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Effect of biochar and FYM on plant population and height of Maize (*Zea mays* L.) under varying fertility levels

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Abstract

A field experiment entitled “Effect of Biochar, FYM on Growth and Productivity of Maize (*Zea mays* L.) under Varying Fertility Levels” was conducted during the *kharif* seasons of 2024 and 2025 at field no. C₃, Agronomy Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, to evaluate the influence of source of biochar, FYM and varying fertility levels on growth, productivity, nutrient uptake, soil fertility and economic performance of maize. The experiment was laid out in a factorial randomized block design with three replications comprising three biochar treatments (A₁: Control, A₂: Lantana biochar @ 4 t ha⁻¹ and A₃: Wheat straw biochar @ 4 t ha⁻¹), two FYM levels (B₁: Control and B₂: FYM @ 5 t ha⁻¹) and three fertility levels (C₁: 75% RDF, C₂: 100% RDF and C₃: 125% RDF).

The results revealed that plant population of maize remained unaffected by different biochar sources, FYM and fertility levels. However, application of lantana biochar @ 4 t ha⁻¹ significantly improved plant height from 45 DAS onwards and remained statistically at par with wheat straw biochar @ 4 t ha⁻¹. Similarly, FYM @ 5 t ha⁻¹ and 125% RDF recorded significantly higher plant height over the control and 75% RDF, respectively, while 125% RDF remained statistically comparable with 100% RDF. Thus, application of lantana biochar @ 4 t ha⁻¹ along with FYM @ 5 t ha⁻¹ under higher fertility levels promoted better vegetative growth of maize

Keywords: Biochar, FYM, Fertility levels, FRBD, maize

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide owing to its high yield potential, wide adaptability and diverse utilization as food, feed and industrial raw material. As a C₄ crop, maize possesses high photosynthetic efficiency and greater yield potential than most cereals (Ranum *et al.*, 2014) ^[10]. However, continuous dependence on chemical fertilizers and declining soil organic matter have adversely affected soil health, nutrient use efficiency and crop productivity. Integrated use of organic amendments with inorganic fertilizers has therefore emerged as a sustainable strategy for maintaining soil fertility and improving crop performance. Among organic amendments, farmyard manure (FYM) enhances soil physical, chemical and biological properties (Reddy and Reddy, 2003; Agegnehu *et al.*, 2017) ^[11, 1], while biochar, a carbon-rich material produced through biomass pyrolysis, improves soil carbon sequestration, nutrient retention, water-holding capacity and microbial activity. Utilization of biochar derived from agricultural residues such as wheat straw and invasive weeds like *Lantana camara* also provides an environmentally sustainable approach for biomass management and climate change mitigation. Combined application of biochar and FYM has been reported to improve nutrient availability, fertilizer use efficiency and crop growth more effectively than their individual application. Nevertheless, information on the optimum fertilizer requirement of maize under integrated application of biochar and FYM is limited, particularly under the agro-climatic conditions of southern Rajasthan. Therefore, the present investigation was undertaken to evaluate the effect of biochar sources, FYM and varying fertility levels on the growth and productivity of maize.

Materials and Methods

The experiment was conducted during *kharif*, 2024 and 2025 at the Agronomy Instructional Farm, Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur. The soil of the experimental site was typical of the region and the climate was sub-humid.

The experiment was laid out in factorial randomized block design (FRBD) with three replications, comprising 18 treatment combinations involving three levels of biochar (*Lantana* biochar@ 4 t ha⁻¹ and wheat straw biochar@ 4 t ha⁻¹) along with control, two levels of FYM (Control and FYM@5 t ha⁻¹) and three fertility levels. The treatment combinations were randomized with the help of random number table (Fisher, 1950) [3]. Maize variety PHM-3 was sown at spacing of 60 cm × 25 cm using seed rate of 25 kg ha⁻¹.

Biochar Preparation

Lantana biochar

In the present experimental field, *Lantana* biochar was used which was prepared through slow pyrolysis in biochar production system (Pratap Kiln) at CTAE, MPUAT, Udaipur. Stalks of *Lantana camara* plant were fed to the pyrolysis reactor in oxygen limiting condition where the temperature goes up to 450 °C for the period of four minutes. This process occurs in three stages, first where the moisture content of the biomass was reduced to less than 10 per cent at the temperature of 180 °C, second where the biochar production starts with the breakdown of hemicellulose and cellulose at the temperature range of 180-360 °C and last stage where lignin breaks down at the temperature of 450 °C.

Wheat straw biochar

First, wheat straw collected in autumn from field no. C₃, Instructional Farm of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, was dried at 105 °C for 4 h. Next, the dried wheat straw was ground using a ball mill at 3,000 r/min for 10 min, then sieved (0.5 mm) and the fraction under the sieve was collected. Third, the collected fractions were washed with distilled water and dried again. Then, the product obtained in the above step was pyrolyzed in a muffle furnace at 500 °C in the absence of oxygen for 2 hours. At last, the wheat straw biochar was successfully prepared

Plant population

The number of plants in net plots area in each experimental unit were counted after thinning (30 DAS) and at crop maturity. These were averaged and expressed in number of plants metre⁻¹ row length.

Plant height

The plant height was measured at 30, 45, 60 DAS and at harvest from ground level to the tip of main stem of tagged plants and the average of five plants was expressed as plant height in centimetre.

Results and Discussion

Plant population

The data pertaining to plant population at 30 DAS and at harvest as influenced by biochar, FYM and fertility levels are presented in Table 1. The results indicated that plant population remained statistically unaffected by different biochar sources, FYM application and fertility levels during both the years as well as in pooled analysis. Although the treatment effects were non-significant, wheat straw biochar @ 4 t ha⁻¹ recorded the highest pooled plant population (4.24 and 4.15 plants m⁻¹ row length at 30 DAS and at harvest, respectively), while the control registered

the lowest values (4.18 and 4.10 plants m⁻¹ row length). Likewise, application of FYM @ 5 t ha⁻¹ produced marginally higher plant population than the control, whereas among fertility levels, 100% RDF recorded the maximum plant population at 30 DAS (4.22 plants m⁻¹ row length) and 125% RDF at harvest (4.14 plants m⁻¹ row length). However, these differences were statistically at par. The non-significant effect of biochar, FYM and fertility levels on plant population may be attributed to the uniform germination potential of seed, optimum moisture conditions at sowing and identical crop establishment practices adopted throughout the experiment. Plant population is largely governed by seed viability and field emergence, whereas biochar, organic manures and fertilizers mainly influence post-emergence growth and crop development. Similar observations were also reported by Lehmann and Joseph (2015) [5], Jeffery *et al.* (2017) [4] and Agegnehu *et al.* (2017) [1].

Plant height

Plant height is an important growth parameter that reflects the overall vegetative development and physiological status of the crop. The data presented in Table 2 (a) and (b) revealed that plant height at 30 DAS remained unaffected by biochar, FYM and fertility levels, whereas significant differences were observed at 45 DAS, 60 DAS and at harvest during both years and in pooled analysis.

Among the biochar treatments, application of *lantana* biochar @ 4 t ha⁻¹ significantly increased plant height over the control from 45 DAS onwards and remained statistically at par with wheat straw biochar. On pooled basis, *lantana* biochar recorded the highest plant height of 135.01, 158.40 and 215.71 cm at 45 DAS, 60 DAS and harvest, respectively, compared with 120.18, 141.36 and 190.11 cm under the control. Wheat straw biochar also significantly enhanced plant height over the control, indicating the beneficial influence of biochar irrespective of source.

Application of FYM @ 5 t ha⁻¹ significantly increased plant height throughout the crop growth period after 30 DAS. The pooled plant height increased from 123.82 to 134.20 cm at 45 DAS, from 145.57 to 157.79 cm at 60 DAS and from 198.55 to 212.91 cm at harvest over the control.

Similarly, increasing fertility levels significantly improved plant height. Application of 125% RDF produced the tallest plants at all growth stages after 30 DAS; however, it remained statistically at par with 100% RDF. Both fertility levels significantly surpassed 75% RDF, indicating that adequate nutrient availability during the vegetative phase promoted rapid plant growth.

The marked improvement in plant height under biochar treatments could be attributed to enhanced soil physical properties, greater nutrient retention, improved soil moisture status and stimulation of beneficial microbial activity, which collectively promoted root proliferation and efficient nutrient uptake. Addition of FYM further improved soil aggregation, nutrient mineralization and biological activity, ensuring a continuous supply of nutrients throughout crop growth. Likewise, higher fertility levels maintained optimum availability of nitrogen, phosphorus and potassium, resulting in enhanced chlorophyll synthesis, photosynthetic efficiency, cell division and cell elongation, ultimately leading to taller plants. These findings corroborate the reports of Agegnehu *et al.* (2017) [1], Mohan *et al.* (2018) [8], Liu *et al.* (2021) [7], Joseph *et al.* (2021) [6], Rahayu *et al.* (2022) [9], Yan *et al.* (2022) [13], Cong *et al.* (2023) [2] and Xu *et al.* (2023) [12] who also observed significant improvement in maize growth following integrated application of biochar, organic manures and balanced fertilization.

Table 1: Effect of biochar, FYM and fertility levels on plant population of maize

Treatments	Plant population (Plants metre ⁻¹ row length)					
	30 DAS			At harvest		
	2024	2025	Pooled	2024	2025	Pooled
Source of biochar						
A ₁ - Control	4.11	4.26	4.18	3.98	4.22	4.10
A ₂ - Lantana biochar 4 t ha ⁻¹	4.12	4.25	4.19	3.99	4.21	4.10
A ₃ - Wheat straw biochar 4 t ha ⁻¹	4.19	4.29	4.24	4.06	4.23	4.15
S.Em.±	0.05	0.04	0.04	0.05	0.04	0.04
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
FYM level						
B ₁ - Control	4.12	4.24	4.18	3.96	4.20	4.08
B ₂ - FYM 5 t ha ⁻¹	4.16	4.29	4.22	4.06	4.24	4.15
S.Em.±	0.04	0.05	0.03	0.04	0.05	0.03
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS
Fertility levels						
C ₁ -75%	4.10	4.25	4.18	3.98	4.21	4.09
C ₂ -100%	4.16	4.28	4.22	4.02	4.22	4.12
C ₃ -125%	4.15	4.26	4.21	4.04	4.24	4.14
S.Em.±	0.05	0.05	0.04	0.05	0.05	0.04
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS

Table 2(a): Effect of biochar, FYM and fertility levels on plant height of maize

Treatments	Plant height (cm)					
	30 DAS			45 DAS		
	2024	2025	Pooled	2024	2025	Pooled
Source of biochar						
A ₁ - Control	31.41	32.03	31.72	119.91	120.45	120.18
A ₂ - Lantana biochar 4 t ha ⁻¹	32.42	33.04	32.73	134.80	135.22	135.01
A ₃ - Wheat straw biochar 4 t ha ⁻¹	32.04	32.65	32.34	130.93	132.74	131.84
S.Em.±	0.42	0.42	0.33	1.56	1.39	1.15
C.D. (P=0.05)	NS	NS	NS	4.48	3.99	3.25
FYM level						
B ₁ - Control	31.56	32.25	31.90	123.36	124.28	123.82
B ₂ - FYM 5 t ha ⁻¹	32.36	32.89	32.63	133.74	134.67	134.20
S.Em.±	0.34	0.52	0.27	1.27	1.70	0.94
C.D. (P=0.05)	NS	NS	NS	3.66	4.88	2.66
Fertility levels						
C ₁ -75%	31.38	31.99	31.68	125.00	125.92	125.46
C ₂ -100%	32.15	32.76	32.45	130.02	130.95	130.48
C ₃ -125%	32.35	32.97	32.66	130.62	131.55	131.09
S.Em.±	0.42	0.52	0.33	1.56	1.70	1.15
C.D. (P=0.05)	NS	NS	NS	4.48	4.88	3.25

Table 2(b): Effect of biochar, FYM and fertility levels on plant height of maize

Treatments	Plant height (cm)					
	60 DAS			At harvest		
	2024	2025	Pooled	2024	2025	Pooled
Source of biochar						
A ₁ - Control	141.07	141.65	141.36	189.77	190.45	190.11
A ₂ - Lantana biochar 4 t ha ⁻¹	158.09	158.71	158.40	215.34	216.08	215.71
A ₃ - Wheat straw biochar 4 t ha ⁻¹	154.99	155.60	155.29	211.02	211.73	211.37
S.Em.±	1.83	1.50	1.30	2.88	2.36	2.04
C.D. (P=0.05)	5.27	4.31	3.66	8.28	6.77	5.75
FYM level						
B ₁ - Control	145.28	145.87	145.57	198.20	198.90	198.55
B ₂ - FYM 5 t ha ⁻¹	157.49	158.10	157.79	212.55	213.27	212.91
S.Em.±	1.50	1.84	1.06	2.35	2.89	1.66
C.D. (P=0.05)	4.31	5.28	2.99	6.76	8.29	4.70
Fertility levels						
C ₁ -75%	147.21	147.80	147.50	199.56	200.26	199.91
C ₂ -100%	153.11	153.72	153.42	206.89	207.60	207.24
C ₃ -125%	153.83	154.43	154.13	209.68	210.40	210.04
S.Em.±	1.83	1.84	1.30	2.88	2.89	2.04
C.D. (P=0.05)	5.27	5.28	3.66	8.28	8.29	5.75

Conclusion

Application of biochar, FYM and varying fertility levels did not exert any significant influence on plant population of maize, indicating that crop establishment remained unaffected by the nutrient management practices adopted in the study. However, significant improvements in plant height were observed from 45 DAS onwards. Among the biochar treatments, lantana biochar @ 4 t ha⁻¹ consistently produced taller plants and remained statistically at par with wheat straw biochar. Application of FYM @ 5 t ha⁻¹ significantly enhanced plant height throughout the crop growth period, while 125% RDF recorded the highest plant height, remaining statistically comparable with 100% RDF. The results suggest that integrated application of biochar and FYM, along with adequate fertility levels, promotes vigorous vegetative growth of maize without affecting crop stand establishment.

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