DIFFERENT COMBINATIONS OF BIOCHAR AND UREA AS A NITROGEN SOURCE: EFFECT ON GROWTH, TUBER QUALITY, AND YIELD OF POTATO

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ARTICLE DETAILS

ABSTRACT

Field research was carried out to examine the biochar effect on growth, tuber quality, and yield of the potato crop. Treatments were laid out in a randomized complete block design with 7 treatments of different combinations of biochar and urea (BC100%, BC60%+Urea40%, BC40%+Urea60%, BC20%+Urea80%, BC0%+Urea100%, Urea100%, BC0%) as nitrogen source with 4 replications, where all treatments supply recommended dose of fertilizer except control treatment (BC). The tested variety of potato was Janakdev. The recorded observations showed that biochar mixed with chemical fertilizer had a significantly superior effect on growth (height, branches number, canopy), marketable tuber weight and number, tuber size, yield, and dry matter % as compared to sole biochar (BC100%), sole chemical fertilizer (Urea100%), and control (BC1) treatments. Among the treatments, BC60%+Urea40% (Biochar applied @ 10 t/ha) had resulted significantly higher marketable tuber weight and number, tuber size, yield, and dry matter %. Our results thus demonstrate that the application of chemical fertilizer in combination with biochar could effectively enhance the plant growth, tuber quality, and yield of the potato crop.

KEYWORDS

Biochar, Urea combination, Biochar rate, Potato growth, Tuber attributes, Yield

1. INTRODUCTION

Cultivated potato (Solanum tuberosum L.) lies in the Solanaceae family and is grown for underground starchy tubers (Hirsch et al., 2013). After wheat and rice, it is the prime food crop (Jansky et al., 2019) addressing food insecurity in developing countries (Wijesinha-Bettoni and Moullé, 2019). However, there are still certain factors like reduction of soil organic matter, soil erosion, landslides, depletion of soil nutrients via leaching or surface runoff, and whatever other form of soil degradation; these all debilitate productivity (Chalise et al., 2019). In the context of the Nepalese hilly agricultural system, annually 2-105 t/ha of soil gets eroded, where 5 t/ha of soil loss corresponds to the removal of 75 kg of Organic Matter, 3.8 kg of Nitrogen, 5 kg of Phosphorous, and 10 kg of Potassium per hectare of land (Tripathi, 2019). Thus, it is evident that conservative and soil reforming farming is requisite particularly for these fragile areas.

Biochar is a porous substance abound in carbon, which is created by pyrolysis of biomass under an oxygen-limited setting for purposeful application to the soil for agriculture and environmental benefits such as soil improvement, waste valorization, and energy production (Lehmann and Joseph, 2015; Manyà, 2012). Biochar application could improve the chemical, physical, and biological qualities of soil, overall enhancing the soil quality (Aslam et al., 2014; Blanco-Canqui, 2017; Ding et al., 2016; Pandian et al., 2016). Moreover, with the present scenario of climate change, fertilizer and pesticide pollution, biochar can address these problems (Ameeloot et al., 2013; Rawat et al., 2019). Nutrient-loaded biochar increases both the nutrient holding ability and exchange capacity when needed, improves fertilizer efficiency, and ultimately increases the yield (Blackwell et al., 2010; Schmidt et al., 2017).

Several experiments have shown the increase in plant height, stems or branches, canopy diameter, and yield of the plant through biochar application (Mollick et al., 2020; Schulz and Glaser, 2012; Youseef et al., 2017). On the contrary, there has been a decrease in leaf area or plant growth, yield, and even death of some plants (Chan et al., 2007; Liu et al., 2016). Liu et al. (2016) have observed the negative impact of biochar on potato growth because of lower assimilation of N and P by its immobilization and the likelihood of phytotoxic impacts of wood-derived biochar on plant growth, so the author has not suggested using biochar derived from wood to the mycorrhizal root system and soil suffering from water deficiency. Sole biochar application also reduced the crop yield in comparison to combined biochar and nitrogen fertilizer treatment (Relbe et al., 2015).

Similarly, in the experiment conducted by Schulz and Glaser (2012), the synergistic effect resulting from the biochar and mineral fertilizer combination showed better plant growth as compared to sole biochar and sole fertilizer. The irregularity in the effect of biochar in crops could be due to the variation in biochar feedstock, crop variety, climatic condition, and pyrolysis condition (Biederman and Harpole, 2013; Bista et al., 2019). Thus the goal of this research was to investigate the effect of different combinations of biochar and urea on the growth, tuber quality, and yield of potato.

2. MATERIALS AND METHODS

2.1 Study Site

The research was conducted on the farm of Potato Crop Development Centre, Nigale, Sindupalchok, Nepal (27°40′45.8″ North, 85°56′01.5″

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Table 1: Plant Height, Number of Branches per Hill, and Canopy Diameter as Influenced by Different Combinations of Biochar and Urea

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Height (cm)</th>
<th>Number of Branches / Hill</th>
<th>Canopy Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 DAP</td>
<td>105 DAP</td>
<td>75 DAP</td>
</tr>
<tr>
<td>BC100%</td>
<td>66.00a</td>
<td>75.05a</td>
<td>14.25b</td>
</tr>
<tr>
<td>BC40%+Urea60%</td>
<td>65.20a</td>
<td>72.90a</td>
<td>10.70a</td>
</tr>
<tr>
<td>BC60%+Urea40%</td>
<td>65.70a</td>
<td>77.25a</td>
<td>12.10a</td>
</tr>
<tr>
<td>BC80%+Urea20%</td>
<td>65.17a</td>
<td>71.85a</td>
<td>11.30a</td>
</tr>
<tr>
<td>Urea100%</td>
<td>59.57b</td>
<td>69.20</td>
<td>10.45d</td>
</tr>
<tr>
<td>Healthy Janakdev</td>
<td>54.90c</td>
<td>68.35</td>
<td>7.55</td>
</tr>
<tr>
<td>F test (α=0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44.30a</td>
<td>50.55</td>
<td>5.15</td>
</tr>
<tr>
<td>LSD (α=0.05)</td>
<td>8.711</td>
<td>9.098</td>
<td>10.214</td>
</tr>
</tbody>
</table>

*** Significant difference at α=0.001 level. Within columns, treatment means followed by the dissimilar letter(s) are significantly different from each other at α=0.05 level DAP = Days after planting

3.2 Tuber Quality and Yield

Figure 1: Marketable and unmarketable tuber weight per 2.7 m² area as produced by different combinations of biochar and urea. Treatment means with the dissimilar letters are significantly different at α=0.05 level. Standard error (SE) of the means is indicated by the vertical bars. The same for below.
Significant differences among treatments were observed for both marketable and unmarketable tuber weight (Figure 2), tuber size (Figure 3), yield (Figure 4), and dry matter (Figure 5). The effect of BC_{40\%}+Urea_{60\%} in marketable tuber weight and number was significantly greater than the remaining treatments; however, it was at par with that of BC_{100\%} and BC_{80\%}+Urea_{20\%} in the case of marketable tuber number. For unmarketable tuber weight and number, BC_{40\%}+Urea_{60\%} resulted significantly lower weight and number and was at par with BC_C in both cases.

Figure 2: Marketable and unmarketable tuber numbers per 2.7 m² area as produced by different combinations of biochar and urea.

Tuber size was produced significantly greater by BC_{40\%}+Urea_{60\%}. Similarly, BC_{40\%}+Urea_{60\%} resulted significantly higher yield (24.3 t/ha) but is statistically similar to BC_{60\%}+Urea_{40\%}, BC_{40\%}+Urea_{40\%}, and BC_{20\%}+Urea_{80\%}.

The yield of biochar added plots was greater as compared to sole urea added and control plots. BC_{40\%}+Urea_{60\%} increased dry matter significantly compared to other treatments except for BC_{20\%}+Urea_{80\%}.

Figure 3: Average tuber size as influenced by different combinations of biochar and urea.

Figure 4: Potato tuber yield as influenced by different combinations of biochar and urea.
From the study, an inference can be drawn that biochar added treatments resulted in higher plant growth (plant height, branches, and canopy) during the later period of f90 and 105 DAP. Similar effect of biochar in plant height improvement was reported in potato (Mollick et al., 2020) and also in oat (Schulz and Glaser, 2012), while canopy in potato experiment (Youseef et al., 2017). Plant height increment by biochar application could be ascribed to moisture absorbing capacity and provision of moisture when needed, higher nutrient retention capacity, synergistic effect of biochar and mineral fertilizer, improvement of soil properties and fertility by the application of biochar (Ding et al., 2016; Schulz and Glaser, 2012; Upadhyay and Neupane, 2020). If mentioned synergistic effect acts and the overall nitrogen level was enhanced, the profuse availability of N could stimulate the growth of canopy, leaves, stem, and lateral branches (Millard and Mckerron, 1986).

Treatment BC$_{40\%}$+Urea$_{60\%}$ superior effect on the production of marketable tuber weight and number, tuber size along with lower unmarketable tuber weight and number resulted highest yield. Biochar added to a nearby amount of BC$_{40\%}$+Urea$_{60\%}$ (10 t/ha) in other experiments on potato had shown a positive effect on marketable tuber number and weight (Mollick et al., 2020; Nair et al., 2018), yield (Mollick et al., 2020; Youseef et al., 2017), and size (Nair et al., 2018). In our experiment, sole biochar (BC$_{100\%}$), sole mineral fertilizer (Urea$_{100\%}$), and control (BC) treatments resulted negative effects, while biochar added with mineral fertilizer produced better results in terms of tuber production. BC$_{40\%}$+Urea$_{60\%}$, consisting of both biochar and chemical fertilizer, had a positive effect through the synergistic effect of biochar and chemical fertilizer for nutrients (Schulz and Glaser, 2012), nitrogen availability, and the ability for water as well as nutrient availability and retention (Herlihy and Carroll, 1969; Youseef et al., 2017). The negative impact of sole biochar application on production could be attributed to the alkalinity effect of biochar, raising pH, in turn, reducing nutrient availability (Saleem et al., 2019). N immobilization, and the probable presence of inherent undesirable compounds (Lehmann and Joseph, 2015; Solaiman et al., 2012; Spokas et al., 2012). Higher dry matter as produced by BC$_{40\%}$+Urea$_{60\%}$ could be attributed to its role in tuber maturity, growth characters (leaves, canopy, stem), water and nutrient uptake (Gebre et al., 2020; Youseef et al., 2017).

In summary, based on our study, the application of biochar mixed with mineral fertilizer (especially at BC$_{40\%}$+Urea$_{60\%}$) Biochar @ 10 t/ha could outperform sole mineral fertilizer and sole biochar application in the yield of potato in case of similar climatic and edaphic settings. Biochar application, as contrast to sole chemical fertilizer, could ameliorate and make favorable biological, chemical, and physical soil conditions for the crop. Biochar’s nutrient holding capacity or nutrient loss minimizing property might have contributed to higher nutrient availability for potato crop. Thus, addition of biochar with chemical fertilizer could make efficient use of synthetic fertilizers with improvement in soil quality leading to supreme effect in terms of crop growth and production.

However, different biochar rates have varying influences based on the crop species. In the experiment conducted by Chan et al. (2007) in radish, 10 t/ha biochar rate resulted lower production than 0 t/ha biochar rate. Similarly, Kraska et al. (2016) reported in their experiment in winter rye that grain yield was significantly superior in treatment applied with biochar at the rate of 20 t/ha than at control and 10 t/ha. Moreover, Brandstal et al. (2010) found no significant effect of 0, 7, and 15 t/ha biochar rates on the yield of turnip rape, fava bean, and wheat. There could also be factors like feedstock and soil types that could influence the biochar rate (Aneseyee and Wolde, 2021; Biederman and Harpole, 2013; Bista et al., 2019). So, selection of biochar rate should be made through evaluation of feedstock, crop, and soil type for a satisfactory result. Regarding this, further attention to research should be paid to test different substrates’ biochar in varying crop species and soils.

5. CONCLUSION

Biochar applied in combination with inorganic fertilizer enhanced plant growth, marketable tuber weight and number, tuber size, dry matter, and yield as compared to treatments of sole inorganic fertilizer, sole biochar, and control. Application of biochar treatment BC$_{40\%}$+Urea$_{60\%}$ (Biochar applied @ 10 t/ha) showed significantly best result in potato production. Further study of various biochars in several crop species and soil types is equally crucial for proper understanding and positive results of biochar application.

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