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Research Paper

Comparative analysis of the growth, yield attributes and grain yield of *kharif* maize (*Zea mays*) under varying doses of biochar, fertility levels, and biofertilizer treatments

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2021 and 2022 at the research farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj Ayodhya, Uttar Pardesh, to evaluate the effect of graded doses of biochar and fertility levels with and without biofertilizer under partially reclaimed sodic soils on maize (*Zea mays* L.) performance. The experiment was laid out in randomized block design (RBD) which with 3 replications. Experiment comprised of 8 treatments, viz. T_1, Control; T_2, 100% RDF 100 : 60 : 40 N, P_2O_5 and K_2O; T_3, 50% RDF + 2.5 t/ha biochar; T_4, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer; T_5, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer + Zn; T_6, 100% RDF + 5 t/ha biochar; T_7, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer; T_8, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn. The study's comparative analysis revealed the positive effects of applying biochar, optimal fertility levels, and biofertilizers on the yield attributes and grain yield of *kharif* maize. Notably, treatment T8 showed significant improvements, with a 53% increase in cob length, 34% increase in cob girth, 83% increase in the number of grains per row, 138.4% increase in grain yield, and 134% increase in stover yield compared to the control treatment. These findings demonstrate the successful impact of application of 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn in enhancing various aspects of maize growth and yield, surpassing the outcomes achieved with the control treatment and may be recommended for achieving high-quality maize production in partially reclaimed sodic soils of eastern Uttar Pradesh and comparable agro-ecoregions.

Key words: Biochar, Fertility levels, Maize, Yield attributes, Yield

Maize (*Zea mays* L.) is the third most important cereal crop in India as well as in the world next to rice and wheat. Globally it is highly valued for its multifarious use as food, feed, fodder and raw material for large number of industrial products. In India, maize is cultivated around 9.47 million ha area, with 28.6 million tonnes production and 3,190 kg/ha productivity (DACNET, 2022). Among Indian states Madhya Pradesh and Karnataka has highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and others. The productivity of maize in India is about 3.19 t/ha, which is slightly more than the half of world average (5.6 t/ha). Over the years, increasing food and industrial demand of maize causes heavy pressure on natural resources and conventional agriculture which leads to threats like declining factor productivity, quality of produce, deterioration in physico-chemical and biological properties of soil, biotic interferences, declining biodiversity, high energy requirements, reduced availability of protective foods, stagnating farm income and global climate change (Abriz and Torabian, 2018).

Sodicity is a major constraint to crop productivity in many parts of the world, and its management is crucial for sustainable agriculture. In an attempt to achieve higher yield, farmers have resorted to using higher than the recommended levels of chemical fertilizer under salt affected soils in many areas in India (Agegnehu *et al.,* 2017). In Eastern Uttar Pradesh, sodicity affects a large area of cropland, and partially reclaimed sodic soils are common. Sodicity can lead to reduced soil fertility, low water infiltration rates, and poor soil structure, which can all impact

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crop yields. To address these issues and develop answers, scientists have suggested switching to a sustainable crop production system. Therefore, understanding the role management factor impacting maize productivity, profitability and soil health is crucial to address future global food and nutritional security towards achieving sustainable agricultural goals.

Biochar is a carbon-rich soil amendment that has gained much attention in recent years due to its potential to improve soil fertility, nutrient cycling and carbon sequestration. It is produced by heating organic material, such as wood or crop residues, in the absence of oxygen, resulting in a porous, carbon-rich material that can be added to soils to improve their physical and chemical properties (Yohanes *et al*., 2015). The recent studies have focused on the use of biochar to improve soil quality and performance for better plant growth and productivity because it provides attachment sites for microbial communities (Adekiya *et al*., 2020) and effectively enhance soil physico-chemical properties by regulating soil *p*H. Biofertilizers, on the other hand, are products containing living microorganisms that can improve plant growth and soil fertility. The use of biofertilizers can help reduce chemical fertilizer use, which can be costly and have negative environmental impacts. Several studies have investigated the effects of biochar and fertility levels on soil properties and crop production, but little is known about their combined effects on performance of maize on partially reclaimed sodic soils in eastern Uttar Pradesh.

Hence, it was hypothesized that study will contribute to the understanding of the effects of biochar and fertility levels on maize performance in partially reclaimed sodic soils and provide insights into their combined use for improving crop productivity in sodic soils. Keeping above facts in view the an experiment was to study the response of maize to graded doses of biochar and fertility levels with and without biofertilizer under partially reclaimed sodic soils of eastern Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif)* seasons of 2021 and 2022 at the Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj Ayodhya (26° 542 North and 81° 82' Eand at an altitude of 113 metre above mean sea-level), Uttar Pardesh. The climate of the site is semi-arid with hot summer and cold winter. The average rainfall received during the cropping period (June-September) was 670.94 mm. August month was the hottest month of the year where the maximum temperature hovers around 26.10 to 32.89°C, while, December was the coldest month when the mean minimum temperature was as low as 8.5°C. Ground frost is commonly associated with the winter seasons. The mean annual rainfall was about 1,067 mm, of which nearly 88.91% was received during the monsoon period from July to September and the rest during the period between October and May. The mean daily U.S. Weather Bureau Class 'A' open pan evaporimeter value reaches as high as 12.9 mm in August and as low as 1.5 mm in December. The mean annual pan evaporation was about 2080 mm. Mean relative humidity attains the maximum value (67.73 to 80.6%) during the south-west monsoon period and the minimum (30 to 45%) during the summer months. The soil of experimental was clay loam in texture with bulk density (1.35 Mg/m^3), *p*H 8.92, EC (0.23 dS/m), high organic carbon (0.41%), low available N (200.40 kg/ha), medium available P (15.40 kg/ha) and high available K (246.31 kg/ha). The experiment was conducted in randomized block design (RBD) comprised of 8 treatments, viz. T_1, Control; T_2, 100% -RDF 100:60:40 N, P_2O_5 and K_2O; T_3, 50% RDF + 2.5 t/ha biochar; T_4, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer; T_5, 50% RDF + 2.5 t/ha biochar + ZMB Biofertilizer + Zn; T_6, 100% RDF + 5 t/ha biochar; T_7, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer; T_8, 100% RDF + 5 t/ha biochar + ZMB Biofertilizer + Zn, replicated thrice.

The nutrients were supplied through biochar (containing 5.3 g/kg N, 0.99 g/kg P and 3.48 g/kg K), urea, diammonium phosphate and muriate of potash respectively. The treatment wise full dose of P and K and half the dose of N were applied as basal at sowing and the remaining N was top-dressed at 35 days after sowing. Maize cultivar, DA-61-A was sown during second week of February at 45 cm × 20 cm crop geometry with a seed rate of 20–22 kg/ha and harvested in the second week of July. The crop was raised with the recommended package of practices. The observations were recorded on yield attributes and yield. The length and girth of 10 cobs were measured from the randomly selected tagged plants of each plot with the help of a thread and centimetre scale. Then the average was worked out and expressed as the length and girth of the cob in cm. Total number of grain row of 10 selected cobs was counted and averaged to get number of grain row/cob. Total number of grains of 10 selected was counted, divided by number of rows/cob and expressed as number of grains/rows. The 10 cobs taken from each plot were shelled separately and counted. The averaged values were reported as number of grains/cob. The grain and stover yield was computed from the harvest of the net plot area from the individual plots and the weight of produce was recorded in kg/plot and finally converted into t/ha by using the conversion factor. The weight of total harvested produce from net plot of each treatment was recorded after sun drying and expressed as biological yield in t/ha.

The data collected for different parameters were subjected to appropriate statistical analysis under randomized block design (RBD) by following the procedure of ANOVA analysis of variance (SAS Software packages, SAS EG 4.3). Significance of difference between means was tested through 'F' test and the least significant difference (LSD) was worked out where variance ratio was found significant for treatment effect. The treatment effects were tested at 5% probability level for their significance.

RESULTS AND DISCUSSION

Growth parameters

The results showed that maximum plant height (206.7 and 212 cm) and dry-matter accumulation (329 and 333 g/plant) at harvest were recorded under T_8 treatment which was statistically at par with T_7 and significantly higher than other treatments, during both the years of experimentation (Fig. 1). The increase in growth parameters may be owing to the availability of nutrients at various critical crop growth stages in optimal amount which might have increased the cell division and cell elongation that results in higher plant height and dry-matter accumulation. These results are in conformity with the findings of Abbas *et al*., (2020). Enhancement in growth and yield attributes leads to better photosynthetic partitioning and source-sink relationship, which gave higher plant and drymatter accumulation. The similar findings were also reported by Zhang *et al*., (2020).

Yield attributes

Across the study years graded doses of biochar and fertility levels had significant effect on yield attributes of maize except number of cobs/plant and number of grains row/cob (Table 1). The maximum number of cobs/plant (1.36 and 1.40) and number of grains row/cob (15.8 and 16) was noticed under T_8 treatment and minimum was recorded in T_1 treatment (1.10 and 1.12). Significant rise in cob length approximately 57% and 50% was found under T_8 treatment followed by T_7 and T_6. During the first year, treatment T_8 resulted the maximum cob girth (15.2 cm) which was statistically at par with T_6 and T_7 and significantly higher than the other treatments. While, during the second year significantly highest cob girth (16.8 cm) was recorded under T_8 followed by T_7. The maximum number of grains/row (33.6 and 35.4) was recorded under T_8 which was statistically at par with T_6, T_7, T_2 and significantly higher than other treatments during both the years of experimentation. The highest number of grains/cob was noticed under T_8 which was significantly higher than other treatments during the first year, while during the second year significant highest number of grains/cob was recorded under T_8 treatment followed by T_7. The higher values of yield attributes were due to the effect on root development, energy transformation and metabolic processes of plant and resulted in more translocation of photosynthates towards the sink development (Faloye *et al.,* 2019a). Increase in yield attributes and yield of maize due to conjoint applica-

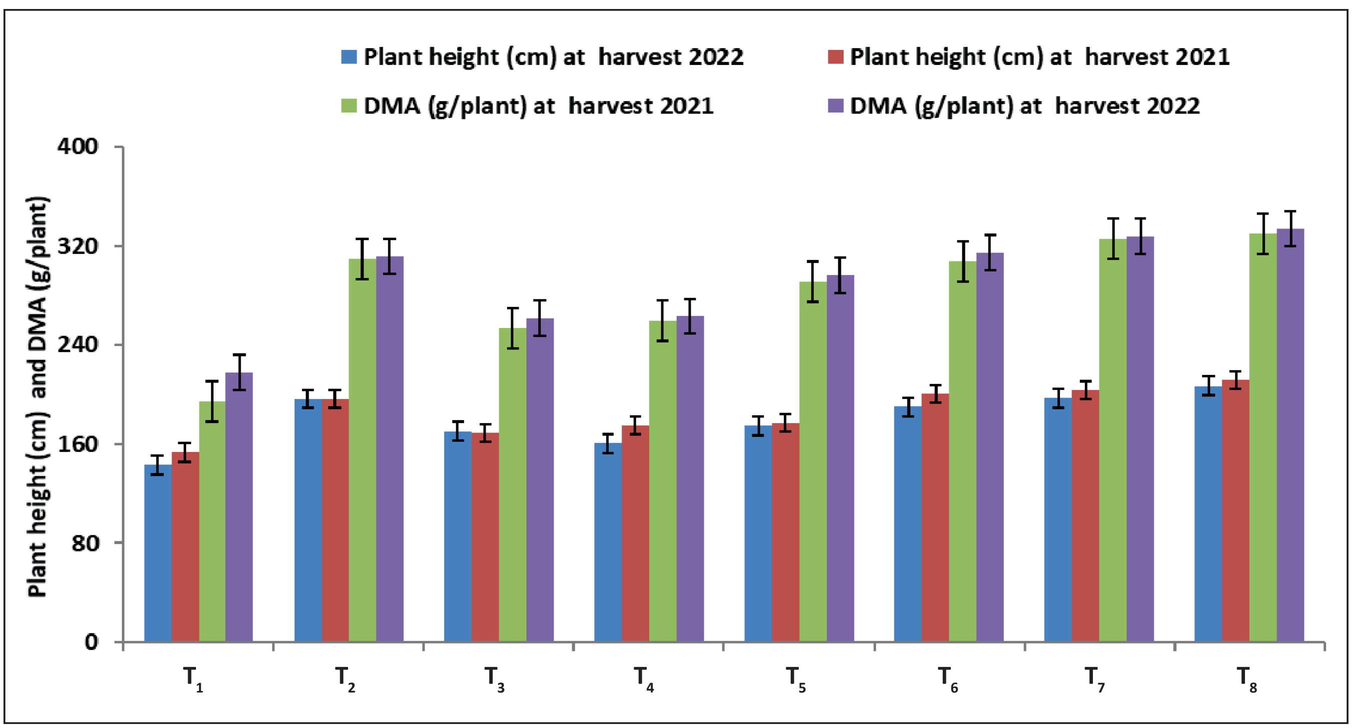

Fig. 1. Effect of graded doses of biochar and fertility levels with and without biofertilizer on growth parameters of maize crop
Treatment details are given under Materials and Methods. DMA, dry-matter accumulation.

Table 1. Effect of graded doses of biochar and fertility levels with and without biofertilizer on yield attributes of maize crop

Treatment	No. of cobs/plant		Cobs length (cm)		Cob girth (cm)		No. of grain rows/cob		No. of grains/row		No. of grains/cob		Grain yield (t/ha)		Stover yield (t/ha)		Biological yield (t/ha)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
T_1	1.10	1.11	12.6	13.3	11.7	11.9	12.3	12.9	18.6	19.1	230	246	2.42	2.52	3.66	3.81	6.09	6.18
T_2	1.17	1.15	16.3	16.7	14.2	15.5	15.2	15.5	31.3	32.5	475	505	5.08	5.10	7.56	7.62	12.6	12.6
T_3	1.14	1.12	16.1	16.4	13.6	13.8	13.6	14.0	24.9	27.7	341	388	4.63	4.72	6.91	7.02	11.5	11.7
T_4	1.07	1.09	15.7	16.5	13.8	14.0	13.8	13.8	27.8	30.4	386	420	4.74	4.76	6.86	7.12	11.6	11.8
T_5	1.09	1.11	16.0	16.8	14.1	15.3	14.6	14.7	29.9	31.8	437	468	4.87	4.88	7.19	7.41	12.0	12.2
T_6	1.16	1.17	19.3	19.8	14.4	15.7	15.0	14.8	30.8	33.2	464	494	5.23	5.25	7.78	7.82	13.0	13.0
T_7	1.18	1.18	19.5	19.7	14.6	16.1	15.2	15.5	32.2	34.1	492	529	5.47	5.51	7.86	8.28	13.3	13.7
T_8	1.20	1.21	19.8	20.0	15.2	16.8	15.8	16.0	33.6	35.4	534	567	5.77	5.82	8.35	8.48	14.1	14.3
SEm±	0.03	0.06	0.26	0.28	0.23	0.24	0.48	0.45	1.19	1.01	8.34	8.55	0.01	0.02	0.19	0.20	0.31	0.34
CD (P=0.05)	NS	NS	0.78	0.81	0.72	0.74	NS	NS	3.05	3.10	36.4	43.5	0.41	0.43	0.58	0.55	0.99	1.02

Treatment details are given under Materials and Methods.

tion of biochar and fertility levels support the development of strong root systems, which ultimately improves the plant growth and development and better diversion of photosynthates towards the sink. It also helps in the efficient absorption and utilization of the other required plant nutrients which ultimately increased the yield attributes (Razzaghi *et al*., 2020). The similar results and observations were also reported by (Faloye *et al.,* 2019b).

Yield (kg/ha)

Yield of maize was significantly influenced by graded doses of biochar and fertility levels during both the year of study (Table 1). Application of treatment T_8 resulted enhanced grain yield by 138.4% and 131% which was statistically at par with T_7 and significantly higher than remain treatments. During the first year significantly maxium stover yield was noticed under T_8 followed by T_7 and T_6 but during the second year higher stover yield was noticed under T_8 which was statistically at par with T_7 and significantly higher than reaming treatments. The treatment T_8 yielded maximum values of biological yield as compared to the other treatments but remained at par with T_7 during both the years of experimentation. It might be owing to the treatments with higher doses of biochar generally exhibited more significant improvements in yield attributes and yield compared to treatments with lower doses. Because it has a high surface area and a porous structure that can adsorb and retain nutrients, such as nitrogen, phosphorus, and potassium. This prevents nutrient leaching and increases the availability of essential nutrients to maize plants, promoting healthier growth and better yield attributes that results in more yield (Majid *et al*., 2017; Gudade *et al*., 2022). Application of biochar improve soil organic carbon, microbial biomass carbon, dehydrogenase activity, earthworm population and water availability, consequently results in good crop growth and productivity (Zheng *et al*., 2017; Ali *et al*., 2020).

Based on the findings of 2 years study it can be inferred that treatment T_8 exhibited remarkable improvements in various yield attributes and yield compared to the control treatment. Specifically, it showed a significant increase of 53% in cob length, 34% in cob girth, 83% in the number of grains/row, 138.4% in grain yield, and 134% in stover yield. These findings highlight the positive impact of treatment T_8 on the overall productivity and yield potential of the crop, indicating its effectiveness in enhancing maize growth and harvest outcomes when compared to the control group. Therefore, implementing a microbiota-driven integrated nutrient management strategy in conjunction with biochar and fertility levels is an energy-efficient and ecologically sustainable approach to ensure the production of high-quality maize in partially reclaimed sodic soils of eastern Uttar Pradesh and other similar agro-ecoregions.

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