AGRONOMIC PERFORMANCE OF MAIZE PRODUCTIVITY AS INFLUENCED BY ORGANIC NITROGEN SOURCES

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ABSTRACT

Organic manure is considered a good source of all essential nutrients and organic matter. It has a number of benefits in comparison with inorganic fertilizers due to its organic nature. These benefits include improved soil structure, enhanced water holding capacity, more pore spaces for aeration for better growth of the plants. Field trials were conducted in randomized complete block design with three replications at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2017 and 2018. The experiment was consisted of two factors i.e. organic nitrogen sources (poultry manure (PM), farmyard manure (FYM) and legume residue (LR) and their ratios i.e. 100:0:0, 0:100:0, 0:0:100, 50:50:0, 0:50:50 and 50:0:50 in the form of non-compost, compost and biochar. A control and inorganic nitrogen (N) fertilizer treatments were also included in the experiment. Results of the data exhibited that PM delayed tasseling, silking and maturity in comparison with FYM and LR. Likewise, PM increased plant height (220 cm), leaf area (343 cm^2), leaf area index (2.94), grains ear^{-1} (493), thousand grain weight (322 g), biological yield (15102 kg ha^{-1}), and grain yield (5370 kg ha^{-1}) as compared to FYM and LR. In similar way, FYM also increased plant height (219 cm) and harvest index (36.7%). Among organic N ratios, the 100:0:0 (non-compost:compost:biochar) delayed tasseling, silking and maturity. Likewise, the ratio of 0:50:50 (non-compost:compost:biochar) enhanced plant height (229 cm), number of leaves $plant^{-1}$ (13.3), leaf area (364 cm^2), leaf area index (3.38), ears m^{-2} (7.2), grains ear^{-1}(509), thousand grain weight (333 g), biological yield (15328 kg ha^{-1}), and grain yield (5607 kg ha^{-1}). It is concluded that application of PM and organic nitrogen ratio of 0:50: 50 (non-compost: compost: biochar) improved yield and yield traits of maize.

Keywords: Biochar, grain yield, maize crop, organic amendments

INTRODUCTION

Maize (Zea mays L.) is the third most important cereal crop in Pakistan after wheat and rice. In Khyber Pakhtunkhwa maize ranks 2^{nd} after wheat on the basis of its importance (Ali et al., 2021). During 2013, it was cultivated in Pakistan on an area of 1087.3 thousand hectares with the total production of 4338 thousand tons and national average yield of 3990 kg ha^{-1}. In Khyber Pakhtunkhwa, it was grown on 475.3 thousand hectares with a total production of 887.8

thousand tones and average yield of 1868 kg ha^{-1} (MNFSR, 2020-2021). Although, soil and climatic conditions of Pakistan are highly favorable and high yielding varieties are also available, yet the yield of maize at farmers' field is low when compared with other maize producing countries like USA, Canada, and Egypt etc. Soil and climatic conditions of Pakistan are ideal for maize production but a number of factors are responsible for the low yield of the crop. Inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield (Nair, 2019).

Organic fertilizers (poultry and farm-yard manure) and crop residues are used for crop production as a partial substitute of synthetic fertilizers, because of the presence of good quantity of macro and micro nutrients in organic manures (Baweja et al., 2019). Among organic manures, the application of poultry manure can particularly increase the growth and crop production (Tiamiyu et al., 2012) because it mineralizes faster than other animal manure and contains basic nutrients required for enhancing growth and yield of crops (Itelima et al. 2018). Decomposition of organic manures took time and the nutrients are released at slow rate and remain in soil for longer time, therefore resulting in long residual effects (Mahmood et al., 2017). Cattle dung is an essential source for crop production and restores nutrients exhausted due to intensive cropping practices. Amanullah, (2016) reported that cattle dung was found more beneficial in terms of higher growth, yield and yield components as compared to the treatment that received no cattle dung. The crop residues help to recycle the nutrients (Jia et al., 2018). Crop residues are good sources of plant nutrients and are important components for the stability of agricultural ecosystems (Li et al., 2015). Plant residues on decomposition produce organic matter and release plant nutrients with the help of soil microorganism (Semenov et al, 2019). Crop residues are rich in N, P and K and should be used as fertilizer, which is the more appropriate way of waste management (Prasad et al., 2020). Crop residues retention has been suggested to improve overall soil fertility and to support sustainable crop production. Incorporation of crop residues is essential for sustaining soil productivity through replenishing soil organic matter (Biswas and Kole, 2017) that not only a key indicator of soil quality, but it also supplies essential nutrients upon mineralization (N, P, and K) and improves soil physical, chemical, and biological properties (Dotaniya et al., 2016).

The biochar application as soil amendment is gaining popularity worldwide due to its potential of improving soil water holding capacity, retention of nutrients and carbon sequestration mostly in recalcitrant form of carbon (Windeatt et al., 2014). The high water retention property of biochar in soils can be linked with high porosity of biochar (Lustosa et al., 2020). It improves plant growth by providing nutrients proficiently and enhances crop yields and also works as soil conditioner (Ullah et al., 2021). Biochar application has positive effects on soil C stability, especially in soil with low native organic matter contents (Riaz et al., 2017). Higher soil water holding capacity, increase in crop yields and decrease in number of irrigations in biochar amended soils has been reported by many researchers (Mohamed et al., 2016). A meta-analysis by Ye et al. (2020) has reported a mean increase of 10% over control treatment in crop yield with biochar application. Likewise, Uslu et al. (2020) obtained an increase ranging from 20-120% in crop productivity with biochar application

Keeping in view the importance of the beneficial effects of crop residues, manures and compost on crop production as source of nitrogen and soil amendment, and higher prices of chemical fertilizers, there is an unavoidable need to search alternative sources of N and other macro nutrients, which are available at farm level. In rural areas of Pakistan, manures (farmyard and poultry manures), and crop residues are commonly available in plentiful amounts without any bulky usage at the farm level (Arif et al., 2017). The use of such organic resources in the form of biochar, compost in different ratios as soil amendments can be evaluated to substitute and/or supplement mineral fertilizers in high input exhaustive wheat-maize cropping system.

MATERIALS AND METHODS

Description of the experimental site

Field experiments were conducted at Agronomy Research Farm, the University of Agriculture Peshawar during summer 2017 and was repeated in summer 2018. The experiment was conducted in randomized complete block design with three replications. The experimental site is located at 34.01° N latitude, 71.35° E longitude at an altitude of 350 m above sea level in Peshawar valley. Peshawar (34.0167° N and 71.5833° E) is located about 1600 km North of the Arabian ocean and has continental type of climate. The research farm is irrigated by warsak canal from river Kabul. Soil is clay loam, low in organic matter (0.87 %), phosphorus (6.57 mg kg^{-1}), potassium (121 mg kg^{-1}) and alkaline (pH 8.2) and is calcareous in nature (Arif et al., 2017). The climate of the area is semiarid where the mean annual rainfall is very low (300 to 500 mm), 60-70% rainfall occurs in summer, while the remaining 30-40% rainfall occurs in winter (Arif et al., 2021).

Materials and treatments

The experimental field was irrigated before sowing of the maize crop and at proper moisture condition, the field was ploughed with cultivator followed by rotavator to prepare a fine seedbed for sowing. The experiment was consisted of two factors i.e., organic nitrogen sources (poultry manure (PM), farmyard manure (FYM) and legume residue (LR)), which were applied in different ratios i.e. 100:0:0, 0:100:0, 0:0:100, 50:50:0, 0:50:50 and 50:0:50 in the form of composted, non-composted and biochar, respectively. The experiment was also had a control and an inorganic N fertilizer treatment for comparison. A total of 200 kg N ha^{-1} was obtained from all these sources. The amount of P and K from these sources so obtained were compensated from inorganic P and K sources using SSP and SOP, respectively. Recommended dose of phosphorus (90 kg ha^{-1}) was applied at the time of seedbed preparation. The inorganic nitrogen was applied in two splits doses i.e. half each at sowing and the remaining half after first irrigation. Composted, non-composted and biochar materials were applied at the time of sowing.

Compost preparation

In order to prepare compost, pits were made, the composting materials (PM, FYM and LR) were dumped in separate pits in moist conditions and covered with plastic and buried in the soil for three months. The composted material was turned over on weekly basis in order to speed up the decomposition process and ensure uniform supply of oxygen.

Chemical analysis of manures (non-composted, composted, and biochar materials)

The organic sources were analyzed for different nutrients i.e. N, P and K and quantity of each organic source was applied in such a way to obtain 200 kg N ha^{-1}. The P and K received by field with these sources were compensated from the inorganic sources of P and K. A composite soil sample was collected and analyzed for different physico-chemical properties before sowing. Soil samples were also collected after harvest of the crop in both years and were analyzed for different physico-chemical parameters. Details of the factors and treatments were as follow: Factor-A: Organic sources (OS), Poultry manure, Farmyard manure, Legume residues (Sesbania) Factor-B: Ratios of different organic forms (non composted: composted: biochar)100:0:0, 0:100:0, 0:0:100, 50:50:0, 0:50:50 and 50:0:50 One control with no N application and second control with N from urea only were used in the experiment for comparison.

Experimental details

The experiment was laid out in randomized complete block design with four replications. The size of each plot was 4.5 m x 5 m. Row to row distance was 75 cm while plant to plant distance was 20 cm. Each plot was having six rows. Maize hybrid CS-200 was sown at the seed rate of 30 kg ha^{-1}. Thinning was done when the crop reached to four leaves stage. A pre-emergence herbicide followed by hoeing was used for weeds control. Irrigation was given according to the climatic conditions and the crop requirements. Insecticides were used in case of insect's attack. Wheat crop was sown in the winter season as a general practice of the farm. The following parameters were studied during the experiment:

Procedures for data recording:

Phenological traits

Data on days to tasseling were recorded by counting number of days from sowing to the date on which 80% plants produced tassels in two central rows. Days to silking data were recorded from the date of sowing to the date on which 80% plants produced silks in two central rows. Data on days to maturity were recorded from sowing till 80% plants became physiological mature as the seeds show a black layer formation at the base of the seed in two central rows.

Plant height for all the treatments in each replication were measured with the help of a measuring tape from the base to tassel tip of the ten randomly selected plants in two central rows and then average plant height was calculated. In each plot five plants were selected randomly and its leaf length and width were measured and then leaf area was calculated with the help of following formula using the correction factor of 0.75 as suggested by Tanko and Hassan (2016):

$$\text{Leaf area (cm}^2\text{)} = \text{Leaf length x leaf width x 0.75}$$

Leaf area index (LAI)

In each plot five plants were selected randomly and their leaf area index was calculated using the following formula:

$$\text{LAI}=\frac{\text{Leaf area plant}^{-1}}{\text{Ground area}}$$

Yield and Yield Components

Data on number of ear m^{-2} were recorded in each plot at one meter row length at three randomly selected places and were converted into number of ear m^{-2} using the formula;

$$\text{Number of ear m}^{-2} = \frac{\int \text{No. of } \textit{ear} \text{ counted}}{\text{Row} - \text{row (m) distance x Row length (m) x No. of rows}} \text{x1}$$

The ears harvested for grain yield were used for the determination of number of grains ear^{-1} by selecting five ears randomly from each plot, dried, shelled and their grains were counted for recording grains ear^{-1}. Data regarding 1000 grains weight were recorded by counting 1000 grains from each plot at random and then were weighed with electronic balance. Biological yield was recorded by harvesting plants from three central rows of each plot and sundried and then weighed. The data were then converted to kg ha^{-1}.

$$\frac{\text{Biological yield (kg)}}{\text{Row} - \text{row (m) distance x Row length (m) x No. of rows}} \text{x10000 m}^2$$

Grain yield data were recorded after shelling of ears of three central rows from each plot and then dried and weighed. The data were then converted into kg ha^{-1}.

$$\frac{\text{Grain yield (kg)}}{\text{Row} - \text{row (m) distance x Row length (m) x No. of rows}} \text{x10000 m}^2$$

Harvest index in percentage was calculated using following formula:

$$\frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}\times 100$$

Statistical analysis

The data recorded were analyzed statistically using analysis of variance techniques appropriate for randomized complete block design. Means were compared using LSD test at 0.05 level of probability, when the F-values was significant (Jan et al., 2009).

Results and Discussion

Days to tasseling

Early tasseling occurred in plots where farmyard manure (FYM) and legume residues (LR) were applied that hastened tasseling by 1 day as compared to poultry manure (PM). Similarly, equal dose of N obtained from both compost and biochar resulted in early tasseling as compared to sole use of non-compost that delayed tasseling by 3 days. Moreover, the planned mean comparison for control vs rest revealed that tasseling was 5 days earlier in no fertilized than fertilized plots (Table 1). The possible reason might be due to the slow release of nutrients from organic sources at appropriate stage which extended the growth cycle of the crop (Ahamd et al., 2017). Muhammad et al. (2019) reported that organic sources significantly delayed tasseling in maize. Likewise, Hammad (2012) reported that addition of nitrogen at later stages delayed tasseling in maize.

Days to silking

Plots applied with FYM and LR hastened silking by 1 day as compared to PM plots. Likewise, combination of 50% compost and 50% biochar resulted in quicker silking as compared to sole use of non-compost that delayed silking by 4 days. The planned mean comparison for control vs rest indicated that silking was 6 days earlier in no fertilized plots as compared to fertilized plots (Table 1). The delay in silking in this study might be due to more nitrogen availability because of the slow release of nutrients from organic sources which extended the vegetative growth of the crop and ultimately delayed silking. Dolan et al. (2006) and Li (2003) found higher nutrients availability and favorable soil conditions due to organic source of N which may cause vigorous crop growth and delay in phenology. Rizwan et al. (2003), Sharif et al. (2004) and Hance et al. (2008) also stated that availability of N from organic sources at proper amount and time delayed silking in maize crop.

Days to maturity

Application of organic manure in the form of PM extended maturity by 1 day as compared with FYM and LR. The combined application of compost and biochar in equal proportion (50%) extended maturity by 4 days than sole use of non compost. The planned mean comparison for control vs rest revealed that maturity was 6 days earlier in no fertilized plots as compared with fertilized plots. Moreover, maturity was earlier by 1 day in plots where organic source of N was applied than inorganic source (Table 1). The interaction between organic sources and their nitrogen ratios indicated that maturity was delayed with application of PM followed by FYM for both sole and combined application of non-compost, compost and biochar except 50% non-compost and 50% biochar plots where delayed maturity occurred with FYM application followed by PM. The reason might be due to increase in nutrients with increase in compost rates and adequate micro and macro nutrients throughout the growing season. Shrestha (2013) reported that increase in nitrogen extends the vegetative stage which ultimately delay the maturity of the crop. However, our results did not agree with Shah et al. (2009) who reported that compost had no effect on days to maturity and this might be due to varietal characteristics. Hammad (2012) stated that nitrogen addition at later stages of the crop delayed physiological maturity of the crop.

Plant height

Application of poultry manure increased plant height by 2% as compared to legume residue. Likewise, combination of 50% compost and 50% biochar increased plant height by 8% as compared to sole use of non-compost. Planned mean comparison revealed that fertilized plots recorded 7.2% taller plants than unfertilized plots and organic form of N application resulted in 4% taller plants than inorganic N fertilization (Table 2). The possible reason for taller plants from combination of organic and inorganic nitrogen sources might be the timely availability of nutrients. Our findings are supported by Makinde and Ayoola (2010) and Ayoola and Makinde (2007) who documented that the application of inorganic and organic fertilizers significantly increased plant height than sole fertilizer application.

Number of ears (m^{-2})

Application of compost and biochar in 50:50 ratios marked the highest increase of 14.2% in number of ear m^{-2} as compared to plots where 100% non-composted materials were applied. Similarly, nitrogen fertilized plots resulted in 8% higher ears m^{-2} over control (Table 2). Malaiya et al. (2004) found that maximum ears were produced with combination of mineral nitrogen and organic manure as compared to unfertilized plots. Dixit and Gupta (2000) and Sarwar et al. (2008) stated that application of compost enhanced the crop growth and increased productive tillers (m^{-2}) in rice and wheat which increased the productivity of the crops.

Number of leaves plant^{-1}

Combined application of compost and biochar each in 50% ratio produced 9.8% higher number of leaves plant^{-1} as compared to 100% sole application of compost. Similarly, planned mean comparison for control vs rest revealed that fertilized plot produced 9.6% higher number of leaves plant^{-1} than control. Mousavi et al. (2020) stated that application of biochar compost significantly increased the number of leaves in maize due to adequate availability of nutrients to the crop.

Leaf area (cm^2)

Application of PM or FYM resulted in 5.9 and 3% increase in leaf area of maize as compared with legume residues plots, respectively. Likewise, combination of 50% compost and 50% biochar resulted in higher leaf area as compared to sole use of non-compost that increased leaf area by 19.3%. The planned mean comparison for control vs rest indicated that leaf area was 14.4% more in fertilized plots as compared with non- fertilized plots. Nitrogen fertilization significantly stimulates growth of leaf because of the absorption capability due to superior photosynthetic surface leaf area increased (Khan et al., 2008). Arif et al. (2012) who found that application of biochar at the rate of 50 tons ha^{-1} produced maximum leaf area in maize as compared with no biochar plots. Increase in leaf area might be due to application of N which improve soil N condition and chlorophyll pigments (Zhao et al., 2003). Similarly, Houles et al. (2007) reported that incorporation of biochar enhanced soil N status and chlorophyll through better N absorption and thus might improve wheat leaf area.

Leaf area index

Plots which received PM increased leaf area index by 4.5% as compared to LR. Likewise, combination of 50% compost and 50% biochar resulted in 37.9% higher leaf area index as compared to sole use of non-compost. The planned mean comparison for control vs rest showed that leaf area index was 26.6% more in fertilized plots as compared with non-fertilized plots. Burke et al. (2012) found increased leaf area due to biochar application. Likewise, Njoku et al. (2015) showed that biochar amended plots had significantly higher leaf area index than control. In similar way, Lashari et al. (2015) and Ahmad et al. (2015) found that application of biochar significantly improved leaf area index in maize and sugar beet crops, respectively.

Grains ear^{-1}

PM and FYM increased in grains ear^{-1} of maize by 5.5 and 3.5% as compared with LR, respectively. Likewise, combination of 50% compost and 50% biochar resulted in higher grains ear^{-1} as compared to sole use of non-compost that increased grains ear^{-1} by 19.3%. The planned mean comparison for control vs rest indicated that grains ear^{-1} was 14.4% more in fertilized plots as compared with non-fertilized plots. The increase in number of grains ear^{-1} of maize might be due to the extended grain filling duration, availability of essential nutrients at critical stages and longer ears. Ali et al. (2015) stated that increase in nitrogen doses increased the grains ear^{-1}. Similarly, Pandey et al. (2000) reported that increase in seed weight was due to the increase in grains ear^{-1} and decrease in non-productiveness of maize ears. Likewise, Bekeko et al. (2013) revealed that application of nitrogen to the crop increased grains ear^{-1}.

Thousand grain weight (g)

Poultry manure application significantly increased thousand grains weight by 2.1% as compared to LR. Application of 50% compost and 50% biochar produced 5.5% more thousand grains weight over 100% sole application of non-compost. Similarly, planned mean comparison for control vs rest indicated that thousand grain weight was 6.7% higher in fertilized plots as compared to control. The planned mean comparison for organic vs inorganic showed that thousand grain weight was 3.5% more in organic fertilized plots as compared with inorganic plots. The increase in 1000-grain weight might be due to the timely availability of nutrients which helps in increase in assimilate production and maximum assimilate migrated towards the grain or sink in comparison with control plots. Yigermal et al. (2019) noted more thousand grain weight with combined application of PM and FYM. Similarly, El-Gawad and Morsy (2017) got more thousand grain weight in maize with the application of PM and sheep manure. Our findings are supported by Farhad et al. (2009) who reported an increase in thousand grain weight with application of different type of organic sources. Likewise, integration of compost and non-compost organic sources with biochar significantly enhanced thousand grain weight as compared with sole single source of fertilizer (Liu et al., 2012). The higher thousand grain weight of 333 g was recorded with combined application of compost and biochar than non-compost (312 g) assuming more nutrients availability for better growth and translocation of assimilate towards sink (Liang et al., 2008).

Biological yield (kg ha^{-1})

Incorporation of PM increased biological yield by 9.9% over LR. Likewise, combination of 50% compost and 50% biochar increased biological yield by 15% as compared to 100% sole application of non compost. Fertilized plots improved maize biological yield by 16.2% as compared to control plots. Moreover, 1.5% increase in maize biological yield was noted in organic fertilized plots as compared to inorganic plots. Ali et al. (2017) reported that biochar application delay growth stages and thus enhance active growing period of maize crop for production of maximum dry matter and improving quality and all enhance soil fertility and ensure availability of essential nutrients that may result in increased vegetative growth. Pandit et al. (2019) explained that biochar application to the soil enhanced the soil structure and fertility which resulted in increased soil productivity and produced higher yield. Our outcomes are also reinforced by Munir et al. (2007) who reported that incorporation of combined organic and inorganic fertilizers resulted in higher biological yield of maize and it might be due to the availability of supplementary nutrients and enhanced nutrients uptake which led to higher biological yield. Boateng et al. (2006) also reported that no fertilizer application resulted in lower biomass while PM in combination with chemical fertilizer had the highest biomass probably due to synergy.

Grain yield (kg ha^{-1})

Poultry manure and FYM significantly increased grain yield by 5.1 and 4% as compared to LR. Application of 50% compost and 50% biochar produced 20.7% more grain yield over 100% sole application of non-compost. Similarly, planned mean comparison for control vs rest indicated that grain yield was 19.9% higher in fertilized plots as compared to control. The planned mean comparison for organic vs inorganic showed that grain yield was 20.03% more in organic plots as compared with inorganic plots. The increase in grain yield might be due to the slow release of nutrients and timely availability of nutrients at appropriate time. The increase in number of grains ear^{-1} with composted dairy manure at higher levels increases grain yield (Ahmad et al., 2017). Loecke et al. (2004) also stated that grain yield of maize increased with composted manure as compared to fresh farmyard manure.

Harvest index (%)

Plots which received LR increased harvest index by 3.3% as compared to PM or FYM. Likewise, combination of 50% compost and 50% biochar resulted in 4.2% higher harvest index as compared to sole use of non-compost. The planned mean comparison for control vs rest showed that harvest index was 3.9% more in fertilized plots as compared with non-fertilized plots. The results are similar with Moser et al. (2006) who stated that increase in harvest index of maize might be due to slow release of nutrients from organic matter. The possible reason for higher harvest index could be the balanced supply of nutrients form combination of organic and inorganic sources of nitrogen (Suge et al., 2011). Our findings are backed by Sara et al. (2018) who documented that harvest index increased with the addition of biochar.

Table 1. Days to tasseling, silking and maturity of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)		Days to tasseling	Days to silking	Days to maturity
Poultry Manure		55 a	60 a	100 a
Farmyard Manure		54 b	59 b	99 b
Sesbania residues		54 b	59 b	99 b
$LSD_{(p=0.05)}$		0.36	0.39	0.36
Non Composted : Composted : Biochar = 100 : 0 : 0		56 a	61 a	102 a
Non Composted : Composted : Biochar = 0 : 100 : 0		55 b	60 b	101 b
Non Composted : Composted : Biochar = 0 : 0 : 100		54 c	59 c	99 c
Non Composted : Composted : Biochar = 50 : 50 : 0		54 c	59 c	99 c
Non Composted : Composted : Biochar = 50 : 0 : 50		54 c	59 c	99 c
Non Composted : Composted : Biochar = 0 : 50 : 50		53 d	58 d	98 d
$LSD_{(p=0.05)}$		0.51	0.55	0.51
Years				
	2017	54.1	59.4	99
	2018	54.6	59.6	100
Significance		*	NS	NS
Control		49	53.3	94
Rest		54.4	59.5	99
Significance		***	***	***
Inorganic		54.8	59.3	98
Organic		54.4	59.5	99
Significance		NS	NS	***

Table 2. Plant height and number of leaves plant^{-1} of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)	Plant height (cm)	Number of leaves plant^{-1}
Poultry Manure	220 a	12.2
Farmyard Manure	219 a	12.3
Sesbania residues	216 b	12.4
LSD$_{(p=0.05)}$	2.12	NS
Desired Organic Nitrogen ratios (R) (%) 200 kg ha^{-1}		
Non Composted : Composted : Biochar = 100 : 0 : 0	212 e	11.5 d
Non Composted : Composted : Biochar = 0 : 100 : 0	223 b	12.3 b
Non Composted : Composted : Biochar = 0 : 0 : 100	217 c	12.2 c
Non Composted : Composted : Biochar = 50 : 50 : 0	216 cd	12.2 c
Non Composted : Composted : Biochar = 50 : 0 : 50	214 de	12.2 c
Non Composted : Composted : Biochar = 0 : 50 : 50	229 a	13.3 a
LSD$_{(p=0.05)}$	3	0.52
Years		
2017	220	12.2
2018	217	12.4
Significance	**	NS
Planned mean comparison		
Control	204	11.2
Rest	218	12.3
Significance	***	**
Inorganic	210	12.2
Organic	218	12.3
Significance	***	NS

Table 3. Leaf area and leaf area index of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)		Leaf area (cm^2)	Leaf area index
Poultry Manure		343 a	2.94 a
Farmyard Manure		333 b	2.86 b
Sesbania residues		324 c	2.82 b
$LSD_{(p=0.05)}$		2.09	0.09
Desired Organic Nitrogen ratios (R) (%) 200 kg ha^{-1}			
Non Composted : Composted : Biochar =	100 : 0 : 0	305 f	2.45 d
Non Composted : Composted : Biochar =	0 : 100 : 0	351 b	3.03 b
Non Composted : Composted : Biochar =	0 : 0 : 100	340 c	2.91 b
Non Composted : Composted : Biochar =	50 : 50 : 0	325 d	2.77 c
Non Composted : Composted : Biochar =	50 : 0 : 50	315 e	2.70 c
Non Composted : Composted : Biochar =	0 : 50 : 50	364 a	3.38 a
$LSD_{(p=0.05)}$		2.96	0.13
Years			
	2017	334	2.87
	2018	332	2.88
Significance		NS	NS
Planned mean comparison			
Control		291	2.27
Rest		333	2.87
Significance		***	***
Inorganic		331	2.82
Organic		333	2.87
Significance		NS	NS

Table 4. Number of ears m^2 and number of grains ear^{-1} of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)	**Number of ears m^{-2}**	**Number of grains ear^{-1}**
Poultry Manure	6.8	493 a
Farmyard Manure	6.7	476 b
Sesbania residues	6.6	467 b
$LSD_{(p=0.05)}$	NS	9.31
Desired Organic Nitrogen ratios (R) (%) 200 kg ha^{-1}		
Non Composted : Composted : Biochar = 100 : 0 : 0	6.3 c	439 d
Non Composted : Composted : Biochar = 0 : 100 : 0	6.9 b	500 ab
Non Composted : Composted : Biochar = 0 : 0 : 100	6.8 b	487 b
Non Composted : Composted : Biochar = 50 : 50 : 0	6.5 c	473 c
Non Composted : Composted : Biochar = 50 : 0 : 50	6.4 c	465 c
Non Composted : Composted : Biochar = 0 : 50 : 50	7.2 a	509 a
$LSD_{(p=0.05)}$	0.21	13.17
Years		
2017	6.7	485
2018	6.7	473
Significance	NS	*
Planned mean comparison		
Control	6.2	370
Rest	6.7	477
Significance	***	***
Inorganic	6.8	435
Organic	6.7	479
Significance	NS	***

Table 5. Thousand grain weight (g) and biological yield (kg ha^{-1}) of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)		**Thousand grain weight (g)**	**Biological yield (kg ha^{-1})**
Poultry Manure		322 a	15102 a
Farmyard Manure		317 b	13916 b
Sesbania residues		316 b	13756 c
$LSD_{(p=0.05)}$		2.26	73.83
Desired Organic Nitrogen ratios (R) (%) 200 kg ha^{-1}			
Non Composted : Composted : Biochar = 100 : 0 : 0		311 d	13224 f
Non Composted : Composted : Biochar = 0 : 100 : 0		323 b	14982 b
Non Composted : Composted : Biochar = 0 : 0 : 100		317 c	14421 c
Non Composted : Composted : Biochar = 50 : 50 : 0		314 cd	14204 d
Non Composted : Composted : Biochar = 50 : 0 : 50		312 d	13389 e
Non Composted : Composted : Biochar = 0 : 50 : 50		333 a	15328 a
$LSD_{(p=0.05)}$		3.2	104.42
Years			
	2017	320	14589
	2018	316	13926
Significance		***	***
Planned mean comparison			
Control		298	12256
Rest		318	14246
Significance		***	***
Inorganic		307	14037
Organic		318	14258
Significance		***	**

Table 6. Grain yield and harvest index (%) of maize as affected by different type of organic sources and their desired nitrogen ratios.

Organic sources (OS)		Grain yield (kg ha^{-1})	Harvest index (%)
Poultry Manure		5370 a	35.5 b
Farmyard Manure		5100 b	36.7 a
Sesbania residues		5049 c	36.7 a
LSD$_{(p=0.05)}$		29.87	0.2
Desired Organic Nitrogen ratios (R) (%) 200 kg ha^{-1}			
Non Composted : Composted : Biochar = 100 : 0 : 0		4642 f	35.1 d
Non Composted : Composted : Biochar = 0 : 100 : 0		5416 b	36.2 c
Non Composted : Composted : Biochar = 0 : 0 : 100		5293 c	36.8 a
Non Composted : Composted : Biochar = 50 : 50 : 0		5210 d	36.7 a
Non Composted : Composted : Biochar = 50 : 0 : 50		4870 e	36.4 bc
Non Composted : Composted : Biochar = 0 : 50 : 50		5607 a	36.6 ab
LSD$_{(p=0.05)}$		42.25	0.3
Years			
	2017	5279	36.2
	2018	5067	36.4
Significance		***	*
Planned mean comparison			
Control		4309	35.2
Rest		5168	36.3
Significance		***	***
Inorganic		5070	36.1
Organic		5173	36.3
Significance		***	NS

CONCLUSIONS:

Application of poultry manure resulted in higher number of grains ear^{-1}, thousand grain weight, biological yield and grain yield of maize. Organic nitrogen ratio of 100:0:0 (non-compost, compost and biochar) produced maximum ear m^{-2}, number of grains ear^{-1}, thousand grain weight, biological yield and grain yield of maize

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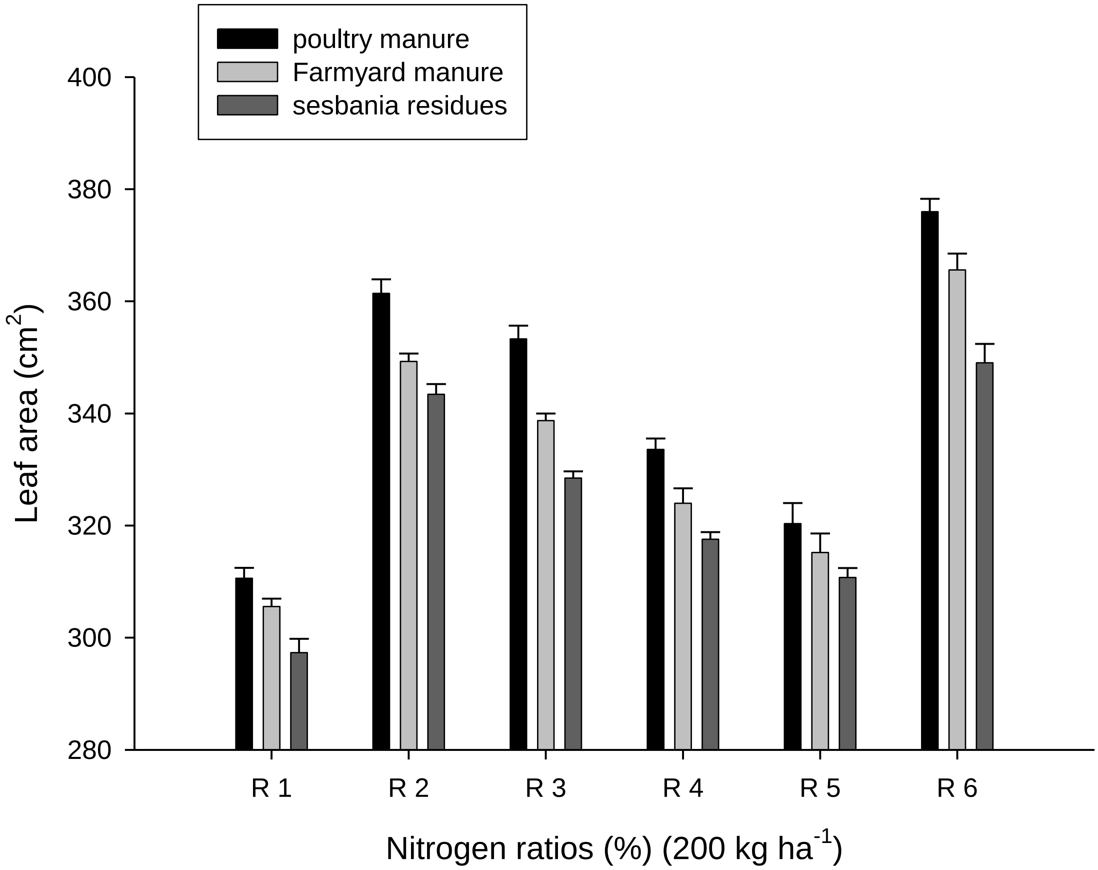
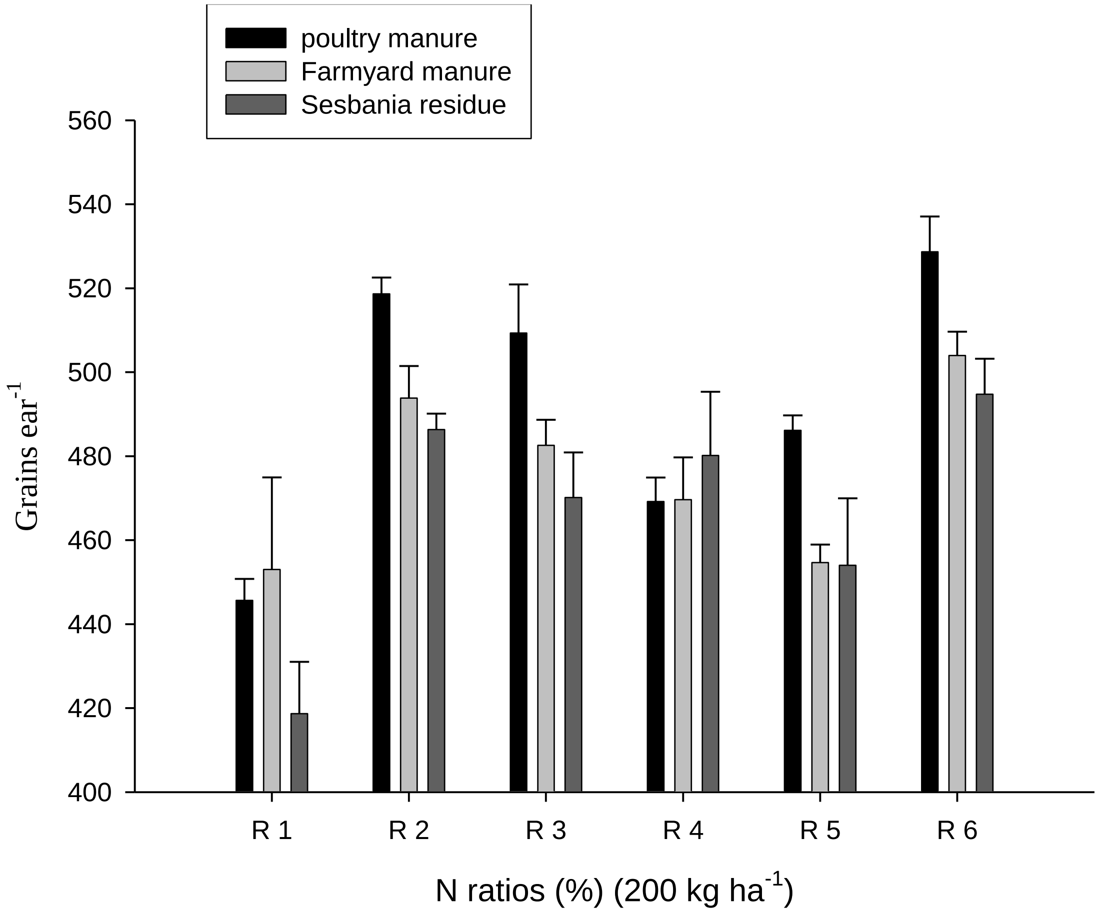


R1=100% Non compost (NS) R2=100% Compost (C)
R3=100% Biochar (B) R4=50% NC+50% C
R5=50% NC+50% B R6=50% C+ 50% B

Fig 1. Interaction between organic sources and their ratios for leaf area (cm^2) of maize.



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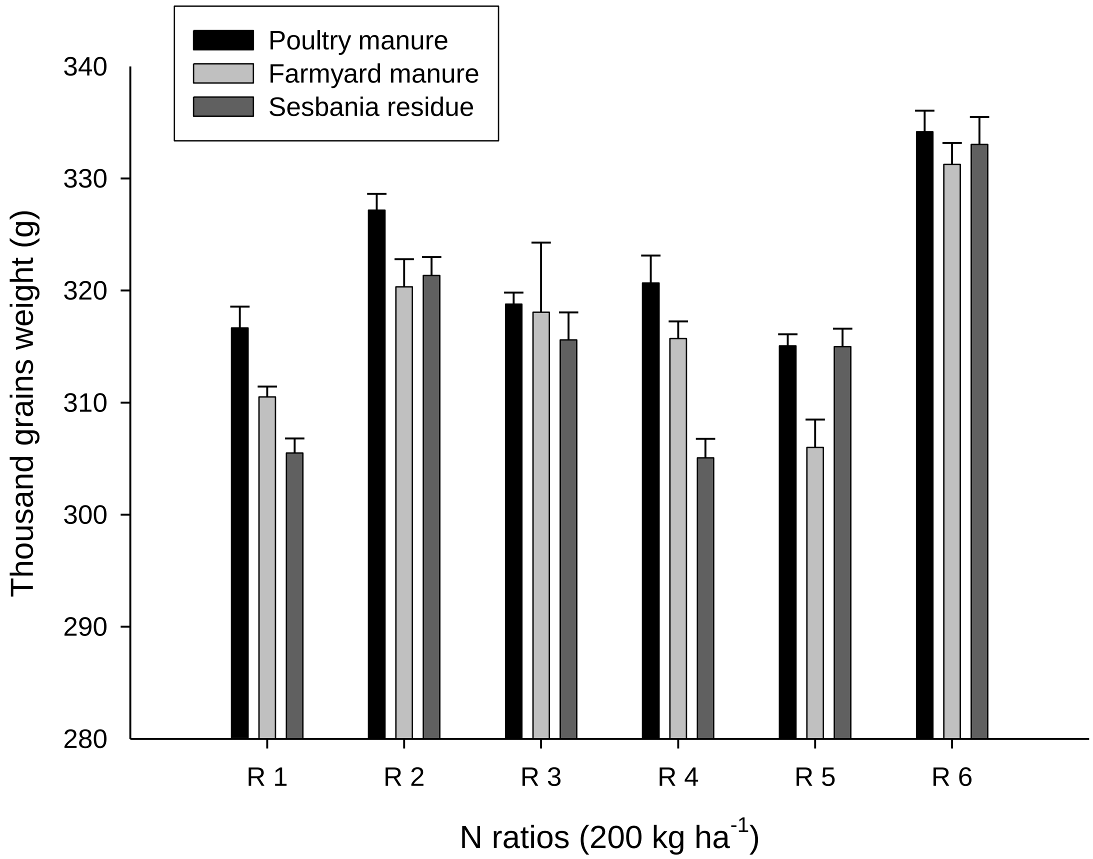
R3=100% Biochar (B) R4=50% NC+50% C
R5=50% NC+50% B R6=50% C+ 50% B

Fig 2. Interaction between organic sources and their ratios for grains ear^{-1} of maize.



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R3=100% Biochar (B) R4=50% NC+50% C
R5=50% NC+50% B R6=50% C+ 50% B

Fig 3. Interaction between organic sources and their ratios for thousand grain weight (g) of maize.

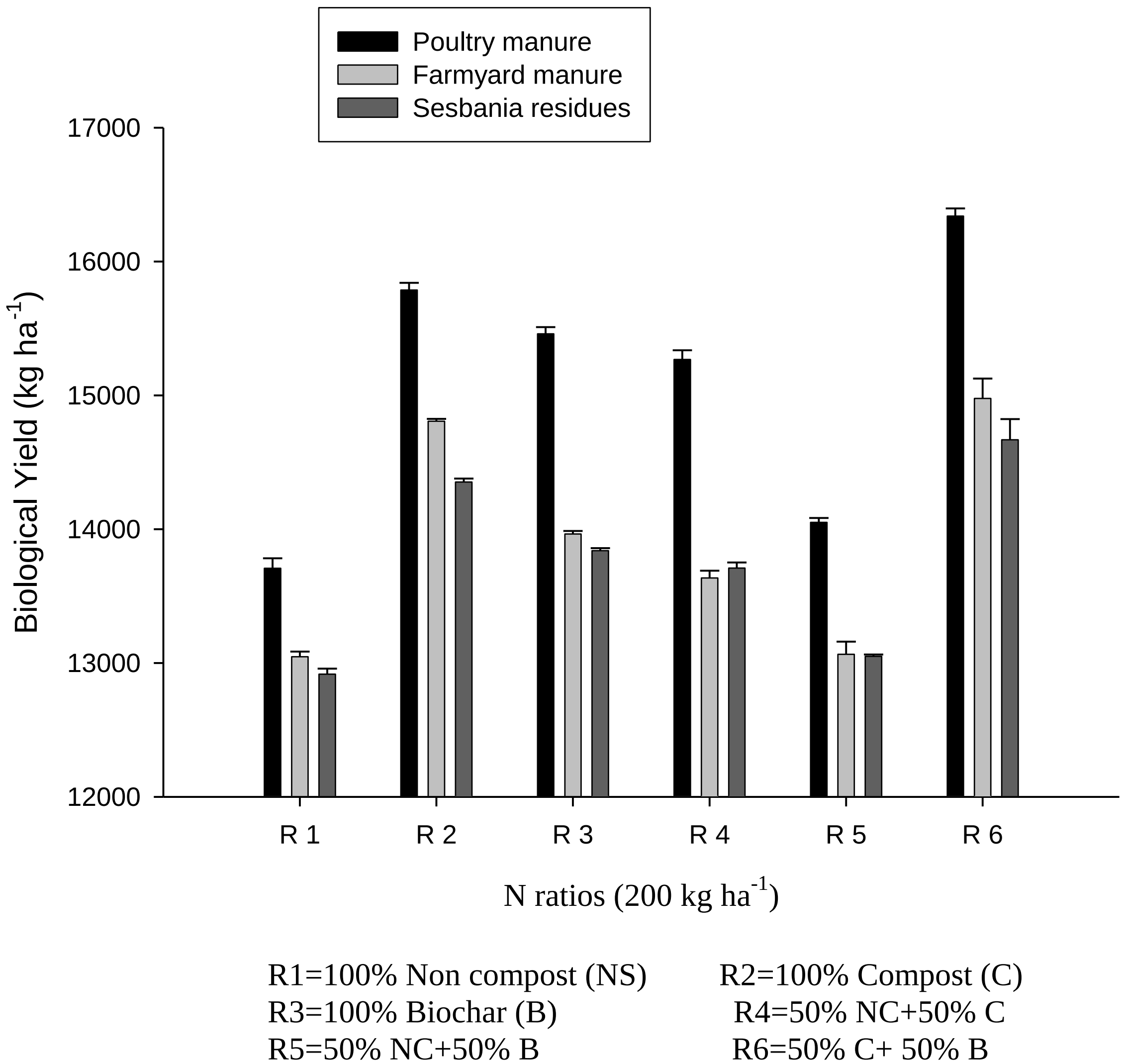
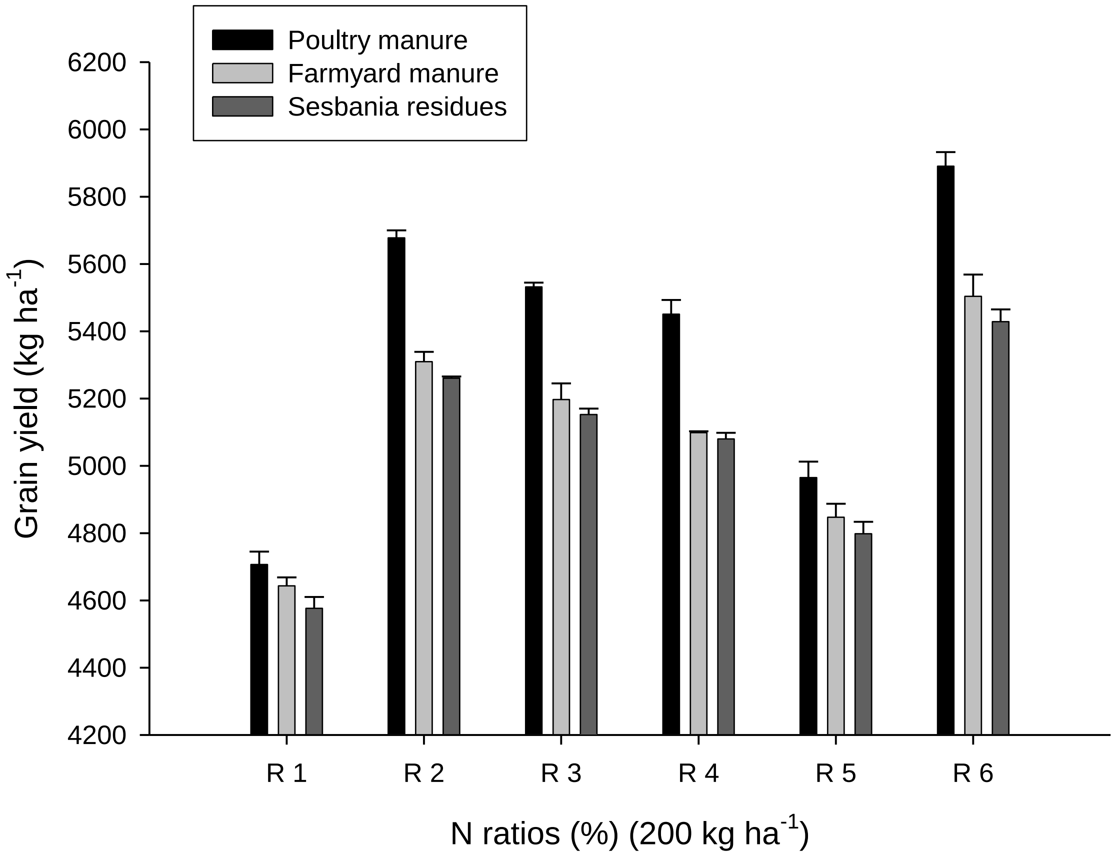


Fig 4. Interaction between organic sources and their ratios for biological yield (kg ha^{-1}) of maize.



R1=100% Non compost (NS) R2=100% Compost (C)
R3=100% Biochar (B) R4=50% NC+50% C
R5=50% NC+50% B R6=50% C+ 50% B

Fig 5. Interaction between organic sources and their ratios for grain yield (kg ha^{-1}) of maize.