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Full Research Article

# Effect of Different Types of Biochar Application on Secondary and Micronutrients Content and Uptake by Fodder Maize

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**Abstract**

An investigation was carried out to study the effect of three biochar applications viz., maize stover (MS), cluster bean stover (CB) and *Prosopis julifera* wood (PJ) and one farm yard manure (FYM) on secondary and micronutrients content and uptake by fodder maize during 2010-11 and 2011-12. The biochar and FYM both were applied @ 5 t and 10 t ha$^{-1}$. The recommended dose of fertilizer (RDF) (80-40-0 kg ha$^{-1}$ N-P-K) was applied in eight treatments and remaining eight treatments comprised of biochar and FYM. The Zn and Fe were applied in form of $ZnSO_4$ @ 20 kg ha$^{-1}$ and $FeSO_4$ @ 40 kg ha$^{-1}$, respectively in all treatments as basal. There was a significant increase in the S and Mn concentration with the application of CB biochar @ 5 t ha$^{-1}$ without RDF and with RDF significantly increased the Mg concentration in maize. Application of PJ biochar @ 5 t ha$^{-1}$ along with RDF significantly increased Ca, Zn and Fe concentration and FYM @ 5 t ha$^{-1}$ along with RDF resulted in the highest Cu concentration in maize. Nutrient uptake like Ca, Mg, S, Cu, higher removals of Zn and Fe in maize and highest available Ca and Mg content were significantly increased with the application of RDF+MS10 while the uptake of Mn and DTPA extractable Zn, Cu, Mn and Fe content in soil were significantly increased with the application of RDF+MS5. CB biochar @ 10 t ha$^{-1}$ along with RDF showed significantly the highest available S content in soil.

## 1. Introduction

Biochar can be described as a kind of charcoal made from the pyrolysis of a range of biomass feedstocks, including crop, wood and yard wastes, and manures (Novak et al., 2009). “Biochar is the porous carbonaceous solid produced by thermo chemical conversion of organic materials in oxygen depleted atmosphere which has physiochemical properties suitable for safe and potentially soil improvement” (Steinbeiss et al., 2009). Currently, very little biochar material is being used in agriculture in India and elsewhere. Therefore, in the future development in crop production with biochars, agronomic values of these products in terms of crop response and soil health benefits need to be quantified. Beneficial effects of biochar in terms of increased crop yield and improved soil quality have been reported (Iswaran et al., 1980; Glaser et al. 2002). However, review of previous research showed a huge range of biochar application rates (0.5-135 t ha$^{-1}$ of biochar) as well as a huge range of plant responses (-29-324%) (Glaser et al., 2002). More importantly, in much of this research, properties of the biochar used in the investigation were not reported.

It is important to understand that biochar is not an actual fertiliser although at times it can supply nutrients to plants, for example calcium, magnesium, sulphur and micronutrient. Biochar is usually limiting in poor soils and the ash from biochar could explain the strong effect of biochar on maize biomass yield especially in coarse texture soil soon after application. Keeping the above facts in mind, the following study has been carried out.

## 2. Materials and Methods

An experiment was carried out during the *Kharif* of 2010-11 and 2011-12 at Agricultural Research Station, Sansoli, district, Kheda, Anand Agricultural University, Gujarat. The experimental soil (Typic Ustochrept) was sandy loam in texture, having pH 8.10, EC 0.15 $dSm^{-1}$, organic carbon 0.24%, available N 200 kg $ha^{-1}$, $P_2O_5$ 30 kg $ha^{-1}$ and $K_2O$ 150 kg $ha^{-1}$. The physical properties of soil sample analysis followed by mechanical analysis (International pipette method) at 0 to 25 cm depth containing clay 4.71%, silt 11.52%, fine sand 0.54%, Available Ca 800 ppm, Available Mg 750 ppm, Available S 8.2 mg $kg^{-1}$, Micro-nutrients (0.005 M DTPA-ex-tractable) Fe, Mn, Zn, and Cu 4.50, 10.62, 0.40 and 1.20 mg $kg^{-1}$. The initial chemical status of different biochar such as maize stover biochar, Cluster bean stover biochar and *Prosopis julifera* biochar were also analysed along with 16 treatments combination which is depicted in (Table 1 and 2). Full dose of P (40 kg $P_2O_5$ $ha^{-1}$) in the form of Single Super phosphate and 50% of N (40 kg N $ha^{-1}$) in the form of urea were applied in furrows at the time of sowing as per treatment. Remaining 50% N (40 kg N $ha^{-1}$) was applied in the form of urea as top-dressing at 30 days after sowing. A common dose of $ZnSO_4$ @ 20 kg $ha^{-1}$ and $FeSO_4$ @ 40 kg $ha^{-1}$ was applied in furrows in all the plots at the time of sowing. The representative soil samples from 0-25 cm depth were collected from each plot after the harvest of maize crop as per standard procedure. After harvest of the crop, whole plant samples (shoot along with leaves) were washed with dilute 0.01 N HCl, single and double deionised water in a sequence and air dried. Then samples were dried in a hot air oven in paper bags at 70 °C till constant weight obtained and preserved for further analysis. These samples were ground in a stainless steel Willey mill to avoid contamination of micronutrients and were preserved in air tight polyethylene bags for further analysis. The processed soil samples were analyzed initially and after the completion of the experiment for important soil properties viz. available nutrients viz., Ca, Mg, S, DTPA extractable micronutrients (Zn, Fe, Mn and Cu).

Table 1: Chemical properties of the biochar used in the experimental field

| Sl. no. | Properties | Maize stover | Cluster bean stover | *Prosopis julifera* wood |
|---|---|---|---|---|
| Chemical properties | | | | |
| 1. | pH (1:2.5) | 8.6 | 8.1 | 8.2 |
| 2. | CEC | 35 | 25 | 18 |
| 3. | Ca content (g $kg^{-1}$) | 3.25 | 2.60 | 2.10 |
| 4. | Mg content (g $kg^{-1}$) | 2.34 | 2.28 | 1.90 |
| 5. | S content (%) | 0.23 | 0.73 | 0.59 |
| 6. | Zn (mg $kg^{-1}$) | 42.15 | 39.36 | 38.15 |
| 7. | Fe (mg $kg^{-1}$) | 310.12 | 218.15 | 201.24 |
| 8. | Cu (mg $kg^{-1}$) | 4.75 | 4.35 | 4.10 |
| 9. | Mn (mg $kg^{-1}$) | 40.35 | 36.15 | 34.15 |
| 10. | C:N ratio | 30.06 | 35.28 | 70.0 |

In plant analysis S was estimated by Turbiditmetric methods. The Ca and Mg were estimated by Versanate titration method (Cheng and Bray, 1951). The micronutrients (Fe, Cu, Mn and Zn) were estimated by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). The dried plant samples (leaf and straw) were ground in a stainless steel blade Willey mill and digested in Di-acid mixture ($HNO_3$:$HClO_4$-4:1 ratios) as per standard procedure (Jackson, 1973). The data obtained for above mention different parameters was subjected to statistical analysis as per the method suggested by Gomez and Gamer (1984) for RBD design.

## 3. Results and Discussion

### *3.1. Micronutrient content and uptake*

#### *3.1.1. Zinc (Zn)*

The zinc concentration in maize shoot was significantly influenced by the application of biochar (MS, CB and PJ) and FYM @ 5 and 10 t with and without RDF treatments in both the year (2011 and 2012) as well as pooled basis. However, the lowest Zn content in maize shoot was found in unfertilized treatment in 2011 and 2012 as well as polled basis. The interaction was found non-significant between year and treatment. The highest Zn concentration of maize plant showed in treatment of RDF+$PJ_5$ in first year and 2nd year as well as pooled basis (Table 3). The application of biochar (MS, CB and PJ) with and without fertilizer treatments decreased in Zn concentration of maize plant with increasing the rate of biochar from 5.0 t $ha^{-1}$ to 10.0 t $ha^{-1}$. Similar results were also true in unfertilized FYM application treatment. It might be due to higher dry matter production with the increasing rate of biochar and FYM from 5.0 t $ha^{-1}$ to 10.0 t $ha^{-1}$. The application of RDF+$FYM_{10}$ recorded significantly higher Zn uptake followed by RDF+$MS_5$, RDF+$MS_{10}$, RDF+$CB_5$ and

Table 2: Treatment details

| | |
|---|---|
| (A) Fertility levels (2) | |
| 1. | Control (AC) |
| 2. | Recommended dose of fertilizer (RDF), (N:$P_2O_5$: $K_2O$): 80-40-0 kg $ha^{-1}$ |
| (B) Level of biochar (8) | |
| 1. | 5 t biochar of cluster bean stover ($CB_5$) |
| 2. | 5 t biochar of maize stover ($MS_5$) |
| 3. | 5 t biochar of *Prosopis julifera* wood ($PJ_5$) |
| 4. | 10 t biochar of cluster bean stover ($CB_{10}$) |
| 5. | 10 t biochar of maize stover ($MS_{10}$) |
| 6. | 10 t biochar of *Prosopis julifera* wood ($PJ_{10}$) |
| 7. | 5 t Farm Yard Manure ($FYM_5$) |
| 8. | 10 t Farm Yard Manure ($FYM_{10}$) |

RDF+$CB_{10}$. It indicated that biochar application in presence of fertilized soil significantly influenced the Zn uptake of maize crop. It might be due to higher dry matter yield. The result indicated that there was a positive significant correlation ($r=0.980^{**}$) with an increase in rate of biochar and fertilized treatments of Zn uptake and dry matter yield of maize plants (Lehamann et al., 2003).

### 3.1.2. Iron (Fe)

The application of biochar (MS, CB and PJ) and FYM @ 5 and 10 t with and without RDF treatment had significant effect (Table 3) on Fe concentration of maize plant in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment. The application of biochar (MS, CB and PJ) with and without RDF treatments remarkably decreased in Fe concentration of maize plant with increase in the rate of biochar application from 5.0 t $ha^{-1}$ to 10.0 t $ha^{-1}$. It might be due to higher dry matter production with the higher rate of biochar and FYM. Similar results were also reported by Randon et al. (2007). Application of RDF+$FYM_{10}$ recorded remarkably higher Fe uptake of maize plant (3030.49 g $ha^{-1}$) followed by RDF+$MS_{5,}$ RDF+$MS_{10}$ and RDF+$CB_{10}$. It indicated that biochar application in presence of fertilized significantly influenced the Fe uptake of maize crop. It might due to higher dry matter yield. Similar results were also reported by Randon et al. (2007).

### 3.1.3. Manganese (Mn)

Application of biochar (MS, CB and PJ) and FYM @ 5 and 10 t with and without RDF treatments have significant influence

Table 3: Zn and Fe content and uptake influence by different treatment of biochar in maize plant

| | Zn | | | | | | Fe | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Content (mg $kg^{-1}$) | | | Uptake (g $ha^{-1}$) | | | Content (mg $kg^{-1}$) | | | Uptake (g $ha^{-1}$) | | |
| Treatment | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | | | | |
| AC+$MS_5$ | 40.41 | 47.45 | 43.93 | 89.49 | 102.23 | 95.86 | 328.14 | 374.85 | 351.50 | 690.89 | 789.24 | 740.07 |
| AC+$MS_{10}$ | 37.45 | 45.14 | 41.30 | 113.95 | 126.84 | 120.40 | 303.17 | 346.33 | 324.75 | 874.34 | 998.80 | 936.57 |
| AC+$CB_5$ | 38.49 | 44.42 | 41.45 | 96.79 | 110.56 | 103.67 | 319.17 | 364.60 | 341.89 | 759.66 | 867.79 | 813.72 |
| AC+$CB_{10}$ | 36.57 | 41.41 | 38.99 | 93.21 | 106.48 | 99.84 | 309.41 | 353.45 | 331.43 | 765.12 | 874.03 | 819.57 |
| AC+$PJ_5$ | 36.42 | 43.21 | 39.82 | 75.82 | 86.62 | 81.22 | 355.62 | 406.25 | 380.94 | 700.31 | 800.00 | 750.15 |
| AC+$PJ_{10}$ | 36.07 | 44.44 | 40.25 | 70.92 | 81.01 | 75.96 | 341.65 | 390.28 | 365.97 | 627.67 | 717.02 | 672.34 |
| AC+$FYM_5$ | 40.85 | 50.33 | 45.59 | 85.05 | 100.97 | 93.01 | 327.99 | 374.68 | 351.34 | 716.63 | 818.65 | 767.64 |
| AC+$FYM_{10}$ | 38.93 | 47.96 | 43.44 | 120.90 | 140.11 | 130.51 | 292.71 | 334.38 | 313.54 | 975.37 | 1114.21 | 1044.79 |
| Fertilized treatment | | | | | | | | | | | | |
| RDF+$MS_5$ | 37.79 | 44.50 | 41.15 | 335.88 | 402.87 | 369.37 | 292.87 | 334.56 | 313.71 | 2388.29 | 2775.71 | 2582.00 |
| RDF+$MS_{10}$ | 35.24 | 41.78 | 38.51 | 330.50 | 384.97 | 357.73 | 281.16 | 321.18 | 301.17 | 2321.15 | 2699.01 | 2510.08 |
| RDF+$CB_5$ | 37.31 | 45.97 | 41.64 | 316.53 | 333.10 | 324.82 | 300.83 | 343.65 | 322.24 | 2196.92 | 2557.10 | 2377.01 |
| RDF+$CB_{10}$ | 35.93 | 44.26 | 40.10 | 279.56 | 325.53 | 302.55 | 299.97 | 342.67 | 321.32 | 2211.41 | 2573.65 | 2392.53 |
| RDF+$PJ_5$ | 41.67 | 51.34 | 46.50 | 207.40 | 251.43 | 229.42 | 315.33 | 413.52 | 364.42 | 1739.47 | 2034.53 | 1887.00 |
| RDF+$PJ_{10}$ | 36.02 | 42.32 | 39.17 | 225.70 | 253.07 | 239.38 | 288.29 | 367.41 | 327.85 | 1671.85 | 1957.28 | 1814.56 |
| RDF+$FYM_5$ | 36.57 | 43.82 | 40.19 | 246.54 | 296.40 | 271.47 | 281.98 | 360.19 | 321.09 | 1827.17 | 2134.72 | 1980.95 |
| RDF+$FYM_{10}$ | 40.00 | 44.56 | 42.28 | 320.69 | 270.70 | 295.70 | 285.76 | 364.52 | 325.14 | 2505.23 | 2909.29 | 2707.26 |
| SEm± | 0.78 | 1.12 | 0.68 | 13.86 | 15.08 | 10.24 | 16.66 | 0.64 | 8.34 | 172.39 | 191.41 | 128.80 |
| CD ($p$=0.05) | 2.26 | 3.23 | 1.93 | 40.04 | 43.55 | 28.97 | NS | 1.84 | 23.58 | 497.84 | 552.75 | 364.30 |
| Y | | | | | | | | | | | | |
| SEm± | | 0.24 | | | 3.62 | | | 2.94 | | | 128.80 | |
| CD ($p$=0.05) | | 0.68 | | | 10.24 | | | 8.33 | | | 364.30 | |
| YXT | | | | | | | | | | | | |
| SEm± | | 0.96 | | | 14.48 | | | 11.79 | | | 182.49 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | | | NS | |

$MS_5$: Maize stock (5 t $ha^{-1}$); $MS_{10}$: Maize stock (10 t $ha^{-1}$); $CB_5$: Cluster bean (5 t $ha^{-1}$); $CB_{10}$: Cluster bean (10 t $ha^{-1}$); $PJ_5$: Prosopis julifera wood ($PJ_5$); $PJ_{10}$: Prosopis julifera wood ($PJ_{10}$); $FYM_5$: Farm Yard Manure (5 t $ha^{-1}$); $FYM_{10}$: Farm Yard Manure (10 t $ha^{-1}$)

on Mn concentration of maize plant in both the year (2011 and 2012) as well as pooled basis of both the year. The interaction was found non-significant between year and treatment (Table 4). The application of biochar (MS, CB and PJ) with RDF treatments decreased in Mn concentration of maize plant with increase in the rate of biochar application from 5.0 t ha$^{-1}$ to 10.0 t ha$^{-1}$.Similar was also true in FYM application. It might be due to higher dry matter production with the higher rate of biochar and FYM. Similar results were also reported by Randon et al. (2007). Application of RDF+MS$_5$ (364.36 g ha$^{-1}$) recorded significantly higher Mn uptake of maize plant followed by RDF+MS$_{10}$, RDF+CB$_{10}$ and RDF+CB$_5$ (Table 3). It indicated that biochar application in presence of fertilized significantly influenced the Mn uptake of maize crop. It might be due to higher dry matter production. Similar types of results are also reported by Major et al. (2006).

### 3.1.4. Copper (Cu)

Application of biochar (MS, CB and PJ) and FYM @ 5 and 10 t with and without fertilized treatments have significant influence on Cu concentration of maize plant in both the year (2011 and 2012) as well as pooled basis of both the year. The interaction was found non-significant between year and treatment. However, the highest Cu concentration of maize was observed in treatment of RDF+FYM$_5$ in year 2011 and 2012 as well as pooled basis (Table 4). The application of biochar (MS, CB and PJ) with and without RDF treatments increased in Cu concentration of maize plant with increase in the rate of biochar application from 5.0 t ha$^{-1}$ to 10.0 t ha$^{-1}$. Similar results

Table 4: Mn and Cu content and uptake influence by different treatment of biochar in maize plant

| Treatment | Mn | | | | | | Cu | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Content (mg kg$^{-1}$) | | | Uptake (g ha$^{-1}$) | | | Content (mg kg$^{-1}$) | | | Uptake (g ha$^{-1}$) | | |
| | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | | | | |
| AC+MS$_5$ | 37.64 | 42.99 | 40.31 | 80.26 | 93.40 | 86.83 | 4.61 | 5.36 | 4.99 | 11.89 | 13.83 | 12.86 |
| AC+MS$_{10}$ | 42.20 | 48.20 | 45.20 | 122.05 | 142.03 | 132.04 | 4.41 | 5.13 | 4.77 | 12.61 | 14.67 | 13.64 |
| AC+CB$_5$ | 45.09 | 51.51 | 48.30 | 107.25 | 124.81 | 116.03 | 3.84 | 4.47 | 4.15 | 8.49 | 9.88 | 9.18 |
| AC+CB$_{10}$ | 45.33 | 51.79 | 48.56 | 113.21 | 131.74 | 122.47 | 4.28 | 4.98 | 4.63 | 8.98 | 10.45 | 9.72 |
| AC+PJ$_5$ | 34.89 | 39.86 | 37.37 | 66.99 | 77.96 | 72.47 | 3.79 | 4.41 | 4.10 | 7.48 | 8.71 | 8.10 |
| AC+PJ$_{10}$ | 43.31 | 49.48 | 46.39 | 78.62 | 91.49 | 85.06 | 3.94 | 4.59 | 4.27 | 7.28 | 8.47 | 7.87 |
| AC+FYM$_5$ | 38.09 | 43.52 | 40.81 | 77.75 | 90.48 | 84.12 | 4.52 | 5.26 | 4.89 | 9.89 | 11.51 | 10.70 |
| AC+FYM$_{10}$ | 37.87 | 43.26 | 40.56 | 114.91 | 133.72 | 124.32 | 4.54 | 5.29 | 4.91 | 15.01 | 17.46 | 16.23 |
| Fertilized treatment | | | | | | | | | | | | |
| RDF+MS$_5$ | 33.43 | 38.66 | 36.05 | 307.95 | 363.82 | 335.88 | 4.47 | 5.26 | 4.87 | 39.18 | 46.14 | 42.66 |
| RDF+MS$_{10}$ | 31.21 | 36.13 | 33.67 | 293.16 | 346.61 | 319.88 | 4.66 | 5.48 | 5.07 | 47.90 | 56.29 | 52.10 |
| RDF+CB$_5$ | 33.25 | 38.46 | 35.86 | 273.48 | 323.71 | 298.59 | 3.91 | 4.60 | 4.26 | 36.49 | 43.01 | 39.75 |
| RDF+CB$_{10}$ | 32.92 | 38.08 | 35.50 | 274.16 | 324.50 | 299.33 | 4.63 | 5.44 | 5.04 | 38.77 | 45.66 | 42.22 |
| RDF+PJ$_5$ | 35.67 | 41.22 | 38.45 | 190.16 | 226.75 | 208.46 | 3.72 | 4.39 | 4.05 | 19.96 | 23.77 | 21.87 |
| RDF+PJ$_{10}$ | 33.56 | 38.81 | 36.19 | 196.04 | 233.59 | 214.81 | 4.30 | 5.06 | 4.68 | 25.03 | 29.67 | 27.35 |
| RDF+FYM$_5$ | 29.79 | 34.50 | 32.14 | 192.81 | 229.83 | 211.32 | 4.69 | 5.51 | 5.10 | 30.98 | 36.59 | 33.79 |
| RDF+FYM$_{10}$ | 27.66 | 32.07 | 29.87 | 242.44 | 287.58 | 265.01 | 4.35 | 5.12 | 4.73 | 36.09 | 42.54 | 39.32 |
| SEm± | 1.73 | 1.67 | 1.20 | 17.28 | 20.64 | 13.46 | 0.17 | 0.18 | 0.12 | 39.18 | 46.14 | 42.66 |
| CD ($p$=0.05) | 5.00 | 4.82 | 3.40 | 49.89 | 59.61 | 38.07 | 0.50 | 0.52 | 0.35 | 47.90 | 56.29 | 52.10 |
| Y | | | | | | | | | | | | |
| SEm± | | 0.42 | | | 4.75 | | | 0.04 | | | 0.50 | |
| CD ($p$=0.05) | | 1.20 | | | 13.45 | | | 0.12 | | | 1.42 | |
| YXT | | | | | | | | | | | | |
| SEm± | | 1.69 | | | 19.03 | | | 0.17 | | | 2.02 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | | | NS | |

MS$_5$: Maize stock (5 t ha$^{-1}$); MS$_{10}$: Maize stock (10 t ha$^{-1}$); CB$_5$: Cluster bean (5 t ha$^{-1}$); CB$_{10}$: Cluster bean (10 t ha$^{-1}$); PJ$_5$: Prosopis julifera wood (PJ$_5$); PJ$_{10}$: Prosopis julifera wood (PJ$_{10}$); FYM$_5$: Farm Yard Manure (5 t ha$^{-1}$); FYM$_{10}$: Farm Yard Manure (10 t ha$^{-1}$)

have also been reported by Rondon et al. (2007). Application of RDF+$MS_{10}$ recorded significantly higher plant Cu uptake of maize plant (54.70 g $ha^{-1}$). It might be due to 3.27 times higher dry matter production by the RDF+$MS_{10}$. It indicated that biochar application in presence of RDF significantly influenced the Cu uptake of maize crop. It might be due to significantly higher dry matter yield produced by CB biochar in presence of fertilizer and FYM in presence of fertilizer. Similar types of results were also reported by the Major et al. (2010).

### *3.2. Available DTPA micronutrient content in soil*

#### *3.2.1. Zinc (Zn) content*

The result indicated that fertilized biochar treatments RDF+$MS_5$ and RDF+$MS_{10}$ showed 17.39% and 21.31% higher DTPA extractable Zn in soil after harvest of maize crop as compared to AC+$MS_5$ and AC+$MS_{10}$, respectively in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 5). It indicated that biochar application in presence of fertilizer application significantly influenced the DTPA extractable Zn in soil. Adsorption of the nutrients in clay particles and retaining of the nutrients is increased and prevents it from leaching. Application of increasing rate of maize stover biochar from 5.0 to 10.0 t $ha^{-1}$ in presence of fertilizer decreased Zn content in soil from 1.09 to 1.13 times as compared to same level of biochar in absence of fertilizer. Similar trend was also observed in cluster bean stover biochar and *Prosopis julifera* wood biochar. This agreement was also supported by Novak et al. (2009) who found that extractable Zn marginally decreased from 13 to 10 mg $kg^{-1}$ with an increase in the addition of pecan shell biochar concentration.

#### *3.2.2. Copper (Cu) content*

The result indicated that there was significant influence of Cu concentration in soil by the application of fertilized biochar, unfertilized biochar and FYM. However, similar trend was

Table 5: DTPA-micronutrient content influence by different treatment of biochar (pooled data of two year)

| | DTPA-Fe (mg $kg^{-1}$) | | | DTPA-Mn (mg $kg^{-1}$) | | | DTPA-Zn (mg $kg^{-1}$) | | | DTPA-Cu (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | | | | |
| AC+$MS_5$ | 7.06 | 8.09 | 7.57 | 13.23 | 15.17 | 14.20 | 1.29 | 1.48 | 1.38 | 1.17 | 1.34 | 1.25 |
| AC+$MS_{10}$ | 6.57 | 7.53 | 7.05 | 12.46 | 14.28 | 13.37 | 1.14 | 1.31 | 1.22 | 1.16 | 1.33 | 1.24 |
| AC+$CB_5$ | 6.91 | 7.92 | 7.41 | 13.46 | 15.43 | 14.44 | 1.20 | 1.38 | 1.29 | 1.00 | 1.14 | 1.07 |
| AC+$CB_{10}$ | 6.82 | 7.82 | 7.32 | 13.35 | 15.30 | 14.32 | 1.17 | 1.34 | 1.25 | 0.97 | 1.11 | 1.04 |
| AC+$PJ_5$ | 6.83 | 7.83 | 7.33 | 13.37 | 15.33 | 14.35 | 1.16 | 1.33 | 1.24 | 0.99 | 1.13 | 1.06 |
| AC+$PJ_{10}$ | 6.25 | 7.17 | 6.71 | 12.35 | 14.16 | 13.25 | 1.11 | 1.27 | 1.19 | 0.94 | 1.08 | 1.01 |
| AC+$FYM_5$ | 6.51 | 7.47 | 6.99 | 12.71 | 14.57 | 13.64 | 1.14 | 1.31 | 1.22 | 0.95 | 1.09 | 1.02 |
| AC+$FYM_{10}$ | 7.25 | 8.31 | 7.78 | 13.94 | 15.99 | 14.96 | 1.17 | 1.34 | 1.25 | 1.06 | 1.22 | 1.14 |
| Fertilized treatment | | | | | | | | | | | | |
| RDF+$MS_5$ | 8.99 | 10.50 | 9.75 | 14.69 | 17.04 | 15.87 | 1.58 | 1.80 | 1.69 | 2.26 | 2.44 | 2.35 |
| RDF+$MS_{10}$ | 7.99 | 9.36 | 8.67 | 18.46 | 20.77 | 19.61 | 1.45 | 1.65 | 1.55 | 2.21 | 2.37 | 2.29 |
| RDF+$CB_5$ | 7.25 | 8.51 | 7.88 | 18.37 | 20.67 | 19.52 | 1.35 | 1.54 | 1.45 | 2.07 | 2.21 | 2.14 |
| RDF+$CB_{10}$ | 7.02 | 8.24 | 7.63 | 17.16 | 19.28 | 18.22 | 1.29 | 1.47 | 1.38 | 2.17 | 2.33 | 2.25 |
| RDF+$PJ_5$ | 6.41 | 7.55 | 6.98 | 17.50 | 19.67 | 18.58 | 1.27 | 1.45 | 1.36 | 2.21 | 2.37 | 2.29 |
| RDF+$PJ_{10}$ | 6.38 | 7.50 | 6.94 | 16.61 | 18.65 | 17.63 | 1.25 | 1.43 | 1.34 | 2.16 | 2.32 | 2.24 |
| RDF+$FYM_5$ | 6.04 | 7.12 | 6.58 | 17.30 | 19.44 | 18.37 | 1.26 | 1.44 | 1.35 | 2.21 | 2.37 | 2.29 |
| RDF+$FYM_{10}$ | 6.29 | 7.41 | 6.85 | 17.53 | 19.70 | 18.61 | 1.32 | 1.50 | 1.41 | 2.21 | 2.38 | 2.30 |
| SEm± | 0.33 | 0.32 | 0.23 | 0.32 | 0.32 | 0.23 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 |
| CD ($p$=0.05) | 0.94 | 0.93 | 0.65 | 0.93 | 0.92 | 0.64 | 0.10 | 0.10 | 0.07 | 0.10 | 0.10 | 0.07 |
| Y | | | | | | | | | | | | |
| SEm± | | 0.08 | | | 0.08 | | | 0.008 | | | 0.008 | |
| CD ($p$=0.05) | | 0.22 | | | 0.22 | | | 0.023 | | | 0.023 | |
| YXT | | | | | | | | | | | | |
| SEm± | | 0.32 | | | 0.32 | | | 0.03 | | | 0.033 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | | | NS | |

also observed in case of Cu like Zn in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 5). The similar types of results were also reported by the Novak et al. (2009) and they indicated that the copper (Cu) concentration of soil was not significantly affected by the biochar addition.

*3.2.3. Manganese (Mn) content*

The result indicated that application of RDF+$MS_5$ recorded significantly higher DTPA extractable Mn in soil (17.17 mg $kg^{-1}$) after harvest of maize crop than AC+$MS_5$, AC+$MS_{10}$, AC+$CB_5$, AC+$CB_{10}$, AC+$PJ_5$, AC+$PJ_{10}$ and AC+$FYM_5$. The combined application of RDF with maize stover biochar, cluster bean stover biochar, *Prosopis julifera* wood biochar and FYM gave 1.24, 1.13, 1.12 and 1.11 times higher Mn concentration in soil over unfertilized application of corresponding biochar and FYM, respectively after 60 days of the maize crop growth in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 5). Novak et al. (2009) found that in pecan shell based biochar; the soil had increased Mn concentrations after the 67 day trial period. This demonstrates that Mn was largely retained during biochar formation due to its high association with a number of organic and inorganic forms in the biomass (Amonette and Joseph, 2009).

*3.2.4. Iron (Fe) content*

It was indicated that available Fe content in soil increased significantly by the application of fertilized maize stover biochar. Application of RDF+$MS_5$ recorded significantly higher DTPA extractable Fe in soil (11.06 mg $kg^{-1}$) after harvest of maize crop than other treatments but it was at par with RDF+$MS_{10}$ (9.99 mg $kg^{-1}$) in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 5). Further, the result indicated that fertilized biochar treatments RDF+$MS_5$, RDF+$MS_{10}$ and RDF+$CB_5$ were highly effective in increasing DTPA extractable Fe in soil by 46.29%, 41.90% and 24.32% as compared to AC+$MS_5$, AC+$MS_{10}$ and AC+$CB_5$, respectively. Results indicated that biochar application in presence of fertilized treatments significantly influenced the available Fe in soil. The above result indicated that maize stover biochar with RDF (RDF+$MS_5$) retain more Fe content in soil as compared to other type of biochar, that is (11.06 mg $kg^{-1}$) and minimum Fe concentration (8.26 mg $kg^{-1}$) was in RDF+$PJ_{10}$. The maize stover biochar showed its superiority over the other type of biochar and it also retained Fe and Mn concentration. Amonette and Joseph (2009) also found that Fe and Mn are associated, and largely retained during biochar formation. Similar type of results also found that poultry litter biochar had the highest amount of Fe compared to peanut hulls and pine chips (Gaskin et al., 2008).

*3.3. Ca, Mg and S content and uptake in plant*

*3.3.1. Calcium (Ca)*

Application of RDF+$PJ_5$ recorded significantly higher plant Ca concentration (0.513%) followed by RDF+$FYM_5$, RDF+$PJ_{10}$, RDF+$MS_{10}$, RDF+$CB_{10}$, RDF+$MS_5$, AC+$PJ_{10}$, AC+$FYM_5$, AC+$FYM_{10}$, AC+$CB_5$ and AC+$MS_5$ (Table 7 and 8). Similar results were also reported by Gaskin et al. (2010). Application of RDF+$MS_{10}$ (46.02 kg $ha^{-1}$) recorded significantly higher plant Ca uptake followed by RDF+$MS_5$. The results clearly indicate that application of biochar in presence RDF treatment positively influenced the Ca uptake of maize crop in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment. The magnitude of Ca uptake increased to the tune of three to four folds as compared to unfertilized biochar. Similar was also true for FYM treatments. It might be due to significantly higher dry matter yield obtained with fertilized biochar treatments. Results indicated that there was a positive significant correlation ($r=0.986^{**}$) with an increase in rate of biochar and fertilized treatments of Ca uptake and dry matter yield of maize plant. Positive effect of biochar application on crop growth, yield and uptake (radish and common bean) has also been reported by several workers (Chan et al., 2007; Asai et al., 2009).

*3.3.2. Magnesium (Mg)*

Application of RDF+$CB_5$ recorded significantly higher Mg concentration of maize plant (0.43%) followed by RDF+$CB_{10}$, RDF+$PJ_{10}$, RDF+$MS_{10}$, RDF+$PJ_5$ and RDF+$MS_5$. It showed that fertilized biochar application significantly influenced the Mg concentration of maize plant in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 7 and 8). Similar results were also obtained by Uzoma et al. (2011). The further results indicate that application of RDF+$MS_{10}$ recorded significantly higher plant Mg uptake (37.34 kg $ha^{-1}$) followed by RDF+$CB_5$, RDF+$MS_5$ and RDF+$CB_{10}$. The results clearly indicate that biochar application in presence of fertilizer significantly influenced the Mg uptake of maize crop. It might be due to higher dry matter production. Results indicated that there was a highly positive significantly correlation ($r=0.957^{**}$) with an increase in the rate of biochar and fertilized treatments of Mg uptake and dry matter yield of maize plant. Similar results have also been reported by Chan et al. (2008).

*3.3.3. Sulphur (S)*

Application of AC+$CB_5$ recorded significantly higher plant S concentration (0.340%) followed by RDF+$CB_5$, RDF+$CB_{10}$, AC+FYM, RDF+$PJ_5$, RDF+$MS_{10}$, AC+$PJ_{10}$, AC+$CB_{10}$, RDF+$MS_5$, AC+$MS_{10}$ and AC+$MS_5$ (Chan et al., 2008). Application of RDF+$MS_{10}$ recorded significantly higher plant S uptake (30.21 kg $ha^{-1}$) followed by RDF+$CB_{10}$, RDF+$MS_5$ and RDF+$CB_5$. It indicated that biochar application in presence of fertilizer significantly influenced the S uptake of maize crop in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 7 and 8). It might be due to higher dry matter yield. In presence of fertilized, MS and CB biochar showed more effectiveness in increasing S uptake of maize shoot as compared to PJ biochar and FYM. In absence of fertilizer, all the type of biochars and FYM failed to show its superiority might be due to low soil fertility status of the experimental soil (8.2 mg $kg^{-1}$). Thereby lower production of dry matter yield. The results indicated that there was a positive significant correlation ($r=0.977^{**}$) with an increase in rate of biochar and fertilized treatments of S uptake and dry matter yield of maize plants (Chan et al., 2008).

### 3.4. *Available Ca, Mg, and S content in soil*

#### 3.4.1. *Calcium (Ca)*

The data depicted in (Table 8) indicated that application of RDF+$MS_{10}$ recorded significantly higher available Ca in soil (1180 ppm) after harvest of maize crop than other treatments. Results indicated that biochar application in presence of fertilized treatments significantly influenced the available Ca in soil in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment. Similar type of results also found that application of biochar increased the Ca concentration in a study conducted on the response of DM production of radish using green-waste (Chan et al., 2007). There was a significant increase in biochar application rate greater than 50 t $ha^{-1}$ and when no N fertilizer was applied and also Adekayode and Olojugba (2010) reported

Table 6: Secondary nutrient content as influenced by different treatment of biochar in maize plant (pooled data)

| Treatment | Ca (mg $kg^{-1}$) | | | Mg (mg $kg^{-1}$) | | | S (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | |
| AC+$MS_5$ | 0.40 | 0.46 | 0.43 | 0.30 | 0.34 | 0.32 | 0.27 | 0.31 | 0.29 |
| AC+$MS_{10}$ | 0.38 | 0.44 | 0.41 | 0.22 | 0.26 | 0.24 | 0.28 | 0.32 | 0.30 |
| AC+$CB_5$ | 0.41 | 0.47 | 0.44 | 0.23 | 0.27 | 0.25 | 0.32 | 0.36 | 0.34 |
| AC+$CB_{10}$ | 0.36 | 0.42 | 0.39 | 0.21 | 0.24 | 0.22 | 0.29 | 0.33 | 0.31 |
| AC+$PJ_5$ | 0.33 | 0.37 | 0.35 | 0.22 | 0.26 | 0.24 | 0.21 | 0.25 | 0.23 |
| AC+$PJ_{10}$ | 0.46 | 0.52 | 0.49 | 0.29 | 0.33 | 0.31 | 0.29 | 0.33 | 0.31 |
| AC+$FYM_5$ | 0.43 | 0.49 | 0.46 | 0.28 | 0.32 | 0.30 | 0.31 | 0.35 | 0.33 |
| AC+$FYM_{10}$ | 0.42 | 0.48 | 0.45 | 0.30 | 0.34 | 0.32 | 0.23 | 0.27 | 0.25 |
| Fertilized treatment | | | | | | | | | |
| RDF+$MS_5$ | 0.71 | 0.77 | 0.74 | 0.59 | 0.64 | 0.61 | 0.55 | 0.59 | 0.57 |
| RDF+$MS_{10}$ | 0.71 | 0.78 | 0.75 | 0.61 | 0.66 | 0.63 | 0.57 | 0.61 | 0.59 |
| RDF+$CB_5$ | 0.71 | 0.78 | 0.75 | 0.63 | 0.69 | 0.66 | 0.57 | 0.62 | 0.60 |
| RDF+$CB_{10}$ | 0.71 | 0.77 | 0.74 | 0.63 | 0.68 | 0.65 | 0.57 | 0.62 | 0.60 |
| RDF+$PJ_5$ | 0.74 | 0.81 | 0.78 | 0.60 | 0.65 | 0.62 | 0.57 | 0.61 | 0.59 |
| RDF+$PJ_{10}$ | 0.72 | 0.79 | 0.76 | 0.61 | 0.66 | 0.63 | 0.54 | 0.58 | 0.56 |
| RDF+$FYM_5$ | 0.72 | 0.79 | 0.76 | 0.53 | 0.58 | 0.55 | 0.48 | 0.51 | 0.50 |
| RDF+$FYM_{10}$ | 0.65 | 0.71 | 0.68 | 0.54 | 0.59 | 0.56 | 0.49 | 0.52 | 0.51 |
| SEm± | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.03 | 0.03 | 0.02 |
| CD ($p$=0.05) | 0.10 | 0.10 | 0.07 | 0.05 | 0.05 | 0.03 | 0.10 | 0.10 | 0.07 |
| Y | | | | | | | | | |
| SEm± | | 0.008 | | | 0.004 | | | 0.008 | |
| CD ($p$=0.05) | | 0.02 | | | 0.011 | | | 0.024 | |
| YXT | | | | | | | | | |
| SEm± | | 0.03 | | | 0.016 | | | 0.034 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | |

Table 7: Secondary nutrient uptake influence by different treatment of biochar in maize plant (pooled data of two year)

| Treatment | Ca (g ha$^{-1}$) | | | Mg (g ha$^{-1}$) | | | S (g ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | |
| AC+MS$_5$ | 8.63 | 9.90 | 9.27 | 6.22 | 7.13 | 6.67 | 5.81 | 6.66 | 6.23 |
| AC+MS$_{10}$ | 11.17 | 12.81 | 11.99 | 6.54 | 7.50 | 7.02 | 8.11 | 9.30 | 8.70 |
| AC+CB$_5$ | 9.89 | 11.34 | 10.62 | 5.45 | 6.25 | 5.85 | 7.55 | 8.66 | 8.10 |
| AC+CB$_{10}$ | 9.02 | 10.34 | 9.68 | 5.11 | 5.85 | 5.48 | 7.11 | 8.15 | 7.63 |
| AC+PJ$_5$ | 6.25 | 7.17 | 6.71 | 4.19 | 4.80 | 4.50 | 4.06 | 4.65 | 4.36 |
| AC+PJ$_{10}$ | 8.43 | 9.66 | 9.05 | 5.25 | 6.01 | 5.63 | 5.47 | 6.27 | 5.87 |
| AC+FYM$_5$ | 8.84 | 10.13 | 9.49 | 5.71 | 6.55 | 6.13 | 6.36 | 7.29 | 6.82 |
| AC+FYM$_{10}$ | 12.95 | 14.85 | 13.90 | 9.17 | 10.51 | 9.84 | 7.23 | 8.29 | 7.76 |
| Fertilized treatment | | | | | | | | | |
| RDF+MS$_5$ | 39.59 | 43.66 | 41.62 | 32.69 | 36.87 | 34.78 | 26.55 | 27.85 | 27.20 |
| RDF+MS$_{10}$ | 41.82 | 46.11 | 43.97 | 34.38 | 38.82 | 36.60 | 28.40 | 29.88 | 29.14 |
| RDF+CB$_5$ | 36.35 | 40.10 | 38.22 | 33.11 | 37.37 | 35.24 | 26.33 | 27.61 | 26.97 |
| RDF+CB$_{10}$ | 36.50 | 40.26 | 38.38 | 32.41 | 36.55 | 34.48 | 26.86 | 28.19 | 27.52 |
| RDF+PJ$_5$ | 26.49 | 29.26 | 27.87 | 20.74 | 23.18 | 21.96 | 17.52 | 17.92 | 17.72 |
| RDF+PJ$_{10}$ | 27.19 | 30.03 | 28.61 | 22.69 | 25.41 | 24.05 | 16.97 | 17.32 | 17.14 |
| RDF+FYM$_5$ | 30.40 | 33.56 | 31.98 | 20.16 | 22.51 | 21.34 | 14.97 | 15.12 | 15.05 |
| RDF+FYM$_{10}$ | 33.60 | 37.07 | 35.33 | 27.18 | 30.56 | 28.87 | 20.31 | 20.99 | 20.65 |
| SEm± | 1.01 | 1.92 | 1.08 | 0.63 | 1.02 | 0.60 | 0.22 | 1.46 | 0.74 |
| CD ($p$=0.05) | 2.92 | 5.54 | 3.07 | 1.82 | 2.95 | 1.70 | 0.64 | 4.23 | 2.09 |
| Y | | | | | | | | | |
| SEm± | | 0.3834 | | | 0.21 | | | 0.26 | |
| CD ($p$=0.05) | | 1.0845 | | | 0.60 | | | 0.74 | |
| YXT | | | | | | | | | |
| SEm± | | 1.5337 | | | 0.85 | | | 1.04 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | |

that application of wood ash at 2 tons per hectare along with RDF (200 kg ha$^{-1}$) significantly higher Ca (3.26 C mol ha$^{-1}$) in maize crop compared to alone wood ash treatments.

*3.4.2. Magnesium (Mg)*

The available Mg content of soil showed a significant alteration by fertilized maize stover biochar, where in RDF+MS$_{10}$ (1127 ppm), recorded maximum available Mg in soil after harvest of maize crop than other treatments in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 8). Results indicated that biochar application in presence of fertilizer significantly influenced the available Mg in soil. Similar type of results were also reported by Major et al. (2010) who found that the available Mg content increased from 64% to 217% over a biochar application rate from 0-20 t ha$^{-1}$.

*3.4.3. S content in soil*

The result indicated that application of RDF+CB$_{10}$ recorded significantly higher available S (16.35 mg kg$^{-1}$) in soil after harvest of maize crop than other treatments in both the year (2011 and 2012) as well as pooled basis. The interaction was found non-significant between year and treatment (Table 8). Further, the result indicated that fertilized biochar treatments RDF+CB$_{10}$, RDF+PJ$_{10}$, RDF+MS$_{10}$ and RDF+CB$_5$ showed its superiority ranging from 3.94% to 21.20% higher available S in soil after harvest of maize crop as compared to unfertilized biochar treatments. It indicated that biochar application in presence of fertilized soil significantly influenced the available S in soil. Similar type results also reported by Novak et al. (2009) who found that application of pecan shell biochar @ 0.5%, 1.0% and 2% along with fertilizer significantly increased sulphur content with an increase in biochar concentration that was added.

Table 8: Influence of biochar affect by different treatments on secondary nutrient content in soil (pooled data of two year)

| Treatment | Ca (mg kg$^{-1}$) | | | Mg (mg kg$^{-1}$) | | | S (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled | 2010-11 | 2011-12 | Pooled |
| Unfertilized treatment | | | | | | | | | |
| AC+MS$_5$ | 827.87 | 949.09 | 888.48 | 719.87 | 863.49 | 791.68 | 10.19 | 12.06 | 11.12 |
| AC+MS$_{10}$ | 865.20 | 991.89 | 928.55 | 825.33 | 917.73 | 871.53 | 9.45 | 10.83 | 10.14 |
| AC+CB$_5$ | 840.00 | 963.00 | 901.50 | 775.87 | 927.69 | 851.78 | 12.27 | 14.07 | 13.17 |
| AC+CB$_{10}$ | 858.67 | 984.40 | 921.53 | 806.67 | 963.00 | 884.83 | 12.35 | 14.83 | 13.59 |
| AC+PJ$_5$ | 865.20 | 991.89 | 928.55 | 781.47 | 934.11 | 857.79 | 12.44 | 12.93 | 12.69 |
| AC+PJ$_{10}$ | 896.00 | 1027.20 | 961.60 | 769.33 | 920.20 | 844.77 | 12.03 | 14.18 | 13.11 |
| AC+FYM$_5$ | 858.67 | 984.40 | 921.53 | 797.33 | 952.30 | 874.82 | 9.77 | 11.20 | 10.49 |
| AC+FYM$_{10}$ | 914.67 | 1048.60 | 981.63 | 862.67 | 1027.20 | 944.93 | 12.95 | 11.94 | 12.45 |
| Fertilized treatment | | | | | | | | | |
| RDF+MS$_5$ | 1084.33 | 1199.73 | 1142.03 | 1017.53 | 1133.17 | 1075.35 | 11.99 | 13.71 | 12.85 |
| RDF+MS$_{10}$ | 1070.67 | 1221.13 | 1145.90 | 1052.07 | 1172.76 | 1112.41 | 13.63 | 15.60 | 14.61 |
| RDF+CB$_5$ | 1032.54 | 1202.20 | 1117.37 | 1040.33 | 1049.54 | 1044.94 | 13.51 | 15.46 | 14.48 |
| RDF+CB$_{10}$ | 1005.46 | 1204.18 | 1104.82 | 1056.20 | 1067.73 | 1061.97 | 12.46 | 15.69 | 14.08 |
| RDF+PJ$_5$ | 969.13 | 1081.29 | 1025.21 | 933.67 | 989.04 | 961.36 | 12.98 | 14.85 | 13.91 |
| RDF+PJ$_{10}$ | 1006.70 | 1112.16 | 1059.43 | 1006.73 | 977.69 | 992.21 | 13.86 | 17.38 | 15.62 |
| RDF+FYM$_5$ | 1017.26 | 1082.03 | 1049.65 | 1021.67 | 1028.14 | 1024.91 | 11.99 | 13.71 | 12.85 |
| RDF+FYM$_{10}$ | 1033.73 | 1110.92 | 1072.33 | 1046.87 | 1057.03 | 1051.95 | 13.67 | 16.79 | 15.23 |
| SEm± | 22.91 | 28.33 | 18.22 | 35.26 | 42.05 | 27.44 | 0.71 | 0.93 | 0.58 |
| CD ($p$=0.05) | 66.16 | 81.81 | 51.53 | 101.83 | 121.42 | 77.60 | 2.04 | 2.68 | 1.65 |
| Y | | | | | | | | | |
| SEm± | | 6.44 | | | 9.70 | | | 0.20 | |
| CD ($p$=0.05) | | 18.21 | | | 27.43 | | | 0.58 | |
| YXT | | | | | | | | | |
| SEm± | | 25.76 | | | 38.80 | | | 0.82 | |
| CD ($p$=0.05) | | NS | | | NS | | | NS | |

## 4. Conclusion

Biochar can be suitably used as an alternative source of organic manure in case of non-availability of FYM. All the organic sources have been found to improve the secondary and micro nutrient content as compared to initial soil nutrient status. The uptake of secondary and micronutrient was found to be higher when biochar was applied along with RDF as compared to sole application of biochar and ultimately improve secondary and micronutrient status in the soil which have direct role in soil fertilization.

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