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Beneficial Effect of Biochar Application on Capsicum Annuum L. Growth and Morphological Properties

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Abstract

This study was carried out to determine the effects of biochar produced from different agricultural wastes on pepper germination and heat stress conditions. In the research, biochars obtained from biomass chicken manure at 500°C pyrolysis temperature were applied at 8 different doses. In the light of the obtained findings, the doses that affected the germination properties at the highest level were selected for all biochars and their effects on germination properties under heat stress conditions were evaluated. Low application doses of all biochars increased seed germination rates compared to control, while the effect of high application doses varied depending on biochar type. Germination time decreased at 0.25% chicken manure application doses. Chicken manure biochar applications increased pepper chlorophyll. Biochar applications generally increased chlorophyll amount in examined plant species. The obtained results showed that biochar applied at the right dose increased germination rate, shortened germination time and positively affected plant development.

Keywords: Biochar, Capsicum, Seedling, Pyrolysis, Dose, Effect

1. Introduction

Nowadays biochar production is done using different biomasses and numerous studies have been and are being conducted on the usability of these biochars as soil improvers. Studies on biochar can be rouped into four categories: chemistry, effects on plant performance, effects on greenhouse gases and climate change, and production technology. It is seen that the studies conducted are generally on forest product wastes and biomass in tropical regions. We can group biochar studies in the literature into two. The first group of studies covers the investigation of the effect of the biochar raw material (biomass) quality and production conditions on the usability properties of biochar in the soil. The second group of studies is the effect of biochar produced by researchers at a temperature they choose according to their own possibilities on soil and plant properties. There are many studies on how different types of plant waste can be used successfully in agriculture. In addition to being a source of useful organic matter, plant wastes have a beneficial potential in terms of plant nutrients. These also allow the use of smaller amounts of chemical fertilizers to enrich soil with low organic matter content. There is a possibility that plant wastes can be used in different environments by mixing them into the soil at a certain dose depending on their properties.

The organic matter content of the soil and the number of microorganisms are very important for the development of plants. In general, soil contains water, air, living organisms and organic matter. These factors are very important for increasing the quality of the soil. Organic matter is necessary for the life of soil organisms. The inadequacy of the organic matter content in the soil naturally causes the vitality in the soil to decrease. Eventually the quality and fertility of the soil will decline. In general, animal manure, plant waste, straw, stubble and other organic materials are used as organic matter sources. It is also an important source of organic matter in humus. The sustainability of agriculture in soils that are constantly exposed to chemical fertilizers without using organic matter is being discussed. Therefore, the need for organic matter should not be ignored. It is very important to keep the plant nutrients and organic matter that the plant needs in a balanced manner. Since organic matter decomposes rapidly in the soil, it is removed from the soil within a certain period of time. For this reason, protecting the organic matter content of the soil with continuous application is important for the sustainability of yield.

Biochar is a carbon rich material obtained by heating in an oxygen free environment. Biochar is obtained from agricultural waste and forest waste by heating process. Biochar source turns into organic matter needed by the soil by transforming the structure of carbohydrates in raw materials into carbon. Studies have shown that biochar has an improving and protective effect on soil quality and also keeps water retention and cation exchange capacity at optimum levels. The pyrolysis properties and pH values of the raw materials to be used in biochar production are very important from an agricultural perspective. Total carbon and nitrogen contents, phosphorus and potassium contents of biochar increase with increasing pyrolysis temperature.

However, the increase in potassium (K) is greater and faster than the increase in phosphorus. When the phosphorus and potassium contents of biochar produced at different temperatures were examined, it was seen that the calcium (Ca) and magnesium (Mg) ratios in biochars such as corn cob and wheat straw decreased with the increase in pyrolysis temperature; the amount of Ca and Mg increased with the increase in pyrolysis temperature in cattle manure, tomato waste and poplar sawdust biochars. Ca and Mg contents and the sulfur and sodium contents of biochars produced at different temperatures were investigated, it was seen that the sulfur content of biochars obtained from sawdust decreased with increasing temperature, while the sulfur content increased in biochars obtained from tomato, bean waste, corn cob and wheat straw. Sodium provided beneficial changes in rice and wheat straw. The high pH value in biochar reduces the benefits of some microelements but can help increase the cation exchange capacity of the soil [1].

When the effect of biochar on soil and plant development is examined, it will be of great benefit in eliminating the factors that hinder the sustainability of agriculture. The prerequisite for the acceptance of the results obtained from scientific studies by farmers is that the recommended practices are practical and economical. Biochar is used in various environmental applications. Various effects have been found on improving soil structure, particularly in areas such as water quality and soil restoration, soil fertility and nutrient cycling. Biochar improves the root system of plants, increasing seed germination and seedling growth in the first three weeks. During the next six months, it improves the nutrients of plants. It protects organic matter from decomposition after 3-6 months. It has been proven that biochar obtained from biomass by pyrolysis process has positive effects on seed germination and root development. Biochar-based seed coating technologies act as “glue” during the direct seed coating process for large-scale seeds, and the selection of appropriate binders can facilitate the positive effects of biochar on seed germination. In this thesis, the effects of biochars obtained from different agricultural wastes (chicken manure, sawdust, vineyard pruning waste, olive pruning waste, walnut shells and toxin- containing figs), which we think will contribute to sustainability and production, on germination, emergence and seedling development parameters of some vegetable species that are difficult to germinate and irregular, were investigated.

1.1 Effect of Biochar

Intensive research is being conducted on the usability of the healing effect of biochar on soil properties and germination of seedlings and seeds. In recent years, as terrestrial pollution has become serious, interest in biochar research has increased in relation to the restoration of agricultural and forest ecosystems [2]. Improvement of soil properties, increased plant productivity and enhanced carbon sequestration are considered to be some of the main benefits of biochar [3]. Biochar provides benefits due to its physical properties, including a large surface area, strong adsorption capacity, and alkaline chemical properties with a pH value of 8–11 [4] to improve soil acidity [5]. An average of 10-11% increase in yield was observed with the application of biochar to the soil [6, 7]. The main mechanisms by which biochar promotes plant growth in soil include increased water holding capacity due to its high porosity (providing additional cation exchange capacities) and retention of plant nutrients because biochar is high in soluble K and P. Biochar is increasingly used for soil restoration in large areas; however, processing, low energy density, and high transportation and storage costs of biochar remain one of the major obstacles to its application [8]. The biggest challenge with biochar use is the formation of dust, which can lead to product loss and adverse effects on human health [9]. Seed coatings consisting of several components can increase plant growth in the early stages through seed germination and root extension, which are beneficial in situations where nutrients and water are deficient [10].

Germination of lettuce (*Lactuca sativa L.*) is improved by pelletizing seeds with different coating materials and using inert materials such as diatomaceous sand and binders. Negative effects on seed germination and seedling development have been demonstrated in sweet corn (*Zea mays L.*) (using non-ionic polyacrylamide as coating material) and also in tomato (*Solanum lycopersicum L.*) [11]. Biochar is used as a biochar carrier to improve the environment by increasing germination and seedling development with seed coatings as well as improving the properties of the surrounding soil. Different materials including binders, fillers and active ingredients are added to facilitate various functions in the biochar base seed coating production process. In addition to providing extra nutrients, it plays various roles in the seed coating process stages to reduce direct contact between different layers other than adhesion and cohesion. Biochar is a natural or synthetic polymer and other chemical compounds typically applied in liquid form as binders during seed germination and growth. The most common binders reported for coated seeds include methylcellulose, gum arabic, sodium alginate, starch and lignin. Inorganic compounds such as sodium hydroxide play an important role in polymer synthesis and are therefore sometimes used as coupling agents based on chemical reactions with matrix materials. NaOH is included in the biochar modification process to increase the surface area and improve ion exchange capacities, improving the oxygen-containing component that can adsorb Pb and Cd. Natural biopolymer materials produced from living organisms or renewable resources are considered sustainable and environmentally compatible.

Biochar-based seed coating is seen as a technology that ensures seed germination and early development, thus enhancing the development of ecosystems. Limited published research has focused on biochar-based coating technologies and has shown neutral or negative effects on native species in North America [12]. However, in a field trial with a range of temperate tree species, the addition of biochar to seeds was found to strongly enhance early seedling development [13]. Biochar has also been shown to have significant effects on seed germination and growth. Therefore, biochar is critical for the development of certain seed coatings. Studies on biochar pellets have shown that dry, toasted biochar pellets are less durable than those made with binders [14].

In the study investigating the effects of the combined application of wood vinegar and biochar on seed germination and seedling growth, the addition of wood vinegar to the medium had no effect on the germination of pepper and tomato, while biochar individually increased seedling growth, including root development and aboveground and belowground biomass production. The effects of biochar obtained from rice husk on early development and nutrient content of vegetable seedlings were investigated. The effects of biochar content in seed mixtures on early growth of lettuce, Chinese cabbage and pepper were determined. As the biochar mixture ratio increased, pH increased and nitrogen content decreased. While the highest phosphorus content was obtained with 30% biochar application, significant increases were observed in the weight of lettuce seedlings and P2O5, K2O, MgO and Na concentrations with 30% and 50% biochar applications. Although the weight of Chinese cabbage seedlings increased with 10% biochar application, the increase was not statistically significant. In addition, an increase in the weight of pepper seedlings was observed with 30% biochar application, but this increase was not found to be statistically significant. With the increase in biochar mixture ratio, K2O concentration in pepper seedlings increased, but P2O5, CaO, MgO and Na concentrations decreased. The effect of biochar obtained from corn stalks at 450°C pyrolysis temperature on the yield and quality of tomato (*Solanum lycopersicum L.*) grown in heavy metal contaminated soil was investigated. The inedible part of tomato accumulated 80% and 84% Cu and Zn, while 20% and 16% of this was transferred to the fruit. The inedible part of tomato retained 99.9% and 99.8% Pb and Cd, while less than 0.1% and 0.2% was transferred to the tomato fruit [15]. The effect of sesame (*Sesamum indicum L.*) planted after adding biochar to the soil was investigated on plant growth, seed yield, mineral nutrients and soil properties, and the addition of biochar obtained from rice husk to the soil increased plant height, yield and total seed number per plant [16].

Biomass yield of B. napus and *L. multiflorum* increased by 15%, 46%, 27%, 18%, 59% and 77% with the applied biochar density, respectively Houben et al. 2013. In *Dactylis glomerata* L. cultivation, biochar obtained from temperatures above 860C caused a decrease in Zn concentration and an increase in Cu and Pb concentration in plant tissues. Wagner and Kaupenjohann 2015. n the study investigating the effects of biochar and fertilizer application on the growth and nutrient accumulation of rice and vegetables, the biochar effect was the most prominent in terms of yield. In this study, the effects of biochar nanoparticles on seed germination and seedling growth were investigated. The effects of biochar on seed germination and growth of rice and tomato seedlings were investigated. Biochar obtained from rice straw and wood sawdust was used at 300C (low temperature), 500C (medium temperature) and 700C (high temperature). Biochar inhibited the germination of rice seed at high temperature. However, it was found that biochar significantly increased the root and shoot length of rice seedling and had a stimulating effect on plant growth. In addition, biochar at high temperature had an inhibitory effect on stem growth, which significantly reduced the shoot length and biomass of the plant while increasing the amount of raw material in terms of lignin. The effects of corn biochar produced by slow pyrolysis technique at 450C on seed germination and Glycine max (L.) Merr. were investigated on soybean (Glycine max (L.) Merr.) seed germination and seedling growth under drought stress. Seed viability, germination percentage, shoot length, membrane stability index, chlorophyll and carotenoid contents of soybean seedlings under water stress were significantly decreased compared to control. While protein content and seed germination rate were not significantly affected under drought conditions ($P<0.05$), a significant increase was observed in sugar and proline contents. Biochar mainly decreased sugar and proline content but other parameters were not affected. Therefore, biochar was considered as an effective tool to reduce water stress effect on soybean seedlings.

It was observed that the Ca and Mg amounts increased with the increase in the pyrolysis temperature in the biochars produced at different temperatures using corn cobs and wheat straw, and in the biochars produced using cattle manure, tomato waste and poplar sawdust, the amount of Ca and Mg increased. Applying hazelnut husk biochar obtained by pyrolysis process to the soil not only provides plant nutrients to the soil but also improves the physical properties of the soil [17]. Straw improves the physical and chemical properties of the soil and is a source of nutrients, but the chemical composition of straw depends on soil and weather conditions, it contains an average of 0.5% nitrogen, 0.25% phosphorus, 0.8% potassium, 35% and 40% carbon. It also contains sulfur, calcium, magnesium, nutrients (boron, copper, manganese, molybdenum, zinc, cobalt) [18]. In previous studies, the effects of combinations of biochar prepared by mixing it with farm manure and mineral fertilizers used as soil conditioners in plant production at different rates on improving soil structure and seed germination were investigated. The study reported that biochar provides benefits in terms of increasing soil fertility, improving plant yield and reducing greenhouse gas emissions. Nowadays, the effect of adding biochar to the plant growing medium on seed germination and seedling and plant development of plant species is being investigated. The effect of biochar obtained from chicken manure (300° and 700°C pyrolysis with 1% dose concentration) on seed germination and plant biomass in barley was found to be maximum in biochar at 700°C pyrolysis with 1% dose concentration [19].

The effects of biochar on seedling growth and absorption of allelochemicals in corn (*Zea mays L.*) waste were evaluated. Extracts obtained from biochar had no effect on germination percentage. However, extracts obtained from biochar produced at high temperatures significantly inhibited plant shoot growth by an average of 16%. Biochar showed significant differences in their capacity to absorb allelochemicals in corn waste Rogovska et al. 2012. Protecting and improving soil fertility by effectively converting excess wood residues in forest areas into biochar increases the resistance of forests to climate change. In the study examining the effect of biochar on seedling root and soil properties of sugar cane plants grown in pots, it was shown that biochar application provided better development in sugar cane root properties at the seedling stage and biochar application resulted in higher shoot/root ratio. Biochar application increased soil pH and significantly increased the concentration of available P, K and organic matter in biochar with 20% application [7]. Biochar generally increased seed germination in wheat at lower biochar application rates and no effect was observed at higher application rates. Wheat seed germination increased from 93% to 98% with 10 t/ha biochar addition. When the effect of biochar doses obtained from rice husk and wood shavings (1%, 2% and 5%) was examined, shoot and root biomass of seedlings increased significantly with 1% and 2% biochar addition Xiao et al. 2020.

When the relationship between biochar properties and effects on seed germination and plant development was examined, it was determined that some biochars contained phytotoxic compounds. The effects of biochars prepared from wood, paper, wheat hulls and sewage sludge on seed germination and plant development in five plant species (crepe, lentil, cucumber, tomato and lettuce) were examined and negative effects on seed germination were observed. Inhibition of root growth was not detected, but in some cases leaf and stem growth was inhibited. The current development of the effects of biochar on plant growth and the effects were found to be important especially in terms of plant yield. The properties of different biochar types and their effects on the toxicity of heavy metals to germinated sorghum seeds were investigated. The first compounds of biochar were identified as naphthalene, phenanthrene, fluoranthene and pyrene. The most abundant inorganic elements were potassium, calcium, magnesium, sodium, aluminum, iron and manganese, strontium and barium were also found significantly. Heavy metals (Cd, Cu and Pb) were also tested for different biochar types. The adsorption data were well characterized by a Langmuir isotherm with maximum adsorption capacities of Cd(II), Cu(II) and Pb(II) of 20.16, 7.83 and 70.92 mg/g. Biochars were obtained from corncob, eucalyptus, fresh pine or willow by pyrolysis at 550°C and their effects on germination or early growth (root and coleoptile length, dry weight) of corn seeds were investigated. The effect of biochar on maize seed had a significant effect on seed weight and coleoptile weight and length, but no significant effect on root weight [20]. The effects of different biochar doses on germination and seedling growth in pepper (*Capsicum annuum L cv*. Stavros) in two soil types (alkaline soil pH 7.2 and acidic pH 6.1) were investigated. All biochar applications in acidic soil substrates increased seed germination by 53- 67%. Biochar application in alkaline soil substrates did not affect seed germination, while biochar application in acidic soils increased seedling height, it decreased in alkaline soils compared to the control [21]. As seen from the research results mentioned above, it is emphasized that the effect of biomass quality, pyrolysis temperature and application doses on seed germination, plant development and soil structure improvement varies. While this effect varies according to the plant type, it has been observed that the application efficiency is generally positive, but in some studies the effect has developed negatively for various reasons.

2. Materials and Methods

In the first part of the study, the effect of biochar obtained from chicken manure on pepper germination characteristics was investigated at 8 different doses (0.25%, 0.50%, 1%, 1.5%, 2%, 2.5%, 5%, 7.5%). The chicken manure biochar and its application doses that provided the highest germination properties among the applications were determined, and the effects of these application doses on the germination properties of pepper under low/high temperature stress were investigated. Considering the data obtained from germination experiments; the effect of the application doses providing the highest germination characteristics among the applications on the emergence and seedling development characteristics of pepper was determined.

2.1 Biomasses Used in the Research and Pyrolysis Process

In the research, biomasses with different properties that are commonly found in our country, difficult to dispose of and/or cannot be evaluated in a qualified way were selected. For this purpose, vineyard pruning waste, olive pruning waste, wood shavings, walnut shells, chicken manure and toxin figs were used as biomass. In the study, each biomass was subjected to pyrolysis process separately, only the toxin fig was subjected to pyrolysis process by mixing it with equal amounts (g) of the other 5 biomass, since it was not suitable for pyrolysis process alone -due to its structure- and was defined as dried fig biochar in the study. A fixed-bed stainless steel 6 cm diameter and 21 cm height vertical reactor (V= 1L) was used in pyrolysis experiments. Biomasses (<6 mm grain size) were dried in an oven at 110°C without any size reduction process and experiments were carried out on dry biomass. After loading 100 g of biomass for each waste in the pyrolysis process, the reactor content was observed to be gas released when the reactor temperature reached 200°C (the temperature at which the release of volatile substances began) with a heating rate of 20°C/min under nitrogen gas flow (10 ml/min) and pyrolysis was continued. It was heated to the desired reaction temperature (500–650°C) and kept at this temperature for 60 min. The volatile substances formed during the experiments were passed through glass condensation traps cooled with ice-water and the liquid product was collected by condensation in these containers. The non-condensable volatile products (gas product) were collected in the gas bag . At the end of the experiment, the reactor was cooled to room temperature under nitrogen gas. The solid product (biochar) in the reactor content and the liquid product collected in the traps were weighed and the yield was calculated with the formula below. Product yield, % = (product amount, g/ biomass amount, g) x 100. The volatile substances formed during the experiments were passed through glass condensation traps cooled with ice-water and the liquid product was collected by condensation in these traps. The non-condensable volatile products (gaseous product) were collected in the gas bag. At the end of the experiment, the reactor was cooled to room temperature under nitrogen gas. The liquid product condensed in ice-water cooled traps during pyrolysis consisted of two phases. The oily phase was found in the lower part and the aqueous phase was found in the upper part. Biochars obtained from biomasses after pyrolysis process.

2.2 Germination Tests

In the germination tests, no treatment was applied to the control group seeds, and biochars obtained from 6 different biomass were applied at 8 concentrations (0.25%, 0.50%, 1%, 1.5%, 2%, 2.5%, 5%, 7.5%) to determine the effectiveness of different application doses. For germination tests, seeds were subjected to 4 replications and 50 seeds per replication under the conditions specified in the ISTA rules. Seeds were planted between paper in petri dishes, control seeds were moistened with only pure water, and the treated petri dishes were moistened with biochar water prepared at the specified dose. Germination tests were carried out in an incubator set at 25ºC for pepper seeds, 20ºC for lettuce and 25ºC for celery seeds. Seeds were checked daily after planting, counted daily and seeds with a radicle length of 2 mm were accepted as germinated. Germination rate (%), average germination time (days) and germination homogeneity coefficient were determined with the data obtained at the end of the germination tests. These features were calculated according to the formulas given below. Germination Rate (%): Germination rate (%) values were calculated by summing the daily counts as a result of the germination tests and taking the arithmetic average of the repetitions. The following equation suggested by Larsen and Andreasen (2004) was used in calculating the germination power [22].

Germination power = $\sum n / N \times 100$
n: Number of germinated seeds
N: Total number of seeds planted

Average Germination Time (days): Average germination time (MGT 50) will be calculated from daily counts made in germination tests calculation.

Average germination time = $\sum(g \times n)/Sn$ g: The day of the count
n: Number of seeds germinated on the day of counting
Sn: Total number of germinated seeds at the end of the test
Germination uniformity: The following equation suggested by researchers was used to calculate germination uniformity (GU). = $\sum n \sum[(Fn-t)\ 2.n]$; n: Number of germinated seeds/ (Fn-t): Average germination time (days).

2.3 Statistical analysis

The obtained data were evaluated in the statistical package program (JMP, Version 8, SAS Institute Inc.) according to the randomized plots trial design, and the differences between the applications were determined by the Tukey test ($P \leq 0.05$) [23].

3. Results and discussion

Effect of chicken manure biochar of Capsicum annuum L. general properties. The effect of chicken manure biochar application doses on the germination rate of pepper seeds was found to be statistically insignificant (Fig.1). At the same time, Bieser et al. (2022) reported in his study that biochar applications had negative effects on lettuce and radish seed germination and seedling development [24]. High seed germination is very important for applications to affect plant development parameters. The effect of chicken manure biochar application doses on the germination time of pepper seeds was found to be statistically significant. As the application doses increased, seed germination time decreased. In control seeds, seed germination time increased. The effect of chicken manure biochar application doses on the homogeneity coefficient of pepper seeds was found to be statistically insignificant.

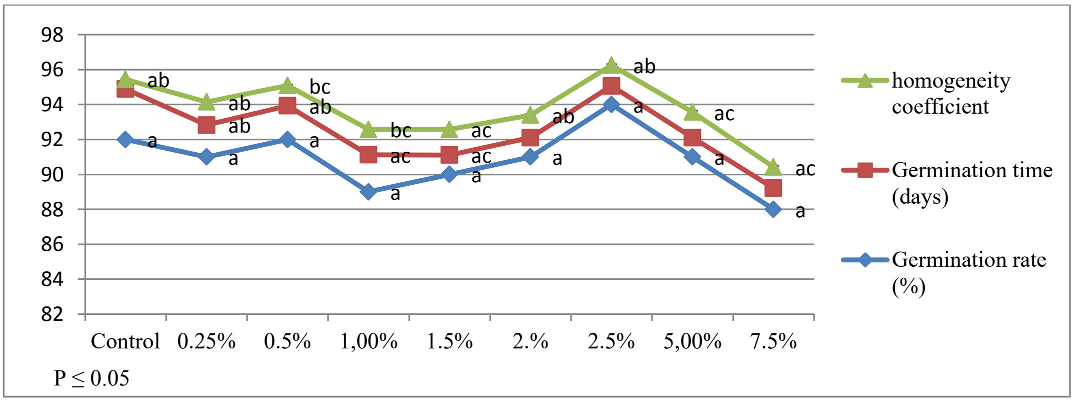

Figure 1: Effect of Chicken Manure Biochar of Capsicum Annuum L

General properties the effect of chicken manure biochar applications on the amount of chlorophyll in pepper was found to be statistically significant. The highest amount of chlorophyll was found at the 0.25% and 0.50% doses, while the lowest amount of chlorophyll was found at the 1.00% dose together with the control (Table 1. ve Fig. 2). In other words, as the dose of chicken manure biochar applications decreases, the amount of chlorophyll in pepper Capsicum annuum L. generally increases, while at high application doses, the amount of chlorophyll decreases. As seen in figure 2, the differences in the sowing between the application doses of chicken manure biochar are illuminated. The application dose of chicken manure biochar decreases chlorophyll and there is organic matter in chicken manure. The effect of high dose chicken biochar on plant seed germination may show different results.

Biochar application dose	Chicken manure biochar	
Control	26.40	c
0.25%	28.84	a
0.50%	29.17	b
1.00%	25.78	bc
Average	27.55	c
LSD	0.62*	

Table 1: Effect of Biochar Applications on Pepper Chlorophyll Content (Spad) in Pepper

There is a lot of salt in chicken manure. Salinity is a negative factor, especially in seed germination. It causes both seed germination and plant development to lag behind in later periods.

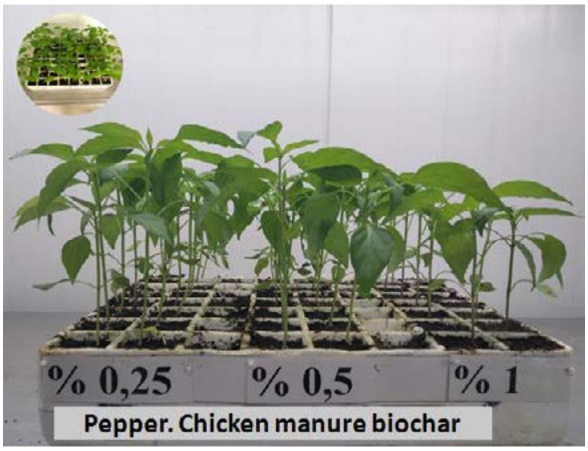

Figure 2: Effect of Chicken Manure Biochar of Capsicum Annuum L

The effect of chicken manure biochar obtained by pyrolysis at 500oC on Capsicum annuum is as seen in the above results; while it has a positive effect at low application doses (0.25% and 0.50%), it has a negative effect on Capsicum annuum at high application dose (1%).

Effect of biochar applications on pepper traits under low temperature stress conditions

The effect of biochar applications on pepper was investigated under low temperature stress conditions. In low temperature stress conditions, the effect of low application dose and high application dose biochar applications on pepper characteristics was negatively affected when compared to the control. The seed germination rate of chicken manure biochar applications was found to be 14% effective at 0.25% and 0.50% application doses (fig.3). The germination time of pepper decreased in the application doses when compared to the control.

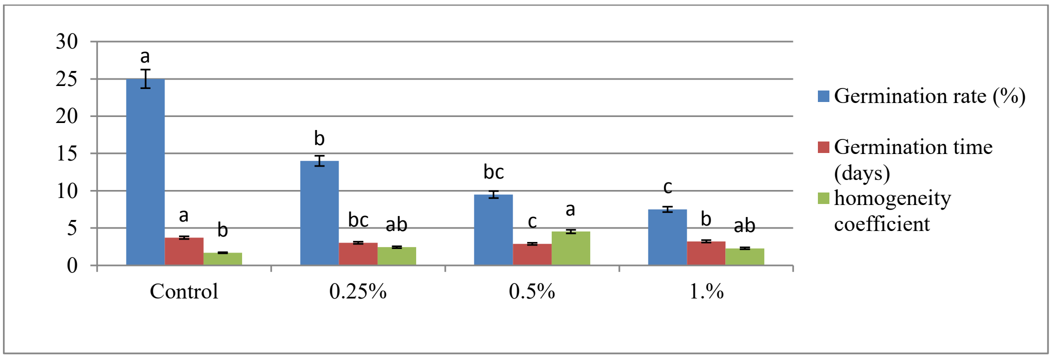

Figure 3: Effect of Biochar Applications on Pepper Under Low Temperature Stress Conditions

The effect of biochar applications on pepper was investigated under low temperature stress conditions. In low temperature stress conditions, the effect of low application dose and high application dose biochar applications on pepper characteristics was negatively affected when compared to the control. The seed germination rate of chicken manure biochar applications was found to be 14% effective at 0.25% and 0.50% application doses (fig.3). The germination time of pepper decreased in the application doses when compared to the control.

4. Conclusion

In the research, biochars obtained from agricultural biomass (chicken manure) at 500°C pyrolysis temperature were

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applied at 8 different doses (%0.25, 0.50%, 1%, 1.5%, 2%, 2.5%, 5%, 7.5%). The effects of biochars and application doses on germination rate, germination time, homogeneity coefficient and seedling development parameters in pepper were investigated. In the light of the obtained findings, the doses that affected the germination properties at the highest level were selected for all biochars and their effects on germination properties under heat stress conditions were evaluated. Low application doses of all biochars (%0.25, %0.50, %1) increased seed germination rates compared to control, while the effect of high application doses (%2, %2.5, %5, %7.5) varied depending on biochar type. Germination time decreased at 0.25% chicken manure application doses. Homogeneity coefficient varied depending on all application doses. 0.25% chicken manure biochar application dose increased germination rate under high temperature stress conditions. Chicken manure biochar applications increased pepper chlorophyll. Biochar applications generally increased chlorophyll amount in examined plant species. The obtained results showed that biochar applied at the right dose increased germination rate, shortened germination time and positively affected plant development. When the results obtained are evaluated together, it is shown that biochar applications can be used effectively in improving germination properties of the examined plant species, increasing seedling quality and improving germination properties under heat stress conditions [25-31].

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