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Evaluation of biofertilizers and biochar on the growth characteristics and yield of hot pepper

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Abstract. *Appah GB, Nkansah GO, Amoatey C. 2021. Effect of the media type and auxin concentration on the growth of cuttings seedlings of pepper. Cell Biol Dev 5: 32-42.* The research was conducted to investigate the effects of High Yield Technology (HYT) biofertilizers, biochar, and inorganic fertilizer on the growth and yield of pepper. The experiment consisted of three factors (HYT, Biochar and inorganic fertilizer) at three levels each (HYT: 100%, 50% and 0%); Biochar: 7t/ha, 3.5t/ha and 0t/ha; inorganic fertilizer: 100%, 50% and 0% of recommended rate). There were twenty-seven treatments with three replications arranged in a randomized complete block design (RCBD). Data were collected on plant height, diameter, number of leaves, number of fruits per plant, yield (t/ha), and soil chemical and microbial properties. The analysis of variance (ANOVA) was used to analyze the data. The results indicated that applying HYT biofertilizers and biochar significantly affected plant height, stem girth, number of leaves and fruit yield, and plant nutrients. The results revealed that 3.5t/ha to 7t/ha biochar + 50-100% HYT biofertilizer combination increased the yield of hot pepper. Microbial count before and after planting also significantly increased with biofertilizers.

Keywords: Biochar, growth, hot pepper, HYT biofertilizers, yield

INTRODUCTION

Hot pepper (*Capsicum* spp.) belongs to the Solanaceae family, of which tomato, potato, tobacco, and petunia are members (Seleshi 2011). Prehistoric people domesticated the Capsicum at least five times in different parts of South and Central America. The genus of *Capsicum* consists of approximately 22 wild and five domesticated species (Seleshi 2011). Despite their vast trait differences, most cultivars of peppers commercially cultivated worldwide belong to the species *C. annuum* L. (Seleshi 2011).

Capsicum fruits are consumed in various ways and are a good source of B2, potassium, phosphorus, and calcium (Seleshi 2011). In addition, according to Nkansah et al. (2011), pepper fruits may be used as a vegetable, spice, and coloring as well as for medicinal purposes.

In Ghana, the pepper is one of the leading vegetable crops exported (Nkansah et al. 2011). Its production is a good source of income for small producers and positively impacts local and export markets (Nkansah et al. 2011). However, Ghana's farmers largely depend on chemical fertilizers and other agrochemicals, such as herbicides and insecticides. The use of such agrochemicals indiscriminately pollutes water bodies and degrades the environment, negatively impacting how attractive agro-inputs remain. Thus, many farmers are resorting to adopting alternative practices such as using organic agro-inputs. As a result, the demand for organic crops for consumption on the international market has been showing an upward trend, with consumers willing to pay a premium price for organic products (Owusu and Owusu 2013).

Generally, excessive amounts of inorganic fertilizers are applied to vegetables to achieve higher yields (Kumar et al. 2011; Retnanimgrum et al. 2021) and maximum value of growth (Yousefi et al. 2011). However, using inorganic fertilizers alone may cause problems for human health and the environment (Sharma et al. 2012). Thingujam et al. (2016) reported that when organic manures are applied with chemical fertilizers, they yield better than when applied individually.

When biofertilizers are applied to seeds or plants, they colonize the rhizosphere or the plant's interior and promote growth by increasing the supply or availability of primary nutrients to the host plant (Shanmuga et al. 2013). High Yield Technology (HYT) is an organic product that helps improve soil fertility (Agrinos 2011). The product comes in three forms: HYT[a,] HYT[b,] and HYT[c] (Agrinos 2011). When the microbes colonize the soil, they also break up bindings in the soil in the process and loosen the soil (Agrinos 2011). Permeable soils with a lot of microbial activity prevent water run-off and additional nutrient loss. Permeable soil is also better capable of storing moisture, which is exceptionally important for plant growth, especially in areas that, on regular bases, are hampered by drought (Agrinos 2011). This project's main objective was to evaluate the effect of biochar and organic substrate (HYT) on the growth and yield of pepper.

MATERIALS AND METHODS

Experimental site

The experiment was carried out at the Forest and Horticultural Crops Research Centre (FOHCREC) in Kade, Ghana. FOHCREC is 114 m above sea level on latitude 6°.1573/ N and longitude 0°.9153/ W (Nkansah et al. 2011). The center is in Ghana's semi-deciduous forest agroecological zone in the Kwaebibrim district of the Eastern Region, 175 km NE of Accra (Nkansah et al. 2011). The soil moisture regime is udic, and the soil temperature regime is isohyperthermic (Finke 2011). The dominant soil is Haplic Acrisol (Nkansah et al. 2011). The area's climate is humid tropical, with a temperature of between 25-38°C (Nkansah et al. 2011). The annual rainfall ranges between 1300mm-1700mm, and the distribution is bi-modal two peaks around June-July and September-October (Nkansah et al. 2011). The rainfall regime during the experimental period is shown in Figure 1.

Experimental material

Pepper variety "Scotch Bonnet" was used for the experiment. It was purchased from Agriseed limited in Accra. HYT biofertilizers were provided by Agrinos (2011), while inorganic fertilizers used were acquired from the Forest and Horticultural Crops Research Centre. Biochar was prepared at the center by pyrolyzing rice husks.

Experimental details

Two field experiments (major and minor planting seasons) were conducted. The major planting season started in April and ended in July, and the minor season commenced in August and ended in November.

Experiment I: Field experiment (major and minor planting seasons)

Previous crop thriving of site

The experimental site used for the mayor planting season was an abandoned citrus plantation that was destroyed, and the site was prepared for the experiment. The experimental site used for the minor season was previously used to cultivate maize and was left to follow for two years.

Experimental layout

These experiments were laid out in a randomized complete block design (RCBD) with four replications. The experiment consisted of 27 treatments replicated four times (Table 1). The treatments included biochar (carbonated rice husk), HYTa and HYTb biofertilizers, and a combination of inorganic fertilizers (Figure 2).

Plot size and planting distance

Each experimental plot was 8 m^2 (8 m x 1 m) with 0.3 m between plots and a 0.6 m pathway. The planting distance adopted at both sites was 70cm ×60 cm, and the plant population per plot was 28.

Cultural practices

Nursery preparation

Seedlings were raised using carbonated rice husk (biochar) as the growing medium. A starter solution of 5 g/L of NPK 15-15-15 was applied two weeks after emergence at 10ml per plant. A nutrient solution of the same concentration and volume was also applied one week after the initial application. Fungicides Mancozeb 80 WP (Mancozeb dithiocarbamate) and Top Cop (Sulphur and Tribasic copper sulphate) were applied alternatively to prevent damping off at 10 g/L and 14 mL/Liter, respectively. In addition, Cyperdicot (dimethoate 250 g/L + cypermethrin 30 g/L) at 7.5 mL/L was applied fortnightly to control the activities of grasshoppers (*Zonocerus variegatus* Linnaeus, 1758), aphids (*Aphis gossypii* Glover, 1877) and white flies (*Bemisia tabaci* Gennadius, 1889).

Biochar preparation

A round-metal drum was cut at both ends and perforated in several places on the cylinder. Firewood was burned inside the drum, and dried rice husk was heaped around the metal drum, being left to pyrolyze. It was watered and then air dried before being weighed into sacks ready for application on the field.

Land preparation and biochar application

The land was deep ploughed and then harrowed twice to give fine tilth during both seasons. Then, the plots were prepared according to the specifications, and biochar was applied at 7.0t/ha (100%), 3.0t/ha (50%), and 0t/ha (0%) for major and minor seasons, respectively. The application was made by incorporating biochar into the top 5 cm of the soil with the aid of a hoe.

HYT biofertilizers were activated into their respective concentrations, then applied to the various experimental plots three days later using a knapsack sprayer. The solution of the mixture (0.9 L) was measured and applied to each treatment plot (8 m^2).

HYT preparation and application

In preparing the HYT, 4 L (100%) and 2 L (50%) of HYT^b were added to 100 L of water and stirred for thorough mixing. The mixture was then allowed to stand for 15 minutes before the same quantity of HYT^a was added and stirred thoroughly. Finally, it was covered and stored away from rain and excessive heat. After 72 hours, the color and smell of the activated solution altered, becoming less pungent in odor, with a light film forming on the solution's surface with foam also appearing, showing the successful activation of the product (Agrinos 2011). The same volume of HYT^b (4 L and 2 L for 100% and 50%, respectively) was then added and agitated to reactivate the enzymes following the Agrinos (2011) protocol. The solution was used for soil application at 900 mL per 8 m^2 close to the root zone of the plants. The process was repeated fortnightly for three months.

HYT^b was added to 100 L of water and applied at 450 mL per 8 m^2 as a foliar application. The process was repeated every fortnight for three months (Table 2).

Thinning

At 7 days after transplanting (DAT), weak crop seedlings were thinned out, retaining only one plant per stand.

Fertilizer application

NPK 15-15-15 at 250 kg/ha (100%) and 125 kg/ha were applied at 14 DAT. Sulphate of ammonia was applied at flowering at 150 kg/ha (100%) and 75 kg/ha (50%). The ring placement method was used to apply the various fertilizer treatments. The application rate per plant was calculated using the area of a hectare and the planting distance as follows:

$$\text{Plant population per hectare} = \frac{\text{Area of a hectare}}{\text{Planting distance}}$$

$$\text{Amount of fertilizer applied per plant} = \frac{\text{Application rate of fertilizer}}{\text{Plant population per hectare}}$$

Cultural practices

The experimental plots were kept free from weeds by regular hand hoeing. Supplementary irrigation was given as and when necessary, as well as necessary plant protection measures. Cymethoate at a rate of 7.5 mL/L of water was sprayed on the field to prevent termites and cricket attacks; Pyrinex 48EC at 3 mL/L (Chlorpyrifos 480 g/L, an organophosphorus compound) was also applied four weeks after transplanting to control aphids (*Aphis* spp.) and white flies (*B. tabaci*). Cyperdicot (dimethoate 250 gm/L + cypermethrin 30 gm/L) at 7.5 mL/L was applied to control the activities of leaf miners (*Liriomyza* spp.), grasshoppers (*Z. variegatus*), aphids (*A. gossypii*) and white flies (*B. tabaci*). Broad spectrum fungicides Mancozeb 80 WP and Top Cop (Sulphur and Tribasic copper sulphate) were applied to prevent fungal attack.

Experimental data collection

The fruits were harvested at maturity and weighed using an electronic scale.

Five plants from each treatment in each replication were randomly selected and tagged for recording on growth, yield and yield components, and fruit quality parameters.

The following data were collected:

Plant height. It was recorded in centimeters from the base of the plant to the terminal growing point of tagged plants at 15, 30, and 45 DAT using a meter rule.

Stem diameter. The diameters were measured using a vernier caliper, and the averages worked out. The diameter was measured from about 5cm from the soil surface around the base of the plants at 15, 30, and 45 DAT.

The number of leaves per plant. The numbers of leaves per plant were counted at 15, 30, and 45 DAT.

Plant canopy size. Plant canopy size was determined using a meter rule. The canopy was measured in the north-south and east-west directions at the 50% flowering stage.

Phenology parameters days to flowering. The number of days taken for 50% of plants to flower was recorded in each treatment.

The number of fruits per plant. The mean fruit number per plant was worked out from the total number of fruits harvested over the entire harvest period of two months.

Fruit yield per plant. The mean fruit weight per plant was calculated from the fruits harvested over all the pickings.

Fruit yield per plot. The total fruit weight from the tagged plants was recorded from the fruits harvested from all the harvested fruits, and fruit yield per plot was computed as:

Fruit yield per plot = Average fruit yield per plant * number of plants per plot

Fruit yield per hectare. The total fruit weight per hectare was computed based on the fruit weight per net plot.

The number of lobes per fruit. The number of lobes found in the fruit was counted and recorded.

Fruit Pericarp thickness. Five fruits from each treatment and replication were dissected transversally, and the thickness of the pericarp was measured with a vernier caliper at the four cardinal points and averaged.

The number of seeds/fruits. The number of seeds in harvested fruits was counted and recorded.

Weight of 100 seeds. A sum of 100 seeds from fruits selected from the tagged plants were weighed.

Soil, biochar, and plant nutrient analyses

Soil and biochar samples were air dried, sieved using a 2 mm mesh, and stored before the laboratory analyses. Plant samples were oven dried at 70°C for 72 hours, milled, and sieved for the analyses of chemical properties.

Soil and biochar chemical properties analyses

Core soil samples were collected randomly from the 0-15cm depth on the site using a soil auger. The soil was then mixed thoroughly, and the bulk sample was taken to the laboratory, air-dried, and sieved to pass through a 2mm screen for chemical analysis. First, the soil pH (1:1 soil/water) and biochar pH (1: 2.5 biochar/water) were determined using a glass calomel electrode system (Crockford and Nowell 1956). Next, the soil N was determined by the micro Kjeldahl method (AOAC 1994), while available soil P was extracted by the Bray P1 extractant, measured by the Murphy blue coloration, and determined on a Spectronic 20 at 882 Um (Murphy and Riley 1962). Next, soil K, Ca, and Mg were extracted with a 1M NH_4OAC (Ammonium acetate) pH 7 solution, then K was analyzed with a flame photometer. At the same time, Mg and Ca were determined with an atomic absorption spectrophotometer (Jackson 1973).

Total nitrogen in the sample was calculated as shown:

$$\%N = \frac{\text{molar mass of N} * \text{titre value} * \text{volume of extract} * 100}{\text{weight of sample} * 1000 * \text{volume of aliquot}}$$

Available P in samples was calculated as shown:

$$P\,(ppm) = \frac{\text{meter reading} * \text{volume of extract}}{\text{weight of sample} * \text{volume of aliquot}}$$

Soil particle size was determined using the Bouyoucos Hydrometer Method (Orhan and Kılınç 2020). But, first, the particle size distribution was determined using the formula:

$$(clay + silt)\% = \frac{\text{5 minutes hydrometer reading}}{\text{mass of soil(g)}} * 100 \rightarrow \quad (\alpha)$$

$$(clay)\% = \frac{\text{5 hours hydrometer reading}}{\text{mass of soil(g)}} * 100 \rightarrow \quad (\beta)$$

$$(sand)\% = \frac{\text{oven dry mass(g)of particles retained on 45}um\text{ sieve}}{\text{mass of soil}} * 100$$

(silt)%= (α) – (β)

Soil microbial analysis

A bottle of about 250 mL volume was washed and covered with aluminum foil and sterilized in an autoclave at 121°C for 15 minutes. A long rope was tied around the neck of the bottle so that the cap of the bottle was opened aseptically and lowered down into the well to a depth of about 1 m ensuring no air escaped. The bottle was raised out of the well, and the lid was carefully replaced. The bottle was labeled, placed in an ice chest loaded with ice packs, and immediately transported to the laboratory for incubation. 9 mL of ¼ strength phosphate saline buffer were added to 1 mL of well water sample for 1 in 10 dilutions.

The pour plate method was used in which 1ml aliquot of the well water sample was transferred aseptically with a micropipette into a sterile petri dish. Ten (10) mL of the sterile plate count agar (PCA) was added when palm hot (45°C), mixed, and allowed to set. It was then incubated at 35°C for 18-24 hours. The microbial growth on the media was counted using the Start Scientific Colony Counter.

Plant analyses

The Kjeldahl digestion procedure described by Okalebo et al. (2002) was used to determine the plants' N, P, K, Mg, and Ca. First, 0.1 g of milled and sieved plant samples were weighed into a cleaned, dry 125 mL Pyrex conical flask. Five milliliters of H_2SO_4 were added and left to stand for about 1 hour. Next, the flask and its contents were heated on a hot plate in a fume chamber, and a few drops of H_2O_2 have added 3-4 drops at a time to avoid vigorous reaction of the content until the solution turned colorless. Then the solution was cooled and transferred into a 100 mL volumetric flask. The content was topped to the mark using distilled water to determine N, P, K, Ca, and Mg. Total nitrogen in plant samples was determined using the micro Kjeldahl distillation and titration method described for soil and biochar above. Available P was determined following color development using the Bray P1 extractant, measured by the Murphy blue coloration (Murphy and Riley 1962) and determined on a Spectrophotometer (model Perkin Elmer Lamda 45). Exchangeable K in samples was read by aspirating directly into the Jenway flame photometer (PFP7). The Atomic Absorption Spectrometer (AAS) determined calcium and Mg in the extract. All parameters determined were expressed in percentages.

Statistical analysis

The data collected were analyzed using analysis of variance (ANOVA) at p=0.05 (GenStat, version 11). Significant differences among treatment means were separated using the least significant difference (LSD) at p= 0.05.

Table 1. Treatment combinations

Treatment	Treatment explanation
T1:F0B0H0	Control
T2:F0B50H0	3.3t biochar
T3:F0B100H0	7t biochar
T4:F50B100H0	50% fertilizer +7t biochar
T5:F50B50H0	50%fertilizer + 3.5t biochar
T6:F50B0H0	50% fertilizer
T7:F100B100H0	100% fertilizer+ 7t biochar
T8:F100B50H0	100% fertilizer + 3.5t biochar
T9:F100B0H0	100% fertilizer
T10:F100B100H100	100% fertilizer+ 7t biochar+ 100% HYT
T11:F50B50H50	50% fertilizer +3.5t biochar+50% HYT
T12:F100B0H100	100% fertilizer+ 100% HYT
T13:F100B0H50	100% fertilizer + 50% HYT
T14:F50B0H100	50% fertilizer + 100% HYT
T15:F50B0H50	50% fertilizer + 50% HYT
T16:F100B100H50	100% fertilizer+7t biochar+ 100% HYT
T17:F100B50H100	100% fertilizer+3.5t biochar + 100% HYT
T18:F100B50H50	100% fertilizer+3.5t biochar +50% HYT
T19:F50B100H100	50% fertilizer+ 7t biochar +50%HYT
T20:F50B100H50	50%fertilizer+7t biochar+ 50%HYT
T21:F50B50H100	50% fertilizer+ 3.5t biochar+100%HYT
T22:F0B100H100	7t biochar +100% HYT
T23:F0B0H50	50% HYT
T24:F0B0H100	100% HYT
T25:F0B100H50	7t biochar +50% HYT
T26:F0B50H100	3.5t biochar +100% HYT
T27:F0B50H50	3.5t biochar +50% HYT

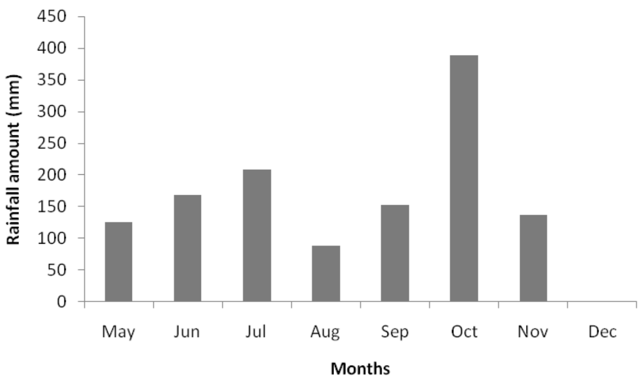

Figure 1. Rainfall distribution at the experimental site during the experimental period from May to December 2011

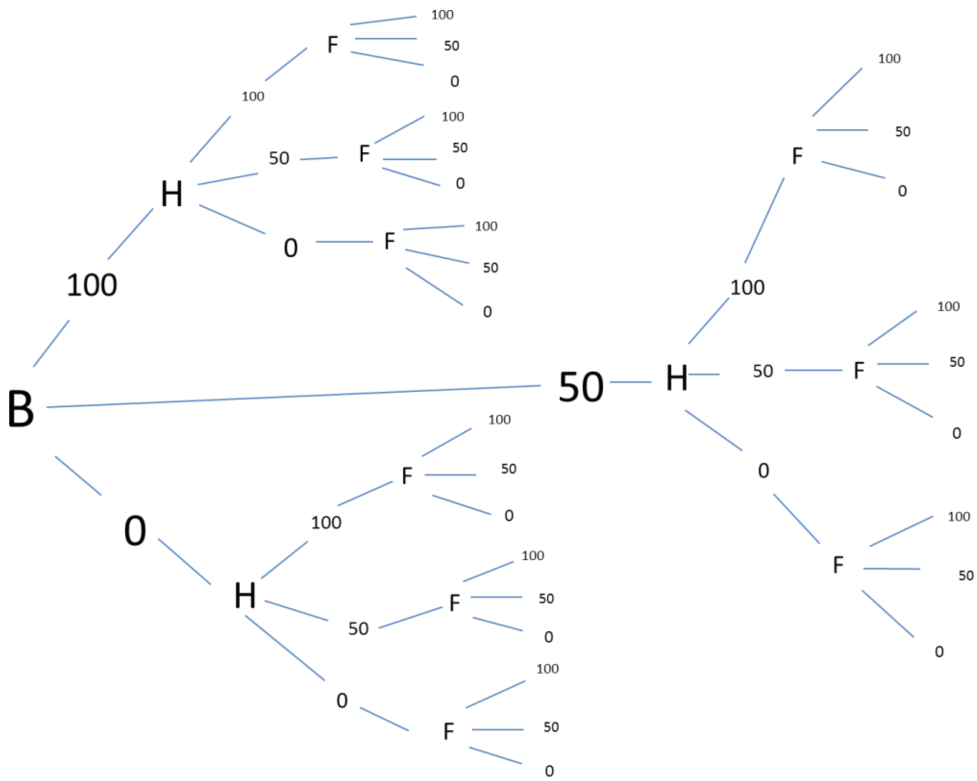

Figure 2. Diagram showing treatment combinations

Table 2. Application regime of HYT

Time/WAT	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Application	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil

Note: WAT: Weeks After Transplanting

RESULTS AND DISCUSSION

Vegetative growth parameters of hot pepper in the major and minor seasons

The study revealed significant differences between the application of HYT biofertilizers and biochar on growth characters and the yield of hot pepper at the vegetative stage in both the major and minor seasons.

The effect of HYT biofertilizer and biochar on the Plant height of hot pepper in major and minor season

Results in Table 3 show the effect of HYT biofertilizer and biochar on plant height in the different seasons. It was observed that there were significant differences in both seasons at the various DATs. At 45 DAT, plant height was significantly increased among the treatments and between the major and minor seasons. In the major season, the highest plant height at 45 DAT was identified to be 39.56 cm for treatment of 50% fertilizer, and the corresponding highest plant height at 45 DAT for the minor season was 35.32 cm for treatment of 100% fertilizer +3.5t biochar +50% HYT. Generally, there was a significant increase in plant height in the major season than in the minor season for the hot pepper among the various DATs.

The effect of HYT biofertilizer and biochar on the stem diameter of pepper in major and minor season

Plant diameter was also used to identify the effect HYT biofertilizer and biochar may have on hot pepper. From Table 3, it was shown that there were significant differences among all the seasons at the various DATs, which are 15, 30, and 45 DATs. For the major season at 15 DAT, the highest plant diameter observed was for the 50% fertilizer with a diameter of 0.51 cm. The lowest plant diameter was found with a combination of 100 fertilizers and 50% HYT. The biofertilizers were noticed to have narrow plant diameters in the major season. At 30 DAT, the widest plant diameter was for the 50% fertilizer only, proving the minimum effect of the HYT fertilizer and the biochar. In the minor season, there were appreciable significant differences observed in the plant diameter from 15 DAT to 45 DAT. The widest plant diameter observed in fertilizer combinations with 100% fertilizer was the value of 0.92 cm. It was also observed that the combination of 100% fertilizer +7t biochar +100% HYT gave the lowest plant diameter at 0.47 cm.

The effect of HYT biofertilizer and biochar on the number of leaves of hot pepper

In the major and minor season experiments, the number of leaves was one of the vegetative growth parameters used to determine the effect of HYT biofertilizer and biochar on hot pepper. Table 3 shows the effect of HYT biofertilizer and biochar on the number of leaves for major and minor seasons, and there were no significant differences for the 15 DAT at the major season. Still, there were significant differences between the 30 and 45 DAT for both major and minor seasons among the various treatments. The lowest number of leaves recorded was for the control during the major season at 15 DAT with 23 leaves. The lowest reading for 30 DAT was 59, still under control, while that of 45 DAT was 101. The highest number of leaves for the major season was 260 for the combination of 50% fertilizer + 50%HYT at 45 DAT. The highest for the minor season was observed for the 50% fertilizer +7t Biochar with the number 183 at 45 DAT. The highest number of leaves for 30 DAT was 120 leaves for the minor, and the 100% fertilizer recorded this.

The effect of HYT biofertilizer and biochar on canopy size of hot pepper for major and minor seasons

Canopy size is one of the growth parameters that show the area covered by the branches and leaves of the plant. It was noticed that there were significant differences in the major and minor seasons for the various fertilizer combinations and control plots, respectively (Table 3). For example, the minor season had the least canopy size of 0.041 m^2 for 50% fertilizer, while the fertilizer combinations 50% fertilizer and 100% HYT had the least (0.121 m^2) for the major season. It was also observed that the canopy size was very wide for a combination of 100% fertilizer + 3.5t biochar + 100% HYT in the minor season with a value of 1.610 m^2.

The flowering of the hot pepper plant

The reproduction of pepper for the seasons was calculated using days to 50% flowering as the main parameter. The observations showed no significant differences in the days to 50% flowering, despite the changes identified in the various fertilizer combinations and the control plot. The longest days to flowering was observed in the control plants (65 days) while the least days to flowering was 53, observed in plants grown with the fertilizer combinations of 50% fertilizer + 7t biochar + 50% HYT, 100% fertilizer + 100% fertilizer + 50% HYT, 100% fertilizer + 3.5t biochar + 100% HYT, 50% fertilizer + 3.5t biochar + 100% HYT (Table 4).

Yield and fruit quality parameters of pepper

The effect of HYT biofertilizer and biochar on number of lobes, number of seeds per fruit, pericarp thickness, and 100 seed weight of pepper

The effects of HYT biofertilizers and biochar in association with the inorganic fertilizers on the fruit quality of pepper were found to be significantly different at a probability of 0.05. Despite the similarities observed in the number of lobes, it was detected that the highest number of lobes was 4, and the lowest was 3. These were mainly recorded for the fertilizer combinations of HYT biofertilizer and inorganic fertilizers, respectively. For the number of seeds per fruit of pepper, the lowest number of seeds per fruit of pepper was 25, and this was observed for the fertilizer combination of 50% fertilizer + 7t biochar + 50% HYT. The control had more seeds per fruit than the other treatments, averaging 31 seeds per fruit. The pericarp thickness of pepper ranged from 1.30 cm to 2.60 cm for the various fertilizer combinations and the control (Table 4). The lowest size pericarp for the treatment combinations was observed for the control (1.30 cm). The highest seed weight was observed in the treatment combination of 50% fertilizer + 50% HYT (0.86 g). The HYT biofertilizer combinations were identified to have increased the weight of 100 seeds.

The effect of HYT biofertilizer and biochar on the yield of hot pepper

Results in Table 4 indicate a yield range of 3.23 kg/plot of 8.1 m^2 (3.99 t/ha) to 17.3 kg/plot (21.9 t/ha) in the major season. The minor season yield ranged from 3.38 kg/plot (4.17 t/ha) to 17.33 kg/plot (21.4 t/ha). The control recorded the least yield of 3.99 t/ha while 100% fertilizer+ 3.5t biochar + 100% HYT and 50% fertilizer + 50% HYT had the highest yield of 21.89 t/ha in the major season. In the minor season, the control again had the least yield (4.17 t/ha), and the highest yield was recorded by 50% fertilizer +50% HYT.

Soil and plant nutrients parameters

The effect of HYT biofertilizer and biochar on plant nutrients

The effect of HYT biofertilizer and biochar on the plant nutrients differed among the various treatments. It was observed that there were significant differences in the various plant nutrients. Calcium ranged from 2.12 ppm to 12.72 ppm for fertilizer combinations of 100% fertilizer +7t biochar + 100% HYT and 3.5t biochar + 100% HYT, respectively, as seen in Table 5. Potassium, on the other hand, ranged from 14.68 ppm to 41. 20 ppm for fertilizer combinations of 50% fertilizer + 7t biochar + 50% HYT and 7t biochar + 100% HYT, respectively. Magnesium was observed to show a larger range of nutrient content from 2.78 ppm to 9.18 ppm for fertilizer combinations of 50% fertilizer + 3.5t biochar and 100% fertilizer + 3.5t biochar + 100% HYT, respectively. The nitrogen content in the plants was observed to have minimal differences, yet the differences were significant. They ranged from 0.99 ppm to 2.12 ppm for fertilizer combinations of 7t biochar and 50% fertilizer + 7t biochar+ 50% HYT, respectively. The last nutrient content observed from the hot pepper was phosphorus; it also ranged from 2.83 ppm to 7.43 ppm for the fertilizer combinations of 7t biochar +50% HYT and 100% fertilizer +100% HYT, respectively.

The effect of HYT biofertilizer and biochar on soil nutrients

The effect of HYT biofertilizers and biochar on the soil nutrients was observed to be different. From Table 5, there were significant differences in the various soil nutrients. Generally, there were high amounts of various nutrients in the soil compared to the plants. Calcium content in soil ranged from 10.55 ppm to 67.61 ppm for fertilizer combinations of 50% fertilizer+7t biochar and 3.5t biochar +50% HYT, respectively. Potassium ranged from 9.08 ppm to 36.30 ppm for the different fertilizer combinations. Magnesium constituted a large range of nutrient contents ranging from 18.17 ppm to 37.51 ppm for the fertilizer combinations. The soil's nitrogen content was not much different even though the differences were with contents ranging from 0.67 ppm to 2.13 ppm. Phosphorus ranged from 0.25 ppm to 18.24 ppm for the fertilizer combinations of 7t biochar and 100% fertilizer + 7t biochar + 100% HYT, respectively.

The effect of HYT biofertilizer and biochar on soil pH and EC

The amount of hydrogen and the soluble salts in the soil differed significantly. Therefore, the HYT biofertilizer combinations considerably affected the pH and the EC. Most fertilizer combinations were observed to make the soil very acidic, with a pH ranging from 4.1 to 5.7. At the same time, the soluble salts were low, ranging from 0.1 to 3.3, indicating the acidic nature of the soil (Table 6).

The effect of HYT biofertilizer and biochar on microbial count

The population of microbes before and after planting was identified to be significantly different for the various periods of the count. Before planting, microbial count ranged from 2325 to 17750, while that of the counting after planting was determined to be from 1700 to 8400 (Table 6).

Discussion

HYT biofertilizer and biochar on vegetative parameters of hot pepper

The study of the evaluation of HYT biofertilizers and biochar on the vegetative parameters of hot pepper showed variation in the various factors under study. The vegetative differences observed in the hot pepper for applying the various fertilizer combinations were significantly different for the study in plant height, stem diameter, and the number of leaves (Table 3) at the various seasons. These differences were also observed in Kiran et al. (2010). In the study, Kiran et al. (2010) observed significant increases in these growth parameters by the plant due to increased fertilizer levels. It could be attributed to the increased uptake of nutrients in the plants leading to enhanced chlorophyll content and carbohydrate synthesis. In this present study, the changes were due to the fertilizer combinations in the biofertilizers and biochar. Jagadeesha (2008) confirmed that that was also confirmed, who observed a considerable change in the various vegetative parameters. The study shows that the recommended dose of fertilizer alone recorded significantly higher values for growth parameters. It could be attributed to the quick and readily available major nutrients like N, P, and K to plants at the early stages of plant growth. At the same time, organic manures recorded significantly lower values for growth parameters because of the slower release of nutrients to the plants.

These results are supported by the report of Thingujam et al. (2016) in brinjal. Kumar and Sharma (2006) studied the effect of different methods of biofertilizer application in tomato seed production. They used four biofertilizers. The study revealed that when *Azotobacter* was applied to the nursery, there was a maximum increase in the number of fruits per plant (19.23), fruit yield per plant (1109 g) and per hectare (356.9 g), 1000 seed weight (3.63 g), seed yield per plant (4.58 g) and per hectare (152.70 kg).

Plant yield is the ultimate manifestation of morphological, physiological, and biochemical processes and growth parameters. Improvement in yield can be realized in two ways, i.e., by adopting the existing varieties to grow better in their environment or by altering the relative proportion of different plant parts to increase the yield of economically important parts (Humphries 1969).

HYT biofertilizer and biochar on the yield of hot pepper

In the present study, the results have indicated that all measured traits of yield and fruit quality of hot pepper were significantly affected by using the various fertilizer combinations of biofertilizer and biochar. An increase in fruit yield and its parameters can be attributed to increasing the number of leaves. Similar findings were also reported by Thingujam et al. (2016) in brinjal. An increase in seed yield and its components may be ascribed to an increase in seed weight per fruit because of an improvement in seed number to adequate mother plant nutrition. Further, it could be due to the influence of other yield attributes such as the number of branches per plant, the number of fruits per plant, increase in fruit weight, fruit length, fruit diameter, and fruit yield per plant.

The fruit yield and parameters increase may be due to a greater number of flowers per plant. It was produced due to the combined application of inorganic fertilizers and biofertilizers. Significant differences in seed yield per plant were noticed in treatment and biofertilizers, where the interaction effect was also significant (Table 4). Significantly higher seed yield per plant was noticed in biofertilizers application. The 100 seed weight, number of lobes, number of seeds per fruit, and pericarp thickness significantly increased the quality and quantity, respectively.

Table 3. The effect of HYT biofertilizer and biochar on plant height, stem diameter, and number of leaves of hot pepper at 15, 30, and 45 DAT and canopy size in the major and minor seasons

Treatm.	Plant height (cm)						Stem diameter (cm)						No. of leaves						Canopy size (m^2)	
	Major season			Minor season			Major season			Minor season			Major season			Minor season				
	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	0.167	0.140	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	15 DAT	30 DAT	45 DAT	Major season	Minor season
T1	18.25	23.40	28.43	14.75	22.81	27.65	0.267	0.272	0.66	0.34	0.41	0.63	23	59	101	29	53	128	0.167	0.140
T2	18.50	23.85	26.80	16.35	23.32	26.68	0.241	0.230	0.63	0.36	0.51	0.68	63	103	137	51	92	124	0.267	0.272
T3	20.75	25.52	28.88	17.56	23.41	26.18	0.393	0.371	0.62	0.36	0.53	0.68	73	115	151	52	83	110	0.241	0.230
T4	23.35	26.25	28.90	18.36	22.96	26.27	0.427	0.389	0.64	0.38	0.57	0.74	73	132	207	66	114	183	0.393	0.371
T5	25.50	31.83	35.10	21.59	26.35	30.38	0.416	0.041	0.78	0.46	0.65	0.83	69	103	148	59	94	138	0.427	0.389
T6	30.75	35.85	39.56	28.77	31.25	34.16	0.321	0.301	0.88	0.47	0.60	0.70	78	158	263	59	100	139	0.416	0.041
T7	22.25	25.25	28.05	18.24	24.35	26.27	0.440	0.365	0.64	0.38	0.54	0.72	68	124	196	64	102	168	0.321	0.301
T8	19.50	24.47	28.05	16.18	23.68	26.83	0.274	0.313	0.78	0.39	0.55	0.82	68	143	229	59	97	129	0.440	0.365
T9	22.25	26.20	29.53	21.12	29.85	33.10	0.154	0.156	0.84	0.41	0.64	0.92	61	144	221	77	120	155	0.274	0.313
T10	20.75	24.60	28.16	20.33	23.32	24.74	0.207	0.205	0.64	0.32	0.39	0.47	71	83	170	46	55	141	0.154	0.156
T11	24.00	30.10	34.25	24.13	30.71	33.66	0.127	0.133	0.69	0.25	0.37	0.55	47	73	106	62	84	113	0.207	0.205
T12	22.75	28.07	31.31	25.26	31.31	34.22	0.170	0.200	0.52	0.32	0.41	0.52	94	126	191	49	80	140	0.127	0.133
T13	24.50	31.32	36.23	20.86	25.89	28.22	0.121	0.122	0.60	0.42	0.35	0.56	54	116	260	29	55	123	0.170	0.200
T14	18.75	22.73	26.96	17.73	23.69	26.34	0.477	0.386	0.87	0.30	0.49	0.86	36	88	139	44	62	119	0.121	0.122
T15	25.00	32.15	35.38	16.26	23.61	26.76	0.131	0.131	0.67	0.30	0.38	0.52	72	118	160	56	94	134	0.477	0.386
T16	24.00	29.90	33.48	22.09	25.55	27.56	0.146	1.610	0.67	0.39	0.48	0.57	44	89	128	45	65	120	0.131	0.131
T17	29.00	35.50	38.20	21.19	27.51	30.45	0.427	0.428	0.55	0.55	0.66	0.91	83	119	146	68	105	131	0.146	1.610
T18	23.00	33.35	38.27	21.60	31.58	35.32	0.235	0.201	0.71	0.38	0.43	0.62	88	131	173	62	103	145	0.427	0.428
T19	22.75	27.70	33.86	22.32	26.62	29.25	0.266	0.268	0.63	0.36	0.45	0.55	53	109	200	28	73	151	0.235	0.201
T20	23.50	28.75	30.95	21.56	26.34	28.60	0.372	0.370	0.54	0.35	0.41	0.50	86	116	162	67	83	127	0.266	0.268
T21	24.75	33.02	36.05	21.41	29.49	32.82	0.465	0.352	0.67	0.34	0.42	0.64	65	110	231	53	99	133	0.372	0.370
T22	22.75	27.92	33.35	22.76	27.31	31.42	0.386	0.393	0.77	0.37	0.56	0.72	40	85	143	25	64	129	0.465	0.352
T23	25.00	29.58	31.85	22.37	27.43	29.51	0.311	0.311	0.64	0.46	0.53	0.67	83	123	173	57	97	147	0.386	0.393
T24	24.00	31.37	34.43	22.39	29.50	32.51	0.358	0.352	0.76	0.43	0.53	0.69	73	114	156	49	86	127	0.311	0.311
T25	21.50	26.70	33.57	17.12	23.34	25.41	0.351	0.303	0.63	0.35	0.44	0.62	55	121	197	31	65	127	0.358	0.352
T26	22.25	27.40	30.62	18.57	23.52	26.31	0.276	0.277	0.66	0.49	0.59	0.74	69	105	235	52	91	132	0.351	0.303
T27	28.75	33.02	37.28	27.11	31.64	33.63	0.08	0.09	0.68	0.32	0.45	0.65	63	100	195	46	73	121	0.276	0.277
LSD (P=5%)	4.483	4.095	4.006	0.1888	11.714	0.1741	0.07737	0.07431	0.0711	0.05233	0.02466	0.00786	96.25	18.33	50.65	0.56	1.32	1.15	0.08	0.09

Table 4. The effect of HYT biofertilizer and biochar on canopy size, flowering, fruit quality, and yield of pepper for major and minor seasons

Treatm.	Days of 50% flowering	Fruit quality				Yield			
						Major season		Minor season	
		No. of lobes	No. of seeds/fruit	Pericarp thickness (cm)	100 seeds weight (g)	(kg/plot)	(t/ha)	(kg/plot)	(t/ha)
T1	65	3	31	1.30	0.58	3.23	3.99	3.38	4.17
T2	55	3	35	1.55	0.56	6.1	7.53	6.9	8.52
T3	57	3	35	1.60	0.61	8.45	10.43	8.5	10.49
T4	62	3	32	1.50	0.55	4.63	5.72	8.68	10.72
T5	55	4	35	1.99	0.66	6.23	7.69	7.23	8.93
T6	60	4	30	2.26	0.71	5.1	6.30	5.48	6.77
T7	57	3	28	1.48	0.53	5.2	6.42	5.6	6.91
T8	57	3	36	1.39	0.47	5.13	6.33	5.93	7.32
T9	53	4	40	2.10	0.61	8.88	10.96	9.18	11.33
T10	55	3	35	1.31	0.72	8.38	10.35	8.43	10.41
T11	57	4	46	2.19	0.74	8.45	10.43	8.48	10.47
T12	57	4	39	1.71	0.59	6.38	7.88	6.45	7.96
T13	53	4	30	2.22	0.67	7.68	9.48	6.93	8.56
T14	56	3	37	2.15	0.68	8.75	10.80	10.13	12.51
T15	54	4	50	2.00	0.86	8.73	10.78	8.45	10.43
T16	56	4	48	2.10	0.71	8.5	10.49	7.75	9.57
T17	53	4	33	2.23	0.66	17.73	21.89	11.28	13.93
T18	56	4	37	2.06	0.65	12.05	14.88	11.73	14.48
T19	55	3	31	1.34	0.60	7.2	8.89	7.1	8.77
T20	53	4	25	2.12	0.83	10.48	12.94	10	12.35
T21	53	4	56	2.28	0.81	17.73	21.89	17.33	21.40
T22	59	3	40	2.06	0.66	5.4	6.67	5.25	6.48
T23	55	4	34	2.18	0.68	10.75	13.27	8.98	11.09
T24	56	4	35	2.18	0.68	8.15	10.06	8.5	10.49
T25	56	3	39	2.35	0.58	6.38	7.88	6.53	8.06
T26	55	4	36	2.10	0.66	9.45	11.67	9.85	12.16
T27	56	4	52	2.30	0.58	8.18	10.10	8.08	9.98
LSD (P= 5%)	0.075	0.59	9.1	0.19	0.07	0.58	3.85	0.69	2.12

Table 5. The effect of HYT biofertilizer and biochar on the amount of hot pepper plant and soil nutrients

Treatm.	Plant					Soil				
	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
T1	1.26	4.60	25.26	9.64	7.35	0.67	9.29	17.55	44.47	34.03
T2	1.34	3.55	18.68	2.78	5.69	1.56	0.37	9.08	41.50	32.58
T3	0.99	3.68	16.25	12.12	6.54	1.44	0.25	15.60	13.35	28.56
T4	1.13	3.69	17.48	9.99	4.98	1.30	3.06	11.53	10.55	24.21
T5	1.23	2.85	26.30	3.16	2.78	1.61	7.38	20.35	12.22	37.51
T6	1.57	5.38	35.10	7.16	5.28	1.39	8.48	32.50	59.19	21.60
T7	1.05	3.69	27.68	7.14	6.44	1.33	2.50	11.33	47.35	37.32
T8	1.32	4.07	30.30	10.23	5.97	1.18	3.22	10.13	39.47	30.22
T9	1.44	3.52	40.45	4.42	4.93	0.70	3.06	9.08	50.29	31.33
T10	1.24	3.49	36.00	7.69	7.21	1.20	18.24	12.60	54.35	25.67
T11	1.08	2.88	27.50	8.56	5.24	1.50	11.07	32.18	30.27	36.27
T12	1.73	7.43	22.83	8.66	7.09	0.85	6.67	32.23	29.08	36.28
T13	1.64	3.33	35.30	6.99	6.86	1.22	9.37	29.10	37.32	33.28
T14	1.68	2.86	30.60	8.48	5.22	1.70	15.99	39.15	33.28	21.47
T15	1.96	3.69	37.50	10.55	8.60	1.31	8.23	36.30	44.55	22.18
T16	1.01	4.02	22.83	2.12	7.66	1.08	11.38	28.30	33.13	27.60
T17	1.25	4.05	35.30	11.33	9.18	1.15	11.30	35.28	29.11	26.14
T18	1.71	4.41	30.60	4.22	4.99	1.30	7.42	24.23	13.69	33.41
T19	1.19	3.69	14.68	9.56	6.03	2.13	8.28	24.83	40.73	30.46
T20	2.12	4.14	34.60	8.34	6.59	1.62	9.35	33.38	54.06	19.60
T21	1.98	4.47	37.70	4.32	6.86	1.31	7.10	30.35	20.23	19.14
T22	1.50	4.22	41.20	5.27	8.53	1.33	8.78	24.58	10.75	33.23
T23	1.13	4.75	31.43	3.14	4.19	1.26	17.39	36.24	45.70	24.62
T24	1.33	4.96	34.40	10.25	7.24	1.33	15.32	42.55	47.84	25.39
T25	1.14	2.83	19.14	10.87	7.12	1.10	3.31	25.85	30.23	25.89
T26	1.31	2.94	17.73	12.72	5.85	1.44	15.46	35.43	35.47	18.17
T27	1.05	3.75	35.20	5.59	5.85	1.69	9.22	33.58	67.61	22.73
LSD (P=5%)	0.07913	0.06993	1.3631	0.1694	0.7077	0.2308	2.103	0.2724	0.4565	4.912

Table 6. The effect of HYT biofertilizer and biochar on the amount of soil pH, EC, and microbial count before and after planting

Treatment	Soil pH	Soil EC (ms/cm)	Microbial count	
			Before	After
T1	5.4	0.4	5525	7225
T2	4.3	0.8	4600	4525
T3	4.2	0.5	4475	4300
T4	4.1	0.2	6375	6325
T5	5.5	0.1	6375	8400
T6	5.5	0.1	8400	4650
T7	4.1	0.1	5825	5650
T8	5.7	0.1	2550	3150
T9	5.6	1.1	4575	4450
T10	4.9	0.3	2400	1800
T11	5.6	1.1	15500	5350
T12	5.2	1.8	3650	2150
T13	5.1	1.9	5350	8150
T14	4.9	0.2	4350	3825
T15	5.3	1.6	4900	2575
T16	5.1	1.5	2750	2550
T17	4.8	3.3	16756	4575
T18	4.5	0.4	17750	4200
T19	5.7	1.5	4200	3800
T20	5.1	2.0	17000	6550
T21	4.9	0.1	11250	2625
T22	5.3	1.1	5050	4650
T23	4.7	0.2	6900	1600
T24	5.4	1.5	4025	4275
T25	4.8	1.0	7900	8400
T26	4.6	1.3	5500	1700
T27	4.9	2.0	2325	4650
LSD (P=5%)	0.1995	0.826	805.9	156.5

Effect of HYT biofertilizer and biochar on the amount of plant and soil nutrients (N, P, K, Mg, and Ca) on hot pepper

Nutrient efficiency measures how much crop is produced per unit of nutrient supplied. The higher the efficiency, the more products are produced per unit of nutrient. The soil quality affects nutrient use efficiency and is evaluated by several indicators. Data concerning the effect of the amount present in the soil and the plant mineral N, P, K, Mg, and Ca levels on hot pepper plants' vegetative growth parameters are shown in Table 5. The present result indicated that the application of N, P, K, Mg, and Ca levels significantly increased in both the soil and plant for the various fertilizer combinations, especially for HYT biofertilizer and biochar. The necessity of N, P, and K for growth has been demonstrated previously; nitrogen supply was desirable for vegetative growth, dry matter accumulation, and nutrient uptake by potato plants (El-Ghamriny and Saeed 2007). The increase in plant growth may be attributed to the beneficial effects of nitrogen on stimulating the meristematic activity for producing more tissues and organs since it plays a major role in the synthesis of structural proteins and other several macromolecules, in addition to its vital contribution to several biochemical processes that related to plant growth (Maftu'ah and Nursyamsi 2015).

Also, nitrogen may be contributed to the activation of cell division and cell elongation (Yanagida et al. 2000). The promoting effect of growth parameters could be attributed to phosphorus as a structural part of high-energy compounds (Marjenah et al. 2016; Razaq et al. 2017). It is also a constituent of the cell nucleus and is essential for cell division and the development of the meristematic tissues (Yang et al. 2016). The obtained results of growth parameters in this investigation are in good agreement with those obtained by El-Ghamriny and Saeed (2007) on different crops.

REFERENCES

Agrinos. 2011. Activation Protocol. Technical Paper 1-3

AOAC. 1994. Official Methods of Analysis. Association of Official Analytical Chemists. 1111 North 19th Street, Suite 20, 16th Edition. Arlington, Virginia, USA.

Crockford L, Nowell R. 1956. Laboratory Manual of Physical Chemistry. John Wiley and Sons, N.Y.

El-Ghamriny EA, Saeed MNA. 2007. Effect of irrigation intervals, Mineral fertilizers and biofertilizers on potato plants grown under sandy soil conditions. I-Growth, water relations, chemical contents, and leaf anatomy. Egypt J Appl Sci 22: 480-511.

Finke PA. 2011. Modeling the genesis of Luvisols as a function of topographic position in loess parent material. Quat Intl 265: 3-17. DOI: 10.1016/j.quaint.2011.10.016.

Humphries EC. 1969. The dependence of photosynthesis on carbohydrates sinks. Current concepts Proceedings of International Symposium on Tropical Root Crops, Univ. West Indies, Kingston. [Jamaica]

Jackson ML. 1973. Soil and Chemical Analysis. Prentice Hall of India Private Limited, New Delhi.

Jagadeesha V. 2008. Effect of organic manures and Biofertilizers on Growth, Seed Yield and Quality In Tomato (*Lycopersicon esculentum* Mill.) Cv. Megha. Department of Seed Science and technology, College of Agriculture, Dharwad University of Agricultural Sciences Dharwad, India.

Kiran JBS, Vyakaranahal SD, Raikar GH, Ravikumar, Deshpande VK. 2010. Seed yield and quality of brinjal as influenced by crop nutrition. Indian J Agric Res 44 (1): 1-7.

Kumar ABM, Narase NC, Raviraja G, Shetty G, Kartik NM. 2011. Effect of organic manures and inorganic fertilizers on available NPK, microbial density of the soil and nutrient uptake of Brinjal. Res J Agric Sci 2 (2): 304-307.

Kumar S, Sharma SK. 2006. Effect of different methods of biofertilizer application in tomato seed production. Seed Res New Delhi 34 (1): 15.

Maftu'ah E, Nursyamsi D. 2015. Potency of various organic materials from swampland as a source of biochar. Pros Sem Nas Masy Biodiv Indon 1: 776-781. DOI: 10.13057/psnmbi/m010417.

Marjenah, Kiswanto, Purwanti S, Sofyan FPM. 2016. The effect of biochar, cocopeat and sawdust compost on the growth of two dipterocarps seedlings. Nusantara Biosci 8: 39-44. DOI: 10.13057/nusbiosci/n080108.

Murphy J, Riley JP. 1962. A modified simple solution method for the determination of phosphates in natural waters. Analytica Chimica Acta 27: 31-36. DOI: 10.1016/S0003-2670(00)88444-5.

Nkansah GO, Ayarna A, Gbokie TJ. 2011. Morphological and yield evaluation of some *Capsicum* pepper lines in two agroecological zones of Ghana. J Agron 10 (3): 84-91. DOI: 10.3923/ja.2011.84.91.

Okalebo JR, Cuthua KW, Woomer PJ. 2002. Laboratory methods of soil and plant analysis- A working manual.TSBF- CIAT and SACRED Africa, Nairobi, Kenya.

Orhan U, Kılınç E. 2020. Estimating soil texture with laser-guided Bouyoucos. Automatika 61 (1): 1-10. DOI: 10.1080/00051144.2019.1654283.

Owusu V, Owusu AM. 2013. Consumer willingness to pay a premium for organic fruit and vegetable in Ghana. Intl Food Agribusiness Manag Rev 16 (1): 67-86.

Razaq M, Zhang P, Shen H, Salahuddin. 2017. Influence of nitrogen and phosphorous on the growth and root morphology of *Acer mono*. PLoS One 12 (2): e0171321. DOI: 10.1371/journal.pone.0171321.

Retnanimgrum E, Wilopo W, Warmada IW. 2021. Enhancement of manganese extraction in a biochar-enriched bioleaching column with a mixed culture of indigenous bacteria. Biodiversitas 22:2949-2955. DOI: 10.13057/biodiv/d220560.

Seleshi D. 2011. Evaluation of Elite Pepper Varieties (*Capsicum* species) for Growth, Dry Pod Yield and Quality under Jimma Condition, South West Ethiopia. [Thesis]. Jimma University, Jimma. [Ethiopia]

Shanmuga PM, Reyaz F, Divyashree K, Babu AKS, Lakshmi PM, Prasad MP. 2013. Pilot scale production of *Azotobacter* biofertilizer and its effect on the growth parameters of *Ocimum sanctum*. Intl J Eng Adv Technol 2: 2249-8958.

Sharma JP, Rattan P, Kumar S. 2012. Response of vegetable crops to use of integrated nutrient management practices. SABB J Food Agric Sci 2 (1): 15-19.

Thingujam U, Pati S, Khanam R, Pari A, Ray K, Phonglosa A, Bhattacharyya K. 2016. Effect of integrated nutrient management on the nutrient accumulation and status of post-harvest soil of brinjal (*Solanum melongena* L.) under Nadia conditions (West Bengal), India. J Appl Nat Sci 8 (1): 321-328. DOI: 10.31018/jans.v8i1.794.

Yanagida M, Ikai N, Shimanuki M, Sajiki K. 2011. Nutrient limitations alter cell division control and chromosome segregation through growth-related kinases and phosphatases. Philos Trans R Soc Lond B Biol Sci 366 (1584): 3508-3520. DOI: 10.1098/rstb.2011.0124.

Yang W, Schuster C, Beahan CT, Charoensawan V, Peaucelle A, Bacic A, Doblin MS, Wightman R, Meyerowitz EM. 2016. Regulation of meristem morphogenesis by cell wall synthases in *Arabidopsis*. Curr Biol 26 (11): 1404-1415. DOI: 10.1016/j.cub.2016.04.026.

Yousefi AA, Khavazi K, Moezi AA, Rejali F, Nadian HA. 2011. Phosphate solubilizing bacteria and arbuscular mycorrhizal fungi impacts on inorganic phosphorus fractions and wheat growth. World Appl Sci J 15 (9): 1310-1318.