and autumn 2017 (**b**). N_0=0 kg N ha^{-1}: N_1=50 kg N ha^{-1}: N_2=100 kg N ha^{-1}: N_3=150 kg N ha^{-1}: N_4=200 kg N ha^{-1}: N_5=250 kg N ha^{-1}

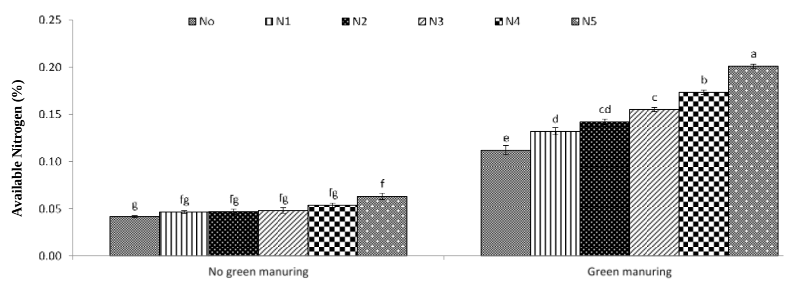

Fig. 4: Interactive effect of green manuring and nitrogen levels on soil available nitrogen in 2017. N_0=0 kg N ha^{-1}: N_1=50 kg N ha^{-1}: N_2=100 kg N ha^{-1}: N_3=150 kg N ha^{-1}: N_4=200 kg N ha^{-1}: N_5=250 kg N ha^{-1}

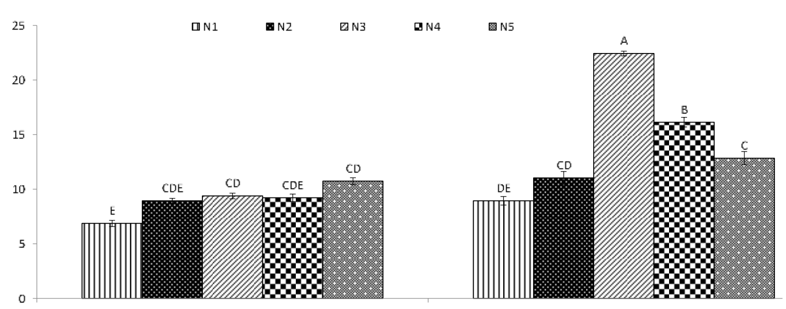

Fig. 5: Interactive effect of green manuring and nitrogen levels on agronomic use efficiency in autumn 2017. N_1=50 kg N ha^{-1}: N_2=100 kg N ha^{-1}: N_3=150 kg N ha^{-1}: N_4=200 kg N ha^{-1}: N_5=250 kg N ha^{-1}

Nutrient fertilization in optimum amount and their continuous supply during whole growing season is important for grain formation and to avoid grain abortion (Nielsen, 2013).

Sesbenia GM significantly improved the soil OM and OC as green manure addition in soil increased microbial population and respiration which increases the decomposition of added material and results in significant improvement in soil OC and OM contents (Paul and Solaiman, 2004; Nawaz *et al.,* 2017; Perdigão *et al.,* 2017) as was recorded in this study (Table 4). The incorporation of GM drives long-term increase of soil microbial biomass and OM (Chander *et al.,* 1997; Biederbeck *et al.,* 1998) and which further improves the N- uptake efficiency and nutrient retention (Cherr *et al.,* 2006). The growing of perennial GM imports additional nutrients as P and K owing to deeper root system from soil which remain accessible for the succeeding crops (Witter and Johansson, 2001) and improved the growth and productivity of crops as recorded in this study (Table 4).

Green manuring also significantly improved the total soil N, P and K contents during both years as the addition of GM into the soils is even effective in releasing nutrients up to three year of plantation (Talgre *et al.,* 2012). Sesbania crop forms symbiotic relationships with the gram negative rhizobia which led to formation of N fixing nodule on the plant root and stem therefore, increased the N pool in the soil (Capoen *et al.,* 2010) as maximum N, P and K was recorded in the plots where GM was done during both years (Table 4). Likewise, Ali *et al.* (2012) noticed that sesbania manuring improves the soil OM, NPK status, soil porosity and decreased the soil pH. Moreover, sesbania GM considerably increased the soil P and K status (Table 4) as the incorporation of GM crops in the soil increased the activities of important micro-organism which increased the mineralization process and therefore, increased the release availability of N, P and K in soil (Adekiya *et al.,* 2017).

The application of different N rates and GM also improved the agronomic N efficiency during both years of experimentation as the conjunctive use of chemical and organic fertilizers improves the soil health and plant nutrient availability (Ayeni *et al.,* 2008). The application of nutrient in an integrated manner ensures the maximum use of native N components as OM, crop residues, and biological nitrogen fixation along with improvement in N recovery (Olesen *et al.,* 2004). In a study, Aulakh and Malhi (2004) reported significant improvement in agronomic N efficiency due to positive interactions among the organic and inorganic sources of plant nutrient.

Conclusion

Green manuring with N application at 150 kg ha^{-1} observed the same maize productivity as was obtained by application of N at the rate 250 kg ha^{-1} without GM. Improvement in maize yield with GM was linked with enhanced soil OM and availability of nutrients. In conclusion, GM improved soil properties, maize productivity and reduced the N requirement of maize crop by more than 40%.

References

Adekiya, A.O., T.M. Agbede, C.M. Aboyeji, O. Dunsin and J.O. Ugbe, 2017. Green manures and NPK fertilizer effects on soil properties, growth, yield, mineral and vitamin C composition of okra (*Abelmoschus esculentus* (L.) Moench). *J. Saud. Soc. Agric. Sci.,* 5: 1–6

Ali, R.I., T.H. Awan, M. Ahmad, M.U. Saleem and M. Akhtar, 2012. Diversification of rice-based cropping systems to improve soil fertility, sustainable productivity and economics. *J. Anim. Plant Sci.,* 22: 108–112

Ashraf, M., T. Mahmood, F. Azam and R.M. Qureshi, 2004. Comparative effects of applying leguminous and non-leguminous green manures and inorganic N on biomass yield and nitrogen uptake in flooded rice (*Oryza sativa* L). *Biol. Fert. Soils,* 40: 147–152

Aulakh, M.S. and S.S. Malhi, 2004. Fertilizers N use efficiency as influenced by interactions with other nutrients. *In*: *Agriculture and the N Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment*, pp: 181–191. Mosier, A.R., J.K. Syers and J.R. Freney (Eds.). Paris, France

Ayeni, L.S., M.T. Adetunji, S.O. Ojeniyi, B.S. Ewulo and A.J. Adeyemo, 2008. Comparative and cumulative effect of cocoa pod husk ash and poultry manure on soil and maize nutrient contents and yield. *Amer.-Euras. J. Sustain. Agric*., 2: 92–97

Aziz, T., S. Ullah, A. Sattar, M. Nasim, M. Farooq and M.M. Khan, 2010. Nutrient availability and maize (*Zea mays*) growth in soil amended with organic manures. *Intl. J. Agric. Biol.,* 12: 621–624

Biederbeck, V.O., C.A. Campbell, V. Rasiah, P.P. Zentner and G. Wen, 1998. Soil quality attributes as influenced by annual legumes used as green manure. *Soil Biol. Biochem.,* 30: 1177–1185

Capoen, W., G. Oldroyd, S. Goormachtig and M. Holsters, 2010. *Sesbania rostrata*: a case study of natural variation in legume nodulation. *New Phytol.,* 186: 340–345

Chander, K., S. Goyal, M.C. Mundra and K.K. Kapoor, 1997. Organic matter, microbial biomass and enzyme activity of soils under different crop rotations in the tropics. *Biol. Fert. Soils,* 2224: 306–310

Chen, X., Z. Cui, M. Fan, P. Vitousek, M. Zhao, W. Ma, Z. Wang, W. Zhang, X. Yan, J. Yang, X. Deng, Q. Gao, Q. Zhang, S. Guo, J. Ren, S. Li, Y. Ye, Z. Wang, J. Huang, Q. Tang, Y. Sun, X. Peng, J. Zhang, M. He, Y. Zhu, J. Xue, G. Wang, L. Wu, N. An, L. Wu, L. Ma, W. Zhang and F. Zhang, 2014. Producing more grain with lower environmental costs. *Nature*, 514: 486–501

Chen, X.P., Z.L. Cui, P.M. Vitousek, K.G. Cassman, P.A. Matson, J.S. Bai, Q.F. Meng, P. Hou, S.C. Yue and V. Römheld, 2011. Integrated soil-crop system management for food security. *Proc. Natl. Acad. Sci. USA,* 108: 6399–6404

Cherr, C.M., J.M. Scholberg and R. McSorley, 2006. Green Manure Approaches to Crop Production. *Agron. J.,* 98: 302–319

Elfstrand, S., B. Birgitta and A. Mårtensson, 2007. Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. *Appl. Soil Ecol.,* 36: 70–82

Hanway, J.J. and H. Heidel, 1952. Soil analysis methods as used in Iowa state college soil testing laboratory. *Iowa Agric.,* 57: 1–31

Ju, X.T., G.X. Xing, X.P. Chen, S.L. Zhang, L.J. Zhang, X.J. Liu, Z.L. Cui, B. Yin, P. Christie and Z.L. Zhu, 2009. Reducing environmental risk by improving N management in intensive Chinese agricultural systems. *Proc. Natl. Acad. Sci. USA,* 106: 3041–3046

Laekemariam, F. and G. Gidago, 2012. Response of maize (*Zea mays* L.) to integrated fertilizer application in Wolaita, South Ethiopia. *Adv. Life Sci. Technol.,* 5: 21–30

Lal, R., 1996. Deforestation and land-use effects on soil degradation and rehabilitation in western Nigeria. 2. Soil chemical properties. *Land Degrad. Dev.,* 7: 99–119

Mandal, U.K., G. Singh, U.S. Victor and K.L. Sharma, 2003. Green manuring: its effect on soil properties and crop growth under rice-wheat cropping system. *Eur. J. Agron.,* 19: 225–237

Marin, A.M.P., R.S.C. Menezes and I.H. Salcedo, 2007. Productivity of maize intercropped or not with Gliricidia amended with two organic fertilizers. *Pesq. Agrop. Bras.,* 42: 615–625

Mehboob, N., W.A. Minhas, A. Nawaz, M. Shahzad, F. Ahmad and M. Hussain, 2018. Surface drying after seed priming improves the stand establishment and productivity of maize than seed re-drying. *Intl. J. Agric. Biol*., 20: 1283–1288

Meng, Q., P. Hou, L. Wu, X. Chen, Z. Cui and F. Zhang, 2013. Understanding production potentials and yield gaps in intensive maize production in China. *Field Crop Res.,* 143: 91–97

Monedero, M.A.S., C. Mondini, M.D. Nobili, L. Leita and A. Roig, 2004. Land application of biosolids. Soil response to different stabilization degree of the treated organic matter. *Waste Manage.,* 24: 325–332

Moodie, C.D., H.W. Smith and R.A. McCreery, 1959. *Laboratory Manual for Soil Fertility Department of Agronomy*, pp: 1–75. State College of Washington Pullman, Washington, USA

Mureithi, J.G., P.M. Mwaura and C.O. Nekesa, 2002. Introduction of legume cover crops to smallholder farms in Gatanga, Central Kenya. *In: Participatory Technology Development for Soil Management by Smallholders in Kenya*, pp: 153–164. Mureithi, J.G., C.C.K. Gachene, F.N. Muyheko, M. Onyango, L. Mose and O. Magenya (Eds.). Proceedings of the second scientific conference of the soil management and legume research network projects, June 2000, Mombasa. Kenya Agricultural Research Institute (KARI), Kenya

Nawaz, A., M. Farooq, R. Lal, A. Rehman, T. Hussain and A. Nadeem, 2017. Influence of sesbania brown manuring and rice residue mulch on soil health, weeds and system productivity of conservation rice-wheat systems. *Land Degrad. Dev*., 28: 1078–1090

Nielsen, R.L., 2013. *Effects of Stress During Grain Filling in Corn.* Agronomy Department, Purdue University, West Lafayette, Indiana, USA

Nkonya, E., C. Kaizzi and J. Pender, 2005. Determinants of nutrient balances in a maize farming system in eastern Uganda. *Agric. Syst.,* 85: 155–182

Odhiambo, J.J., J.B. Ogola and T. Madzivhandila, 2010. Effect of green manure legume-maize rotation on maize grain yield and weed infestation levels. *Afr. J. Agric. Res.,* 5: 618–625

Olesen, J.E., P. Sørensen, I.K. Thomsen, J. Eriksen, A.G. Thomsen and J. Berntsen, 2004. Integrated nitrogen input systems in Denmark. *In*: *Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment,* pp: 129–140. Mosier, A.R., J.K. Syers and J.R. Freney (Eds.). Island Press, Washington DC, USA

Olsen, S.R., 1954. *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate*. USDA, Washington DC, USA

Paul, G.C. and A.R.M. Solaiman, 2004. Changes in microbial biomass carbon and nitrogen in upland sugarcane soil amended with different organic materials. *Commun. Soil Sci. Plant Anal.,* 35: 2433–2447

Perdigão, A., J. Pereira, N. Moreira, H. Trindade and J. Coutinho, 2017. Carbon and nitrogen mineralisation from green manures as alternative nitrogen sources in Mediterranean farming. *Arch. Agron. Soil Sci.,* 63: 1546–1555

Salim, M., M. Akram, M.E. Akhtar and M. Ashraf, 2003. *Rice Production Hand Book*, pp: 42–45. PARC, Islamabad, Pakistan

Shah, S.T.H., M.S.I. Zamir, M. Waseem, A. Ali, M. Tahir and W.B. Khalid, 2009. Growth and yield response of maize (*Zea mays* L.) to organic and inorganic sources of nitrogen. *Pak. J. Life Soc. Sci*., 7: 108–111

Shah, Z. and M.I. Ahmad, 2006. Effect of integrated use of farm yard manure and urea on yield and nitrogen uptake of wheat. *J. Agric. Biol. Sci.,* 1: 60–65

Steel, R.G.D., J.H. Torrie and D.A. Dicky, 1997. *Principles and Procedures of Statistics, A Biometrical Approach,* 3rd edition, pp: 352–258. McGraw Hill, Inc., Book Co. New York, USA

Talgre, L., E. Lauringson, H. Roostalu, A. Astover and A. Makke, 2012. Green manure as a nutrient source for succeeding crops. *Plant Soil Environ.,* 58: 275–281

Vitousek, P.M., R. Naylor, T. Crews, M.B. David, L.E. Drinkwater, E. Holland, P.J. Johnes, J. Katzenberger, L.A. Martinelli and P.A. Matson, 2009. Nutrient imbalances in agricultural development. *Science,* 324: 1519–1520

Wasaya, A., M. Tahir, T.A. Yasir, S. Ul-Allah and M. Hussain, 2018. Impact of tillage systems and temporal nitrogen application on soil properties, nitrogen uptake and net returns in maize. *Intl. J. Agric. Biol*., 20: 1953–1960

Witter, E. and G. Johansson, 2001. Potassium uptake from the subsoil by green manure crops. *Biol. Agric. Hortic.,* 19: 127–141

Xie, Z., S. Tu, F. Shah, C. Xu, J. Chen, D. Han, G. Liu, H. Li, I. Muhammad and W. Cao, 2016. Substitution of fertilizer-N by green manure improves the sustainability of yield in double-rice cropping system in south China. *Field Crop Res.,* 188: 142–149

Yang, L., W. Cao, K. Thorup-Kristensen, J. Bai, S. Gao and D. Chang, 2015. Effect of *Orychophragmus violaceus* incorporation on nitrogen uptake in succeeding maize. *Plant Soil Environ.,* 61: 260–265

Yasmeen, H., M. Yaseen, M.Z. Aziz, M. Naveed, M. Arfan-ul-Haq and T. Abbas, 2018. Wheat residue management improves soil fertility and productivity of maize. *Intl. J. Agric. Biol*., 20: 2181–2188

Yu, W., C. Elleby and H. Zobbe, 2015. Food security policies in India and China: Implications for national and global food security. *Food Secur.,* 7: 405–414

Zheng, X., S. Han, Y. Huang, Y. Wang and M. Wang, 2004. Re-quantifying the emission factors based on field measurements and estimating the direct N_2O emission from Chinese croplands. *Glob. Biogeochem. Cycl.,* 18: 1–19

Zhou, J., B. Gu, W.H. Schlesinger and X. Ju, 2016. Significant accumulation of nitrate in Chinese semi-humid croplands. *Sci. Rep.*, 6: 1–8

[Received 04 May 2019; Accepted 07 Jun 2019; Published 10 Nov 2019]