INFLUENCE OF ORGANIC AMENDMENTS ON MAIZE PRODUCTIVITY

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Abstract

A field study was conducted at Agronomy Research Farm, The University of Agriculture, Peshawar in the summer 2023 to evaluate the response of biochar, farmyard manure and NPK application on maize yield. The field trial was conducted in randomized complete block design with 3 replications. Plot size of 3 m x 4.5 m with a plant-to-plant distance of 25 cm and row to row distance of 75 cm was maintained. Three levels of biochar (0, 5 and 10 t ha^{-1}), three levels of farmyard manure (0, 4 and 8 t ha^{-1}) and two levels of NPK (0% and 50% (N: 75 kg, P: 60 kg, and K: 45 kg ha^{-1}) of the recommended dose) were studied on maize hybrid CS-200. Biochar and farmyard manure were applied to the soil 20 days before sowing the crop. Experimental results revealed that the effect of biochar, farmyard manure and NPK application on the duration of emergence, emergence m^{-2}, number of plants at harvest (ha^{-1}) and number ears m^{-2} of maize was non-significant. Biochar application at the rate of 10 t ha^{-1} to soil significantly enhanced plant height (194 cm), numbers of grains ear^{-1} (403), thousand grains weight (355 g), biological yield (12260 kg ha^{-1}), grain yield (4013 kg ha^{-1}), harvest index (33 %) and soil pH (7.66) with delayed days to tasseling (56), days to silking (64) and days to physiological maturity (104). Farmyard manure application at the rate of 8 t ha^{-1} to soil significantly increased plant height (193 cm), numbers of grains ear^{-1} (400), thousand grains weight (352 g), biological yield (12187 kg ha^{-1}), grain yield (3943 kg ha^{-1}), harvest index (32 %), soil pH (7.62) and soil electric conductivity (1.19 dS m^{-1}) with delayed days to tasseling (56), days to silking (64) and days to physiological maturity (104). NPK application at the rate of 50 % of the recommended dose maintained maximum plant height (191 cm), numbers of grains ear^{-1} (402), thousand grains weight (349 g), biological yield (11958 kg ha^{-1}) grain yield (3788 kg ha^{-1}), harvest index (31 %), and soil electric conductivity (1.23 dS m^{-1}) with delayed days to tasseling (55), days to silking (63) and days to physiological maturity (103). It is concluded that maize crop with the application of biochar at 10 t ha^{-1}, farmyard manure at 8 t $ha^{-1}$and NPK 50% (N: 75 kg, P: 60 kg, and K: 45 kg ha^{-1}) of the recommended dose performed better and thus recommended for higher seed yield and productivity.

Keywords: Agronomy, Farmyard, Biochar, Maize Crop, Physiological

DOI:	https://zenodo.org/records/14270234
Journal Link:	https://jai.bwo-researches.com/index.php/jwr/index
Paper Link:	https://jai.bwo-researches.com/index.php/jwr/article/view/66
Publication Process	Received: 8 Jul 2024/ Revised: 18 Sep 2024/ Accepted: 23 Sep 2024/ Published: 03 Oct 2024
ISSN:	Online [3007-0929], Print [3007-0910]

| *Indexing:* | Academia.edu DRJI doi zenodo Google INDEX COPERNICUS INTERNATIONAL |
| *Publisher:* | BWO Research International (15162394 Canada Inc.) https://www.bwo-researches.com |

Introduction

Maize (*Zea mays L.*) ranks as the third most important cereal crop after wheat and rice (Nemati et al., 2012). Maize is a cross pollinated and major cereal grown throughout the world (Ramzani et al., 2017). This annual plant reproduces through cross-pollination. Maize is used for human food, animal feed and raw material for industries. Globally it is a staple food and in certain countries it makes up almost one-third of the total amount of calories and protein consumed (Chulze et al., 2010). In addition to having a shorter growing season and the ability to use inputs more effectively, maize has the potential to produce higher number of grains per unit area. It can be grown in spring and summer twice a year with success. Maize has high nutritional value than other crops and has around 72% starch, 10% proteins, 4.8% oil, 8.5% fiber, 3% sugar and 1.7% ash (Chaudhary et al., 1993). The overall production of maize in Pakistan was about 5.7 million tons from an area of 1,229 thousand hectares with an average yield of 3990 kg per hectare while in Khyber Pakhtunkhwa maize was cultivated on 474 thousand hectares with the production of about 0.867 million tons and average yield was 1868 kg per hectare (Ministry of national food & security, 2018).

The conversion of organic waste into biochar for application on soil is an environment friendly management technique (Gonzaga et al., 2018) The outcome of heating biomass, wood, dung, and leaves in a closed container with little to no air is biochar a carbon-rich material that appears to be a more stable carbon source that can remain in the soil for hundreds or even thousands of years (Lehmann et al., 2006) When used as a soil supplement, biochar can increase plant growth and fertility, enhance carbon sequestration, help with waste management and immobilize substances. Biochar contains a high content of organic materials and a large surface area. Therefore, by enhancing soil quality, it provides a suitable home for soil microbes and increases soil biota (Lehmann et al., 2011). The use of biochar in low fertile soil is a useful technique to improve soil carbon, soil health and crop productivity (Glaser et al., 2002). Biochar characteristic has attained an increasing interest to reclaim nutrients poor soils (Khoshgoftarmanesh et al., 2011).

Organic fertilizers, such as farmyard manure, sheep waste and poultry manure can be utilized to replace chemical fertilizers in crop production since the value of organic manures cannot be overstated. Due to soil fertility loss, there is an increasing global interest in the usage of organic manures. Ensure sustainable crop production, farmers often use organic fertilizers (Delate and Camberdella, 2004). The benefit of organic fertilizers, applying organic fertilizers for nutrient recycling has emerged as a successful strategy for sustainable agriculture. The impact on crop productivity method improves crop yields by enhancing nutrient utilization within the soil. The current levels of crop production of high yielding varieties cannot be sustained by using FYM alone as a substitute for inorganic fertilizer (Efthimiadou et al., 2010). Thus, the best way to maintain a healthy and sustainably productive soil is to apply both organic manures and inorganic fertilizers simultaneously, a practice known as integrated nutrient management (Dejene et al., 2012). Natural fertilizers promote seed germination and root growth by means of bettering soil water conserving ability, and preserve excellent ventilation. Corn yield vastly elevated through the addition of

FYM and treated with conventional fertilizers (Lehmann et al., 2011).

Since mineral nutrients are the main factors that increase crop productivity, nutrient management is crucial for obtaining the potential yield in maize production system (Khoshgoftarmanesh et al., 2011). Implementing efficient nutrient management practices is crucial for both environmental and economic sustainability. Nitrogen, a vital component of proteins, nucleic acids, and chlorophyll, plays a key role in capturing sunlight for photosynthesis (Amanullah et al., 2009). Phosphorus, often the second limiting nutrient in soils, is necessary for growth, sugar and starch utilization, and overall yield potential (Ayub et al., 2002). Finally, potassium significantly impacts enzyme activity, photosynthesis, water regulation, and stress tolerance through its influence on stomata movement, protein synthesis, phloem transport, and nutrient balance (Nemati et al., 2012).

This study investigates the combined effects of NPK fertilizers, farmyard manure, and biochar on maize yield. The primary goal is to discover the best mix of these soil amendments for increasing maize productivity effectively and sustainably. By examining their individual and combined effects, the study hopes to provide practical recommendations for increasing maize production.

This study sought to determine the best mix of biochar, farmyard manure, and NPK fertilizers to optimize corn productivity, driven by the known benefits of these amendments on maize yield.

Materials And Methods

To explore the effect of organic amendments on maize production, the experiment was carried out in the summer of 2023 at the Agronomy Research Farm of the University of Agriculture Peshawar in Pakistan. Three replications of the randomised complete block design (RCBD) were used. The space measured 3 m by 4.5 m, with plants spaced 25 cm apart in six rows separated by 75 cm. 30 kilogrammes of the maize hybrid seed variety CS-200 were planted per hectare.

Treatments1

Applications of biochar range from 0 to 10 t ha^{-1}. 2Farmyard manure (FYM) is applied at three different levels: 0, 4, and 8 t ha^{-1}. 3Two NPK fertilizer dosages were tested: a control (no fertilizer) and half of the recommended dosage (150:120:90 kg ha^{-1} for N: P:K).

Experimental Procedure

Coal and farmyard manure were added into the soil.

Planting: The maize seeds were sown with the proper spacing to ensure steady development.

Fertilization: Half of the recommended dosage of NPK fertilizers was applied to the designated plots.

Irrigation: With weather-related adjustments, the crop was watered in accordance with the regular schedule.

Weed Control: Weeds were manually plucked to lessen competition.

Data Collection

During the growth stage: Days till emergence, tasseling, silking, and physiological maturity. Quantity of sprouting seeds per square meter the plant's height. After harvest:
1. Amount of greenery per hectare.
2. Number of ears per square meter.
3. Amount of grain in per ear.
4. Weight in grammes (g) or thousand grains.
5. Life yield (kg ha^{-1}).
6. Grain yield (kg ha^{-1}).
7. Harvest index (%).
8. Soil characteristics include pH and electrical conductivity (EC) according to Rhoads (1982) and McLean (1982).

Statistical Analysis

Data were examined using statistical techniques at a 5% probability level, as recommended by Steel and Torrie (1997). This made it possible to accurately assess the results of the treatment. In order to provide insights into sustainable farming techniques, this analytical approach sought to fully evaluate the effects of both organic and inorganic soil amendments on maize growth, yield, and soil health indicators.

RESULTS

Days to emergence and Emergence m^{-2}

The table 1 shows how biochar, farmyard manure (FYM), and NPK fertilizer levels affect maize output. The data's organization shows how different factors interact and affect the mean yield (t ha^{-1}) overall.

Table 1. Days to emergence of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Means NPK x FYM
0 (control)	0	7	7	6	7
	4	6	6	7	6
	8	6	7	7	7
75 : 60 : 45	0	6	6	6	6
	4	6	6	6	6
	8	6	6	7	6
		NPK x B			NPK
0		7	6	7	7
75 : 60 : 45		6	6	6	6
		FYM x B			FYM
	0	7	6	6	6
	4	7	6	7	6
	8	6	7	7	7
Means		6	6	7	

LSD value (P≤0.05) for Biochar = ns
LSD value (P≤0.05) for FYM = ns
LSD value (P≤0.05) for NPK = ns

Table 2. Emergence (m^{-2}) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	6	6	7	6
	4	7	7	6	6
	8	7	6	6	7
75 : 60 : 45	0	7	6	7	7
	4	6	6	6	6
	8	7	6	7	7
		NPK x B			NPK
0		7	6	6	6
75 : 60 : 45		7	6	6	6
		FYM x B FYM			
	0	7	7	7	7
	4	6	6	6	6
	8	7	6	7	6
Mean		7	6	6	

LSD value (P≤0.05) for Biochar = ns
LSD value (P≤0.05) for FYM = Ns
LSD value (P≤0.05) for NPK = ns

Days to tasseling

The data depicted in Table 3 below shows that application of biochar, farmyard manure, and NPK had significantly influenced tasseling in maize. However, there was no significant interaction observed between biochar, farmyard manure, and NPK regarding days to tasseling. Mean values of the data cleared that application of 10 t ha^{-1} biochar resulted in longer tasseling period (56 days), whereas control plots exhibited shorter period from sowing to tasseling (54 days). With the application of 8 t ha^{-1} farmyard manure tasseling stage was delayed (56 days), while no application of farmyard manure to plants led to earlier tasseling stage (53 days). The use of NPK at 50% level prolonged the tasseling period (55 days), whereas no NPK application shortened it to 54 days

Table 3. Days to tasseling of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha-1)	Farmyard manures Levels (t ha-1)	Biochar Levels(t ha-1) 0	5	10	Mean FYM x NPK
0 (control)	0	52	53	53	53
	4	54	54	55	54
	8	55	56	57	56
75 : 60 : 45	0	53	53	54	53
	4	55	55	56	55
	8	56	57	57	57
		NPK x B			NPK
0		54	55	55	54 b
75 : 60 : 45		55	55	55	55 a
		FYM x B			FYM
	0	53	54	56	53 c
	4	53	55	56	55 b
	8	54	56	57	56 a
Mean		54 c	55 b	56 a	

LSD value (P≤0.05) for Biochar = 1.0

LSD value (P≤0.05) for FYM = 1.0

LSD value (P≤0.05) for NPK = 1.0

Means of same category followed by different letters are significantly different (P ≤ 0.05) using LSD test.

Days to silking

The days to silking in maize were significantly impacted by biochar, farmyard manure (FYM), and NPK levels, according to the mean values in Table 4. However, there was no statistically significant interaction between these components. The results showed that whereas no biochar treatment caused an earlier silking stage at 62 days, adding 10 t ha^{-1} of biochar delayed silking to 64 days. Similarly, when 8 t ha^{-1} FYM was applied, silking started early at 62 days, but when FYM was not administered, silking took longer, reaching 64 days. It took 63 days for maize treated with 50% of the recommended NPK dose to reach the silking stage in terms of NPK levels, as opposed to 62 days when no NPK was administered.

Table 4 Days to silking of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha-1)	Farmyard manures Levels (t ha-1)	Biochar Levels(t ha-1) 0	5	10	Mean FYM x NPK
0 (control)	0	61	61	62	61
	4	62	62	63	62
	8	63	64	64	64
75 : 60 : 45	0	61	62	63	62
	4	63	64	64	64
	8	64	64	65	64
		NPK x B			NPK
0		63	62	63	62 b
75 : 60 : 45		63	63	64	63 a
		FYM x B			FYM
	0	61	63	64	62 c
	4	62	63	64	63 b
	8	62	64	64	64 a
Mean		62 c	63 b	64 a	

LSD value (P≤0.05) for Biochar= 0.49

LSD value (P≤0.05) for FYM = 0.49

LSD value (P≤0.05) for NPK = 0.40

Means of same category followed by different letters are significantly different (P ≤0.05) using LSD test.

Days to physiological maturity

The number of days until maize reached physiological maturity was significantly impacted by the amounts of biochar, farmyard manure (FYM), and NPK, as indicated by the mean results in Table 5. These elements did not, however, significantly interact with one another. Biochar Levels: Plots without biochar matured earlier at 102 days, while those treated with 10 t ha⁻¹ biochar took 104 days to attain physiological maturity. FYM Levels: Plots with 8 t ha⁻¹ of FYM applied matured later at 104 days, while plots without any FYM application matured earlier at 102 days. NPK Levels: Maize subjected to 50% of the recommended NPK dose demonstrated delayed physiological maturity at 103 days, but untreated plots reached physiological maturity earlier at 102 days.

Plant height

Table 6 depicts that the height of maize plants was significantly affected by the application of biochar, farmyard manure and NPK while interactions between these factors were not found significant. Mean values of the data illustrated that the taller plants (194 cm) were observed in 10 t ha⁻¹ of biochar applied plots, while the shorter plants (184 cm) were found in control plots. For farmyard manure, the maximum plant height (193 cm) was achieved with an application of 8 t ha⁻¹, whereas the minimum plant height (185 cm), was observed in 0 t ha⁻¹ applied plants. Considering NPK application, the taller plants (191 cm) were recorded with 50% NPK application while the short stature plants (186 cm), were noted when no NPK was applied.

Number of plant at harvest (ha⁻¹)

Table 7 shows the impact of NPK application, biochar, and farmyard manure (FYM) on the number of maize plants at harvest. The results demonstrate that neither biochar, FYM, or NPK levels, nor their interactions, had a significant effect on the number of maize plants at harvest. This suggests that neither of these factors, nor their combinations, affected plant survival or retention during the growth season, and that the ultimate plant population was constant across all treatments.

Table 5 Days to physiological maturity of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha⁻¹)	Farmyard manures Levels (t ha⁻¹)	Biochar Levels(t ha⁻¹)			Mean FYM x NPK
		0	5	10	
0 (control)	0	100	101	103	102
	4	101	102	103	102
	8	102	104	105	104
75 : 60 : 45	0	101	103	104	103
	4	102	103	103	103
	8	105	105	105	105
		NPK x B			NPK
0		103	102	102	102 a
75 : 60 : 45		103	104	103	103 b
		FYM x B			FYM
	0	101	102	103	102 c
	4	102	102	105	103 b
	8	104	103	105	104 a
Mean		102 c	103 b	104 a	

LSD value (P≤0.05) for Biochar = 1.22

LSD value (P≤0.05) for FYM = 1.22

LSD value (P≤0.05) for NPK = 1.00

Means of same category followed by different letters are significantly different at (P ≤ 0.05) using LSD test.

Table 6. Plant height (cm) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha⁻¹)	Farmyard manures Levels (t ha⁻¹)	Biochar Levels(t ha⁻¹)			Mean FYM x NPK
		0	5	10	
0 (control)	0	175	179	180	178
	4	183	183	189	185
	8	191	195	201	196

75 : 60 : 45	0	176	180	186	181
	4	188	191	194	191
	8	195	198	207	200
		NPK x B			NPK
0		187	184	187	186 b
75 : 60 : 45		190	189	193	191 a
		FYM x B			FYM
	0	176	186	193	185 c
	4	179	187	196	188 b
	8	183	192	204	193 a
Mean		184 c	187 b	194 a	

LSD value (P≤0.05) for Biochar = 2.90

LSD value (P≤0.05) for FYM = 2.90

LSD value (P≤0.05) for NPK = 2.37

Means of same category followed by different letters are significantly different at (P ≤ 0.05) using LSD test.

Table 7. Number of plants at harvest (ha^{-1}) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels(t ha^{-1})	Biochar Levels(t ha^{-1})			Mean FYM x NPK
		0	5	10	
0 (control)	0	50000	53571	55158	52910
	4	53174	52381	50000	51851
	8	51190	54762	55158	53703
75 : 60 : 45	0	50000	53968	50396	51455
	4	52777	53571	52380	52909
	8	53174	53571	55158	53968
		NPK x B			NPK
0		52777	53836	51851	52821
75 : 60 : 45		53703	51190	53439	52777
		FYM x B			FYM
	0	50000	52976	52182	51719
	4	53769	52976	54167	53637
	8	52777	51190	55158	53042
Mean		52122	53090	53186	

LSD value (P≤0.05) for Biochar = ns

LSD value (P≤0.05) for FYM = ns

LSD value (P≤0.05) for NPK = ns

Number of ear m^{-2}

Table 8 displays the number of ears per square meter (m^{-2}) of maize. The results demonstrate that the application of farmyard manure (FYM), biochar, or NPK levels, nor their interactions, had a significant effect on the number of ears per square meter. This finding suggests that variations in these soil amendments and fertilizer applications did not significantly alter the distribution or growth of maize ears within the experimental plots. Ear numbers were consistent across treatments, indicating that these factors did not significantly impact the maize crop's capacity to reproduce in the given conditions.

Table 8 Number of ears m^{-2} of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1})			Mean FYM x NPK
		0	5	10	
0 (control)	0	7	7	8	7
	4	7	7	8	8
	8	7	8	7	7
75 : 60 : 45	0	7	8	7	7
	4	7	8	7	7
	8	7	8	7	7
		NPK x B			NPK
0		7	8	7	7
75 : 60 : 45		7	7	7	7
		FYM x B FYM			
	0	7	7	7	7
	4	8	8	8	8
	8	7	8	7	7
Mean		7	8	7	

LSD value (P≤0.05) for Biochar = ns

LSD value (P≤0.05) for FYM = ns

LSD value (P≤0.05) for NPK = ns

Number of grains ear^{-1}

Table 9 displays the statistical analysis of how different amounts of biochar, farmyard manure (FYM), and nitrogen (NPK) application affects the number of grains per ear of maize. The results indicated that the quantity of grains per ear was significantly impacted by biochar, FYM, and NPK levels, but not by their interactions. Biochar Levels: The control plots (no biochar) had the lowest grain count (374 grains per ear), while the highest grain count (403 grains per ear) was produced by 10 t ha^{-1} of biochar. FYM Levels: Untreated plots displayed a lower grain count (376 grains per ear), whereas plots treated with 8 t ha^{-1} FYM produced more grains per ear (400 grains).

Table 9. Number of grains ears^{-1} of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1})			Mean FYM x NPK
		0	5	10	
0 (control)	0	320	347	353	340
	4	372	375	383	376
	8	386	410	416	404
75 : 60 : 45	0	360	379	389	376
	4	394	405	405	401
	8	422	410	456	429
		NPK x B			NPK
0		372	374	374	373 b
75 : 60 : 45		412	392	403	402 a
		FYM x B			FYM
	0	340	383	404	376 c
	4	363	390	410	388 b
	8	371	394	436	400 a
Mean		374 b	387 ab	403 a	

LSD value (P≤0.05) for Biochar = 13

LSD value (P≤0.05) for FYM = 13

LSD value (P≤0.05) for NPK = 11

Means of same category followed by different letters are significantly different (P ≤ 0.05) using LSD test.

Thousand grains weight (g)

The application of biochar, farmyard manure (FYM), and NPK significantly affected the thousand-grain weight of maize, according to the mean data in Table 10. However, no significant interactions between these components were discovered. Levels of Biochar: The heaviest grains (355 g) were produced by 10 t ha^{-1} biochar, and the second-heaviest grains (343 g) were produced by 5 t ha^{-1} biochar. The lightest grains (332 g) were found in plots that did not employ biochar. FYM Levels: 8 t ha^{-1} FYM was used to achieve the highest thousand-grain weight (352 g), which was followed by 4 t ha^{-1} FYM (344 g). The control plots (no FYM) had the lowest grain weight (335 g). NPK Levels: The maximum thousand-grain weight (349 g) was found in plots with a 50% NPK treatment.

Table 10. Thousand grains weight (g) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1})			Mean FYM x NPK
		0	5	10	
0 (control)	0	281	322	332	312
	4	335	338	342	338
	8	362	364	366	364
75 : 60 : 45	0	330	323	341	331
	4	344	349	352	348
	8	356	366	378	367
		NPK x B			NPK
0		336	335	342	338 b
75 : 60 : 45		344	348	355	349 a
		FYM x B			FYM
	0	305	340	359	335 c
	4	322	344	365	344 b
	8	337	347	372	352 a

Mean		332 c	343 b	355 a	

LSD value (P≤0.05) for Biochar = 9.56

LSD value (P≤0.05) for FYM = 9.56

LSD value (P≤0.05) for NPK = 7.81

Means of same category followed by different letters are significantly different (P ≤ 0.05) using LSD test.

Biological yield (kg ha^{-1})

Table 11 displays the average biological yield data for maize and shows that biochar, farmyard manure (FYM), and NPK levels had a significant effect on output. However, these characteristics did not interact in a way that was statistically significant. The highest biological yield (12,260 kg ha^{-1}) was obtained from the application of 10 t ha^{-1} biochar, whereas the lowest yield (11,076 kg ha^{-1}) was obtained from the control plots (no biochar).FYM Levels: The maximum biological output (12,187 kg ha^{-1}) was produced by 8 t ha^{-1} FYM, while the second-highest yield (11,707 kg ha^{-1}) was produced by 4 t ha^{-1} FYM. The lowest yield (11,182 kg ha^{-1}) was seen in the plots that did not get FYM application. NPK Levels Plots fertilized with 50% NPK produced the highest biological yield (11,958 kg ha^{-1}).

Table 11 Biological yield (kg ha^{-1}) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	9563	10119	10922	10201
	4	11150	11401	12142	11565
	8	12023	12499	13015	12513
75 : 60 : 45	0	9728	10983	11294	10669
	4	11904	12068	12375	12116
	8	12725	13170	13373	13089
		NPK x B			NPK
0		11737	11494	11048	11426 b
75 : 60 : 45		11698	11890	12286	11958 a
		FYM x B			FYM
	0	9645	11527	12374	11182 c
	4	10551	11735	12835	11707 b
	8	11108	12259	13194	12187 a
Mean		11076 c	11740 b	12260 a	

LSD value (P≤0.05) for Biochar = 483

LSD value (P≤0.05) for FYM = 483

LSD value (P≤0.05) for NPK = 394

Means of same category followed by different letters are significantly different (P ≤ 0.05) using LSD test.

Grains Yield (kg ha^{-1})

Table 12 presents Mean data, indicating that grain yield of maize was significantly influenced by the application of biochar, farmyard manure, and NPK. However, no significant interactions were observed among these factors. The higher grain yield (4013 kg ha^{-1}) was attained through application of biochar at a rate of 10 t ha^{-1}, followed by (3587 kg ha^{-1}) with 5 t ha^{-1}, while control plots yielded the lower (3275 kg ha^{-1}) seed yield. Application of farmyard manure at 8 t ha^{-1} resulted in the maximum grain yield (3943 kg ha^{-1}), followed by (3572 kg ha^{-1}) with 4 t ha^{-1}, whereas plots without farmyard manure yielded minimum (3360 kg ha^{-1}) seed yield. Similarly, the higher grain yield (3788 kg ha^{-1}) was obtained with 50% NPK application, while no application of NPK led to the lower yield (3463 kg ha^{-1}).

Table 12 Grains yield (kg ha^{-1}) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	2567	2645	3029	2747

	4	3178	3330	3760	3423
	8	3888	4121	4647	4219
75 : 60 : 45	0	2721	3159	3320	3067
	4	3604	3697	4044	3782
	8	4201	4482	4860	4514
		NPK x B			NPK
0		3529	3463	3396	3463 b
75 : 60 : 45		3620	3750	3992	3788 a
		FYM x B			FYM
	0	2644	3391	4044	3360 c
	4	2902	3514	4302	3572 b
	8	3175	3902	4754	3943 a
Mean		3275 c	3587 b	4013 a	

LSD value (P≤0.05) for Biochar = 188
LSD value (P≤0.05) for FYM = 188
LSD value (P≤0.05) for NPK = 154

Means of same category followed by different letters are significantly different (P ≤ 0.05) using LSD test.

Harvest Index (%)

Statically analyzed data showed that application of biochar, farmyard manure, and NPK positively influenced the harvest index of maize, with no significant interaction (Table 13). The highest harvest index, was recorded (33 %) with the application of 10 t ha^{-1} of biochar, followed by (31 %) with 5 t ha^{-1}, while unaltered plots had the lower harvest index (29 %). For farmyard manure, the maximum harvest index (32 %), was achieved with an application of 8 t ha^{-1}, followed by (31 %) with 4 t ha^{-1}, whereas plots with no farmyard manure had minimum harvest index (30 %). NPK application at a rate of 50 % resulted in the higher harvest index, (31 %), while control plots had the lowest harvest index (30 %)

Soil pH

Table 14 depicts significant variations in soil pH resulting from the application of biochar and farmyard manure. while non-significant variance in soil pH was observed with the application of NPK and all possible interactions between biochar, farmyard manure, and NPK. Statistical analyzed data showed that biochar application increased soil pH (7.66) with 10 t ha^{-1} compared to untreated plots (7.41). Similarly, the application of 8 t ha^{-1} of farmyard manure led to higher soil pH (7.62) compared to control plots (7.44).

Soil Electrical Conductivity (dS m^{-1})

Soil electrical conductivity of maize field was significantly affected with farmyard manure and NPK application (Table 15). However, biochar application and all interactions were calculated non-significant. Soil electrical conductivity (EC) was higher (1.19 dS m^{-1}) with the application of 8 t ha^{-1} of farmyard manure compared to untreated plots (1.17 dS m^{-1}), and the highest EC was recorded in plots treated with 50% NPK. 1.23 dS m^{-1}). Control plots exhibited lower soil EC level (1.13 dS m^{-1}).

Table 13 Harvest index (%) of maize as influenced by biochar, farmyard manure and NPK application

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	27	27	28	27
	4	29	29	31	30
	8	32	33	36	34
75 : 60 : 45	0	28	29	29	29
	4	30	31	33	31
	8	33	34	36	34
		NPK x B			NPK
0		30	30	31	30 b
75 : 60 : 45		31	31	32	31 a
		FYM x B			FYM
	0	27	30	33	30 c
	4	28	30	34	31 b
	8	29	32	36	32 a
Mean		29 c	31 b	33 a	

LSD value (P≤0.05) for Biochar = 1.10

LSD value (P≤0.05) for FYM = 1.10

LSD value (P≤0.05) for NPK = 0.90

Means of same category followed by different letters are significantly different ($P \leq 0.05$) using LSD test.

Table 14. Soil pH of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	7.16	7.25	7.32	7.24
	4	7.34	7.61	7.68	7.54
	8	7.74	7.80	7.88	7.80
75 : 60 : 45	0	7.17	7.32	7.33	7.27
	4	7.50	7.56	7.70	7.59
	8	7.75	7.79	7.82	7.79
		NPK x B			NPK
0		7.51	7.52	7.56	7.53
75 : 60 : 45		7.55	7.54	7.56	7.55
		FYM x B			FYM
	0	7.16	7.42	7.75	7.44 c
	4	7.28	7.58	7.80	7.55 b
	8	7.33	7.69	7.85	7.62 a
Mean		7.41 c	7.55 b	7.66 a	

LSD value (P≤0.05) for Biochar = 0.05

LSD value (P≤0.05) for FYM = 0.05

LSD value (P≤0.05) for NPK = ns

Means of same category followed by different letters are significantly different at ($P \leq 0.05$) using LSD test.

Table 15. Soil electrical conductivity(ds m^{-1}) of maize as influenced by biochar, farmyard manure and NPK application.

NPK Levels (kg ha^{-1})	Farmyard manures Levels (t ha^{-1})	Biochar Levels(t ha^{-1}) 0	5	10	Mean FYM x NPK
0 (control)	0	1.04	1.03	1.02	1.03
	4	1.12	1.15	1.17	1.15
	8	1.21	1.22	1.18	1.20
75 : 60 : 45	0	1.10	1.15	1.18	1.14
	4	1.23	1.25	1.29	1.26
	8	1.30	1.27	1.29	1.29
		NPK x B			NPK
0		1.12	1.12	1.14	1.13 b
75 : 60 : 45		1.22	1.22	1.24	1.23 a
		FYM x B			FYM
	0	1.07	1.17	1.25	1.17 c
	4	1.09	1.20	1.24	1.18 b
	8	1.10	1.23	1.24	1.19 a
Mean		1.15	1.18	1.20	

LSD value (P≤0.05) for Biochar = ns

LSD value (P≤0.05) for FYM = 0.02

LSD value (P≤0.05) for NPK = 0.02

Means of same category followed by different letters are significantly different ($P \leq 0.05$) using LSD test.

Discussion

Our study findings found that application of biochar, farmyard manure, and NPK fertilizer does not significantly influence the time it takes for maize seedlings to emerge (days to emergence) or the density of emerged seedlings per square meter (emergence m^{-2}) (Shah et al., 2009). This study finding aligns with previous research by Free et al. (2010) who conducted a study, and similar results with biochar application in spring maize. Similarly, the less significant effect from farmyard manure on emergence is consistent with findings by Sabourifard et al. (2023) who suggest that the slow breakdown of organic manure may not release nutrients during critical stages of maize emergence. Additionally, Singh and Sukul (2019) highlight the potential importance of timing and application rates for farmyard manure to optimize its influence on early emergence and plant density. Our study supports these observations, suggesting that further exploration of application timing and manure composition might be beneficial for future investigations.

NPK doses did not significantly affected days to emergence and emergence m^{-2} of maize. Our results are inconformity with that of (Kareem et al. 2020) who suggested that seeds were sufficiently nourished by their endosperm reserves, and any additional nutrients provided by the fertilizer did not own to observable differences in the timing or density of seedling emergence. Similar results were also observed by (Otieno et al. 2019) who reported that NPK fertilizers are crucial for supporting plant growth later in the growing season, their role during the initial stages of emergence was less pronounced, especially when seeds have considerable internal nutrient reserves.

Our study revealed that biochar application significantly delayed the time it took for maize plants to reach tasseling, silking, and physiological maturity. This delay can likely be attributed to biochar's ability to improve soil fertility and enhance the availability of essential nutrients. By providing a more sustained nutrient supply, biochar may have prolonged the vegetative growth stage of maize plants, consequently delaying the reproductive stages like tasseling, silking, and maturity. These findings are consistent with observations of (Ali et al. 2017), who also found that biochar application influenced plant growth stages in their study. Farmyard manure also significantly affected days to tasseling, silking and physiological maturity of maize. The possible reason for delayed in tasseling, silking and maturity of maize might be the availability of timely and balanced nutrients helped the plant to enhance its vegetative growth and thus resulted in late tasseling, silking and maturity stages. Our results are in agreement with those of (Faisal et al. 2015) who reported that tasseling and silking was delayed in those plots where FYM was used at the rate of 20 tons per hectare. (Makinde and Ayoola, 2010) also reported that use of organic manure increased plant growth and caused in delayed phenology.

NPK treatment significantly affected days to tasseling, silking and physiological maturity of maize. Nitrogen often delays reproductive stages due to increased vegetative growth, as observed by (Shrestha et al. 2018). Conversely, phosphorus and potassium contribute to robust root development and water balance, potentially influencing the timing of tasseling, silking, and maturity (Karkia et al., 2020). Balancing NPK application rates and timing is crucial for optimizing maize yield and reproductive success.

Physiological parameters like plant height of maize were significantly affected by different levels of biochar incorporation. Taller plant was observed with biochar at the rate of 10 t ha^{-1} while shorter plants were seen in untreated plots. Our results are in line with that of (Burke et al. 2012) and (Njoku et al. 2016). This height increase may be attributed to biochar ability to enhance cell expansion, as demonstrated by (Viger et al. 2015). (Ahmad et al. 2015), (Lashari et al. 2018) documented significant rise in plant height with biochar application in maize cultivation. Farmyard manure application at the rate of 8 t ha^{-1} produced taller plants as compared to control plots. The use of farmyard manure significantly enhanced plant height (Ali et al., 2013). FYM is rich in both macro and micronutrients, plays a vital role in promoting plant growth. Its efficacy lies in improving soil organic carbon levels and enhancing soil structure, nutrient availability and uptake (Baca et al., 2022). (Warren et al. 2016) stated that farmyard manure, particularly from pig sources, enriches the soil with essential nutrients, contributing to increased plant development.

The height of maize plants was significantly influenced by NPK fertilization, and is consistent with the findings of (Wajid et al. 2007). The increase in plant height could be due to the stimulation of cell division, elongation, and nucleus formation by elevated nitrogen levels (Islam et al., 2017). Our results are in line with (Prajapati et al. 2018) who reported that application of phosphorus and potassium in NPK fertilizers have contributed to enhanced plant growth through their roles in cellular processes and structural development. (Abayomi et al. 2016) reported that an increase in leaf area with nitrogen application, suggests that the growth promoting effects extend beyond plant height to include foliage development.

our study found no significant effect of biochar, farmyard manure, or NPK application on the number of maize ears per square meter (m^{-2}) or plant population at harvest (plants ha^{-1}), likely due to the initial planting strategy and thinning practices, biochar application did significantly influence yield components. This suggests biochar may have a more pronounced effect on factors like kernel count or grain weight, warranting further investigation into these areas. Plants treated with 10 t ha^{-1} of biochar produced cobs with a greater number of heavier grains compared to other treatments. This aligns with findings by (Liang et al. 2016), who suggested that biochar's porous nature and large surface area improve soil moisture and nutrient availability, potentially influencing yield components like grain number per ear and thousand-grain weight. Farmyard manure application, particularly at the 8 t ha^{-1} rate, yielded the highest number of kernels per ear and the heaviest thousand-grain weight. This aligns with research by (Oktem et al. 2020) and (Tasneem et al. 2014) who observed similar positive effects of farmyard manure on these key grain yield components.

The application of NPK resulted in a significant increase in the number of grains ear^{-1} of maize plants. Similarly, heavier grain weights were observed with foliar application of nitrogen (Rahman et al., 2014). This increase in number grain ear^{-1} and 1000 grain weight may be attributed to the positive effects of nitrogen on maize growth, increased photosynthesis, and transfer of photosynthetic materials (Aghdam et al., 2014). Application of N and P enhanced thousand grains weight by increasing dry matter production, reducing source limitation, extending the duration and period of grain filling (Rahman et al., 2014).

Our study revealed that biochar application, particularly at a rate of 10 t ha^{-1} a significant increased biological yield, grain yield, and harvest index. These findings align with observations by (Sohi et al., 2009) who reported similar yield enhancements with biochar amendments. Biochar's positive impact can likely be attributed to its influence on soil properties. Increased water holding capacity (WHC) and cation exchange capacity (CEC) facilitate improved nutrient uptake by plants and create more favorable conditions for beneficial soil microbes (Sohi et al., 2009). Furthermore, biochar may reduce nutrient leaching while enhancing nitrogen availability, potentially leading to increased photosynthate production and ultimately, greater plant biomass (Steiner et al., 2008).

This translates to a higher harvest index, indicating a more efficient allocation of resources towards grain production. While farmyard manure application also positively impacted biological and grain yield, as observed in studies by Negi and Mahajan (2020) and (Baqa et al., 2021), the effect wasn't as pronounced as with biochar in this experiment. Further investigation is needed to determine the optimal application rates and potential synergistic effects when combining biochar with other amendments like farmyard manure.

Similar to biochar and farmyard manure, NPK fertilizer application yielded a significant increase in both biological yield and grain yield. This aligns with research by (Gholami et al., 2011) who reported similar positive effects of NPK on maize yield. The observed improvements in yield can likely be attributed to NPK's influence on factors crucial for grain filling. These fertilizers provide a readily available source of essential nutrients like nitrogen, phosphorus, and potassium, each playing critical roles in various plant growth processes. For example, nitrogen may contribute to a longer grain filling period by promoting cell division and delaying senescence (Islam et al., 2017). Our study suggests that NPK application may have facilitated several positive outcomes, potentially including an extended growing period, increased single leaf area, a higher number of kernels per ear, and ultimately, thousand-grain weight. The combined effect of these factors translates to a significant increase in overall grain yield. Furthermore, the observed increase in harvest index strengthens this connection. A higher harvest index indicates a more efficient allocation of plant biomass towards grain production, suggesting a positive association between harvest index, individual yield components, and overall grain yield in maize.

Soil pH of maize was significantly affected by biochar application of 10 t ha^{-1} as compared to untreated plots. Our results are in line with (Xu et al., 2014) who reported that biochar incorporation to soil can increase soil pH and improve soil quality. Improved physico-chemical and biological properties of soils like aggregation of soil colloids, water holding capacity, soil pH and beneficial microbial populations ultimately enhance crop yields. These findings are similar to (Zhang et al., 2016) that biochar have a neutral to slightly alkaline pH, the actual effect on soil pH can depending on factors such as the type and amount of biochar applied, soil type and environmental conditions. Farmyard manure recorded lower soil pH as compared to control plots. Our results are in line with (Masood et al., 2014) who reported that decrease in soil pH could be attributed to the decomposition of organic matter in farmyard manure, which releases acidic compounds into the soil. Such findings are consistent with Iqbal et al. (2020) who suggested that organic amendments like farmyard manure can lead to soil acidification due to the release of organic acids during decomposition.

Significant effect was observed with farmyard manure and NPK application on soil EC. Soil electrical conductivity was notably higher with the application of 8 t ha^{-1} of farmyard manure compared to untreated plots. Our results are in line with the finding of Ozlu and Kumar, (2018) who documented that FYM contains soluble salts, such as potassium, sodium, and calcium that contributed to the overall conductivity of the soil solution. Geng et al. (2019) reported that decomposition of organic matter in farmyard manure releases soluble ions into the soil solution, further increasing conductivity. Highest soil electrical conductivity was recorded in plots treated with 50% NPK as compared to control. Our results are in line with Phares et al. (2022) who suggested that rise in conductivity by applying NPK fertilizer reflects alterations in soil properties and nutrient dynamics. These findings are similar to Zhang et al. (2022) who reported that soluble ions present in NPK fertilizers contributed to increased soil conductivity by introducing soluble salts into the soil solution.

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