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EFFECTS OF BIOCHAR AND ZEOLITE INTEGRATED WITH NITROGEN ON SOIL CHARACTERISTICS, YIELD AND QUALITY OF MAIZE (*ZEA MAYS* L.)

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Abstract

World population is increasing with massive rate and to achieve the goal of feeding 8.6 billion people by 2030, development of Good Agricultural practices (GAP) is imperative. The subject study was executed to appraise the impact of zeolite for improving soil property and quality which will ultimately enhance crop yields. For this purpose, zeolite (at rate of 1, 3 & 05 tons ha^{-1}) blended with nitrogen (at rate of 0 & 140 kg $^{-1}$) was administered in the soil and its residual effects were evaluated for 3 consecutive years. All treatments were applied with equal amount of phosphorus and potassium. The treatment with the highest rate of zeolite (Z_3 = 05 tons ha^{-1}) gave promising results and improved the soil electrical conductivity (EC) by 24%, bulk density by 2.5%, soil water holding capacity by 20.6% and total carbon by 22% as compared to control. Zeolite addition has also increased total nitrogen in soil up to 1.1 times, available phosphorus by 1.3 times and extractable potassium by 2.4% over the control. Zeolite performance was almost persistent through all 3 years. In all 3 years zeolite showed no significant effect over pH of the soil. Treatments of zeolite blended with nitrogen depicted similar results as of sole zeolite treatments, except total nitrogen which is because of more nitrogen supply into soil in some treatments. Zeolite application improved soil properties due to its porous structure which conserves moisture and also increased the fertilizer use efficiency. Increase in total nitrogen may be the result of increased microbial activity in the soil.

Keywords: Biochar, Maize, Nitrogen fertilizer, Plant growth, Soil properties, Zeolite.

Introduction

Maize (*Zea mays* L.) is an essential cereal crop but its growth is quite tough in our soils. To keep in mind the progressive growth of human population and the limited cultivated land resources, we have to manage more crop production within these limited resources (Alam *et al.,* 2021). Biochar is made by a technique known as pyrolysis of biomass and it contains char and ash. The major component (70–95%) of biochar is carbon (Luostarinen *et al.,* 2010). Also, biochar made by straws has the ability to decompose eighteen times less than that of uncharred straws over a period of 2 years. The process of burning biomass to make biochar is different from the actual burning process because in the later one due to plenty of oxygen available for burning almost all the carbon (C) present in biomass is oxidized into carbon dioxide (CO_2), while a very small amount of carbon is left behind in ashes. So, by restricting the oxygen supply, large portion of carbon is retained in the biochar (Lehmann *et al.*, 2003).

Soils having low cation exchange capacity (CEC) present in tropical and sub-tropical areas, biochar is the best solution to increases agriculture production. In degraded soils biochar addition improves the soil quality and crop yield. Nutrient efficiency is improved by biochar supplementation which not only improves nutrient balance in the soil but also lowers the rate of nutrient application by minimizing leaching (Lehman *et al*., 2009; Chan & Xu, 2009). Biochar application in the soil has been attracting a widespread attention because of the biochar potential to upsurge soil carbon sequestration as well as reducing the atmospheric concentration of carbon dioxide (Lehmann *et al*., 2003). This increased carbon sequestration in the soil also improves soil quality due to vital role of carbon in biological, physical and chemical soil. DeLuca *et al.,* (2009) found that augmentation of biochar in the soil results in increased biological availability of N, P, K nutrients and other metal ions in poor soils. Adding biochar in soil improves vital chemical and physical features of the soil. But this increase in pH remains for 1 to 2 years and due to buffering capacity of the soil pH stabilizes itself to original value (Lehmann *et al*., 2009). As per Glaser *et al.,* (2000), increased soil cation exchange capacity and pH results in upsurge of available phosphorus and other base cations.

Mineral use for agricultural production is now becoming a worldwide trend, and zeolite compounds have special place in this category. Zeolites are crystals of alkali and alkaline earth's hydrated aluminosilicates, having three-dimensional solid crystalline structure. Almost 40 kinds of zeolites have been discovered worldwide which have become the subject of debate due to their potential use in agriculture and industries. Zeolite commercial use is very rare but more than 300,000 tons of zeolite is being mined every year in Japan, United States, Hungary, Italy, Bulgaria, Yugoslavia, Mexico, Russia, Germany and Korea. As reported by Mumpton (1999), zeolites have potential use in agriculture due to their three major characteristics: greater cation exchange capacity, increased potential for absorption and more water holding capacity. Zeolite blended with phosphate rock acts as precise system for delivery of plant nutrients (Allen *et al.*, 1995). Increased nitrogen utilization with urea as a source blended with zeolite was reported by He *et al*. (2002) also increased nitrogen use efficiency reduce ammonia volatilization losses and increased yield was reported. Bernardi *et al*. (2008) also reported zeolite application that increased the water use efficiency by increasing water holding due to porous structure and maximum water availability to the plants.

Well defined absorption and increased biological activity are characteristics of zeolite treated soil. Application of zeolite shows promising results in terms of soil chemical and physical health. Out of 40 discovered zeolites; Clinoptilolite, Mordenite, Phillipsite, Heulandite, Faujasite, Laumontite, Chabazite, Analcime and Erionite are of practical use. Main attributes of these minerals are that these are inexpensive and can be easily explored and mined (Mumpton, 1999). These mineral zeolites can be specifically used in acidic soils. Acidic soils (grey forest, podzolic, boggy, soddy podzolic, yellow, peat, red) are broadly stretched in all continents which shows high (3-6) acidity. These soils are impractical for growing many crops which are being grown on neutral soils. Liming method is used generally to minimize acidity and maximize fertility in these types of soils which is based on enrichment of soil exchangeable complex showing alkaline reaction with calcium cations. However, the past century end brought new techniques for elimination of this problem and it seems that zeolites can also fulfill this need. It is an established that contrary to liming, single dose of zeolite can minimize the pH for a long time (2-3 years) (Kavoosi, 2007). So, a new opportunity for treating acidic soils has become accessible without liming.

Other significant characteristics like ability to retain more quantity of water and keep it in their pore even at high temperatures have attracted many growers for its use. Zeolite application in soil improves its chemical as well as physical properties. Encouraging impact of zeolite in non-irrigated land is clearly observed than the irrigated lands and depends largely on the dose of zeolite applied. As in irrigated lands more water is available with adequate nutrient, zeolite effect on these soils seems to show less promising results. Microorganisms, the living entities present in soil, substantially improves soil fertility. Microorganism population and their composition is greatly affected by the humus in the upper layer of soil. Several other factors also affect their activity like: temperature, acidity of soil and humidity. Their population can be increased by fertilizer especially organic substances. It has been reported that natural zeolite application increases the colonies of microorganism and this is a very promising character. The reason of microorganism growth is that zeolite helps them in decomposition process. Also, the porous structure of zeolite acts as shelter to them and provides humidity (Andronikashvili & Urushadze, 2008). Therefore, this investigation was aimed to gauge the outcome of previously applied biochar and zeolite in blend with nitrogen on grain quantity and quality of maize and also to appraise the impact of biochar and zeolite after 3rd year of their application on soil characteristics.

Materials and Methods

The standard preparation of seed bed was done for cultivating the maize. Maize (*Zea mays*) cultivar Islamabad Gold was sown @ 25 kg ha^{-1} with hand drill maintaining 50 cm row to row distance and thinning was done after 20 days of emergence to maintain 25 cm plant to plant distance, for one year at PMAS-AAUR research farm (kontt) during July 2016. Recommended fertilizer doses of phosphorus and potassium @ 100 kg and 80 kg ha^{-1} respectively was added at sowing. The statistical design used for conducting the study was split plot design with nitrogen in sub plots and biochar, zeolite treatments in main plots. Main plot volume was 4 m x 6 m bearing 2 sub plots of 4m x 3m. Treatments were applied to the soil, treatments are $T_1 = B_0N_0$ (control), $T_2 = B_0N_1$, $T_3 = B_1N_0$, $T_4 = B_1N_1$, $T_5 = B_2N_0$, $T_6 = B_2N_1$, $T_7 = B_3N_0$, $T_8 = B_3N_1$, $T_9 = Z_0N_0$ (control), $T_{10} = Z_0N_1$, $T_{11} = Z_1N_0$, $T_{12} = Z_1N_1$, $T_{13} = Z_2N_0$, $T_{14} = Z_2N_1$, $T_{15} = Z_3N_0$ and $T_{16} = Z_3N_1$.

While: B_0 = Biochar control, B_1 = Biochar @ 03 tons ha^{-1}, B_2 = Biochar @ 6 tons ha^{-1}, B_3 Biochar @ 09 tons ha^{-1}, Z_0 = Zeolite control, Z_1= Zeolite @ 1 ton ha^{-1}, Z_2 = Zeolite @ 03 tons ha^{-1}, Z_3 = Zeolite @ 05 tons ha^{-1}, N_0 = Nitrogen control and N_1 = Nitrogen @ 140 kg ha^{-1}.

Crop yield parameters: Number of cobs plant^{-1} was determined by taking three samples from each plot and then taking average of the samples. Cob length of maize was determined by taking three samples from each plot, measured with meter tape in cm and then taking average. Three random samples were taken from individual plot and then circumference was measured in cm of each sample. Average cob girth then was calculated. Cob weight was calculated by taking three samples from each plot, taking weight of each in grams and then taking average. Three samples from each plot were taken and seeds removed from it. Seeds then were totaled with help of seed counter and grains cob^{-1} were measured by taking average of three. To work out 1000-grain weight, weighted average of three individual specimens of 1000 grains were picked up indiscriminately apiece. Seed yield plot^{-1} was calculated by threshing sun dried cobs manually that is then changed into seed yield hectare^{-1}. In the same manner, harvested plant samples were sundried, weighted and then total biomass hectare^{-1}(TBH) was worked out.

Harvest index computed by subsequent way:

$$\text{H.I.} = \frac{\text{Economic output}}{\text{Plant biomass}} \times 100$$

Crop quality parameters

Protein contents (%): Near infrared reflectance spectroscopy system (NIRS) was used to quantify Protein contents (Sato *et al*., 2001).

Carbohydrate contents (%): Total sugar content of *Maize* seed was figured colorimetrically by the Anthrone method as per Laboratory Manual in Biochemistry, Jayaraman (1981).

Ash contents (%): Ash content was determined following the method of Anon., (2012).

Soil quality parameters

pH: The pH of the soil was recorded in accordance with the procedure of McLean (1982).

Electrical conductivity (EC): To put a figure on electrical conductivity, approach of Rhoades (1982) was practiced.

Bulk density (g cm^{-3}): Bulk Density of the core samples was figured out in accordance with Campbell and Henshall (1991).

Total nitrogen after harvest (mg kg^{-1}): Total nitrogen before planting and after harvest was determined by Kjeldahl method (Anon., 2012).

Available phosphorus (mg kg^{-1}): Soil samples upto 20cm depth were taken and available phosphorus was determined before and after cropping period.

For this purpose, method described by Olsen & Sommers (1982) was used.

Extractable potassium (mg kg^{-1}): Extractable potassium was estimated by the method of Page *et al*., (1992).

Total carbon (mg kg^{-1}): Total carbon was identified prior to crop planting and post cutting using method of Page *et al*., (1992).

Results

Number of cobs plant^{-1}: The one of determinant factor for maize crop yield is cobs total per plant. Data with respect to the influence of biochar, zeolite and nitrogen amendments on number of cobs plant^{-1} (Table 1). Biochar, zeolite and nitrogen amendments had insignificant impact on count of cobs plant^{-1}. The maximum number (1.17 and 1.13) of cobs per plant were obtained by applying biochar @ 09 tons ha^{-1} and zeolite @ 05 tons ha^{-1} with Nitrogen 140 kg ha^{-1} respectively.

Cob length (cm): The major attribute of maize plant that has direct relationship with crop seed yield is cob length. Table 1 reflects a significant raise in cob length from application of biochar, zeolite and nitrogen amendments. Maximum cob length (17.17 cm and 17.01 cm) was detected in soil administered with Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) respectively while the minimal cob length was documented in controls. (Biochar) and Z_0N_0 = Control (Zeolite). Plots with biochar amendments and without nitrogen fertilizer reflected non-significant difference. While plots with biochar @ 09 tons ha^{-1} and 6 tons/ha with 140 kg ha^{-1} nitrogen (B_3N_1 and B_2N_1) showed non-significant increase of 17.17 cm and 16.77 cm respectively. This increase might be due to the enhanced water and fertilizer retention in the microscopic pores of biochar.

Cob girth (cm): Cob girth indicates the yield and health of the plant; more cob girth directly relates to grain yield. Data regarding impact of biochar and zeolite blended with nitrogen on cob length in maize crop is reflected in Table 1. A significant increase in cob girth was noted by nitrogen usage. Nitrogen application @ 140 kg ha^{-1}, in all the treatments, significantly increased the cob girth than the treatments with zero nitrogen level. Highest cob girth (15.34 cm) was recorded in treated soil with Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1). This increase perhaps be due to surge in nitrogen supply to plant which in response produced healthy cobs. Lowest cob girth (10.12 cm and 10.10 cm) was recorded in both biochar and zeolite control respectively.

Table 1. Integrated effect of biochar and zeolite with nitrogen on the number of cobs plant^{-1}, cob length. (cm), cob girth (cm), cob weight (g), grain cob^{-1} and 1000 grain weight (g).

Treatments	No. of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Cob weight (g)	Grain cob^{-1}	1000 grain weight (g)
T1	1.00	13.11 c	10.12 b	99.83 e	250.67 c	202.00 c
T2	1.00	15.26 b	15.30 a	156.00 c	323.67 b	261.33 b
T3	1.00	13.21 c	10.13 b	101.17 e	253.00 c	204.00 c
T4	1.03	15.90 b	15.31 a	159.33 c	328.67 b	261.00 b
T5	1.00	13.23 c	10.14 b	104.00 de	257.33 c	208.33 c
T6	1.10	16.77 a	15.32 a	165.00 b	335.00 ab	265.33 ab
T7	1.00	13.25 c	10.15 b	108.00 d	260.00 c	210.00 c
T8	1.17 $^{N.S.}$	17.17 a	15.34 a	172.33 a	342.00 a	271.33 a
T9	1.00	13.05 c	10.10 b	99.00 f	249.00 d	201.00 c
T10	1.00	15.30 b	15.06 a	155.00 c	321.67 b	260.00 b
T11	1.00	13.15 c	10.12 b	101.67 ef	255.00 cd	205.33 c
T12	1.03	15.85 b	15.07 a	158.17 c	326.00 b	262.00 ab
T13	1.00	13.27 c	10.17 b	105.33 de	261.00 cd	208.00 c
T14	1.07	16.65 a	15.08 a	163.33 b	334.00 ab	264.00 ab
T15	1.00	13.30 c	10.19 b	109.00 d	265.00 c	209.00 c
T16	1.13 $^{N.S.}$	17.01 a	15.09 a	169.00 a	339.33 a	269.00 a

The figures with different letters show significant differences

Cob weight (g): Cob weight is an important characteristic of maize plant in terms of its economic yield. Significant increase was noted by the administration of biochar and zeolite combined with nitrogen (Table 1). Maximum cob weight (172.33 g and 169.0 g) was noted in Biochar application @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) respectively accompanied by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1)165 g and Zeolite @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_2N_1) 163.33 g while minimum cob weight (99.83 g and 99 g) was observed in B_0N_0 and Z_0N_0 respectively. In treatments with biochar application max cob weight (172.33 g) was witnessed in treatment Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) followed by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 165 g, Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 159.33 g, Biochar @ 0 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_0N_1) 156 g, Biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) 108 g, Biochar @ 6 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_2N_0) 104 g, Biochar @ 03 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_1N_0) and control 99.83 g.

Grain cob^{-1}: In maize production grains per cob is a critical criterion that is equivalent to economic yield. Grain per cob data of maize crop treated with biochar, zeolite and nitrogen (Table 1). In Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) maximum grains per cob 343 and 339.33 respectively were observed while least number of kernels per cob were observed in B_0N_0 and Z_0N_0. Soil treated with Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) produced highest grains per cob 343 followed by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 335, Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 328. Sole biochar application @ 09 tons ha^{-1} without urea produced 260 seeds per cob which are more than the control i.e. 250.67.

1000 grain weight (g): A direct relation to every cereal crop in terms of economic yield is grain weight. A notable increase in 1000 grain weight was noted by biochar and zeolite usage blended with nitrogen (Table 1). The supreme 1000 grain weight (271.33 g and 269 g) was logged in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) respectively. Biochar amendment @ Biochar 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) produced grains with more weight than the other treatments. Highest 1000 grain weight (271.33 g) was noted in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) followed by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 265.33 g and Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 261 g. Zeolite application @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) showed the highest (269 g) significant results followed by zeolite @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_2N_1) 264 g and @ 1 ton ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_1N_1) 262 g.

Seed yield (kg ha^{-1}): Seed yield is the parameter of utter importance and main objective of any study on cereal crop. Data regarding seed yield showed a significant increase with biochar and zeolite administration blended with nitrogen (Table 2). Highest grain yield (4499 kg ha^{-1}) was observed in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) accompanied by Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) that is 4442 kg ha^{-1}. Biochar soil amendment Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) produced maximum (4499 kg ha^{-1}) seed yield, 4339 kg ha^{-1} and 4261 kg ha^{-1} seed yield was produced by application of Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) and Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) subsequently. Biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) also showed significant increase 3142 kg ha^{-1} in seed yield than B_2N_0 and B_1N_0. Similarly, Zeolite also improved the seed yield (Ming and Mumpton, 1989). Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) gave seed yield of 4442 kg ha^{-1} followed by Z_2N_1 4293 kg ha^{-1} and Z_1N_1 4263.3 kg ha^{-1}. Solitary zeolite application in Z_3N_0 (05 tons ha^{-1} + Nitrogen 0 kg ha^{-1}) also significantly increased the seed yield (3119.7 kg ha^{-1}) than Z_2N_0 (03 tons ha^{-1} + Nitrogen 0 kg ha^{-1}) and Z_1N_0 (1 ton ha^{-1} + Nitrogen 0 kg ha^{-1}).

Table 2. Integrated effect of biochar and zeolite with nitrogen on seed yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%).

Treatments	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T1	3030.0 e	10049 f	30.15 c
T2	4201.3 c	13197 d	31.83 a
T3	3037.0 e	10102 f	30.07 c
T4	4261.0 c	13652 c	31.21 ab
T5	3063.0 e	10145 ef	30.20 c
T6	4339.0 b	14103 b	30.77 bc
T7	3142.0 d	10229 e	30.71 bc
T8	4499.0 a	14712 a	30.68 bc
T9	3021.7 e	9996 f	30.23 e
T10	4210.7 c	13211 d	31.87 a
T11	3035.0 e	10118 e	30.36 de
T12	4263.3 bc	13550 c	31.47 b
T13	3049.7 de	10198 e	30.27 e
T14	4293.0 b	13995 b	30.68 cd
T15	3119.7 d	10168 e	30.36 de
T16	4442.0 a	14521 a	30.77 c

The figures with different letters show significant differences

Table 3. Integrated effect of biochar and zeolite with nitrogen on protein content (%), carbohydrate content (%) and ash content (%).

Treatments	Protein content (%)	Carbohydrate content (%)	Ash content (%)
T1	6.430 h	73.17 a	1.178 d
T2	8.050 d	71.81 e	1.320 c
T3	6.787 g	72.70 b	1.189 d
T4	8.347 c	71.68 f	1.340 b
T5	7.013 f	72.40 c	1.187 d
T6	8.650 b	71.53 g	1.345 ab
T7	7.233 e	72.07 d	1.189 d
T8	8.937 a	71.36 h	1.351 a
T9	6.430 h	73.16 a	1.182 f
T10	7.913 d	71.82 e	1.328 d
T11	6.700 g	72.72 b	1.185 ef
T12	8.217 c	71.69 f	1.337 c
T13	6.887 f	72.43 c	1.189 e
T14	8.547 b	71.57 g	1.343 b
T15	7.190 e	72.09 d	1.187 e
T16	8.803 a	71.38 h	1.350 a

The figures with different letters show significant differences

Biological yield (kg ha^{-1}): In corn, because of its usage in silage making and other household purposes, biological yield is also considered a vital parameter. In Table 2 data regarding biological yield reflected a notable enhancement with maximum in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) 14712 kg ha^{-1} and 14521 kg ha^{-1} respectively. While, minimum yield was observed in controls B_0N_0 and Z_0N_0. Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) substantially enhanced crop biological yield to maximum of 14712 kg ha^{-1} accompanied by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 14103 kg ha^{-1}, Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 13652 kg ha^{-1}. Sole biochar application @ 09 tons ha^{-1} without nitrogen also significantly increased crop biological yield. Likewise, Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) produced biological yield of 14712 kg ha^{-1} followed by Z_2N_1 13995 kg ha^{-1} and Z_1N_1 13550 kg ha^{-1}.

Harvest index (%): Data pertinent to harvest index is documented in Table 2. B_0N_1 and Z_0N_1 showed significant increase in harvest index it was minimum in both controls. B_1N_1 is at par with B_0N_1.

Quality parameters

Protein content (%): Protein is essential part of human nutrition and diet. Corn is one of the cereals which has high amount of protein in it. Data regarding protein content influenced by biochar and zeolite blended with nitrogen is presented in Table 3. Highest percentage (8.937% and 8.803%) of protein was recorded in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) respectively. Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) upsurged protein percentage in corn significantly (8.937%) followed by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 8.65% and Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 8.345%. Lowest protein percentage was observed in control (B_0N_0). In the same way, zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) also proved helpful in bringing significant increase (8.803%) in protein content of maize followed by Z_2N_1 8.547% and Z_1N_1 8.217%.

Carbohydrate contents (%): Carbohydrates occupy the major portion in cereal nutritional value. In Table 3 data regarding carbohydrate content shows that minimum carbohydrate content (71.36% and 71.38%) were observed in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1), respectively.

Ash contents (%): Ash contents are mainly composed of salts and inorganic constituents. Table 3 showed that high amount of ash percentage (1.351% and 1.35%) was observed in Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1), respectively. While, minimum amount of ash content was present in both controls B_0N_0 and Z_0N_0. This surge in ash matter was mainly because of improved availability of nutrients to the plant by application of biochar and zeolite. Administration of biochar and zeolite improved the nutrient use efficiency which in turn resulted into more nutrient deposition in the maize grains producing higher level of ashes.

Soil parameters

pH of the soil: The major attribute which regulates the availability of nutrients to plants and overall productivity is the pH level of the soil. Both biochar and zeolite had no impact on the said property of the soil, after 3 years of their application (Table 4). Biochar application in 2nd year @ Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) significantly increased the soil pH while after 3rd year all treatments of biochar shows pH value at par.

Table 4. Integrated effect of biochar and zeolite with nitrogen on pH of the soil, EC of the soil and bulk density (g cm^{-3}) of the soil.

Treatments	pH of the soil		EC of the soil		Bulk density (g cm^{-3}) of the soil	
	Year 2	Year 3	Year 2	Year 3	Year 2	Year 3
T1	7.37 b	7.38	47.9 e	48.2 f	1.497 a	1.499 a
T2	7.37 b	7.38	48.4 d	48.7 f	1.498 a	1.497 a
T3	7.37 b	7.38	51.8 c	50.3 e	1.485 b	1.486 b
T4	7.38 b	7.38	52.1 c	50.9 d	1.487 b	1.487 b
T5	7.40 a	7.39	55.6 b	54.9 c	1.476 c	1.476 c
T6	7.40 a	7.39	55.9 b	55.3 c	1.473 c	1.475 c
T7	7.41 a	7.39	65.6 a	66.6 b	1.454 d	1.458 d
T8	7.41 a	7.39 N.S.	65.8 a	67.1 a	1.456 d	1.459 d
T9	7.38	7.39	51.3 d	51.1 d	1.496 a	1.496 a
T10	7.38	7.39	51.4 d	52.3 c	1.495 a	1.496 a
T11	7.38	7.38	52.9 c	52.1 c	1.480 bc	1.481 bc
T12	7.38	7.39	53.7 c	52.6 c	1.481 b	1.483 b
T13	7.38	7.39	56.3 b	58.1 b	1.478 cd	1.479 c
T14	7.38	7.39	56.3 b	58.4 b	1.476 d	1.476 d
T15	7.38	7.39	61.7 a	63.2 a	1.467 e	1.468 e
T16	7.38 N.S.	7.38 N.S.	61.8 a	63.4 a	1.466 e	1.469 e

The figures with different letters show significant differences

Electrical conductivity of the soil: Electrical conductivity (EC) of the soil is indication of the nutrient's quantity. Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) showed maximum (67.1 and 63.2) value of EC after 3rd year of their administration. Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) showed maximum value (67.1) of EC followed by B_3N_0 (66.6), B_2N_1 (55.3) and B_2N_0 (54.9) after 3rd year of their application. After 2nd year of biochar application maximum EC value was also observed in B_3N_1 while B_3N_0 was at par with the later one. Zeolite in the same manner also increased the soil EC. Maximum EC (63.2) after 3rd year was observed in zeolite treatment @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) accompanied by zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0). While, Z_2N_1 was at par with later (Table 4).

Bulk density (g cm^{-3}): The attribute of soil that determines the plant root penetration, water and nutrient availability, is bulk deensity. Data regarding influence of biochar and zeolite blended with nitrogen on bulk density of soil is reflected in Table 4. Both biochar and zeolite considerably decreased bulk density of soil after 2nd as well as 3rd year of their application. After 3rd year maximum drop in bulk density (1.458) was witnessed in biochar treatment @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) followed by Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) 1.459, Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 1.475, Biochar @ 6 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_2N_0) 1.476, Biochar @ 03 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_1N_0) 1.486, Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 1.487, Biochar @ 0 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_0N_1) 1.497 and control 1.499. Likewise, zeolite application also minimizes the bulk density of soil after 2nd and 3rd year of its application. zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0) showed minimum (1.468) value followed by zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_0) 1.469 after 3rd year.

Total nitrogen after harvest (mg kg^{-1}): Nitrogen is a vital primary nutrient which is vital for plant growth and development. In Table 5, data regarding total nitrogen after harvest is presented. Both biochar and zeolite in boosted the total nitrogen after harvest. After 3rd year of biochar application, they increased the total nitrogen after harvest significantly. Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) showed maximum value (2.63 mg kg^{-1}) of total nitrogen after harvest followed by Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 1.94 mg kg^{-1}, Biochar @ 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_1N_1) 1.71 mg kg^{-1} and Biochar @ 0 ton ha^{-1} + Nitrogen 140 kg ha^{-1} (B_0N_1) 1.29 mg kg^{-1}. Minimum value was documented in control (B_0N_0). After 2nd year similar trend was observed. Zeolite after 3rd year of its application showed better results than that of biochar. Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) maximized total nitrogen to 3.18 mg kg^{-1} followed by 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_2N_1) 2.19 mg kg^{-1} and 1 ton ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_1N_1) 1.91 mg kg^{-1}. After 2nd year zeolite also provided best results.

Available phosphorus (mg kg^{-1}): Phosphorus is a vital plant nutrient which has major role in cell division, photosynthesis and respiration. Effect of biochar and zeolite combined with nitrogen showed a significant increase in available phosphorus (Table 5). 3rd year data showed maximum available phosphorus (7.76 mg kg^{-1} and 7.34 mg kg^{-1}) with Biochar tratment @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) and Zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0) respectively. Biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) showed maximum increase in value (7.76 mg kg^{-1}) of available phosphorus followed by Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) 7.70 mg kg^{-1}, Biochar @ 6 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_2N_0) 6.80 mg kg^{-1} and Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 6.79 mg kg^{-1}, after 3rd year of application. 2nd year results for available phosphorus showed similar pattern with slight difference. Similarly, zeolite increased phosphorus availability to plants. On 3rd year, Zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0) showed significant increase of 7.34 mg kg^{-1} slightly more than previous year that was 7.30 mg kg^{-1}. Results for Z_3N_1 were at par with previously mentioned Z_3N_0.

Table 5. Integrated effect of biochar and zeolite with nitrogen on total nitrogen (mg kg^{-1}) after harvest, available phosphorus (mg kg^{-1}) and extractable potassium (mg kg^{-1}).

Treatments	Total nitrogen (mg kg^{-1}) after harvest		Available phosphorus (mg kg^{-1})		Extractable potassium (mg kg^{-1})	
	Year 2	Year 3	Year 2	Year 3	Year 2	Year 3
T1	1.01 g	0.81 g	2.83 e	2.85 e	51.69 d	52.70 d
T2	1.30 d	1.29 d	2.79 e	2.74 f	52.55 d	51.95 d
T3	1.02 g	0.83 g	4.60 d	4.65 d	72.46 c	74.54 c
T4	1.63 c	1.71 c	4.67 c	4.63 d	71.40 c	71.95 c
T5	1.11 f	0.98 f	6.76 b	6.80 c	95.25 b	94.34 b
T6	1.87 b	1.94 b	6.74 b	6.79 c	97.04 b	91.87 b
T7	1.20 e	1.10 e	7.75 a	7.76 a	140.67 a	143.56 a
T8	2.60 a	2.63 a	7.79 a	7.70 b	137.50 a	141.74 a
T9	0.94 h	0.81 h	3.11 d	3.12 d	38.60 d	37.31 d
T10	1.67 e	1.51 d	3.14 d	3.11 d	39.54 d	36.19 d
T11	1.01 g	0.98 g	5.40 c	5.40 c	83.13 c	79.76 c
T12	1.49 c	1.91 c	5.41 c	5.38 c	84.39 c	81.20 c
T13	1.09 f	1.02 f	6.16 b	6.17 b	109.14 b	112.14 b
T14	1.67 b	2.19 b	6.13 b	6.16 b	106.75 b	109.74 b
T15	1.29 d	1.20 e	7.30 a	7.34 a	125.56 a	128.25 a
T16	3.09 a	3.18 a	7.31 a	7.31 a	128.02 a	130.34 a

The figures with different letters show significant differences

Table 6. Integrated effect of biochar and zeolite with nitrogen on total carbon (mg kg^{-1}) in the soil.

Treatments	Total carbon (mg kg^{-1}) in the soil	
	Year 2	Year 3
T1	5.31 d	5.22 d
T2	5.34 d	5.25 d
T3	6.42 c	6.31 c
T4	6.39 c	6.33 c
T5	8.53 b	8.56 b
T6	8.51 b	8.59 b
T7	12.06 a	12.12 a
T8	12.10 a	12.14 a
T9	7.67 d	7.02 d
T10	7.69 d	7.01 d
T11	8.05 c	7.79 c
T12	8.06 c	7.77 c
T13	8.20 b	8.23 b
T14	8.19 b	8.26 b
T15	8.47 a	8.56 a
T16	8.44 a	8.58 a

The figures with different letters show significant differences

Extractable potassium (mg kg^{-1}): Potassium being an essential plant nutrient has important contribution in intake and outflow of carbon dioxide and act as enzyme activator. Data regarding extractable potassium in is soil presented in Table 5. Biochar and zeolite after 2 and 3 year of their application showed significant results regarding extractable potassium. Biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) showed maximum increase in value (143.56 mg kg^{-1}) of extractable potassium followed by Biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) 141.74 mg kg^{-1}, Biochar @ 6 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_2N_0) 94.34 mg kg^{-1} and Biochar @ 6 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_2N_1) 91.87 mg kg^{-1}, after 3rd year of application. 2nd year results also showed significant increase in extractable potassium with maximum value (140.67 mg kg^{-1}) in biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) and least (51.69 mg kg^{-1}) in control. Likewise, zeolite also performed well in terms of extractable potassium in 2nd and 3rd year both. After application on 3rd year, Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) showed considerable surge of 130.34 mg kg^{-1} which is slightly more than previous year i.e. 128.02 mg kg^{-1}. In both 2nd and 3rd years, minimum value was observed in control Z_0N_0 i.e. 38.60 mg kg^{-1} and 37.31 mg kg^{-1}.

Total carbon (mg kg^{-1}): Carbon in soil is directly related to organic matter quantity in soil and so affects the productivity of the soil. In Table 6 data regarding total carbon showed a significant increase in value with the gradual increase in biochar and zeolite. After 3rd of their administration, biochar @ 09 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (B_3N_1) presented maximum value (12.14 mg kg^{-1}) of total carbon followed by biochar @ 09 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (B_3N_0) 12.12 mg kg^{-1}. Lowest value (5.22 mg kg^{-1}) was recorded in control (B_0N_0). 2nd year data also showed the same pattern with maximum value (12.10 mg kg^{-1} and 12.06 mg kg^{-1}) of (B_3N_1) and (B_3N_0) respectively, while lowest value (5.31 mg kg^{-1}) was spoted in control (B_0N_0). Comparable results were also published by Lehmann *et al.* (2009). In the same way, after 3rd year of zeolite application significant increase (8.58 mg kg^{-1}) was noted in Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) followed by Zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0) 8.56 mg kg^{-1}. While, lowest value (7.02 mg kg^{-1}) was recorded in control (Z_0N_0). Similar statistical sequence was witnessed in 2nd year data with highest values (8.47 mg kg^{-1} and 8.44 mg kg^{-1}) in Zeolite @ 05 tons ha^{-1} + Nitrogen 0 kg ha^{-1} (Z_3N_0) and Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) respectively.

Discussion

Biochar is the organic matter with high porosity and low density. It may be difficult to wet when becomes dry like sphagnum moss, but has the ability to retain large quantity of water. As Briggs *et al*., (2005) reported, in sandy soils, its effect in improving soil water holding capacity is of great importance. Biochar of different origin has different capacity to impact water holding capacity. As per Novak *et al*., (2009), biochar baked of switch grass has outstanding capability to enhance water holding capacity of soil having light texture than the biochar made of poultry litter, peanut hulls and pecan shells. On clayey soils biochar application has no significant effect and may even reduce it (Major, 2009). Basic aim of the researchers is to find the potential of biochar to conserve moisture in areas of low water availability. Zeolite amendments @ 05 tons ha^{-1}, 03 tons ha^{-1} and 1 ton ha^{-1} with nitrogen 140 kg ha^{-1} (Z_3N_1, Z_2N_1 and Z_1N_1) also increased the cob length by 17.01 cm, 16.58 cm and 15.98 cm respectively. Major *et al*., (2010) also produced comparable results with use of biochar. Zeolite @ 05 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_3N_1) generated more grains per cob (339.33) than 03 tons ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_2N_1) i.e. 334 and 1 ton ha^{-1} + Nitrogen 140 kg ha^{-1} (Z_1N_1) i.e. 326. Z_3N_0 also showed non-significant increase than Z_2N_0 and Z_1N_0.

In low fertility soils, biochar effect on crop productivity and soil quality has been detected, including tropical acidic soils. In a nutshell, over unamended control up to 300% yield increase were obtained when biochar in adequate amount was applied (Van Zweiten *et al*., 2010). In flooded type rice paddy of Chinese soils, biochar enhanced up to 14% yield (Zhang *et al*., 2010). Positive effects of biochar at longer run were also detected in some studies, performed over many years (Steiner *et al*., 2007). Poor soils gave better results due to biochar addition than the fertile soils. Fertile soils of temperate climates with more organic contents showed 4-20% increase in yield (Major, 2009). Sometimes due to biochar application reduction in yield was also observed. This reduction is relatively short term during decomposition of unstable biochar fraction. Also, decrease in nitrogen mobilization was observed with biochar addition (Asai *et al*., 2009). Gaskin *et al*. (2010) reported a decrease in maize yields with biochar treatment @ 22 t/ha in contrast to control in fertilized conditions. Reduction in yield was observed at both 11 t/ha and 22 t/ha levels of biochar only during first year not in second year of the experiment. Contrary to other organic soil amendments like green manures, animal manures and composts, biochar is sturdy and even permanent soil amelioration. The process by which biochar boost soil productivity and are reported to date are discussed under and uncharred amendments were also described. Though, later one does not remain in the soil for long period of times.

Soil structure is key attribute of soil that exerts influence on soil's chemical, physical and biological properties (Bronick & Lal, 2005). The growth and germination of plants and water transportation also influenced by this key factor. Soil aggregation is the rearrangement of soil particles through cementation after the flocculation process. This is a vital characteristic of soil for providing resistance against erosion and sustaining soil porosity (Canton *et al*., 2009). Organic carbon present in soil is the main part and used as a binding agent in formation of soil aggregates (Bronick and Lal, 2005). Due to long term soil cultivation, organic matter is lost which is the main reason for soil degradation (Jastrow, 1996). Biochar addition tends to improve soil structure and productivity (Atkinson *et al*., 2010). Biochar behave as a binding material in formation of soil aggregates and protects it against the degradation (Saran *et al*., 2009). Verheijen *et al*., (2010) showed that slow oxidation characteristics of biochar govern the durable effects upon soil aggregation. Many factors like feedstock. Soil basic characteristics and process of making influence the biochar effect on soil properties. Some studies have also shown the negative effect due to change in above factors. Biochar not including switch grass did not recover infiltration rate or soil aggregation (Busscher *et al*., 2010). As per Peng *et al*., (2011), biochar influences characteristics of soil like pore space distribution, bulk density, water holding capacity and aeration. Soil pH is the vital characteristic of soil that determines the nutrient availability to crop plant. Change in soil pH after biochar addition has been the cause of plant positive and negative response. According to Van Zwieten *et al*., (2010), wheat showed 40% height increase after paper mill sludge biochar application to acidic soil while no response was noted in soil having neutral pH. Elevated soil pH was reported by biochar application in most of the soils (Peng *et al*., 2011).

Due to biochar application, elevated cation exchange capacity (CEC) of soil has been recorded which in return upsurge the nutrient retention of soil. Lehmann *et al*., (2003) reported that in intense rainfall areas, use of biochar is a success to upsurge the CEC of the soil. The CEC of biochar is greatly affected by the pyrolysis temperature, high temperature causes the CEC to boost (Lehmann *et al*., 2009). Biochar has a great effect on nutrient retention and addition. Biochar ash contains nutrients like calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn) and phosphorus (P). Chan & Xu (2009) reported that nitrogen (N) is present in very minute quantity in biochar because during process of pyrolysis a huge amount of nitrogen is lost through volatilization. The remaining portion of nitrogen is not available to crop plants. Plant nutrients in unstable pool of biochar are readily available to plants but like any mobile soluble nutrient of soil they are vulnerable to leaching (Gaskin *et al*., 2010). According to Cheng *et al*. (2006), biochar in a long run, has positive effect of plant nutrients and after application due to surface weathering it become more oxidized. The benefits of biochar are not only limited to improved nutrition or water retention in plants but also more number of bacteria, *Pseudomonas* spp. and fungi were explored in biochar amended soils. In rhizosphere, the positive effect of biochar on microbes is of great importance. Many chemicals found in biochar are phytotoxic in high amounts but beneficial in less (Graber *et al*., 2010). Biochar treated soils have more quantities of fungal, nematode and bacterial feeders. As per Solaiman *et al*., (2010), band application of biochar in wheat tends to improve mycorrhizal colonization in roots of crop a year after and beneficial effects are reported even after 2 years. Ogawa (1994) reported that biochar addition in soil have the ability to positively affect the Nitrogen fixers living freely in soil. Thies & Rilling (2009) reported that oxygen present in small pores of biochar tends to improve colonization of beneficial microbes also Fe and Mn present in biochar have positive effect on microorganisms' growth.

Zeolites due to their high porosity can hold more than 60% water of their weight. Water present in these pores can be easily dispersed and reabsorbed with keeping the zeolite structure intact (Kocakusak *et al*., 2001). Zeolites ensure everlasting water storage in the soil during dry periods and wetting them again is easy. Zeolites facilitate the lateral movement of water in root zone. By this phenomenon large quantity of water can be saved. Moreover, their high absorption bulk makes them a better carrier of pesticides. Likewise, Kavoosi (2007), explored the use of clinoptilolite to increase rice yields, nitrogen use efficiency and its recovery. Three levels 8, 16 and 24 t/ha zeolites were applied in the soil with and without nitrogen @ 60 kg ha^{-1}. Their effects on biological and grain yield, nitrogen use efficiency and recovery, available potassium and other soil parameters were observed. Significant increase in biological, economic and tillers of rice grain were reported by him. He reported that zeolite blended with nitrogen gave maximum yield as compared to control. Zeolite treatment to soil also increased available potassium in soil by rice crop. The lowest nitrogen recovery was observed in 60 kg N ha^{-1}, while maximum recovery was reported in field treated with 16 and 8-ton zeolite per hectare respectively. Maximum increase (65%) was in plot with zeolite 16 ton ha^{-1}. Efficiency of nitrogen use was also improved. Urotadze *et al*., (2002) reported 100 % surge in wheat crop yield by application of zeolite in contrast to control with zero fertilizer. Increase in salicylic acid by application of zeolite in peas (Kumar, 1997), nightingales eye beans (Singh, 1980), and soybean (Kumar, 1999) were reported. Salicylic acid is reported to decrease the high and low temperature stress in many plants (Senaratna *et al*., 2000). Our findings are comparable to Torii (1978) who reported that zeolite application @ 48 tons/acre increased the economic yield of apple by 1338%. 2 to 8 kg/tree zeolite application is helpful in establishing strong orchard. Zeolites are helpful in improving the yields of almost all crops. Fertilizer retention in soil and then slow release is associated with ample application of zeolite mineral. Many macro nutrients like potassium (K), nitrogen (N), magnesium (Mg), calcium (Ca) and other micro nutrients are influenced positively by zeolite application.

Zeolite application in soil helps the plant nutrients to retain in soil and then gradually release it with passage of time. This attribute improves the crop economic yield with same amount of fertilizer with zeolite as compared to fertilizer with no zeolite. Leaching (loss of nutrients into soil deeper layers) is one of the major problems associated with lower crop yields (Flanigen & Mumpton, 1981). Due to spongy structure of zeolite nutrients are absorbed in it especially in sandy soils (Anon., 2004). The ability of nutrient retention and then slow and timely release enhancing crop growth and yield (Nommik & Vahtras, 1982). This practice is also environment friendly as fertilizers are huge contributors to greenhouse gasses. Salt and water holding capacity of soil is also affected positively by application of zeolites. Soil analysis after harvest also confirmed the presence of Ca $^{2+}$, Mg^{2+}, Na^{+} and K^{+} in zeolite treated soil. It has been established that soil amended with zeolite can counter the negative effects of salinity and improve the nutrient balance in soil. Bigelow *et al*., (2001) reported that 10% zeolite application with green sand in *Agrostis stolonifera* (creeping bent grass) improved noting as compared to control. Improved water retention in soil and CEC is reported to be the cause of this betterment. Zeolite due to negative charge on it is the best trap for positive ions such as potassium, sodium, calcium, barium and other cation groups like ammonia and water. Due to this negative charge on zeolite alkali metals are engrossed similarly as water (Mumpton, 1999). These exceptional (CEC, hydration dehydration, adsorption and catalytic) qualities of zeolite helpful in better nutrient use and increased yields (Pond & Mumpton, 1989; Mumpton & Fishman, 1977).

Conclusion

This study showed that maximum 1000 kernel weight (34.3%), biological yield (46.4%), seed yield (48.5%) and protein content (39%) were documented in B_3N_1 treatment over the control. It was also recorded that treatment B_3N_1 increased EC by 47.9-65.8 ms m^{-1}, total nitrogen after harvest by 1.01-2.60 mg kg^{-1} and total carbon by 5.31-12.10 mg kg^{-1} during 2nd year whereas, EC by 48.2-67.1 ms m^{-1}, total nitrogen after harvest by 0.81-2.63 mg kg^{-1} and total carbon by5.2-12.14 mg kg^{-1} during 3rd year of the research. While sole application of biochar in treatment B_3N_0 also increased available phosphorus by 2.83-7.79 mg kg^{-1} and extractable potassium by 51.69-137.50 mg kg^{-1} during 2nd year and available phosphorus by 2.85-7.70 mg kg^{-1} and extractable potassium by 52.70-141.74 mg kg^{-1} during 3rd year of the research. Lowest bulk density 1.458 g cm^{-3} was recorded in treatment B_3N_0. Minimum bulk density (1.466 g cm^{-3}) was observed in treatment Z_3N_1. Both biochar and zeolite have the tendency to remain in the soil for several hundred years with very little decomposition rate. They both are helpful in mitigating water and nutrient stress for the plants. They increase nutrient availability, increase organic matter especially carbon, decrease bulk density of the soil to facilitate root penetration and most of all due to their porous structure they amplify soil water holding capacity.

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