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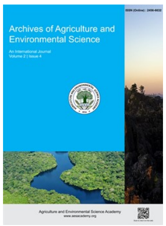

ORIGINAL RESEARCH ARTICLE

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# Effect of biochar and plastic mulch on growth, yield, and yield attributing characteristics of spring maize (*Zea mays* L.)

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**ABSTRACT**

Spring maize is an important crop to meet the growing demand for maize. Moisture stress is an important yield limiting factor during the dry spring period. Biochar and plastic mulch help in soil moisture conservation and might contribute to the growth and yield of maize. A field experiment was conducted to evaluate the effects of biochar application and plastic mulch on growth, yield, and yield attributing characteristics of spring maize (*Zea mays* L.) in a sandy loam soil at Rampur, Chitwan, Nepal in 2018. The experiment was laid out in a split-plot design (SPD) with three replications. The Main plots were allocated to the mulching (mulching, and no mulching) while the Subplot was to the biochar rates of 0 t/ha, 5 t/ha, 15 t/ha, and 25 t/ha. There were twenty-four plots of each plot size 4.8 × 1.5 $m^2$. The grounded biochar passed through a 1 mm sieve and was applied in the well-prepared plots two weeks before seed sowing. The maize seeds were sown at 60 cm row to row and 25 cm plant to plant distance. There were no significant effects due to both factors on maize seed emergence, plant height, number of leaves per plant, leaf area index, root length, dry matter content, stover yield, and yield attributes. But the yield was significantly influenced by their interactions. Significantly highest grain yield (2.58 t/ha) was obtained from 25 t/ha with plastic mulch followed by plastic mulch with 15 t/ha biochar (2.06 t/ha) and the least was recorded from control plots (1.19 t/ha). From the result, it can be concluded that the application of a higher biochar rate of 25 t/ha with plastic mulch contributes to a higher yield of spring maize.



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## INTRODUCTION

Maize (*Zea mays* L.) is the second most important cereal crop in our country. The demand for maize grain is increasing due to the increased demand for maize for the poultry and livestock industries, as well as an increase in the country's population (Ghimire *et al*., 2018). Spring maize is one of the important interventions to meet the growing demand of the country. The yield of the crop during this season is limited by high temperatures resulting in moisture stress. Water stress due to drought is probably the most important abiotic factor limiting the growth and development of plants and crops (Khalili *et al*., 2013). In Nepal, low soil fertility, and poor soil moisture are considered the important factors responsible for the low productivity of maize (Govind *et al*., 2015). Maize production during spring is largely related to soil water. Low soil water availability due to high evaporation can significantly reduce crop growth. Application of biochar in soil and covering the soil surface with mulch might help in soil moisture conservation.

Biochar is a carbon-rich product obtained when biomass such as wood, manure, or leaves is heated at relatively low temperatures (<700°C) in a closed container with little or no available air (Lehmann and Joseph, 2009). The use of biochar as a soil amendment has been growing as it has the potential to boost soil fertility by raising soil pH, increasing water and nutrient holding capacity, improving cation exchange capacity, and making a more suitable habitat for soil microorganisms (Lehmann *et al*., 2006). The application of biochar significantly increases total soil porosity, and readily available water (Qian *et al*., 2020). Ahmed *et al*., (2017) found that the application of biochar in coarse sandy soil improved the water content of the soil due to an increase in porosity. Another benefit associated with biochar is its ability to sequester carbon from the atmosphere and transfer it to soil (Laird, 2009). Similarly, mulching is the practice of covering the soil to make favorable conditions for plant growth, development, and efficient production. It may have many purposes in agriculture, but moisture conservation and erosion control are the most important objectives. Besides this, it also helps to suppress weeds and raises the soil temperature. Plastic mulches are completely impermeable to water; therefore, it prevents direct evaporation of moisture from the soil and thus limits water losses and soil erosion over the surface. Iqbal *et al.* (2020) reported that mulch can effectively minimize water vapor loss, soil erosion, weed problems, and nutrient loss. In this regard biochar and plastic mulch which have combined effects to improve soil properties can be one of the better options for increasing maize productivity of spring maize.

## MATERIALS AND METHODS

The experiment was conducted at the research block of Agriculture and Forestry University, Rampur, Chitwan, Nepal from 31 March 2018 to 6 July 2018. The geographical location of the experimental site is at 27°37' N latitude and 84°25' E with an elevation of 228 meters above sea level. The experimental field was fallow before the experiment. The soil was sandy loam, pH value of 5.89, and with low organic matter content (0.85%). Similarly, the total nitrogen, available phosphorus, and exchangeable potassium were 0.13%, 54.25 kg $ha^{-1}$, and 289.06 kg $ha^{-1}$ soil respectively. The total rainfall during the crop season was 122.16 mm and the relative humidity ranged from 75.0% to 80.0%. The mean maximum temperature during the experimental period ranged from 30.84°C to 23.73°C. The crop sown for the experiment was maize and the variety was Arun-2. The experiment was carried out in a split-plot design (SPD) with three replications. The Main plots were allocated to the mulching (mulching, and no mulching) while the Subplot was to the biochar rates (0 t/ha, 5 t/ha, 15 t/ha, and 25 t/ha). In each replication, main plot treatments were first randomly assigned followed by a random assignment of the subplot treatments within each main plot. There were twenty-four plots of each plot size 4.8 × 1.5 $m^2$. The grounded biochar passed through a 1 mm sieve and was applied in the well-prepared plots two weeks before seed sowing. The maize seeds were sown at 60 cm row-to-row and 25 cm plant-to-plant distance. There were altogether eight rows with six plants in each row (*viz.* forty-eight plants in each plot). Among forty-eight plants, five plants were tagged for data collection from all experimental units. The bio-morphological characters of five tagged plants were recorded at the different specified periods. Similarly, after crop harvest data on yield and yield attributes were recorded. The data were first tabulated in Microsoft Excel and analyzed using R-studio. Means separation was done using Duncan's Multiple Range Test (DMRT) at 1 % and 5% levels of significance (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### Number of seed emergence

The results showed relatively higher seed emergence from plastic mulch plots compared to non-mulch plots (Figure 1), this might be due to increased topsoil temperature (Snyder *et al*., 2015). The relatively higher emergence might also be attributed to the restriction of soil water from evaporation (Zhou *et al*., 2009).

### Plant height

There was no significant difference in plant height due to biochar and Plastic mulch (Table 1). In the later stage plot treated with a high dose of biochar and plots with plastic mulch produced relatively higher plant height as compared to non-mulch. Rajablariani and Sheykhmohamady (2015) observed that plastic mulch improved soil temperature and moisture, prevented the loss of nutrients, and developed a soil microclimate favorable for the growth and development of the crop.

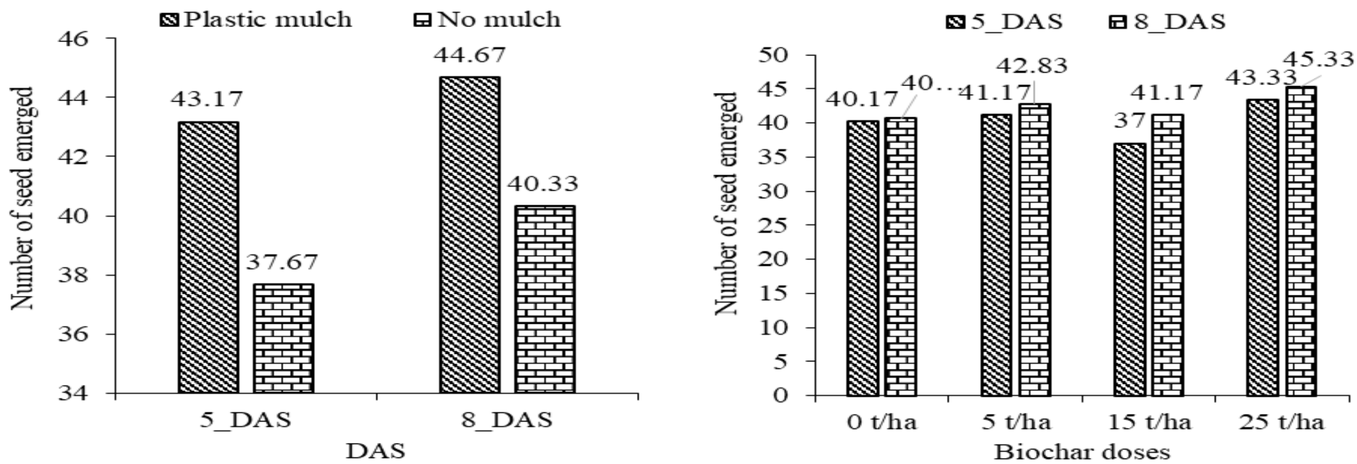


**Figure 1.** *Number of maize seeds emerged as influenced by plastic mulch and biochar respectively at different growth periods at Rampur, Chitwan, Nepal, 2018.*

**Table 1.** Biochar and mulching effects on plant height at different growth periods of maize at Rampur, Chitwan, Nepal, 2018.

| Treatments | Plant height (cm) | | | | |
|---|---|---|---|---|---|
| | 30_DAS | 45_DAS | 60_DAS | 75_DAS | 90_DAS |
| Mulching | | | | | |
| Plastic mulch | 98.65 | 197.70 | 231.60 | 240.95 | 217.65 |
| No mulch | 93.40 | 192.45 | 226.62 | 237.80 | 209.55 |
| LSD (0.05) | 15.73 (NS) | 17.07 (NS) | 11.78 (NS) | 14.90 (NS) | 16.95 (NS) |
| Sem (±) | 15.36 | 5.18 | 14.98 | 15.32 | 8.79 |
| C.V. (%) | 19.6 | 3.3 | 8 | 7.8 | 5 |
| Biochar | | | | | |
| 0 t/ha | 96.37 | 190.3 | 223.27 | 231.93 | 206.57 |
| 5 t/ha | 91.80 | 193.1 | 226.60 | 234.60 | 214.40 |
| 15 t/ha | 100.93 | 202.1 | 237.03 | 242.40 | 216.43 |
| 25 t/ha | 95.00 | 194.8 | 229.53 | 248.57 | 217.00 |
| LSD (0.05) | 23.32 (NS) | 25.06 (NS) | 16.55 (NS) | 20.58 (NS) | 25.26 (NS) |
| Sem (±) | 15.06 | 16.98 | 9.59 | 12.73 | 16.89 |
| C.V. (%) | 19.2 | 10.7 | 5.1 | 6.5 | 9.7 |
| Grand mean | 96.03 | 195.08 | 229.11 | 239.38 | 213.6 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at a 5 % level of significance.

**Table 2.** Biochar and mulching effects on number of leaves at different growth stages of maize at Rampur, Chitwan, Nepal, 2018.

| Treatments | Number of leaves | | | | |
|---|---|---|---|---|---|
| | 30_DAS | 45_DAS | 60_DAS | 75_DAS | 90_DAS |
| Mulching | | | | | |
| Plastic mulch | 7.77 | 10.65 | 11.13 | 9.63 | 8.48 |
| No mulch | 7.15 | 9.78 | 10.38 | 8.75 | 8.33 |
| LSD (F0.05) | 0.59 (NS) | 0.99 (NS) | 0.62 (NS) | 0.78 (NS) | 0.58 (NS) |
| Sem (±) | 0.57 | 0.29 | 0.83 | 0.76 | 0.89 |
| C.V. (%) | 10.4 | 11.4 | 9.5 | 10.2 | 13.1 |
| Biochar | | | | | |
| 0 t/ha | 7.37 | 9.77 | 10.13 | 9.00 | 8.06 |
| 5 t/ha | 7.40 | 10.30 | 10.63 | 9.16 | 8.30 |
| 15 t/ha | 7.53 | 10.40 | 11.07 | 9.23 | 8.63 |
| 25 t/ha | 7.53 | 10.40 | 11.20 | 9.37 | 8.63 |
| LSD (0.05) | 0.96 (NS) | 1.55 (NS) | 0.90 (NS) | 1.29 (NS) | 0.82 (NS) |
| Sem (±) | 0.56 | 0.59 | 0.56 | 0.82 | 0.49 |
| C.V. (%) | 9.3 | 7.2 | 6.4 | 10.9 | 7.2 |
| Grand mean | 7.46 | 10.22 | 10.76 | 9.19 | 8.41 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance

### Number of leaves per plant

Plastic mulch and different doses of biochar showed a relative increase in the number of leaves per plant but the result was statistically nonsignificant (Table 2). From biochar plots number of leaves showed a relative increase with increasing rates of application which was similar to Ndor, *et al.*, (2015) stated that there was no significant difference in the number of leaves and plant height in both years of trial with the application of biochar, however, increased application of biochar resulted in a relative increase in both parameters. The relative increase in the number of leaves with increased levels of biochar might be due to the higher availability of nutrients and liming effect of biochar.

### Root length

There were no significant effects on the length of maize root due to mulching and different levels of biochar (Table 3). The length of maize root was found relatively longer in plots with higher rates of biochar and from mulched plots. The reason might be, the addition of highly porous biochar makes the soil more porous in nature which permitted more growth of the root. It was found that the numbers and length of maize roots were significantly higher with the addition of biochar at the rate of 200 gm/pot compared to the control (Ndor *et al.*, 2016). Similarly, plastic mulch increased the soil temperature and conserved moisture that helped in the growth of roots.

### Above ground dry matter accumulation

The mean above-ground dry matter of maize due to mulching and different doses of biochar were 0.65 t/ha, 2.54 t/ha, and 5.03 t/ha at 30, 45, and 60 days of sowing (Table 4). There were no significant effects on above ground dry matter content of maize due to mulching and different levels of biochar however, it was relatively higher in both cases.

**Table 3.** Biochar and mulching effects on root length at different growth periods of maize at Rampur, Chitwan, Nepal, 2018.

| Treatments | Root length (cm) | | |
|---|---|---|---|
| | 30_DAS | 45_DAS | 60_DAS |
| Mulching | | | |
| Plastic mulch | 17.40 | 18.65 | 20.76 |
| No mulch | 16.51 | 16.88 | 20.58 |
| LSD (0.05) | 2.12 (NS) | 2.31 (NS) | 1.93 (NS) |
| Sem (±) | 2.38 | 4.86 | 1.19 |
| C.V. (%) | 17.2 | 33.5 | 7.1 |
| Biochar | | | |
| 0 t/ha | 16.13 | 17.03 | 19.72 |
| 5 t/ha | 17.05 | 17.53 | 20.42 |
| 15 t/ha | 17.22 | 17.55 | 20.96 |
| 25 t/ha | 17.44 | 18.93 | 21.59 |
| LSD (0.05) | 3.13 (NS) | 3.52 (NS) | 2.84 (NS) |
| Sem (±) | 2.16 | 1.73 | 2.16 |
| C.V. (%) | 15.6 | 11.9 | 12.8 |
| Grand mean | 16.96 | 17.76 | 20.67 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance.

**Table 4.** Biochar and mulching effects on above ground dry matter at different growth periods of maize at Rampur, Chitwan, Nepal, 2018.

| Treatments | Above ground dry matter (t/ha) | | |
|---|---|---|---|
| | 30_DAS | 45_DAS | 60_DAS |
| Mulching | | | |
| Plastic mulch | 0.65 | 2.59 | 5.41 |
| No mulch | 0.64 | 2.49 | 4.65 |
| LSD (0.05) | 0.21 (NS) | 0.91(NS) | 1.06 (NS) |
| Sem (±) | 0.19 | 1.42 | 1.17 |
| C.V. (%) | 37.3 | 68.4 | 28.5 |
| Biochar | | | |
| 0 t/ha | 0.62 | 2.11 | 4.39 |
| 5 t/ha | 0.63 | 2.54 | 4.90 |
| 15 t/ha | 0.65 | 2.58 | 5.21 |
| 25 t/ha | 0.69 | 2.94 | 5.63 |
| LSD (0.05) | 0.32 (NS) | 1.31 (NS) | 1.55 (NS) |
| Sem (±) | 0.22 | 0.75 | 0.98 |
| C.V. (%) | 41.6 | 36 | 24 |
| Grand mean | 0.65 | 2.54 | 5.03 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance

**Table 5.** Biochar and mulching effects on root dry matter at different growth stages of maize at Rampur, Chitwan, Nepal, 2018.

| Treatments | Root dry matter (t/ha) | | |
|---|---|---|---|
| | 30_DAS | 45_DAS | 60_DAS |
| Mulching | | | |
| Plastic mulch | 0.25 | 0.64 | 0.69 |
| No mulch | 0.23 | 0.52 | 0.62 |
| LSD (0.05) | 0.09 (NS) | 0.33 (NS) | 0.19 (NS) |
| Sem (±) | 0.05 | 0.57 | 0.05 |
| C.V. (%) | 27.3 | 120.2 | 9.7 |
| Biochar | | | |
| 0 t/ha | 0.17 | 0.38 | 0.54 |
| 5 t/ha | 0.24 | 0.56 | 0.55 |
| 15 t/ha | 0.27 | 0.66 | 0.69 |
| 25 t/ha | 0.27 | 0.71 | 0.85 |
| LSD (0.05) | 0.13 (NS) | 0.47 (NS) | 0.25 (NS) |
| Sem (±) | 0.08 | 0.27 | 0.18 |
| C.V. (%) | 40.8 | 57.2 | 35.1 |
| Grand mean | 0.24 | 0.58 | 0.66 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance

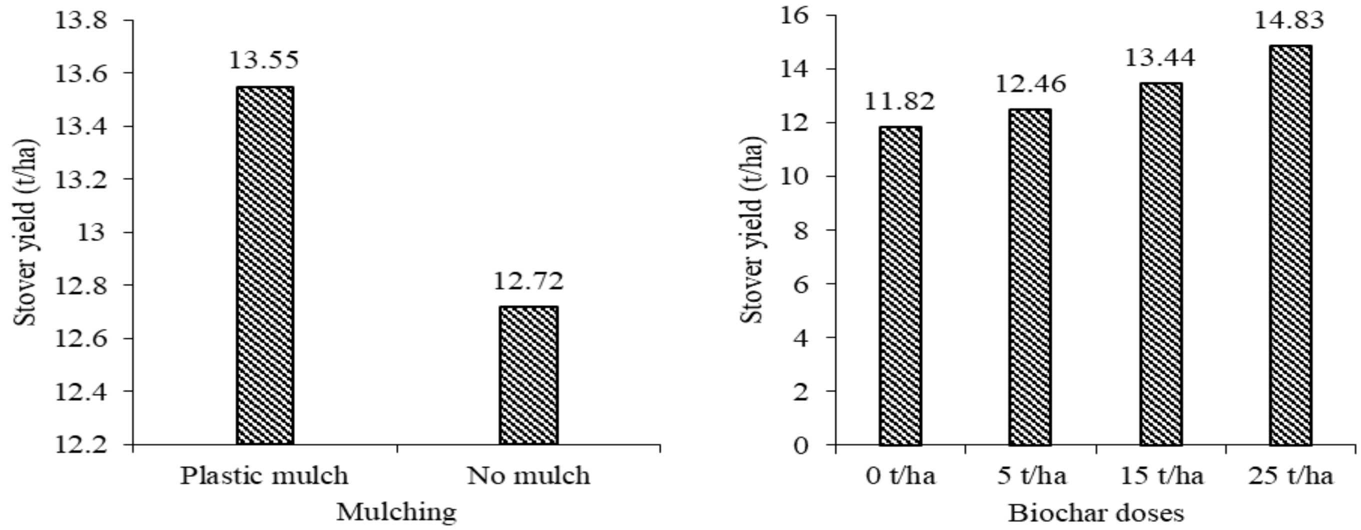


**Figure 2.** *Stover yield of maize as influenced by mulching and biochar respectively at harvest at Rampur, Chitwan, Nepal, 2018.*

**Table 6.** Biochar and mulching effects on yield attributes of maize at harvest at Rampur, Chitwan, Nepal, 2018.

| Treatments | Ear length (cm) | Ear diameter (mm) | Number of kernel row/ear | Number of kernel/row | 1000 grain weight (gm) | Grain yield (t/ha) |
|---|---|---|---|---|---|---|
| Mulching | | | | | | |
| Plastic mulch | 14.51 | 38.37 | 11.53 | 23.86 | 318.66 | 1.96 |
| No mulch | 13.04 | 38.01 | 11.83 | 20.47 | 305.89 | 1.41 |
| LSD (0.05) | 1.22 (NS) | 2.06 (NS) | 0.66 (NS) | 3.63 (NS) | 18.37 (NS) | 0.46 (NS) |
| Sem (±) | 1.81 | 1.45 | 0.8 | 5.27 | 16.94 | 0.44 |
| C.V. (%) | 16.1 | 4.6 | 8.4 | 29.1 | 6.6 | 32.2 |
| Biochar | | | | | | |
| 0 t/ha | 12.92 | 37.79 | 11.2 | 20.77 | 313.86 | 1.45 |
| 5 t/ha | 13.5 | 36.98 | 11.87 | 20.78 | 301.65 | 1.65 |
| 15 t/ha | 14.23 | 38.65 | 11.6 | 21.59 | 314.13 | 1.76 |
| 25 t/ha | 14.44 | 39.35 | 12.07 | 25.53 | 319.47 | 1.89 |
| LSD (0.05) | 1.90 (NS) | 2.85 (NS) | 0.90 (NS) | 5.25 (NS) | 27.35 (NS) | 0.74 (NS) |
| Sem (±) | 1.08 | 1.77 | 0.44 | 3.42 | 16.55 | 0.26 |
| C.V. (%) | 9.6 | 5.7 | 4.6 | 18.9 | 6.5 | 19.2 |
| Grand mean | 13.77 | 38.19 | 11.68 | 22.17 | 312.28 | 1.69 |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance.

### Root dry matter

The data on root dry matter is influenced by biochar and mulching at different growth stages of maize (Table 5). There were no significant effects on the total root dry matter of maize due to mulching and different levels of biochar but it was relatively higher in both cases.

### Stover yield

There was no significant effect on the stover yield of maize due to mulching and different levels of biochar (Figure 2). Plastic mulch and different doses of biochar showed relatively higher stover yield.

### Yield and yield attributes

There was no significant effect on yield attributes of maize due to mulching and different levels of biochar but they were relatively higher as the rate of biochar increased and in mulched plots (Table 6). The yield attributes of maize were relatively increased with the plastic mulch and biochar doses. Pinjari *et al.* (2009) reported that cob length, cob girth, number of grains per cob, number of grain rows, and weight of grain per cob were significantly higher under plastic mulch compared to no mulch. The increase in cob length, 1000 grain weights, and grain yield of maize might be due to better nutrient use efficiency under rice husk biochar application (Islam *et al.*, 2018).

The grain yield was significantly influenced by the interactions between mulching and levels of biochar (Table 7). Significantly the highest grain yield (2.58 t/ha) was obtained from 25 t/ha with plastic mulch followed by plastic mulch with 15 t/ha biochar (2.06 t/ha) and the least was recorded from control plots (1.19 t/ha). Higher yield of maize in a mulched plot with an increased dose of biochar might be the greenhouse effect under plastic mulch that significantly increased the top soil temperature and accelerated the maize growth and yield (Pramanik *et al.*, 2015); Water content in topsoil becomes more stable as evaporation is inhibited and transfer of water from deeper soil layer to topsoil by capillary action, that results in increased maize yield under plastic mulch (Li *et al.*, 2013). Similarly, biochar helps in improving the physical and chemical properties of soil (Major *et al.*, 2010), accumulates high levels of soil organic carbon that could enhance nitrogen efficiency and increase crop productivity (Pan *et al.*, 2009) and, Yamato *et al.* (2006) reported that the maize yield was increased from 20 % -140 % with the application of biochar in soil compared to control.

**Table 7.** Grain yield of maize as influenced by the interactions between mulching and biochar doses at Rampur, Chitwan, Nepal, 2018.

| Mulching | Grain yield (t/ha) Biochar | | | |
|---|---|---|---|---|
| | 0 t/ha | 5 t/ha | 15 t/ha | 25 t/ha |
| Plastic mulch | 1.31[c] | 1.61[bc] | 2.06[b] | 2.58[a] |
| No mulch | 1.19[c] | 1.58[bc] | 1.46[c] | 1.69[bc] |

Treatment means in columns followed by common letters (s) are not significantly different from each other based on DMRT at 5 % level of significance

## Conclusion

The yield of spring maize was significantly influenced by the interaction effect of biochar and plastic mulching but not by their individual effect. Significantly highest grain yield (2.58 t/ha) was obtained from 25 t/ha with plastic mulch followed by plastic mulch with 15 t/ha biochar (2.06 t/ha) and the least was recorded from control plots (1.19 t/ha). Based on the result it can be concluded that the application of 25t/ha biochar with plastic mulching has a positive role in the growth and yield attributes of maize, which increases the yield of spring maize.



## REFERENCES

Ahmed, F., Arthur, E., Plauborg, F., Razzaghi, F., Kørup, K., & Andersen, M. N. (2018). Biochar amendment of fluvio-glacial temperate sandy subsoil: Effects on maize water uptake, growth and physiology. *Journal of Agronomy and Crop Science*, *204*(2), 123-136.

Dynamics of Maize consumption and its implication in maize technology demand in Nepal. In B.M.Prasanna, Aparna Das and Kelah K. Kaimenyi (eds.) 2018. Book of Extended summaries, 13th Asian Maize Conference, and Expert Consultation on Maize for Food, Feed, Nutrition and Environmental Security. Ludhaina, India. October 8-10, 2018. CIMMYT, Mexico D.F. p. 184-190.

Ghimire, Y. N., Timsina, K. P., Devkota, D., Gautam, S., Choudhary, D., Poudel, H., & Pant, J. (2018). Dynamics of maize consumption and its implication in maize technology demand in Nepal. CIMMYT.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Iqbal, R., Raza, M. A. S., Valipour, M., Saleem, M. F., Zaheer, M. S., Ahmad, & Nazar, M. A. (2020). Potential agricultural and environmental benefits of mulches—a review. *Bulletin of the National Research Centre*, *44*(1), 1-16.

Islam, S. J. M., Mannan, M. A., Khaliq, Q. A., & Rahman, M. M. (2018). Growth and yield response of maize to rice husk biochar. *Australian Journal of Crop Science*, *12*(12), 1813-1819, https://doi.org/10.21475/ajcs.18.12.12.p944

Govind, K. C., Karki, T., Shrestha, J. and Achhami, B. B. (2015). Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, *1*(1), 1-9.

Khalili, M., Naghavi, Aboughadareh, M.R.,& Rad,, H.N. (2013). Effects of drought stress on yield and yield components in maize cultivars ( *Zea mays* L.). *International Journal of Agronomy and Plant Production*, *4*, 809 -812.

Laird, D. A., Brown, R. C., Amonette, J. E., & Lehmann, J. (2009). Review of the pyrolysis platform for coproducing bio-oil and biochar. *Biofuels, bioproducts and biorefining*, *3*(5), 547-562.

Lehmann, J., & Joseph, S. (2012). Biochar systems. In *Biochar for environmental management* (pp. 179-200). Routledge.

Lehmann, J., Gaunt, J., & Rondon, M. (2006). Bio-char sequestration in terrestrial ecosystems–a review. *Mitigation and adaptation strategies for global change*, *11*(2), 403-427.

Li, S. X., Wang, Z. H., Li, S. Q., Gao, Y. J., & Tian, X. H. (2013). Effect of plastic sheet mulch, wheat straw mulch, and maize growth on water loss by evaporation in dryland areas of China. *Agricultural water management*, *116*, 39-49.

Major, J., Rondon, M., Molina, D., Riha, S. J., & Lehmann, J. (2010). Maize yield and nutrition during 4 years after biochar application to a Colombian savanna oxisol. *Plant and soil*, *333*(1), 117-128, https://doi.org/10.1007/s11104-010-0327-0

Ndor, E., Dauda, S. N., & Azagaku, E. D. (2015). Response of maize varieties (Zea mays) to biochar amended soil in Lafia, Nigeria. *American Journal of Experimental Agriculture*, *5*(6), 525-531, https://doi.org/10.9734/AJEA/2015/12375

Ndor, E., Jayeoba, J. O., Asadu, C. L. A., & Iheshiulo, E. M. A. (2016). Growth, Nutrient uptake and dry matter yield of maize (*Zea Mays* L.) grown in soil amended with Rice husk and sawdust biochar. *International Journal of Scientific Research in Agricultural Sciences*, *3*(3), 099-103, https://doi.org/10.12983/ijsras-2016-p0099-0103.

Pan, G., Zhou, P., Li, Z., Smith, P., Li, L., Qiu, D., ... & Chen, X. (2009). Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region, China. *Agriculture, ecosystems & environment*, *131*(3-4), 274-280, https://doi.org/10.1016/j.agee.2009.01.020

Pinjari, S. S., RANSHUR, M. T. N., & BHONDAVE, T. (2009). Effect of polythene mulch on corn. *International Journal of Agricultural Sciences*, *5*(2), 643-647.

Qian, Z., Tang, L., Zhuang, S., Zou, Y., Fu, D., & Chen, X. (2020). Effects of biochar amendments on soil water retention characteristics of red soil at south China. *Biochar*, *2*(4), 479-488.

Rajablariani, H. R., & Sheykhmohamady, M. (2015). Growth of Sweet Corn and Weeds in Response to Colored Plastic Mulches. *Journal of Advanced Agricultural Technologies*, *2*(1), 42–45, https://doi.org/10.12720/joaat.2.1.42-45

Snyder, K., Grant, A., Murray, C., & Wolff, B. (2015). The effects of plastic mulch systems on soil temperature and moisture in central Ontario. *HortTechnology*, *25*(2), 162-170.

Pramanik, P., Bandyopadhyay, K. K., Bhaduri, D., Bhattacharyya, R., & Aggarwal, P. (2015). Effect of mulch on soil thermal regimes-a review. International Journal of Agriculture, Environment and Biotechnology, 8(3), 645-658.

Yamato, M., Okimori, Y., Wibowo, I. F., Anshori, S., & Ogawa, M. (2006). Effects of the application of charred bark of Acacia mangium on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil science and plant nutrition*, *52*(4), 489-495.

Zhou, L. M., Li, F. M., Jin, S. L., & Song, Y. (2009). How two ridges and the furrow mulched with plastic film affect soil water, soil temperature and yield of maize on the semiarid Loess Plateau of China. *Field Crops Research*, *113*(1), 41-47, https://doi.org/ 10.1016/j.fcr.2009.04.005