OPEN ACCESS

Plant Health 04 (01) 2025. 01-12

DOI: 10.33687/planthealth.04.01.5239

Check for updates

Available Online at EScience Press

Plant Health

ISSN: 2305-6835

https://esciencepress.net/journals/planthealth

Effect of Biochar on the Performance of Exotic Lettuce Cultivars

[a]Muhammad Asghar, [a]Abdul Mateen Khattak, [a]Ahmad Farooq*, [b]Razia Bibi, [a]Manzoor Ahmad, [c]Aamir Khan, [a]Shahbaz Ahmad, [a]Waqas Habib, [d]Tariq Rahim, [e]Ghani Gul

a Department of Horticulture, The University of Agriculture Peshawar 25000, Pakistan.

b Department of Botany, University of Science and Technology Bannu, Pakistan.

c Directorate of Agriculture Extension Khyber Pakhtunkhwa, Pakistan.

d Department of Agriculture Extension and Communication, The University of Agriculture Peshawar, Pakistan.

e Directorate of Agriculture Research Merged Area, Khyber Pakhtunkhwa, Pakistan.

ARTICLE INFO

Article History

Received: January 17, 2025

Revised: March 29, 2025

Accepted: May 17, 2025

Keywords

Lettuca sativa

Organic farming

Red Laurel

Miky white

ABSTRACT

Lettuce is one of the most important crops used for commercial purposes. For organic lettuce production, a study on the effect of biochar on the performance of exotic lettuce cultivars was conducted in a randomized complete block design with two factors in a split-plot arrangement. There were five different concentrations of biochar (0, 6, 12, 18, and 24 tons ha^{-1}) and five lettuce cultivars (Cv.) Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White. The biochar treatments were assigned to main plots, while subplots were allotted to lettuce cultivars. Lettuce seedlings germinated in pots were transplanted to the field after five weeks of sowing. Prior to transplanting, biochar was applied to the soil as per the required concentrations. The results showed significant differences among the cultivars as well as the biochar concentrations regarding most of the parameters studied. The Lettuce Cv. Red Laurel produced maximum fresh and dry head weight. Maximum plant height was recorded for Cv. Red Oak-leaf. The maximum number of leaves, head diameter, head height, root length, seed yield, and leaf area were noted in Cv. Milky White. Cultivar Romaine took the maximum days to flowering, days to seed production, and seeds per plant. It also resulted in maximum chlorophyll content and the best taste. Regarding the biochar concentrations, maximum plant height, leaf area, number of leaves, head diameter, days to flowering, root length, head height, seed yield, days to seed production, chlorophyll content, fresh head weight, and dry head weight were produced by plants supplied with 24 tons ha^{-1} biochar. The experiment concluded that biochar had good effects on the growth and development of lettuce and would be useful for the organic production of the crop.

Corresponding Author: Ahmad Farooq

Email: farooqwazir61@gmail.com

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is a leafy vegetable that belongs to the Compositae family. It is the first commercially grown salad crop that is marketed globally. It has an ancient history being cultivated since 550 B.C.; however, its appearance occurs in artwork of a 4500-year-old Egyptian tomb, indicating its much older past (Karam *et al*., 2002; Duke *et al*., 2007; Mou, 2008). Globally, lettuce is cultivated on 1.29 million hectares, with a total production of approximately 29.7 million tons. In Pakistan, lettuce is cultivated on an area of 258 hectares, with a total production of 278 tons (Mou, 2008; FAOSTAT, 2021; MNFSR, 2024). In China and Egypt, its stems are cooked, pickled, dried, eaten raw, or made into

 DOI: 10.33687/planthealth.04.01.5239

a sauce; its leaves are sometimes used in cigarettes that are free of nicotine (Mou, 2008).

It is a valuable source of carbohydrates, proteins, fatty acids, dietary fiber, vitamin E and C, lutein, phenols, calcium, potassium, iron, phytochemicals, and carotenoids. These nutrients play a crucial role in protecting important biological constituents, such as DNA, lipoproteins, and cell membranes, from oxidative damage, thereby promoting overall health and well-being (Hooper and Cassidy, 2006; Szeto *et al.,* 2004). It is fat-free and primarily composed of water, making it a low-calorie vegetable. It is favored by individuals looking to reduce body weight while still obtaining essential nutrients (Maboke, 2009; Kim *et al*., 2016).

Biochar is the carbon-rich product obtained from feedstock (wood, manure, straw, sludge, etc.). The feedstock undergoes a pyrolysis process at 300-900 °C in an oxygen free condition. A liquid, gaseous, and solid product is formed during the process; the solid material is known as biochar (wang and wang, 2019). Biochar has a high pH, large surface area, and highly porous biomass. It has a positive influence on soil and can enhance plant growth as other organic wastes like manure and compost (Gul *et al*., 2015; Gull and Whalen, 2016). It can improve soil organic matter content, buffering capacity, cation exchange capacity, water holding capacity, and soil aeration; it can mitigate abiotic stress, ultimately benefiting overall plant and soil health (Patel *et al*. 2017; Luo *et al*., 2017; Anwar *et al*., 2015; Lehmann and Joseph, 2015). Moreover, it helps in improving cation exchange capacity, which increases nutrient retention and availability in soil, which can indirectly affect pH balance (Lehmann and Joseph, 2015). Considering the importance of lettuce and biochar, an experiment was conducted with the following objectives: (1); To assess the effect of biochar on the production of lettuce cultivars. (2): Producing organic lettuce. (3): To see whether any interaction exists between the lettuce cultivars and biochar concentrations.

MATERIALS AND METHODS

Experimental design

The experimental trial was conducted in a Randomized Complete Block Design with a split-plot arrangement. The main plots were assigned to different biochar levels (0, 6, 12, 18, and 24 tons ha^{-1}), while the subplots were assigned for different cultivars (Cv. Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White). In total, there were 25 treatments, and each treatment was replicated three times, resulting in a total of 75 experimental units. The biochar was procured from a market in Peshawar, while lettuce seeds were obtained from Department of Horticulture, The University of Agriculture Peshawar, Pakistan.

Experimental procedures and cultural practices

Seeds of lettuce cultivars were sown in plastic pots (18'' Length x 10'' Diameter). Silty loam soil was collected from the Ornamental Nursery at The University of Agriculture Peshawar, Pakistan. The pots were filled with leaf mold and silty loam soil in 1:1. Instantly after sowing, sprinkle irrigation was applied. The pots were placed in a plastic tunnel to protect them from unfavorable environmental conditions. Depending on the cultivar, the seeds took 10 to 15 days to germinate. When the seedlings reached 3-4 leaves stage, they were transplanted to the field. After reaching optimal vegetative growth half of the plants were harvested for analysis and others were left for seed production. Throughout the growing period, measures were taken to control insects, pests and diseases, and other cultural practices were performed as needed.

Studied parameters

Data were recorded on Plant height (measuring tape), Head diameter (measuring tape), Head height (measuring tape), Head fresh weight (digital balance Hytek Sf-400 C), Head dry weight (digital balance Hytek Sf-400 C), Number of leaves $plant^{-1}$, Leaf area (leaf area meter CI-201), Chlorophyll content (SPAD meter Konica Minolta Spad-502 plus), Taste, Days to flowers, Days to seed production and Seed yield.

Statistical analysis

The data were analyzed with the statistical software "STATISTIX 8.1" using the two-way analysis of variance (ANOVA) technique (Steel and Torrie, 1980). The least significant difference test (LSD) was used for means comparison in case the data were significant at the 5% significance level (Williams and Abdi. 2010).

RESULTS

The data relating to head diameter, head height, head fresh weight, and head dry weight are presented in Table 1. The data No. of leaves $plant^{-1}$, Leaf area, Chlorophyll content and Taste are presented in Table 2. The data of Plant height, days to flowers production, Days to seed production, and Seed yield (ton ha^{-1}) are

 DOI: 10.33687/planthealth.04.01.5239

presented in Table-3. Statistical analysis shows that there were significant differences among the lettuce cultivars ($P \leq 0.01$) as well as Biochar concentrations ($P \leq 0.05$) in terms of head diameter, head height, head fresh weight, head dry weight, No. of leaves plant^{-1}, Leaf area, Chlorophyll content, Taste, Plant height, days to flowers production, Days to seed production and Seed yield (ton ha^{-1}). The interaction between Biochar concentrations and lettuce cultivars was non-significant.

Plant height (cm)

The means concerning biochar concentration revealed that maximum plant height (147.0 cm) was observed in 24 tons ha^{-1}, while the minimum plant height (141.7 cm) was recorded in control. The means regarding plant height of cultivar showed that the maximum plant height (158.2 cm) was shown by Cv. Red oak-leaf followed closely by Cv. Milky white (148.8 cm). The minimum plant height (128.5 cm) was produced by Cv. Large speed. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved plant height of 101.55%, 90.68%, 111.64%, 99.80%, and 105%, respectively. Among the lettuce cultivars, the Red Oak-leaf cultivar had the maximum plant height. Lettuce cultivars are divided into categories; each cultivar has a specific growth and environmental variation. These distinct traits make each cultivar suitable for specific growing conditions and offer a diverse range of options for growers to select the most suitable lettuce variety for their needs (Grant 2018). According to Shahbaz (2022) the maximum plant height was detected in open filed while minimum plant height was observed in partial shade. According to Khan (2022) the Cv. Red Oak-leaf produced the tallest plant height among the lettuce cultivars, while Cv. Large Speed produced the minimum plant height. Our findings are similar to Farooq *et al*., (2023), who also observed that Cv. Red Oak-leaf achieved the maximum plant height, while Cv. Large Speed recorded the minimum plant height. Biochar application significantly increase the K element content and provide essential organic matter for plant growth (Lu *et al*., 2014; Rodriguez *et al*., 2019). Biochar application acts as a growth booster for plants and aids in nutrient retention in the soil, thereby positively affecting plant growth (Kurniawan *et al*., 2016). Higher doses of biochar results in an increase in organic carbon content soil and subsequently support plant growth (Githinj 2014). Our results are similar to Upadhyay *et al.,* (2014), who observed that the highest concentration of biochar resulted in the maximum plant height.

Head diameter

Among the various lettuce cultivars, the highest head diameter was observed in Cv. Milky White (35.1 cm), followed closely by Cv. Red Laurel (30.8 cm). Cv. Large Speed and Red Oak-leaf recorded 27.8 cm and 25.1 cm head diameters, respectively. The smallest head diameter was found in Cv. Romaine (23.3 cm). Regarding the biochar concentrations, the maximum (30.1 cm) head diameter was recorded in plants supplied with 24 tons ha^{-1} of biochar, closely followed by 18 tons ha^{-1} concentration (29.5 cm). The minimum head diameter (26.7 cm) was observed in control plants. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved head diameter of 115.36%, 104.12%, 94%, 87.27%, and 131.46%, respectively.

The variations in head diameter among these cultivars can be attributed to genetic differences associated with each group. These specific characteristics contribute to the differences in head diameter observed among the various lettuce cultivars (Gosh, 2019). It was found that lettuce grown in an open field displayed the largest head diameter compared to the lettuce plants grown under partial shade. This difference in head diameter suggests that sunlight availability plays a significant role in influencing the growth and development of lettuce heads, with greater exposure to sunlight resulting in larger head sizes (Shahbaz, 2022). Our results are similar with Farooq *et al*., (2023), whose findings indicated that the Cv. Milky White lettuce cultivar recorded the maximum head diameter, while Cv. Romaine lettuce achieved the minimum head diameter.

Biochar can enhance soil water retention capacity, facilitating better water absorption by the plant. Improved nutrient absorption promotes optimal photosynthesis, which results in good plant production (Kusumaningrum *et al*., 2007). Galadima *et al*., (2020) studied the effects of biochar application on lettuce head diameter during two cultivation periods, significant differences were observed compared to the control group. The plant head diameter significantly increased by 30 tons of biochar application, while the control produced the lowest head diameter. Our results are similar with Awad *et al*., (2017), who observed higher head diameter in lettuce plants with the concentration of 20 tons of biochar.

Head height (cm)

Mean values regarding biochar concentrations show that the maximum (46.6 cm) head height was observed in plants that were treated with 24 tons ha^{-1}, while the minimum (37.2 cm) head height was observed in the control. The means of cultivars revealed that the maximum (46.6 cm) head height was attained by the Cv. Milky White, followed by Cv. Romaine with 42.1 cm head height, while Cv. Large speed resulted in minimum head height (32.6 cm). Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved head height of 104.30%, 87.63%, 94.62%, 113.17%, and 125.27%, respectively.

Lettuce cultivars are classified into various distinct categories, each exhibiting unique growth characteristics and adaptability to specific environmental conditions (Grant, 2018). Romaine varieties, for instance, exhibit upright growth with tightly folded leaves, typically reaching heights of 20-25 cm. In the current study, Cv. Milky White displayed the highest head height, which could be attributed to the genetic potential of the cultivar. These findings align with previous research by Afton (2008), who observed that romaine lettuce produced taller heads compared to crisp head lettuce, which formed smaller heads. Furthermore, our studies are consistent with the findings of Farooq *et al*., (2023), who also reported that the Cv. Milky White achieved the maximum head height, while the Cv. Large Speed exhibited the minimum head height.

The application of biochar has been found to enhance soil water retention, fertility, and crop yield (Awad *et al*., 2017). Biochar plays a crucial role in nitrogen retention by minimizing leaching and gaseous losses, thus promoting better nutrient retention in the soil. It enhances phosphorus availability by reducing the leaching process, leading to improved nutrient utilization in the soil (Jeffery *et al*., 2011; Zhang *et al*., 2012). Our results are similar with Subedi *et al*., (2016), Lin *et al*., (2015), and Liu *et al*., (2017), who all observed that higher concentrations of biochar significantly influenced the head height of different vegetables.

Head fresh weight (g)

The mean value regarding biochar shows that the maximum head fresh weight $plant^{-1}$ (441.3 g) was produced by 24 tons ha^{-1}, while the minimum head fresh weight $plant^{-1}$ (397.5 g) was produced by control. In case of cultivars, the highest head fresh weight was recorded in the Cv. Red Laurel with an average weight of 500.4 g, followed closely by Cv. Large Speed (448.3 g). On the other hand, the lowest head fresh weight was observed in the Cv. Red Oak-leaf, with an average weight of 294.3 g. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved head fresh weight of 125.90%, 112.80%, 74%, 107.12%, and 106.50%, respectively. Lettuce cultivars have more leaves, resulting in higher fresh and dry mass of leaves. These differences in growth and yield can be attributed to the genetic characteristics of each cultivar Reshma *et al*., (2007). According to Shahbaz (2022), the maximum head fresh weight was observed in open filed while the minimum head fresh weight was observed in partial shade. Plant fresh weight is a significant parameter that characterizes the process of photosynthesis. Higher fresh weights indicate an efficient photosynthesis process and buildup of assimilate. Khan (2022) reported that the highest head fresh weight was recorded for the Cv. Wrapped Lettuce, whereas the lowest leaf fresh weight was observed for the Cv. Red Oak-leaf. Our studied parameters are in line with Farooq *et al*., (2023) who found that Cv. Red Laurel produced the highest head fresh weight whereas the lowest fresh head weight was noted for Cv. Red Oak-leaf. Adding biochar in soil can enhance soil's water retention capacity, facilitating better water absorption by the plant. Improved nutrient absorption promotes optimal photosynthesis in plants, and the assimilated nutrients are translocated to all parts of the plant, resulting in the production of moist biomass (Kusumaningrum *et al*., 2007). Jia *et a*l., (2012) assessed the effects of biochar on lettuce head weight during two farming stages revealed significant differences between the first and second seasons regarding lettuce head weight, with notably higher values observed in the second season. Our studied parameter is similar to that of Carter *et al*., (2013) and Silitonga *et al*., (2018) who found that the biochar application increases the fresh weight of plants.

Head dry weight (g)

The head dry weight data showed that Cv. Red Laurel exhibited the highest head dry weight (32.6 g), followed closely by Cv. Large Speed (31.9 g). On the other hand, Cv. Red Oak-leaf had the lowest head dry weight (23.7 g). Concerning the biochar concentrations, the maximum (30.4 g) head dry weight was produced by plants applied with 24 tons ha^{-1} biochar, closely followed by 18 tons ha^{-1} (29.3g) and 12 tons ha^{-1} (29.1g) biochar concentrations. The minimum head dry weight (27.9g) was produced in control. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved head dry weight of 116.85 %, 114.34 %, 84.95 %, 105 %, and 97.50 %, respectively. An increase in the number of leaves and the fresh weight of the lettuce head effects dry weight of lettuce cultivars. The dry weight of plant leaves is an indicator of its accumulated mass as a result of photosynthesis. As a result, more leaves and higher fresh weight of the head contribute to an overall rise in the dry weight of lettuce plants (Atikah and Widyawati, 2019). According to Shahbaz, (2022), maximum head dry weight was observed in open field while minimum was recorded in partial shade. According to Rahayu *et al.*, (2022) and Khan (2022) Cv. Wrapped Lettuce Showed the highest leaf dry weight per plant, while Cv. Red Oak-leaf had the lowest leaf dry weight per plant. Our study in line with Farooq *et al.*, (2023) Cv. Red Laurel exhibited maximum dry head weight while Minimum dry weight was recorded for Cv. Red Oak-leaf. Biochar when added to soil, it can impact soil properties and enhance nutrient use efficiency in crops (Kusumaningrum *et al.*, 2007). Applying biochar to plants with the proper dosage can enhance microbial activity in the soil, leading to increased accessibility of organic material. This ideal organic substance in soil positively influences plant growth and expansion (Warnock *et al.*, 2007). Shen *et al.*, (2020) reported that dry weight of the plants treated with biochar was highest in the group receiving biochar treatment. The best performance was observed in the group receiving 30% biochar, resulting in the highest average dry weight yield. Our studied parameter is similar with Silitonga *et al.*, (2018) who found that the biochar application increases the plant's dry weight.

Number of leaves plant^{-1}

The means concerning biochar concentration showed that the plants grown in 24 tons ha^{-1} produced the maximum number of leaves plant^{-1} (33.1). Whereas, those grown in control formed the minimum number of leaves plant^{-1} (31.8). The means concerning among the cultivars revealed that the maximum number of leaves (38.4) was produced by Milky white, followed closely by Cv. Romaine and Red laurel 36.3 and 31.0, respectively. Whereas the minimum number of leaves plant (26.1) was produced by Cv. Large Speed. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved 97.48 %, 82 %, 85.53 %, 114.15 %, and 120.75 % leaves plant^{-1}, respectively. Lettuce cultivars exhibit diverse responses concerning growth and yield constraints. The variation in the number of leaves is associated with the specific cultivar. Hereditary differences among lettuce cultivars might be responsible for the observed variations in the amount of leaves plant^{-1}. According to Reshma *et al.*, (2007) genetic variation plays a significant role in the cultivar's overall performance and responses to various environmental factors. According to Shahbaz, (2022), maximum leaves were produced in open field and minimum leaves were produced in partial shade. According to Khan, (2022) Cv. Wrapped Lettuce resulted in the maximum number of leaves plant^{-1}, while the minimum leaves plant^{-1} were observed in Cv. Red Oak-leaf. Our study is in line with Farooq *et al.*, (2023) who found that the Cv. Milky White resulted in the maximum leaves and the minimum leaves were observed in Cv. Red Oak-leaf. Biochar application to soil leads to an increase in soil pH, which in turn impacts nutrient availability for plants; as a result, biochar can serve as a prospective nutrient reservoir for plants, making it a valuable soil amendment for improving soil properties and promoting plant growth (Hatyadi, 2015). Biochar can impact the development of leaves, which is influenced by nutrient captivation and accessibility in the soil. This, in turn, may positively influence leaf development and overall plant growth (Surachman *et al.*, 2020). Our results are similar to those of Larosa *et al.*, (2014) and Carter *et al.*, (2013), who observed that biochar application significantly improved the number of leaves in lettuce and Chinese cabbage (*Brassica chinensis*).

Leaf area (cm^2)

The mean values of the Cv. Milky white showed maximum (1487.7 cm^2) leaf area followed by Romaine and Red laurel 1451.8 cm^2 and 1426 cm^2, respectively. While the Red oak leaf produced the minimum (1367.2 cm^2) leaf area. Regarding the biochar concentration, the maximum (1450.4 cm^2) leaf area was recorded in 24 tons ha^{-1} and 18 tons ha^{-1} (1437.8 cm^2) followed by 12 tons ha^{-1} and 6 tons ha^{-1} with 1424.5 cm^2 and 1417 cm^2 leaf area respectively. While minimum leaf area was observed in control (1409.7 cm^2). Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved leaf area of 101.20 %, 99.80 %, 97 %, 103 %, and 105.53 %, respectively. When numerous lettuce cultivars were evaluated in terms of leaf area, Cv. Milky White demonstrated the largest leaf area in contrast to other cultivars. The variations in leaf area observed might be attributed to inherited and genetic traits present in each cultivar. According to Hay and Porter (2006), leaf area is a plant growth trait that is influenced by various factors, including gene expression and metabolic pathways. According to Shahbaz, (2022) maximum leaf area was observed in an open field, while minimum was observed in partial shade. Leaf area is an important parameter that explains the procedure and ratio of photosynthesis in plants. A larger leaf area allows plants to capture more sunlight, leading to increased photosynthesis, growth, and productivity (Hussien *et al*., 2020). According to Khan (2022) maximum leaf area was produced by Cv. Wrapped Lettuce, whereas the Cv. Red Oak-leaf produced minimum leaf area. Our study is in line with Farooq *et al*., (2023) who found that the maximum leaf area was observed in Cv. Milky White, while minimum leaf area was recorded in Cv. Red Oak-leaf. The incorporation of biochar into soil leads to changes in the pore-size distribution, ultimately leading to enhanced water permeability. As a result, water can move more easily through the soil, which can have positive effects on plant growth and water availability for the crops (Asai *et al*.,2009). Biochar prevents the leaching of nutrients and enhances the efficiency of microorganisms in soil, thus improving soil fertility and root growth. When the roots of a plant grow well, they translocate adequate water and mineral nutrients to leaves (Ren *et al*., 2021). Our study is in line with Awad *et al*., (2017), who found that the maximum leaf area is observed in higher concentration of biochar.

Chlorophyll content (SPAD)

The average values of chlorophyll content indicate that Cv. Romaine showed the highest chlorophyll content (44.5 SPAD), followed by Cv. Large Speed (41.5 SPAD). On the other hand, Cv. Red Laurel recorded the lowest chlorophyll content (30.2 SPAD). Regarding the biochar, the mean value showed that the highest chlorophyll content (40.1 SPAD) was observed in the 24 tons ha^{-1} biochar concentration, closely followed by the 18 tons ha^{-1} concentration (39.6 SPAD). The control group exhibited the minimum chlorophyll content (35.8 SPAD). Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved chlorophyll content of 84.36 %, 115.92 %, 100.28 %, 124.30 %, and 109.22 %, respectively.

Among the various lettuce cultivars, Cv. Romaine displayed the highest chlorophyll content, surpassing all the other cultivars. The observed variations in chlorophyll content can be attributed to the genetic differences inherent in each cultivar. These genetic traits play a significant role in influencing chlorophyll production and accumulation; ultimately leading to the observed differences in chlorophyll content among the lettuce cultivars (Cassetari *et al*., 2015). Caldwell and Britz (2006) also observed variances in the chlorophyll content of lettuce cultivars. According to Shahbaz, (2022) the maximum chlorophyll was observed in open field while minimum was recorded in partial shade. Our study is in line with Farooq *et al*., (2023) who found that the maximum chlorophyll content was observed in Cv. Romaine while minimum chlorophyll content was observed in Cv. Red Laurel.

Compared to the control treatment, the biochar addition resulted in a considerable increase in total chlorophyll. The lower chlorophyll concentration in the control treatment might be due to the inhibition of certain enzymes required for chlorophyll production as well as decreased mineral absorption, such as Mg, which is required for pigment synthesis. The biochar amendment likely facilitated a more favorable environment for chlorophyll synthesis and nutrient uptake, resulting in the observed increase in total chlorophyll content (kazemi *et al*., 2010). Wang (2010) found that wheat leaves chlorophyll content was enhanced with biochar application. Our findings are in line with Afsharipoor *et al*., (2011) and Narkheda *et al*., (2011), who reported that the biochar enriched chlorophyll content in vegetables grown in organic-amended soil.

Taste

The taste data showed that Cv. Romaine exhibited the most favorable taste with a score of 9.0 out of 10, followed by Cv. Large Speed and Red Laurel with the taste scores of 8.5 and 6.7, respectively. On the other hand, Cv. Red Oak Leaf and Milky White had the lowest taste scores of 5.0 and 5 out of 10, respectively. It's important to note that both Cv. Red Oak Leaf and Milky White lettuce had an unpleasant taste. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved taste score of 100 %, 126.87 %, 74.63 %, 134.33 %, and 74.63 %, respectively. Lettuce cultivars are classified into 5 distinct sets, each possessing its own unique flavor, texture, and adaptability to various environmental conditions. These diverse groups offer a wide range of options for growers, allowing them to select the cultivars that best suit their preferences and the specific conditions of their growing environments (Grant 2018). Crisphead lettuce is characterized by a mild flavor and a crunchy texture, providing a refreshing eating experience. In contrast, Romaine lettuce offers a slightly sweeter and more pronounced taste, adding a bold flavor profile to salads and dishes. On the other hand, Red Oak-leaf lettuce is renowned for its crispness and mild flavor, making it a popular choice among lettuce varieties (Kim *et al*. 2016). During our research, we found that the Romaine and Large Speed cultivars exhibited a fragrant and desired taste, whereas Cv. Milky White had an unpleasant taste. These distinctive taste variations among lettuce cultivars can be attributed to genetic differences and variations in their genetic makeup. Genetic factors play a crucial role in shaping the taste profile of each lettuce cultivar, contributing to the observed differences in taste during our study. According to Shahbaz (2022) the maximum taste was recorded in partial shade while minimum was observed in open field. Our study is in line with Farooq *et al*., (2023) who found that the Cv. Romaine had the best taste, with a score of 7.8 out of 10, while cultivars Red Oak-leaf and Milky White showed similar taste scores, both receiving the minimum scores of 3.7 and 3.6 out of 10, respectively. Additionally, they observed that Cv. Milky White had an unpleasant taste.

Days to flower

The mean data indicates that Cv. Romaine had the longest time to flowering, taking approximately 168.3 days, following closely behind, Cv. Red Oak leaf took about 117.6 days to reach flowering. Cv. Red Laurel and Large Speed had similar flowering times, with both taking approximately 153.5 and 151 days, respectively. On the other hand, Cv. Milky White had the shortest time to flowering, requiring only about 143.7 days. Among the biochar concentrations, maximum days to flowering (158.3) were recorded for 24 tons ha^{-1} concentration, closely followed by 18 tons ha^{-1}, 12 tons ha^{-1} and 6 tons ha^{-1} having means which took 157.2, 156.1 and 153.7 days to flowering, respectively. Minimum days to flowering (151) were taken by control plants. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White took 101.66 %, 100 %, 106 %, 111.46 %, and 95.17 % days to flowering, respectively. Lettuce cultivars displayed notable variations in the number of days required to reach flowering. In this context, Cv. Milky White and Cv. Red Oak-leaf exhibited the shortest time to flowering when compared to the other cultivars. Factors such as flowering time can influence the overall growth and productivity of lettuce crops, making the choice of cultivar a critical decision for growers (Olasantan, 2007). These differences in flowering time could be attributed to genetic variation among the cultivars. According to Shahbaz, (2022), the maximum days to flowering were observed in an open field, while the minimum days to flowering were recorded in partial shade. According to Khan, (2022) the Cv. Red Laurel took minimum days to flowering, while the Cv. Iceberg took maximum days to flowering. Our study is in line with Farooq *et al*., (2023) who found that the Cv. Romaine took the maximum days to flowering, whereas Cv. Milky White took the minimum days to flowering. The addition of biochar to soil enhances water absorption and aids in the uptake of chemical nutrients. The optimal nutrient absorption can lead to increased photosynthesis in plants (Kusumaningrum *et al*. 2007). Organic matter in the soil helps growth and improvement in plants. Biochar interferes in soil carbon content which leads to change in C:N ratio and microbial population. This increase in C:N ratio delay flowering (Warnock *et al*., 2007; Galinato *et al*., 2011). Our results are in line with Yuan, (2012), who found that flowering was delayed with increasing the level of biochar.

Days to seed production

The mean data indicated that Cv. Romaine had the longest time to reach seed production, taking approximately 189.3 days, following closely behind, Cv. Red Laurel took approximately 178.5 days to seed production. On the other hand, Cv. Milky White had the shortest time to seed production, taking only about 168.4 days. Among the various concentrations of biochar, the longest time to seed production (186.2 days) was observed in plants treated with 24 tons ha^{-1}, although it was statistically similar to plants treated with 18 tons ha^{-1} (181.3 days), 12 tons ha^{-1} (178.8 days), and 6 tons ha^{-1} (175.7 days). On the other hand, the shortest time to seed production (172 days) was recorded in the control group. Compared to the control, cultivars Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White took 103.78%, 101.74%, 106.45%, 110%, and 97.91% days to seed production, respectively. Perwelbaum (2010), reported that flowering time varied among the lettuce cultivars. The process of seed formation usually occurs within the window of 12 to 21 days after anthesis. It was observed that cultivars Milky White and Large Speed had shortest time to flowering among the lettuce cultivars. This early flowering in these specific cultivars consequently led to a reduced duration required for seed production. As a result, the quicker flowering process of Milky White and Large Speed cultivars likely contributed to their faster seed production compared to the other lettuce cultivars. Conversely, other cultivars with delayed flowering also experienced delayed seed production. Khan (2022) observed that Cv. Red Laurel exhibited the shortest duration to seed production, while Cv. Iceberg took the longest time to reach seed production. These findings are consistent with Farooq *et al*., (2023), who observed that Cv. Romaine had the longest duration to seed production, while Cv. Milky White had the shortest duration to seed production. Biochar has various reimbursements when added to the soil. It enhances soil physical and chemical properties, promotes soil biological operations, detoxifies soil impurities and improves plant health. The addition of biochar to the soil enhances soil fertility and overall soil properties (Haider *et al.,* 2017; Liu *et al*., 2017). The very porous structure and wide surface area of biochar are crucial physical properties. This porosity and surface area create an ideal environment for soil microorganisms such as mycorrhizae and bacteria. Additionally, the porous structure of biochar facilitates essential nourishing cations and anions, enhancing nutrient availability in the soil (Nelissen *et al*., 2015; Galinato *et al*., 2011). The days to seed production delayed. The results are in line with Yuan (2017), who observed that biochar delayed flowering.

Seed yield (tons ha^{-1})

The means regarding the biochar concentration showed that the plants supplied with 24 tons ha^{-1} biochar produced maximum (1.98 tons ha^{-1}) seed yield, closely followed by those supplied with 18 tons ha^{-1} and 12 tons ha^{-1} biochar, producing 1.97 tons ha^{-1}, and 1.92 tons ha^{-1} seed yield, respectively. Plants grown in the control treatment achieved minimum (1.84 tons ha^{-1}) seed yield. The means regarding the lettuce cultivars showed that maximum (2.24 tons ha^{-1}) seed yield was achieved by Cv. Milky White, followed by Cv. Romaine (2.15 tons ha^{-1}) and Cv. Red Laurel (2.06 tons ha^{-1}). Minimum seed yield (1.33 tons ha^{-1}) was recorded for Cv. Red Oak-leaf. Compared to control cultivars. Red Laurel, Large Speed, Red Oak-leaf, Romaine, and Milky White achieved seed yield of 111.96%, 100%, 72.28%, 116.85%, and 121.74%, respectively. Among the lettuce cultivars, Cv. Milky White had the greatest seed production. Genetic diversity might explain the variance in seed output among cultivars. Each cultivar's unique characteristics play a crucial role, as some have a greater capability to produce higher yields than others (Zhao and Carey, 2009). Additionally, the difference in growing periods contributes to the diverse seed yield outcomes, as lettuce cultivars have varying times to maturity that influence their overall seed production (Zhao and Carey, 2009). These findings align with Welbaum (2010), who reported a wide range of seed yield for lettuce cultivars, spanning from half to two tons per hectare. According to Shahbaz, (2022), maximum lettuce seed yield was observed in an open field, while the minimum seed yield was observed in partial shade. Cv. Khan (2022) reported that Red Laurel had the highest seed output, while Cv. Wrapped Lettuce had the lowest. Our results are in line with Farooq *et al*., (2023) who observed that Cv. Milky White resulted in maximum seed yield, while minimum seed yield was observed in Cv. Romaine. The application of biochar increases production by improving soil structure (Zheng *et al*., 2017; Sun *et al*., 2020). Sahin *et al*., (2017) stated that biochar in calcareous soil improved significantly the lettuce seed yield. Kammann *et al*., (2011) found that biochar on sandy soil improved plant development. Our findings corroborate those of Gunes *et al.,* (2014 and 2015), who observed maximum seed yield with the application of biochar.

CONCLUSION

Plants supplied with the biochar concentration of 24 tons ha^{-1} demonstrated maximum performance in various growth and production parameters: head diameter, fresh head weight, dry head weight, root length, days to flowering, days to seed production, seed yield (tons ha^{-1}), number of leaves plant^{-1}, head height, plant height, chlorophyll content, and leaf area. This suggests that the application of 24 tons ha^{-1} of biochar had a positive influence on the overall growth and productivity of the lettuce plants, leading to enhanced performance in multiple aspects of their development. The maximum fresh head weight was recorded for Cv. Red Laurel. On the other hand, Cv. Milky White produced the highest number of leaves and seed yield (tons ha^{-1}).

However, despite its high yield, Cv. Milky White was not preferred due to its shape and bitter taste. Cultivars Romaine and Large Speed were preferred for their superior taste. Additionally, cultivar Red Oak-leaf exhibited a lower head weight and seed yield, but its attractiveness was enhanced by the presence of red leaves attributed to its high anthocyanin content.

CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

REFERENCES

Afsharipoor, S., T. Poorsadegh. and Z. Gholami. 2011. The assessment of learning on Islamic Azad University branch Firooz-Abad University Students' awareness about AIDS. Iranian Journal of Medical Microbiology, *5*(3), pp.52-60.

Afton, W. 2008. Evaluation of growth characteristics, yield, and marketability and nitrate levels of lettuce (*Lactuca sativa* L.) cultivars produced in south Louisiana. LSU. Master's thesis. 4382.

Anwar, M.R., Li Liu, D., Farquharson, R., Macadam, I., Abadi, A., Finlayson, J., Wang, B. and Ramilan, T., 2015. Climate change impacts on phenology and yields of five broadacre crops at four climatologically distinct locations in Australia. *Agricultural Systems*, *132*, pp.133-144.

Asai, H., B.K. Samson, H.M. Stephan, K. Songyikhangsuthor, K. Homma, Y. Kiyono and T. Horie. 2009. Biochar amendment techniques for upland rice production in Northern Laos. 1. Soil physical properties leaf SPAD and grain yield. Field Crops Res. 11(1):81-84

Atikah TA, Widyawati W (2019) The growth and yield of four varieties of lettuce (Lactuca sativa L.) in different planting media. Eurasia J Biol Sci 13:2085–2091

Awad, Y.M., S.E. Lee, M.B.M. Ahmed, N.T. Vu, M. Farooq, I.S. Kim, Kim, H.S. Vithanage, M. Usman, M. Al-Wabel and E. Meers. 2017. Biochar, a potential hydroponic growth substrate, enhances the nutritional status and growth of leafy vegetables. J. Clean. Prod. 15(6): 581-588.

Caldwell, C.R., and S.J. Britz. 2006. Effect of supplemental ultraviolet radiation in the carotenoid and chlorophyll composition of greenhouse grown leaf lettuce cultivars. J. Food Comp. Ana. 19(6-7): 637-644.

Carter, S., S. Shackley, S. Sohi, T.B. Suy and S. Haefele. 2013. The impact of biochar application on soil properties and plant growth of pot grown lettuce (*Lactuca sativa*) and cabbage (*Brassica chinensis*). Agron. 3(2): 404-418.

Cassetari LS, Gomes MS, Santos DC, Santiago WD, Andrade J, Guimarães AC, Souza JA, Cardoso MG, Maluf WR, Gomes LA (2015) β-Carotene and chlorophyll levels in cultivars and breeding lines of lettuce. Acta Hortic 1083:469–473

De la Rosa, J.M., Paneque, M., Hilber, I., Blum, F., Knicker, H.E. and Bucheli, T.D., 2016. Assessment of polycyclic aromatic hydrocarbons in biochar and biochar-amended agricultural soil from Southern Spain. *Journal of Soils and Sediments*, *16*, pp.557-565.

Duke, J.A., P.A.K. Duke and L.D. Judith. 2007. Duke's Handbook of Medicinal Plants of the Bible. CRC Press. P. 232.

FAOSTAT Statistics of the food and agriculture organization of the united nation. 2021. Accessed 21, June, 2021, from http://wwww.fao.org/faostat/en#data/QC/

Farooq, A., Khattak, A.M., Gul, G., Habib, W., Ahmad, S., Asghar, M. and Rashid, T., 2023. Effect of moringa leaf extract on the performance of lettuce cultivars. *Gesunde Pflanzen*, *75*(5): 1449-1459.

Galadima, M.M., A.L.A. AZİZ, E. YILMAZ, and U.Z. İlker. 2020. Effect of biochar applications on certain quality parameters and lettuce yield (*Lactuca sativa* L.). Mediterr. Agri. Sci. 33(3): 417-424.

Galinato, S.P., Yoder, J.K. and Granatstein, D., 2011. The economic value of biochar in crop production and carbon sequestration. *Energy policy*, *39*(10), pp.6344-6350.

Githinji, L., 2014. Effect of biochar application rate on soil physical and hydraulic properties of a sandy loam. *Archives of Agronomy and Soil Science*, *60*(4), pp.457-470.

Gosh, J. 2019. 18 types of lettuce. http://www.onlyfoods.Net/ types of lettuce. Html. Accessed on 15/Aug/2022.

Grant. A., 2018. Different lettuce types: Varieties of lettuce for garden. Gardening knows how web site. Available at: http://www.Gardening know how.com.

Gul, S. and J.K. Whalen. 2016. Biochemical cycling of nitrogen and phosphorus in biochar-amended soils. Soil Biol. Biochem. 10(3): 1-15.

Gul, S., J.K. Whalen, B.W. Thomas, V. Sachdeva and H. Deng. 2015. Physico-chemical properties and microbial responses in biochar-amended soils: mechanisms and future directions. J. Agric. Ecosyst. Environ. 206: 46-59.

Gunes, A., A. Inal, M.B. Taskin, O. Sahin, E.C. Kaya and A. Atakol, 2014. Effect of phosphorus-enriched biochar and poultry manure on growth and mineral composition of lettuce (*Lactuca sativa* L.) grown in alkaline soil. Soil Use Manag. 30(2): 182-188.

Gunes, A., A. Inal, O. Sahin, M.B. Taskin, O. Atakol and N. Yilmaz. 2015. Variations in mineral element concentrations of poultry manure biochar obtained at different pyrolysis temperatures, and their effects on crop growth and mineral nutrition. Soil Use Manag. 31(4): 429-437.

Haider, G., D. Steffens, G. Moser, C. Mueller and C.I. Kammann. 2016. Biochar reduced nitrate leaching and improved soil moisture content without yield improvements in a four-year field study. Agri. Ecosyst. Environ. 23(7): 80-94.

Hay, R.K. and Porter, J.R., 2006. *The physiology of crop yield* (pp. xiii+-314).

Hooper, L., and A. Cassidy.2006. A review of the health care potential of bioactive compounds. J. Sci. Food. Agr. 86(12): 1805-1813.

Hossain, M.Z., M.M. Bahar, B. Sarkar, S.W. Donne, Y.S. Ok, K.N. Palansooriya, M.B. Kirkham, S. Chowdhury and N. Bolan. 2020. Biochar and its importance on nutrient dynamics in soil and plant. Biochar. 7: 1-42.

Jia, J., B. Li, Z. Chen, Z. Xie and Z. Xiong. 2012. Effects of biochar application on vegetable production and emissions of N_2O and CH_4. Soil sci. plant Nutr. 58(4): 503-509.

Kammann, C.I., S. Linsel, J.W. Gößling and H.W. Koyro. 2011. Influence of biochar on drought tolerance of Chenopodium quinoa Wild and on soil–plant relations. Plant and Soil 345(1): 195-210.

Karam, F., O. Mounzer, F. Sarkis and R. Lahoud. 2002. Yield and nitrogen recovery of lettuce under different irrigation regimes, J. Appl. Hort. 4(2): 70-76.

Kazemi, R., Ronaghi, A., Yasrebi, J., Ghasemi-Fasaei, R. and Zarei, M., 2019. Effect of shrimp waste–derived biochar and arbuscular mycorrhizal fungus on yield, antioxidant enzymes, and chemical composition of corn under salinity stress. *Journal of Soil Science and Plant Nutrition*, *19*, pp.758-770.

Khan, A. 2022. Performance of exotic lettuce cultivars under different environmental condition. The University of Agriculture Peshawar. (M.Sc. Thesis).

Kim, M. J., Y. Moon, J. C. Tou, B. Mou, and N. L. Waterland. 2016. "Nutritional Value, Bioactive Compounds and Health Benefits of Lettuce (*Lactuca sativa* L.). *J. Food Compo Analy.* 4(9): 19-34. https://doi.org/10.1016/j.j fca.2016.03.004

Kurniawan, T.A., Othman, M.H.D., Liang, X., Goh, H.H., Gikas, P., Chong, K.K. and Chew, K.W., 2023. Challenges and opportunities for biochar to promote circular economy and carbon neutrality. *Journal of environmental management*, *332*, p.117429.

Kusumaningrum, I., R.B. Hastuti and S. Haryanti. 2007. Pengaruh perasan Sargassum crassifolium dengan konsentrasi yang berbeda terhadap pertumbuhan tanaman kedelai (*Glycine max* (L) Merill). Anatomi Fisiologi, 15(2): 7-13.

Lehmann, J. and S. Joseph. 2015. Biochar for environmental management: science, technology and implementation. Routledge.

Lin, X.W., Xie, Z.B., Zheng, J.Y., Liu, Q., Bei, Q.C. and Zhu, J.G., 2015. Effects of biochar application on greenhouse gas emissions, carbon sequestration and crop growth in coastal saline soil. *European Journal of Soil Science*, *66*(2), pp.329-338.

Liu, Q., B. Liu, Y. Zhang, Z. Lin, T. Zhu, R. Sun, X. Wnag, J. Ma, Q. Bei, G. Liu, X. Lin, Z. Xie. 2017. Can biochar alleviate soil compaction stress on wheat growth and mitigate soil N_2O emissions. Soil. Bio. Biochem. 10(4): 8-17

Lu, K., Yang, X., Shen, J., Robinson, B., Huang, H., Liu, D., Bolan, N., Pei, J. and Wang, H., 2014. Effect of bamboo and rice straw biochars on the bioavailability of Cd, Cu, Pb and Zn to Sedum plumbizincicola. *Agriculture, Ecosystems & Environment*, *191*, pp.124-132.

Luo, C., Yang, J., Chen, W. and Han, F., 2020. Effect of biochar on soil properties on the Loess Plateau: Results from field experiments. *Geoderma*, *369*, p.114323.

Maboko, M.M., and C.P. Duplooy. 2009. Effect of plant spacing on growth and yield of lettuce (*Lactuca* *sativa* L.) in a soilless production system. South African. J. plant soil. 26(3): 195-198.

Ministry of National Food Security & Research (MNFSR). 2024. Fruit, Vegetables and Condiments Statistics of Pakistan, 2022-23. Accessed September, 24, 2024, from www.mnfsr.gov.pk.

Mou, B., 2008. Lettuce. In Vegetables I 75-116. Springer, New York, NY.

Narkhede Sachin, B., Bendale, A.R., Jadhav, A.G., Patel, K. and Vidyasagar, G., 2011. Isolation and evaluation of starch of Artocarpus heterophyllus as a tablet binder. *Int J PharmTech Res*, *3*, pp.836-840.

Nelissen, V., G. Ruysschaert, M. Abusi, D. Hose, D. Beuf, A. Barri, P. Boeckx. 2015. Impact of a woody biochar on properties of a sandy loam soil and spring barley during a two-year field experiment. Eurp J. Agron. 62: 65-78.

Olasantan, F.O., 2007. Effect of population and sowing dates of pumpkin on soil hydrothermal weed control and crop growth in pumpkin in to crop. Eup. J. Agri. 43: 365-380.

Oliveira, F.R., Patel, A.K., Jaisi, D.P., Adhikari, S., Lu, H. and Khanal, S.K., 2017. Environmental application of biochar: Current status and perspectives. *Bioresource technology*, *246*, pp.110-122.

Rahayu, M., Nurmalasari, A.I. and Aprilya, K., 2022, December. Upland rice growth on giving of biochar and organic fertilizer. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1114, No. 1, p. 012036). IOP Publishing.

Rahayu, M., Nurmalasari, A.I. and Aprilya, K., 2022, December. Upland rice growth on giving of biochar and organic fertilizer. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1114, No. 1, p. 012036). IOP Publishing.

Ren, T., Wang, H., Yuan, Y. (2021). Biochar increases tobacco yield by promoting root growth based on a three-year field application. Sci Rep, 11, 21991.

Reshma, V.S., D.M. Panchlohai and M.N. Adrash. 2007. Effect of GA3 spray on gladiolus cultivars under dry condition of vidharba region. Int. J. App. Bio. Sci. 5(3): 123-129.

Sahin, O., M.B. Taskin, E.C. Kaya, O. Atakol, E. Emir, A. Inal and A. Gunes. 2017. Effect of acid modification of biochar on nutrient availability and maize growth in a calcareous soil. Soil Use.Manag. 33(3): 447-456.

Shahbaz, A. 2022. Effect of sowing dates on lettuce yield, grown in the Open field and partial shade. The University of Agriculture Peshawar (Msc. Thesis)

Shen, Q., Wang, Z., Yu, Q., Cheng, Y., Liu, Z., Zhang, T. and Zhou, S., 2020. Removal of tetracycline from an aqueous solution using manganese dioxide modified biochar derived from Chinese herbal medicine residues. *Environmental research*, *183*, p.109195.

Silitonga, M., Sipayung, P., Sitorus, I.M., Siahaan, R., Hutauruk, S., Fajar, T.S.A., Sarumaha, S.R.D. and Panjaitan, D., 2018, November. The effect of biochar dose and NPK fertilizer on the production and growth of pak choi plant. In *IOP Conference Series: Earth and Environmental Science* (Vol. 205, No. 1, p. 012028). IOP Publishing.

Steel R.G.D and Torrei J.H (1980) Principles and procedure of statistics. McGraw-Hill. New York. USA.

Subedi, R., N. Taupe, S. Pelissetti, L. Petruzzelli, C. Bertora, J.J. Leahy and C. Grignani. 2016. Greenhouse gas emissions and soil properties following amendment with manure derived biochars: Influence of pyrolysis temperature and feedstock type. J. Environ. Manag. 16(60): 73-83.

Sun, H., D. Feng, Y. Zhao, S. Sun, J. Wu, P. Wang, G. Chang, X. Lai, H. Tan and Y. Qin. 2020. Mechanism of catalytic tar reforming over biochar: Description of Volatile-H_2O-char interaction. Fuel, 27(5): 117-954.

Surahman, A., Soni, P. and Shivakoti, G.P., 2018. Reducing CO2 emissions and supporting food security in Central Kalimantan, Indonesia, with improved peatland management. *Land use policy*, *72*, pp.325-332.

Szeto, Y.T., T.C. Kwok and I.F. Benzie. 2004. Effects of a long-term vegetarian diet on biomarkers of antioxidant status and cardiovascular disease risk. Nutrition. 20(10):863-866.

Upadhyay, K. P., George, D., Swift, R. S., & Galea, V. (2014). The Influence of Biochar on Growth of Lettuce and Potato. Journal of Integrative Agriculture, 13(3), 541–546.

Wang, G.J., Z.W. Xu and Y. Li. 2016.Effects of biochar and compost on mung bean growth and soil properties in a semi-arid area of Northeast China. Int. J. Agri. Bio. 1(8): 1056-1060

Wang, J., and Wang, S. (2019). Preparation, modification and environmental application of biochar: a review. Journal of Cleaner Production, 227: 1002-1022.

Warnock, D.D., Lehmann, J., Kuyper, T.W. and Rillig, M.C., 2007. Mycorrhizal responses to biochar in soil–concepts and mechanisms. *Plant and soil*, *300*, pp.9-20.

Welbaum D.G (2010) Vegetable seed production: lettuce. https:// Welbaum. Spes.Vti. Edu/seed production/ lettuce. Html. Accessed on 1/August/2021.

Williams, L. J., and H. Abidi. 2010. Fishers least significant difference (LSD) test Encyclopedia of research design. 21(8): 840-853.

Yuan, Y., Bolan, N., Prévoteau, A., Vithanage, M., Biswas, J.K., Ok, Y.S. and Wang, H., 2017. Applications of biochar in redox-mediated reactions. *Bioresource technology*, *246*, pp.271-281.

Zhang, A.F., R.J. Bian, G.X. Pan, L.Q. Cui, Q. Hussain, L.Q. Li, J. Zweng, X. Zheng, X. Han and X. Yu. 2012. Effects of biochar amendment on soil quality, crop yield and greenhouse gas emission in a Chinese rice paddy: A field study of 2 consecutive rice growing cycles. Field Crops Res. 12(7): 153-160.

Zheng, J., Han, J., Liu, Z., Xia, W., Zhang, X., Li, L., Liu, X., Bian, R., Cheng, K., Zheng, J. and Pan, G., 2017. Biochar compound fertilizer increases nitrogen productivity and economic benefits but decreases carbon emission of maize production. *Agriculture, Ecosystems & Environment*, *241*, pp.70-78.