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Residual Effect of Nitrogen Management on Physiological Traits of Green Gram in Reclaimed Sodic Soil

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Abstract

Experiment was conducted during 2012 and 2013 to evaluate the residual effect of N management options on green gram growth, nutrient uptake, sequestered carbon and physiological characters at two period (45 and 56 days) on a sandy loam reclaimed sodic soil of Trans Gangetic Plains of India. The results indicated that different N management options significantly influenced the biomass, carbon sequestration, NPK content and uptake, gas exchange parameters and soil microbial biomass. At 45 and 56 days after sowing, the photosynthetic rate in 100% RDN +10 Mg ha^{-1} FYM was increased by 67.0 and 53.0 % as compared to control (no nitrogen) treatment. Highest biomass, carbon sequestration, nutrient uptake and content were recorded in 100% RDN +10 Mg ha^{-1} FYM for shoot and root in both the period of study. This study suggests inclusion of green gram in maize-wheat cropping system for improving soil health and bringing sustainability.

Key words: Green gram; Photosynthetic traits; Biomass and Carbon sequestered; NPK uptake

Introduction

Legumes play an important role in Indian agriculture and constitute an important group of crops, as they restore soil fertility, improve physical conditions of soil and provide nutritious food and fodder. Among legume crops, green gram [*Vigna radiata* (L.) Wilczek] is one of the significant crops which is widely grown as food grain legume in the Middle East including India, Pakistan, South-East Africa and Peru. Green gram is a short duration summer season pulse crop which is grown primarily for its protein rich edible seeds. Being short duration crop it requires less water than other summer crops; hence, it can also be grown in rainfed areas.

Intensive use of inorganic N source tends to create soil fatigue and NO_3- N leaching into water sources, causing ill effects to the ecosystem (Kumar *et al.*, 2008). Therefore, legumes can be used as an alternative or supplementary to chemical N fertilizer due to its potential in improving crop growth, quality and yield of cereal by increasing the availability of N uptake (Ibrahim *et al.*, 2012). Legumes forms symbiotic association with *rhizobium* which have ability to fix atmospheric N and their interaction play a significant role in the agricultural crop production.

In agriculture N is known as the imperative factor in plant growth; being constituent of chlorophyll N also governs the photosynthetic activity. Potash governs fruit quality, increases disease resistance; prevent lodging and capability of plants to survive under moisture stress. Phosphorus plays role in development of fruit, root and flower. Uptake of these nutrients may affect qualitatively and quantitatively the growth and yield (Rathore *et al.*, 2008), where the growth conditions may affect the biological composition of a plant (Din *et al.*, 2011). Optimum nodulation for biological nitrogen fixation requires ideal conditions such as nutrient availability, optimum soil moisture etc. Legume plants provide abundant supply of N through nodulation and the uptake by plants from the soil. On the other hand, excess N may inhibit nodules production (Reynolds, 2005) thus application of N fertilizer in legume field is of great concern for successful production of legume crops as well as succeeding crop (Varges and Ieda, 2000).

Trans-Gangetic basin, predominating in rice-wheat system, is popularly known as "Food-Mine" of India. But, productivity of the crops on the basin has stagnated in last few decades. Possible reasons documented are mainly three, first, excessive loss of soil organic carbon (SOC) due to cultivation (oxidation of SOC due to deep tillage, lack of cover to soil during hot dry summer) and unscientific crop management (burning of straw and crop residue, and lack of cereal-legume rotation etc.); second, excessive flood irrigation from canal which causes rise in water table and thus soil salinity (upward movement of salts during hot dry summer season); third, excessive use of fertilizers particularly urea, which promotes oxidation of organic matter and exacerbates the emission of CO_2 from soil to the atmosphere.

Crop diversification (maize-wheat) by inclusion of legume may help to overcome the major challenges viz. declining factor productivity and deterioration of the resource base, and plays a vital role in sustainable agricultural production. Therefore, an attempt was made to find out the residual effect of organic and inorganic fertilizer on physiological parameters of green gram, sustaining soil fertility, crop yield and productivity of successive crop and the role of green gram incorporation in sequestering carbon.

Materials and Methods

Description of experimental site and climate

The field study was conducted at the experimental field of Central Soil Salinity Research Institute (CSSRI), Karnal, (29°43′ N, 76°58′ E; 245 m above the mean sea level), Haryana, India during 2012 and 2013. The annual mean minimum and maximum temperature of the site are 18.8° C and 29.2° C, respectively. Annual rainfall ranges between 700 and 800 mm.

Experimental details

To study the residual effect different nitrogen management strategies on green gram, a randomized complete block design experiment with 3 replications was conducted with different combination of inorganic and organic sources of nitrogen [T_1 = 100% recommended dose of nitrogen (RDN)+10 Mg ha^{-1}FYM, T_2 = 100% RDN, T_3 = 75% RDN + 25 % N through FYM, T_4 = 50 % RDN + 50% N through FYM, T_5 = 50% N through FYM, T_6 = 25% N through FYM and T_7 = No nitrogen] was given to maize and wheat crops under maize-wheat-green gram cropping system. RDN and P_2O_5 was 150 and 60 kg ha^{-1}for both maize and wheat crop, however the K_2O was 60 and 30 kg ha^{-1} for maize and wheat, respectively. Surface sterilized seeds of green gram [*Vigna radiata* (L.) Wilczek] cv. SML 668 was sowed on residual fertility through zero tillage for enhancing biomass production per unit area and time after the harvest of wheat crop. Initially experimental soil was low in available N, medium to high in available P and high in available K in both the soil profiles (0-15 and 15-30 cm) studied (Fig. 1).

Plant material and growth conditions

The plot area for each treatment was 33.6 m^2 and it was replicated thrice. Plant samples were collected at 56 days after sowing for studying the response of different N management on biomass, NPK content in green gram. For biological yield (Mg ha^{-1}), shoot and root biomass were collected from 1m row length by excavating to 30 cm. The plant samples thus collected were washed thoroughly, dried at 60°C, finely grind and digested in di-acid mixture of HNO_3 and $HClO_4$ in 9:1 ratio. Nitrogen content was determined by modified micro Kjeldahl method (Jackson, 1973). Phosphorus was determined by vanadomolybdo-phosphoric acid yellow colour method (Jackson, 1973) and K by flame photometer (PFP7, Jenway, Bibby Scientific, UK).

Plant height, physiological parameters (gas exchange characteristics), microbial biomass carbon (MB-C) and carbon sequestered (in root and shoot) were studied at 45 and 56 days after sowing. Fully expanded leaves were used for measurement of gas exchange parameters. Photosynthetic rate (P_N), stomatal conductance (gS), transpiration (E) was measured with an infrared open gas exchange system (LI-6400, LICOR Inc., Lincoln, NE, USA). Relationships

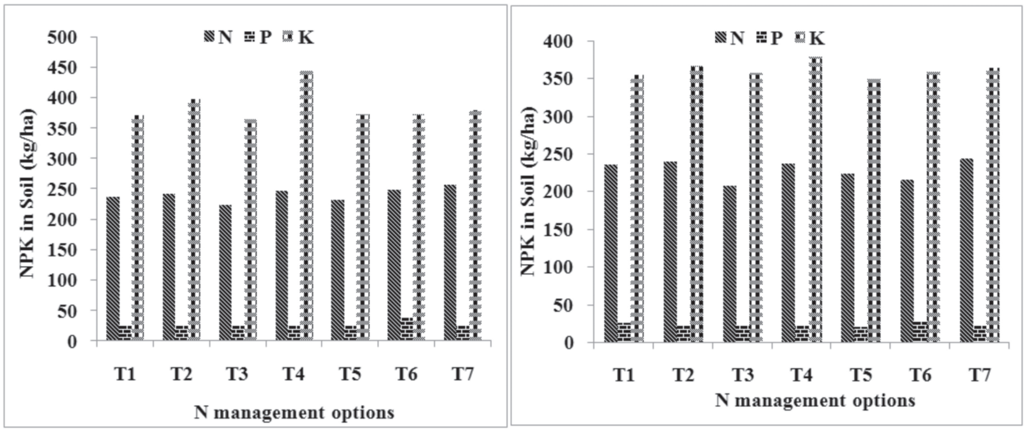

Fig. 1. Initial NPK status in soil (a) 0-15 cm and (b) 15-30 cm soil depth
Treatments depict as: T_1 = 100% recommended dose of nitrogen (RDN)+10 Mg ha^{-1} FYM, T_2 = 100% RDN, T_3 = 75% RDN + 25 % N through FYM, T_4 = 50 % RDN + 50% N through FYM, T_5 = 50% N through FYM, T_6 = 25% N through FYM and T_7 = No nitrogen

were developed to calculate instantaneous water use efficiency (WUE) (µmol mol^{-1}) as P_N/E.

MB-C was estimated by the chloroform-fumigation incubation method of Jenkinson and Powlson (1976). Ten gram soil sample was rewetted to 40–60% WHC (water holding capacity) and fumigated with ethanol-free chloroform ($CHCl_3$) in a vacuum desiccators. Following fumigant removal, the soil was extracted with 0.5 M K_2SO_4 (soil: solution ratio of 1:2.5) through 30 min horizontal shaking at 200 rpm and filtered. A duplicate soil sample without fumigation (unfumigated) was also extracted with 0.5 M K_2SO_4 in a similar fashion. Both the extracts of fumigated and unfumigated soil were subjected to wet oxidation separately with potassium per sulphate and 0.025 N H_2SO_4 by heating on a digestion block at 120 °C for 2 h. Evolved CO_2 was then trapped in 0.1 N NaOH solution. The amount of CO_2 evolved was determined by back titration with 0.05 N HCl. The MB-C was computed by subtracting the amount of CO_2 evolved in fumigated soil from that of unfumigated one. A sub-sample of soil was drawn for moisture determination so as to express the data on oven dry weight basis. The amount of the MB-C in soil was calculated as follows:

$$\text{MB-C} = \frac{\text{OCF} - \text{OCUF}}{\text{KEC}}$$

Where, OCF and OCUF depict the organic carbon extracted from fumigated and unfumigated soil, respectively (expressed on oven dry basis), and KEC is the efficiency of extraction. A value of 0.45 is considered as a general KEC value for microbial extraction efficiency and used for calculation. Estimation of carbon content was done by the CHNS analyser (Anderson and Ingram, 1993).

Statistical analyses

All the data were subjected to variance analysis using statistical software (SAS Version 9.3, SAS Institute Inc., Cary, NC, USA). The mean pair wise comparisons were based on the Duncan multiple range test (DMRT). Correlation analysis was performed to determine the relationship between the traits using the Pearson coefficient procedure.

Results and Discussion

The present study was conducted to evaluate the response of different N management options on biomass, nutrient uptake, gas exchange parameters, soil MB-C and sequestered carbon in green gram under maize-green gram-wheat cropping system. After the harvest of wheat crop in 2012 and 2013, green gram was sown on residual fertility through zero tillage for the purpose of enhancing biomass production per unit area and time. The results indicated that biological yield in terms of root and shoot biomass was almost similar in all treatments, which indicated better soil health with different N management options. To maximize yield responses under different N management options (organic and inorganic), a comprehensive study in green gram was pursued. The results presented in Table 1 (analysis of variance) indicated significant variability ($p<0.01$) among all the studied traits under different N management options as indicated by their mean sum of squares. Data presented in Table 1, indicated better performance under RDN + 10 Mg ha^{-1} FYM among all the treatments studied. The favourable effects of RDN along with FYM on plant height might be attributed to more availability of macro and micro nutrients and improvement in soil water holding capacity (Khandkar *et al.*, 2012). Among different N management treatments in preceding wheat crop, greengram crop recorded 32.87 cm plant height at 45 DAS in 100% RDN treatment, whereas, the application of 10 Mg ha^{-1} FYM along with 100% RDN increased plant height to 36.63 cm. But in the absence of nitrogen source, 28.9 % reduction in plant height was observed as compared to 100% RDN treatment (Table 2). The enhanced growth observed in the treatments of FYM over the control could be partly due to more favorable moisture regime in the root zone and partly due to more efficient utilization of nutrients released from decomposition of the added FYM besides improving the soil physical properties specially aggregation (Chiroma *et al.*, 2006; Hanan and Kinyali, 2010).

Results pertaining to gas exchange characteristics showed that there was a significant difference among different treatments of N management at 45 days after sowing. Among different treatments, 100% RDN + 10 Mg ha^{-1} FYM in preceding wheat crop showed better gas exchange properties in greengram i.e. photosynthetic rate (P_N) 16.83 μmolCO$_2$m^{-2}sec^{-1}, stomatal m^{-2}sec^{-1} (Table 2). Whereas the absence of N fertilization showed poorest gas exchange characteristics (P_N 10.08 μmol CO$_2$ m^{-2} sec^{-1}; gS 0.83 mmol CO$_2$ m^{-2} sec^{-1} and E 13.23 μmol H$_2$O m^{-2} sec^{-1}), respectively, at 45 DAS. But the application of FYM alone or in combination with inorganic N fertilizers showed increased photosynthetic rate and stomatal conductance in comparison to control treatment (no nitrogen). Increase of nitrogen application led to subsequent increase in leaf chlorophyll content. This might be due to efficient absorption and assimilation of nitrogen by the plant which serves as a constituent of chlorophyll in the plant tissue. Chlorophyll is strongly related to nitrogen concentration in the soil and is constituent of chlorophyll, protein, amino acids and photosynthetic activity (Sumeet *et al.*, 2009). At 45 DAS, water use efficiency (WUE) of control treatment (no nitrogen) was 0.76, which increased to 0.98 in 100% RDN treatment. Greengram showed higher WUE where FYM was applied to the soil as source of nitrogen fertilizer alone or in combination with inorganic N (Table 2). In comparison to 100% RDN+10 Mg ha^{-1} FYM (1.24), greengram had 22.5 % reduction in WUE than control treatment. The effective use of nitrogen fertilizer increased leaf photosynthesis, promoted root development, and extended space for root to extract water and nutrients in soil (Li *et al.*, 1999, Shangguan *et al.*, 2004). Similar findings were also reported by Wang *et al.* (2012).

Maintenance of moisture regime in soil has positive influence on microbial activity. When nitrogen source was not applied externally, MBC was (121.33 μg g^{-1}). Highest MBC was recorded under treatment T_1 = 100% RDN + 10 Mg ha^{-1} FYM (177.67 μg g^{-1}) which were nearly equivalent to T_3 (173.33 μg g^{-1}). MB-C was higher by 24.01% in 100% RDN treatment (T_2) as compared to control treatment at 45 DAS. Mean MB-C among different N options management was 154.76 μg g^{-1}. N uptake is closely linked to biomass accumulation and ultimately carbon sequestration. Carbon sequestrated by root and shoot was 0.45 and 0.99 Mg C ha^{-1}, respectively at 45 DAS in 100% RDN treatment. The application of FYM with 100% RDN had 18.18 and 15.55 % higher carbon sequestration by root and shoot, respectively (0.52 and 1.17 Mg C ha^{-1}) as compared to 100% RDN treatment (Table 2). Among gas exchange attributes of green gram at 45 DAS (Table 2), the highest positive correlation was observed between sequestered C (root and shoot) with r =1.00**. Transpiration rate (E) showed significant negative correlations with all studied traits except gS, where it was positively

Table 1. Growth, NPK content and their uptake by green gram under different N management options in preceding wheat crop

Source of variance	Degree of freedom	Analysis of variance among growth, NPK content and their uptake (mean sum of squares)							
		Shoot DW (Mg ha^{-1})	Root DW (Mg ha^{-1})	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Nitrogen uptake (kg ha^{-1})	Phosphorous uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Replication	2	0.0039*	0.0002	0.0007	0.000	0.0002	72.83	0.275	0.916
Treatment	6	0.2694**	0.0009**	0.0705**	0.007**	0.0158	169.25**	2.318*	59.122**
Error	12	0.0006	0.0001	0.0004	0.000	0.0005	29.35	0.544	0.482

N management in wheat	Shoot DW (Mg ha^{-1})	Root DW (Mg ha^{-1})	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Nitrogen uptake (kg ha^{-1})	Phosphorous uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
T$_1$:100% RDN + 10 Mg ha^{-1} FYM	2.85^{a}	0.23^{a}	2.46^{a}	0.33^{a}	1.34^{a}	52.48^{a}	5.89^{a}	30.47^{a}
T$_2$:100% RDN	2.27^{e}	0.23^{a}	2.31^{b}	0.20^{e}	1.32^{ab}	45.67^{a}	4.16^{bc}	26.59^{b}
T$_3$:75 % RDN + 25 % N through FYM	2.40^{d}	0.22^{a}	2.19^{d}	0.24^{c}	1.32^{ab}	46.65^{a}	4.89^{ab}	27.18^{b}
T$_4$:50 % RDN + 50 % N through FYM	2.74^{b}	0.20^{b}	2.32^{b}	0.21^{d}	1.28^{b}	44.19^{ab}	4.22^{bc}	24.84^{c}
T$_5$:25 % N through FYM	2.18^{f}	0.20^{b}	2.10^{e}	0.20^{e}	1.23^{c}	34.95^{bc}	3.61^{bc}	20.27^{e}
T$_6$:50 % N through FYM	2.62^{c}	0.20^{b}	2.23^{c}	0.25^{b}	1.23^{c}	34.53^{c}	4.05^{bc}	22.63^{d}
T$_7$: No nitrogen	2.06^{g}	0.19^{b}	2.00^{f}	0.19^{f}	1.13^{d}	32.82^{c}	3.21^{c}	17.42^{f}
General Mean	2.45	0.21	2.23	0.23	1.26	41.61	4.29	24.20
CV (%)	1.01	4.54	0.89	1.80	1.81	13.02	17.20	2.87

Pearson's correlation coefficients for association

Traits	Shoot DW (Mg ha^{-1})	Root DW (Mg ha^{-1})	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Nitrogen uptake (kg ha^{-1})	Phosphorous uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
Shoot DW (Mg ha^{-1})	1	0.337	0.224	0.353	0.423^{*}	0.541^{**}	0.593^{**}	0.636^{**}
Root DW (Mg ha^{-1})		1	0.351	0.377^{*}	0.790^{**}	0.633^{**}	0.590^{**}	0.778^{**}
Nitrogen (%)			1	0.152	0.385^{*}	0.841^{**}	0.260	0.382^{*}
Phosphorous (%)				1	0.402^{*}	0.382^{*}	0.894^{**}	0.488^{*}
Potassium (%)					1	0.678^{**}	0.597^{**}	0.875^{**}
Nitrogen uptake (kg ha^{-1})						1	0.641^{**}	0.807^{**}
Phosphorous uptake (kg ha^{-1})							1	0.794^{**}
Potassium uptake (kg ha^{-1})								1

Means with at least one letter common are not statistically significant ($p \leq 0.05$) using DUNCAN's Multiple Range Test
DW = dry weight
*- significant at $p \leq 0.05$, **- significant at $p \leq 0.01$

Table 2. Gas exchange characteristics (P_N- Photosynthetic rate, gS- Stomatal conductance, E- Transpiration rate, WUE- Water use efficiency), microbial C-content and C sequestration at 45 DAS in green gram

Source of variance	Degree of freedom	Analysis of variance among gas exchange characteristics at 45 DAS (Means sum of squares)							
		Plant height	P_N (µ mol CO_2 m^{-2} sec^{-1})	gS (m mol CO_2 m^{-2} sec^{-1})	E (µ mol CO_2 m^{-2} sec^{-1})	WUE	MBC (µ gm^{-1})	C Seq.(S) Mg C ha^{-1}	C Seq.(R) Mg C ha^{-1}
Replication	2	24.818	0.192	0.0000	0.2090	0.0026	0.6190	0.0002	0.0000
Treatment	6	57.609**	19.460**	0.0893**	5.1895**	0.0868**	1135.08**	0.0406**	0.0082**
Error	12	6.881	0.279	0.0001	0.1134	0.0031	4.3413	0.0003	0.0001

N management in wheat	Plant height (cm)	P_N	gS	E	WUE	MBC	C Seq. (Shoot)	C Seq. (Root)
T_1:100% RDN + 10 Mg ha^{-1} FYM	36.63^{a}	16.83^{a}	1.17^{a}	13.55^{a}	1.24^{a}	177.67^{a}	1.17^{a}	0.52^{a}
T_2:100% RDN	32.87^{abc}	10.37^{de}	0.99^{c}	10.61^{c}	0.98^{bc}	159.67^{c}	0.99^{c}	0.45^{c}
T_3:75 % RDN + 25 % N through FYM	33.83^{ab}	14.80^{b}	0.97^{c}	12.28^{b}	1.20^{a}	173.33^{b}	0.97^{c}	0.43^{c}
T_4:50 % RDN + 50 % N through FYM	30.83^{bcd}	10.71^{de}	1.02^{b}	10.40^{c}	1.03^{b}	159.00^{c}	1.02^{b}	0.46^{b}
T_5:25 % N through FYM	28.67^{cd}	12.36^{c}	0.84^{e}	13.52^{a}	0.91^{c}	139.33^{e}	0.84^{e}	0.38^{e}
T_6:50 % N through FYM	27.93^{de}	11.29^{d}	0.91^{d}	12.40^{b}	0.91^{c}	153.00^{d}	0.91^{d}	0.41^{d}
T_7: No nitrogen	23.37^{e}	10.08^{e}	0.83^{e}	13.23^{a}	0.76^{d}	121.33^{f}	0.83^{e}	0.37^{e}
General Mean	30.59	12.35	0.96	12.29	1.01	154.76	0.96	0.43
CV (%)	8.58	4.28	1.78	2.74	5.55	1.35	1.78	1.78

Pearson's correlation coefficients for association

Traits	Plant height	P_N	gS	E	WUE	MBC	C Seq. (Shoot)	C Seq. (Root)
Plant height	1	0.608^{**}	0.705^{**}	-0.130	0.744^{**}	0.785^{**}	0.740^{**}	0.738^{**}
P_N (µ mol CO_2 m^{-2} sec^{-1})		1	0.557^{**}	0.467^{*}	0.843^{**}	0.694^{**}	0.606^{**}	0.604^{**}
gS (m mol CO_2 m^{-2} sec^{-1})			1	-0.146	0.684^{**}	0.764^{**}	0.959^{**}	0.959^{**}
E (µ mol CO_2 m^{-2} sec^{-1})				1	-0.078	-0.243	-0.197	-0.197
WUE					1	0.916^{**}	0.777^{**}	0.775^{**}
MBC (µ gm^{-1})						1	0.843^{**}	0.841^{**}
C Seq.(S) Mg C ha^{-1}							1	1.000^{**}
C Seq.(R) Mg C ha^{-1}								1

Means with at least one letter common are not statistically significant ($p \leq 0.05$) using DUNCAN's Multiple Range Test
*- significant at $p \leq 0.05$, **- significant at $p \leq 0.01$

correlated (r = 0.467*). Stomatal conductance was also positively correlated with sequestered C (r = 0.959**), clearly showed that increased physiological attributes under optimal N supply which might have resulted into higher assimilates production and yield (Table 2).

With increased crop growth-period i.e. at 56 days after sowing, plant height also increased to 35.17 cm in 100% RDN treatment. Increased in plant height might likely be due to favourable effect of N and P on promoting vigorous plant growth through efficient photosynthesis and dry matter production as N is the main constituent of chlorophyll molecule and P is the major component of ATP and sugar phosphate needed for effective carbon fixation (Lloveras *et al*., 2001, Iqtidar *et al*., 2006). The application of 10 Mg ha^{-1} FYM alongwith 100% RDN had maximum plant height (40.50 cm). It might be associated with stimulating effect of nitrogen levels on various physiological processes including cell division and cell elongation of the plant. Whereas, minimum plant height was recorded with control treatment (Table 3).

Treatment T_1 i.e. 100% RDN + 10 Mg ha^{-1}FYM showed better gas exchange properties in compared to other treatments. 100% RDN treatment showed photosynthetic rate (P_N) of 13.58 μ mol CO_2 m^{-2} sec^{-1} and stomatal conductance (gS) of 0.97 m mol CO_2 m^{-2}sec^{-1}, respectively at 56 DAS. But the application of 10 Mg ha^{-1} FYM along with 100% RDN showed increased photosynthetic rate and stomatal conductance (16.14 μ mol CO_2 m^{-2} sec^{-1} and 0.96 mol CO_2 m^{-2} sec^{-1}). Whereas, absence of N source (T_7), recorded 22.31% reduction in P_N and 25.8% reduction in gS in comparison to 100% RDN treatment (Table 3). With increased age, i.e. from 45 DAS to 56 DAS transpiration rate increased in all N management treatments. Greengram showed 12.58 mmolH_2Om^{-2}sec^{-1}transpiration rate (E) in 100% RDN treatment (Table 2). The applied 10 Mg ha^{-1} FYM along with 100% RDN showed higher transpiration rate (14.43 mmol H_2O m^{-2} sec^{-1}) whereas, absence of N source, caused reduction in transpiration rate. Plant water use efficiency also varied significantly due to different N doses applied (Table 3). Highest WUE (1.28) was observed in T_3 while lowest in T_7 i.e. 0.86 which was at par with T_5 (0.87).

Microbial biomass is a small but very dynamic component of soil organic matter fluctuating with the weather, crop, input and season (Mandal *et al*., 2007). Estimated microbial biomass carbon was 164.83 μg g^{-1} under 100% RDN treatment, which increased to 184.5 μg g^{-1} when 10 Mg ha^{-1} FYM was supplemented with 100% RDN. The release of organic C from roots into the soil might be regarded as a pool of reduced C that no longer contributed to dry matter production. However, it is well established that rhizo-deposits stimulate biological activity as found in the present study as well, and benefit plants by enhancing nutrient availability (Raiesi, 2004). MB-C in control treatment (no nitrogen) was lower by 22.14 % than 100% RDN treatment at 56 DAS. Mean carbon sequestered by roots reduced by 74.4% at 56 DAS as compared to 45 DAS, whereas shoot showed 33.79 % increment in sequestered C values for the same period of study. At 56 DAS, sequestered carbon was 0.11 and 1.34 Mg C ha^{-1} by roots and shoots, respectively in 100% RDN treatment. The application of 10 Mg ha^{-1} FYM along with 100% RDN showed increased carbon sequestration, but absence of N source caused 11.94 and 27.3 % reduction in carbon sequestration by roots and shoots as compared to 100% RDN treatment (Table 3). At 56 DAS, the highest correlation was observed between P_N and MBC (r = 0.873, pd”0.01). Both traits (P_N and MBC) were found positively correlated with plant height with r = 0.861 ($p \leq 0.01$) and r = 0.864 ($p \leq 0.01$), respectively. Whereas E and WUE were highly correlated but negatively (r = -0.703, $p \leq 0.01$).

Data presented in Table 1 showed significant variability ($p \leq 0.01$) for NPK content and their uptake. It is documented that N nutrition has significant effects on root and shoots relations (Feng and Liu, 1996). Similarly, root and shoot biomass was maximum under 100% RDN + 10 Mg ha^{-1} FYM treatments (0.23 and 2.85 Mg ha^{-1}) while minimum under control treatment(0.19 and 2.06 Mg ha^{-1}). Higher availability of nutrients in organic fertilizer was the main factor contributing to higher biomass of plants. Root biomass did not show much variability as T_4, T_5, T_6 and T_7 had

Table 3. Gas exchange characteristics (P_N- Photosynthetic rate, gS- Stomatal conductance, E- Transpiration rate, WUE- Water use efficiency), microbial C-content and C sequestration at 56 DAS in green gram

Source of variance	Degree of freedom	Analysis of variance among gas exchange characteristics at 56 DAS (mean sum of squares)							
		Plant height	P_N (μ mol CO_2 $m^{-2} sec^{-1}$)	gS (m mol CO_2 $m^{-2} sec^{-1}$)	E (μ mol CO_2 $m^{-2} sec^{-1}$)	WUE	MBC (μ gm^{-1})	C Seq.(S) Mg C ha^{-1}	C Seq.(R) Mg C ha^{-1}
Replication	2	5.159	0.436	0.0019	0.089	0.0045	22.155*	0.0003	0.0001
Treatment	6	70.928**	10.983**	0.0254**	3.395**	0.0675**	1085.028**	0.0834 **	0.0008 **
Error	12	1.676	0.221	0.0005	0.080	0.0018	3.474	0.0011	0.0001

N management in wheat	Plant height	P_N	gS	E	WUE	MBC	C Seq. (Shoot)	C Seq. (Root)
T_1:100% RDN + 10 Mg ha^{-1}FYM	40.50^{a}	16.14^{a}	0.96^{a}	14.43^{a}	0.92^{de}	184.50^{a}	1.66^{a}	0.13^{ab}
T_2:100% RDN	35.17^{b}	13.58^{b}	0.97^{a}	12.58^{cd}	1.00^{c}	164.83^{c}	1.34^{d}	0.11^{cd}
T_3:75 % RDN + 25 % N through FYM	35.93^{b}	14.19^{b}	0.78^{c}	11.11^{e}	1.28^{a}	173.33^{b}	1.38^{cd}	0.12^{bc}
T_4:50 % RDN + 50 % N through FYM	33.65^{b}	11.65^{cd}	0.87^{b}	12.10^{d}	0.99^{cd}	148.33^{e}	1.59^{b}	0.10^{ef}
T_5:25 % N through FYM	31.31^{c}	12.45^{c}	0.86^{b}	13.48^{b}	0.87^{e}	143.33^{f}	1.44^{c}	0.10^{de}
T_6:50 % N through FYM	29.75^{c}	11.45^{d}	0.81^{c}	12.18^{d}	1.13^{b}	158.67^{d}	1.56^{b}	0.13^{a}
T_7:No nitrogen	25.35^{d}	10.55^{e}	0.72^{d}	12.80^{c}	0.86^{e}	128.33^{g}	1.18^{e}	0.08^{f}
General Mean	33.09	12.86	0.85	12.67	1.01	157.33	1.45	0.11
CV (%)	3.91	3.66	2.63	2.23	4.23	1.18	2.26	6.52

Pearson's correlation coefficients for association

Traits	Plant height	P_N	gS	E	WUE	MBC	C Seq. (Shoot)	C Seq. (Root)
Plant height	1	0.861**	0.693**	0.225	0.143	0.864**	0.578**	0.440*
P_N (μ mol CO_2 $m^{-2} sec^{-1}$)		1	0.642**	0.363	0.180	0.873**	0.391	0.524*
gS (m mol CO_2 $m^{-2} sec^{-1}$)			1	0.454*	-0.185	0.582**	0.506*	0.353
E (μ mol CO_2 $m^{-2} sec^{-1}$)				1	-0.703**	0.091	0.269	0.046
WUE					1	0.408	0.022	0.442*
MBC (μg m^{-1})						1	0.552**	0.750**
C Seq.(S) Mg C ha^{-1}							1	0.596**
C Seq.(R) Mg C ha^{-1}								1

Means with at least one letter common are not statistically significant ($p \leq 0.05$) using DUNCAN's Multiple Range Test

*- significant at $p \leq 0.05$; **- significant at $p \leq 0.01$

statistically similar root biomass. While shoot biomass recorded 9.25 % reduction in T_7 treatment and 25.55 % increment in T_1 treatment as compared to 100% RDN treatment. Marschner (1995) reported that in the responsive zone (i.e. concentration range where nutrients limit plant growth), increasing nitrogen supply enhances both shoot and root growth, but usually the shoot growth is more than the root growth. Similar trend was found for NPK content as well as uptake in all the treatments. Statistically significant variations were found among all the treatments for NPK content in greengram shoot. Higher content (2.46 % N, 0.33 % P and 1.34 % K) were observed when 10 Mg ha^{-1} FYM was applied with 100% RDN, while lowest content (2.0 % N, 0.19 % P and 1.13 % K) was recorded under control treatment. Supplementing organics (FYM) with inorganic N fertilizers enhances the available N content of the soil due to hastened mineralization, once the requirement of N by microbes is met through inorganic nitrogen (Sharma and Gupta, 1998). K content was statistically at par in 100% RDN + 10 Mg ha^{-1} FYM, 100% RDN and 75% RDN + 25 % N through FYM treatments. This could be due to ability of farmyard manure to improve structural and hydrological soil properties (Palm *et al.*,1997). N played pivotal role in improving WUE and soil water use (SWU), while phosphorus played an important role in increasing total SWU and water extraction from deep soil layer (Dang, 1999). Potassium supply increase root growth, maintains cell turgor, reduces water loss and wilting in plants hence improves drought resistance (Tiwari, 2002).The standing greengram crop was ploughed down in the same plot on 56th day (before the onset of monsoon) for timely sowing of *kharif* maize.

Perusal of the data presented in table 3 for NPK uptake showed statistical significant difference for N uptake. 100% RDN + 10 Mg ha^{-1} FYM had 37.48 % higher N uptake compared to control treatment. Even treatments 25% N through FYM or 50% N through FYM showed statistically higher N uptake then control treatment. Highest P uptake was observed in T_1 treatment followed by T_3 but these two treatments were statistically at par. Maximum K uptake was obtained when 10 Mg ha^{-1} FYM was applied with 100% RDN (30.47 kg ha^{-1}), whereas, minimum uptake was recorded for T_7 treatment (17.42 kg ha^{-1}). It might be due to that applied fertilizers increased cation exchange capacity of roots which makes them more efficient in absorbing nutrients (Tamhane *et al.*, 1964). The application of FYM facilitates the increased availability of N and P in the soil and reduced fixation capacity, which enhanced their uptake (Yadav *et al.*, 2013). The results from correlation study indicated that 10 Mg ha^{-1} FYM along with 100% RDN treatment enhanced the photosynthetic machinery as well as enriched the nutrient uptake. Significantly higher correlation was observed between nutrient content and nutrient uptake i.e. N content and N uptake ($r = 0.841$, $p \le 0.01$), P content and P uptake ($r = 0.894$, $p \le 0.01$) and K content and K uptake ($r = 0.875$, $p \le 0.01$). Significant correlation was also observed between N uptake and K uptake ($r = 0.807$, $p \le 0.01$), P uptake and K uptake ($r = 0.794$, $p \le 0.01$).

Conclusions

From this study, it could be concluded that integrated use of organic and inorganic fertilizers increased microbiological activities, plant height, carbon sequestration, improved photosynthetic machinery, as well as nutrient uptake. Hence inclusion of green gram in maize-wheat cropping system is recommend for sustaining the productivity of the successive crop as well as its role in improving soil health.

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