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Original article

The impact of different biochars on Stemphylium leaf blight (SLB) suppression and productivity of onion (*Allium cepa* L.)

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ABSTRACT

Objectives: Onion is a highly consumed vegetable crop in many countries, being a vital component of every dish. Recent studies indicated that different plant residues' and animal manure-based biochars have strong impacts on the growth and development of plants. However, the impact of these biochars on disease suppression remains elusive. Therefore, this two-year study assessed the impact of animal and plant residues-based biochars on the suppression of Stemphylium leaf blight (SLB) of onion and productivity of the crop.
Methods: Three pyrolyzed biochars cotton sticks, wheat straw and poultry litter) were used in the study. Biochars were prepared in the laboratory and applied to soil prior to crop sowing in same concentration during both years of study.
Results: Poultry litter biochar had the highest impact on allometric traits and productivity of onion, and successfully reduced SLB severity. The control treatment had the lowest productivity and the highest disease severity during both years of the study. The remaining biochars (cotton sticks and wheat straw) had moderate influence on growth and development of onion plants. The disease severity was higher compared to poultry litter; however, it was lower in both biochars than control treatment. It is concluded that different animal and plant residues-based biochars could be used to improve plant health. Nonetheless, the response of these biochars will be crop-specific.
Conclusion: Poultry litter biochar can be successfully used to suppress SLB in onion and productivity of the crop. Nevertheless, the actual mechanisms involved in disease suppression warrant further investigation.

1. Introduction

The onion (*Allium cepa* L.) vegetable has become a significant income source for farmers throughout this world as it is cultivated for domestic and commercial purposes. Onion is a major source of vitamin C. It was cultivated on ~ 5 million ha with 100 million tons production during 2019. As it is consumed more than any other vegetables, its demand is increasing day by day (Selvaraj et al., 2014; Fitiwy et al., 2015; Gebretsadkan et al. 2020). The growth and productivity of vegetable crops are affected by numerous

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biotic and abiotic factors. Plant pathogens have a critical role in decreasing the production of onion every year throughout the world. From these biotic factors, soil-borne fungi have become a limiting factor to onion production (Gebretsadkan et al., 2020).

Burning of onion leaves starting from the tip to downwards is commonly observed. There are many names for this complex disease, i.e., initial tip burning, botrytis leaf blight caused by (*Botrytis squamosa*), downy mildew (*Peronospora destructor*), purple blotch (*Alterneria porri*) Stemphlium leaf blight (*Stemphylium vesicarium*) and basal rot (*Fusarium oxysporum*) (Abdel-Hafez et al., 2014; Riaz et al., 2020). This type of disease complex also shows other major symptoms besides leaf burning, which make it easier to identify the causal agent (Abo-Elyousr et al., 2017; Marcuzzo and Haveroth, 2016). Besides biotic factors, many abiotic factors are also primarily responsible for the initiation of this disease. From these abiotic factors, deficiency of boron, sulphur and nitrogen, acquaintance to salinity and ozone have a major role in developing the disease (Ahmad et al., 2013). These complex symptoms often appear at the nursery stage and disappear during later growth stages after transplanting. It has been observed from different studies that some plants having such symptoms often recover. The maximum plantation in nurseries have a significant role in the development of tip-burn or blight symptoms (Riaz et al., 2020).

One of the most destructive fungus, i.e., *Stemphylium vesicarium* Wallr (Simmons) causes *Stemphylium* leaf blight (SLB) of onion. This devasting fungus has a wide range of host species, including onion, chilli pepper, pear and garlic (Gedefaw et al., 2019; Vitale et al., 2017). The SLB and onion thrips (*Thrips tabaci*) cause major leaf damage in onions. The onion thrips play a synergistic role along with the fungus to aggravate the disease. The major symptoms of SLB in onion include the leaf tip-burn, necrosis of leaf tissues, wilting of leaves, turning of leaves into black color with profuse production of conidia, water soaked lesions on leaves and dieback of leaf tissues (Leach et al., 2020).

The SLB is more widespread in warm humid growing conditions, which play an encouraging role in the development of the disease. This disease has a significant impact on onion plants. The rate of photosynthesis in onion plants is reduced because of leaf dieback. *Stemphylium vesicarium* has both sexual and asexual stages. During the asexual stage, *S. vesicarium* has the ability to produce the maximum number of conidial spores on leaves and during the sexual stage, *Pleospora allii* are formed which can release the ascospores in pseudothecial form during the cropping season of onion. The ascospores released from overwintered pseudothecia have a significant role in the development of SLB epidemic in many territories of America and other countries. It was concluded from many studies that *S. vesicarium* could attack via functioning tissues or dead tissue with the help of developing appressoria (Hay et al., 2019; Hoepting, 2018).

Application of organic amendments like green manure, organic wastes, peats, composts and animal manure are being used to manage several soil-borne phytopathogens. These type of materials are incorporated in soil to strengthen its quality. These organic amendments have successfully managed the many soil-borne phytopathogens, including *Gaeumannomyces graminis tritici*, *Phytophthora*, *Sclerotium*, *Thielaviopsis basicola*, *Macrophomina phaseolina*, *Verticillium dahlie*, *Rhizoctonia solani*, *Fusarium*, *Pythium* and *Aphanomyces euteiches.* The retort of soil borne pathogens populations to organic matter (OM) modifications has become a consistent feature for various soil-borne pathogens which have a low level of saprophytic activity like *Verticillium dahlie* and *Thielaviopsis basicola* and OM types organic wastes and crop residues having C-N ratio<15 (Bonanomi et al., 2010).

Keeping in view the importance of SLB of onion, this two-year study was conducted to infer the roles of different biochars in disease suppression and productivity of onion. Three biochar substrates (cotton sticks, wheat straw and poultry litter) were used to check their impact on allometric traits like plant height, leaf blade length, leaf length, leaf width, leaf area, root length, bulb dry weight, bulb diameter, neck diameter and yield of onion crop and on SLB disease severity. It was hypothesized that biochars will differ in their efficacy to suppress SLB and improving onion productivity. The results will help to manage SLB on sustainable basis with improved soil health.

2. Materials and methods

2.1. Experimental site

The study was conducted at farmers filed in Alipur, Punjab, Pakistan. The experimental area belongs to semi-arid region having high temperature during summer and moderate temperature in winter. The soil of the experimental area was silt–clay. The soil samples were collected and analyzed prior to initiate the experiments during both years of the study. The climatic data regarding temperature, pH, and relative humidity were collected with Hobo data logger. The soil properties of the experimental site are given in Table 1 and climatic data of both years is summarized in Fig. 1.

2.2. Nursery raising

The seeds of three onion cultivars, i.e., Red Imposta, Faisalabad Red and Phulkara were obtained from Ayub Agricultural Research Institute Faisalabad. All of the cultivars were susceptible to SLB of onion. The seeds of all cultivars were surface sterilized with sodium hypocotyl prior to sowing and then allowed to soak under the natural sunlight. The nursery of each cultivar was prepared. All agronomic practices were applied regularly.

2.3. Preparation of biochars

To check the impact of plant residues and animal manure-based biochars on allometric traits of onion and management of SLB disease, three biochar substrates, including cotton sticks, wheat straw and poultry litter were used. The biochars prepared in a gas operated furnace. Plant residues, i.e., wheat straw and cotton sticks were obtained from nearby farm, while poultry litter was collected from a local poultry farm. The pyrolysis of the obtained material was completed in a gas-operated airtight stainless steel furnace with thermos gauge having 10 kg size. The materials did not have direct contact with heat during the combustion process. All the material was pyrolyzed at 400 ^{0}C for 2 h by following the prescribed methods (Azhar et al., 2019; Rafique et al., 2019). Physical properties of all the biochar substrates were measured in both years before incorporation into the allocated plots (Table 2). All the biochar substrates were crushed and then incorporated into soil. The plots having no biochar application was considered as control.

2.4. Data collection

Data relating to allometric traits, yield related parameters and disease severity index were recorded using standard procedures. Leaf area was recorded at the harvest of crop using a leaf area meter (DT Area Meter, model MK2; Delta-T Devices, Cambridge, UK). A 0.5 m^2 area was harvested, weighed and leaf area of preweighed leaves was measured. The heights of ten randomly selected plants from each experimental units were measured and averaged to record plant height. The width and length of 10 randomly selected leaves from each experimental unit were measured and averaged. Yield and its related parameters were obtained by

Table 1
Physical and chemical properties of experimental site prior to initiate the experiment during both years of study.

Soil properties	Unit	Years		Soil Texture	Unit	Years	
		2018–19	2019–20			2018–19	2019–20
Chemical Analysis				Physical analysis			
Organic matter	%	0.43	0.52	Silt	%	52.35	53.34
Total nitrogen	%	0.24	0.28	Sand	%	23.60	21.26
Available phosphorus	mg kg^{-1}	11.19	12.09	Clay	%	24.05	25.40
Available potassium	mg kg^{-1}	212.29	232.83	Textural class		Silt-clay	Silt-clay
pH		7.98	7.81				
EC	dS m^{-1}	2.41	2.34				

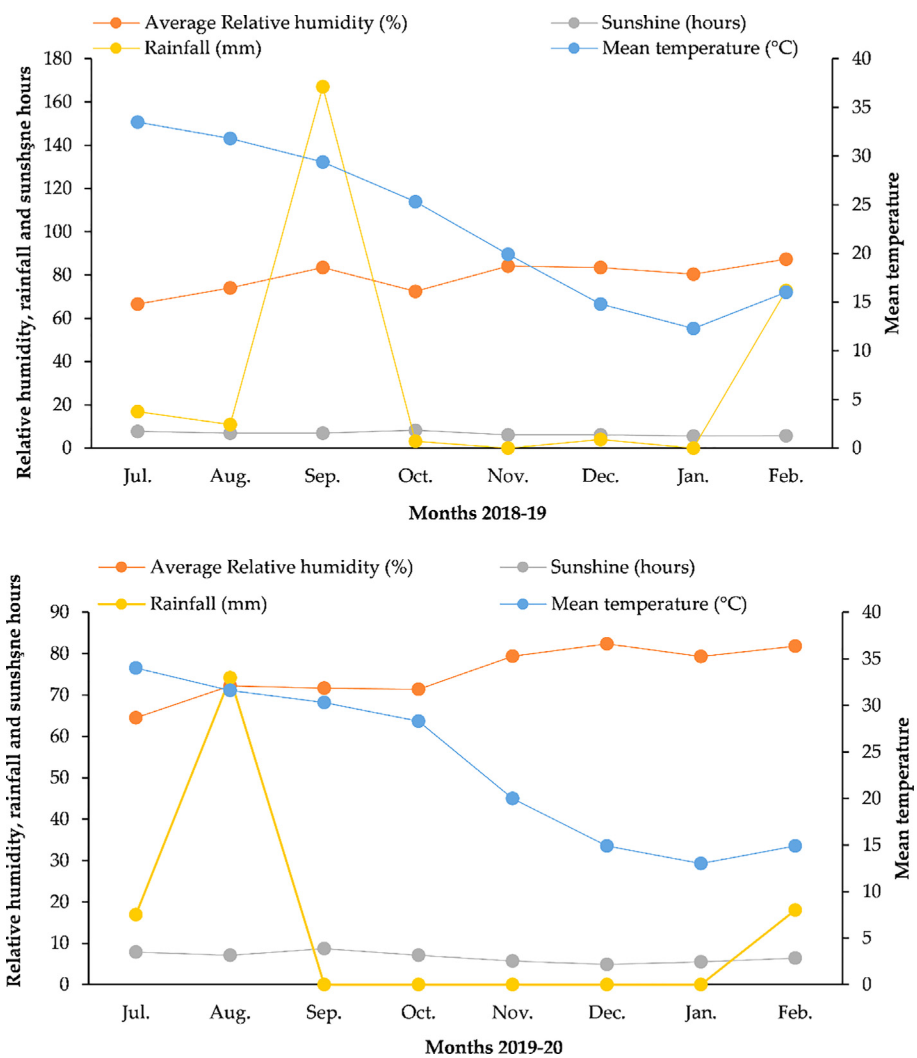

Fig. 1. The climatic data of the experimental site during both years of the study.

using standard method of yield calculation as 1000 bulb weight. For comparison of different cultivars in terms of resistance against SLB, disease severity index was calculated on percentage basis for every experimental unit. The disease rating was scored from 0 to 4 scale. 0 = no visible symptoms, 1 = >1–25% leaf area has symptoms, 2 = 26–50% leaf area has symptoms, 3 = 51–75% leaf area has symptoms and 4 = 76–100% leaf area has symptoms. The level of resistance and susceptibility of tested cultivars was calculated by a reformed disease rating scale. Disease severity index was calculated by following (Hussein et al., 2007).

2.5. Statistical analysis

The collected data were tested for normality and homogeneity of variance, which indicated a normal distribution. Thus, original data was used in statistical analysis as it met the normality assumption of analysis of variance (ANOVA). Paired *t* test was used to infer the differences among experimental years, which was significant. Therefore, data of each year were analyzed, presented and interpreted separately. Two-way ANOVA was used compare biochar substrates and cultivars. Most of the interactions were signif-

Table 2
Physical and chemical characteristics of different biochars used in the study.

Properties	Wheat straw		Cotton sticks		Poultry litter	
	2018–19	2019–20	2018–19	2019–20	2018–19	2019–20
pH	8.45	8.98	7.93	8.12	6.75	6.90
EC dS m^{-1}	9.30	9.91	8.62	8.69	10.21	10.67
Organic Matter %	3.12	3.76	1.65	1.61	77.12	80.23
Total Nitrogen %	1.61	1.71	1.21	1.34	5.14	5.67
Total Carbon %	34.23	34.89	23.18	31.08	44.78	45.67
C:N ratio	21.26	20.40	19.00	32.45	8.71	8.05
Carbonate Calcium%	19.12	20.76	18.21	20.25	–	–
Phosphorus (mg kg^{-1})	367.32	387.12	299.0	311.09	23,021	24,045
Potassium (mg kg^{-1})	9912	10,021	6523	6890	23,456	23,190
Zn (mg kg^{-1})	87.5	89.12	68.98	78.22	281.78	290.17
Mn (mg kg^{-1})	40.71	45.56	41.34	48.64	466.14	475.66
Cu (mg kg^{-1})	13.00	13.89	12.45	13.12	319.45	345.67
Fe mg kg^{-1})	311.4	345.6	190.32	181.90	1912	2067

icant; therefore, these were presented and interpreted in the manuscript. Least significant difference test at 5% probability was used to separate the means where ANOVA indicated significance (Arif et al., 2021).

3. Results

Different allometric traits (i.e., plant height, leaf blade length, leaf length, leaf width, leaf area, root length, bulb dry

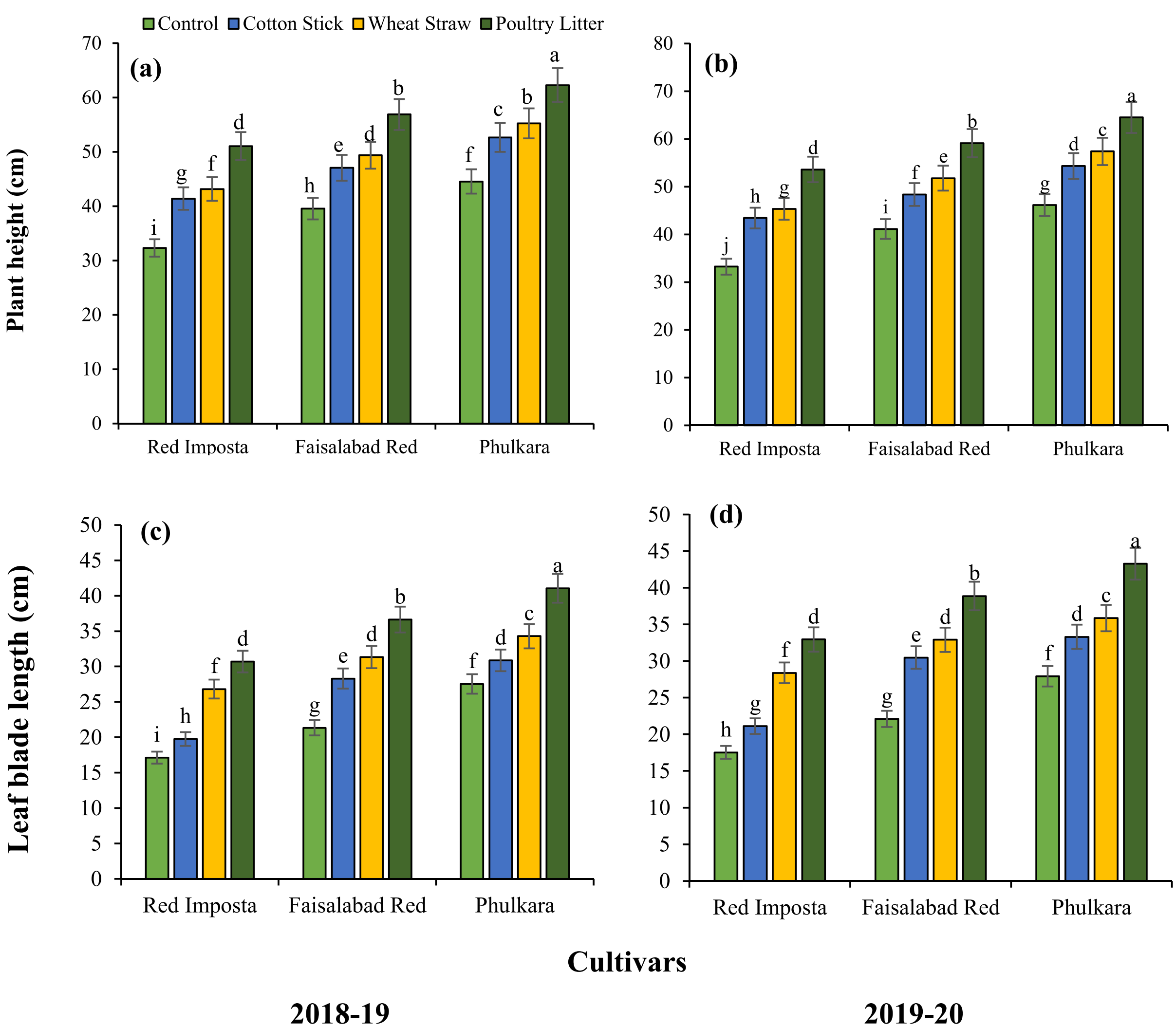

Fig. 2. The impact of different biochar substrates on plant height (a and b) and leaf blade length (c and d) of different onion cultivars during 2018–19 and 2019–2020.

weight, bulb diameter, neck diameter and yield) of different cultivars were significantly ($p < 0.05$) altered by biochars included in the study. The highest values of all allometric traits were noted with poultry litter biochar, whereas the lowest values were recorded for control treatment. Similarly, disease severity was also low in poultry litter biochar. The rest of the biochars (cotton sticks and wheat straw) also improved allometric traits and lowered disease severity compared to the control treatment. Nonetheless, the highest disease severity index and the lowest values of these traits were noted for control treatment.

The highest plant height (62.30 cm during 2018–19 and 64.52 cm in 2019–20) was recorded for Phulkara cultivar with poultry litter biochar, whereas Red Imposta with control treatment had the lowest plant height during both years of study. Overall, plant height was 62.30, 56.89 and 51.08 cm during 2018 for Phulkara, Faisalabad Red and Red Imposta, whereas these values were 64.52, 59.11 and 53.60 cm, respectively during 2019 (Fig. 2a and 2b).

Similar results as of plant height were recorded for leaf blade length during both years. Phulkara cultivar with poultry liter biochar recorded the highest leaf blade length (46.19 and 48.77 cm during 1st and 2nd year, respectively). Red Imposta cultivar with control treatment had the lowest leaf blade length during both years of study (Fig. 2c and 2d).

It was observed that application of different biochar substrates had not only significantly enhanced the allometric traits of onion but also successfully reduced the disease severity in every cultivar. Many modern cultural approaches are being employed now a days to enhance the productivity of vegetables and fruits plants. These innovative approaches like soil amendments with different biochar substrates has also reduced the activity of soil-microorganisms in terms of causing diseases in these plants. During both years of study, it was observed that onion thrips (*Thrips tabaci*) and some other pests of onion had started their infection at early stage after transplanting the plants from nursery to fields. These pests were monitored regularly to check their infestation also but data was not included in this study. These pests were managed by some recommended pesticides at early stage. Only one spray of Bifenthrin was applied in both years of this study to manage the pests of onion. It was observed that these pests have minimal attack on onion plants.

Many researchers have revealed in their studies that onion thrips and *Stemphylium vesicarium* are major concerns to cause the SLB in onion. Onion thrips is considered as to interrelate synergistically with many fungal and bacterial pathogens to cause the plant diseases. It was observed from this study that onion thrips and *Stemphylium vesicarium* have less or no relationship to cause the SLB in onion. However, both onion thrips and SLB starts to develop their infection on leaves of onion. Nevertheless, onion

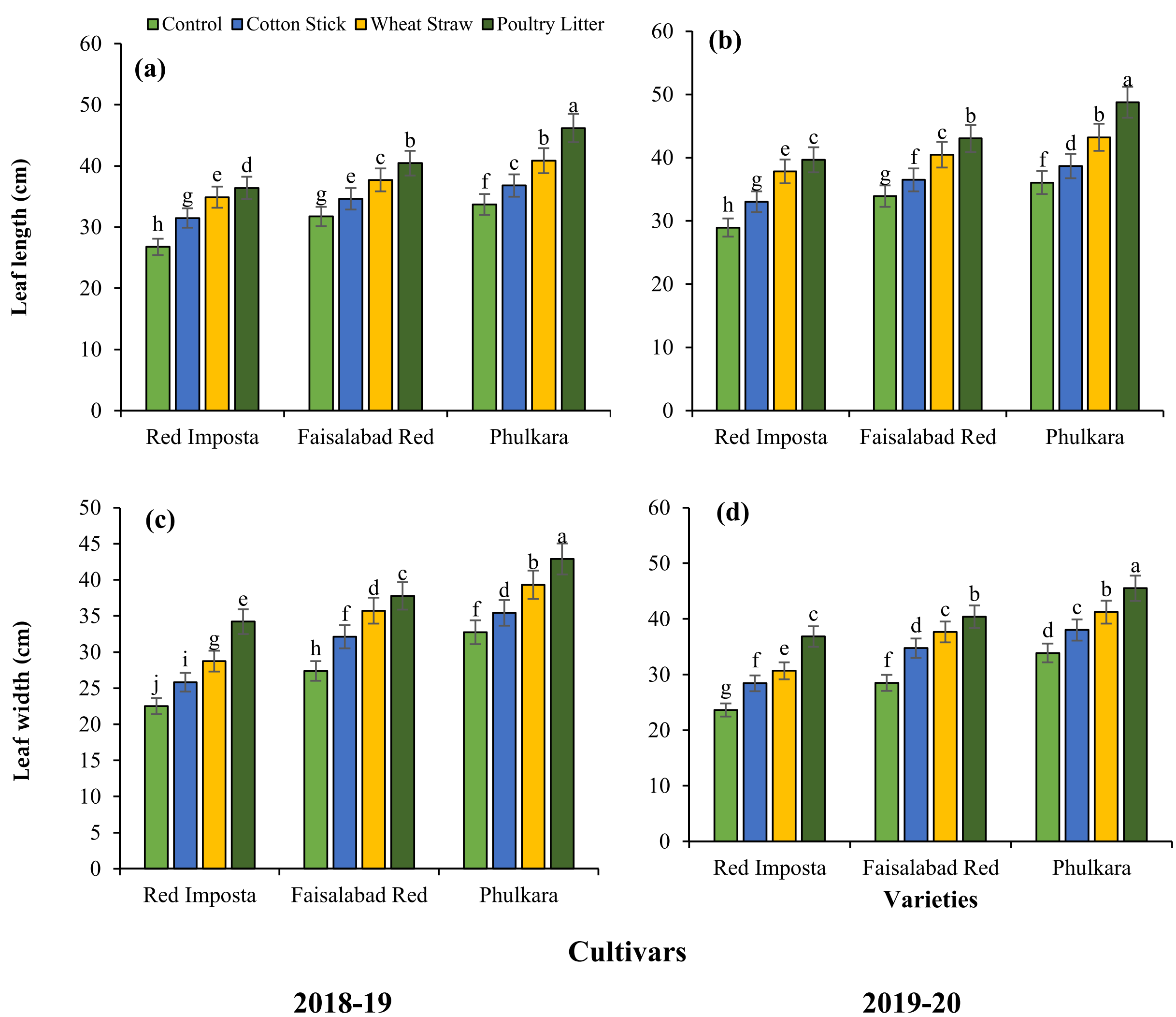

Fig. 3. The impact of various biochar substrates on leaf length (a and b) and leaf width (c and d) of different onion cultivars during 2018–19 and 2019–20.

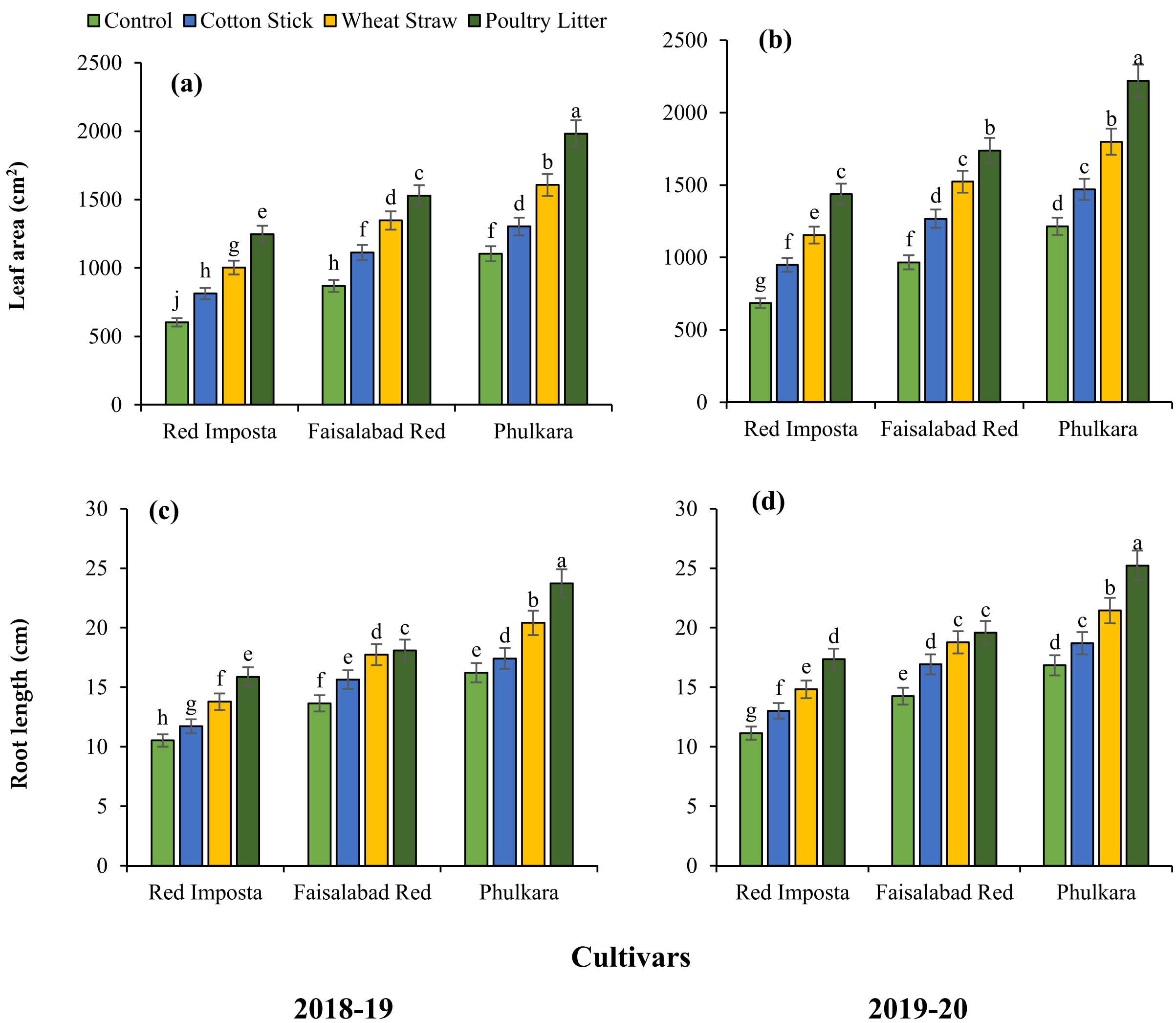

Fig. 4. The impact of various biochar substrates on leaf area (a and b) and root length (c and d) of different onion cultivars during 2018–19 and 2019–20.

thrips suck the cell sap of leaves and blocks the movement of xylem and phloem during photosynthesis process. Sometimes, the symptoms caused by onion thrips intermingle with SLB but after sometime pathogen start to show the spores on leaves.

The transplanting time of onion seedlings had a strong reflecting impact of edaphic factors and environmental conditions on enormous scale on allometric traits like crop growth, bulb size, bulb yield and bulb quality and overall yield which can be a significant comparative impact from one area to another. It was concluded from this study that nursey preparation and transplanting time had a huge impact on development of many soil borne diseases. If transplanting time is before the recommended time then it can affect not only on allometric traits development but also can provide a favorable environmental conditions for the soil borne pathogens to start their infection at early stage of crop. During both years the crop was sown on recommended time and all cultural practices were applied timely to check their impact on productivity and also on disease suppression. If SLB pathogen finds strong favorable environmental conditions then it might be very difficult to manage it and can cause a huge economic loss on quality and quantity of crop. All three onion cultivars like Red Imposta, Faisalabad Red and Phulkara were transplanted on same date and an equal type of soil amendments cultural practices were applied in both years.

There was a balanced application of fertilizer during both years of study. It was suggested in many studies that Nitric oxide can play an essential role in the reproduction of *S. vesicarium* and *S. eturmiunum*. Thus, Nitric oxide can boost the synthesis of melanin in both *S. vesicarium* and *S. eturmiunum.* Most importantly the biosynthesis of melanin can enhance the reproduction process of both soil borne fungus which can cause SLB in onion. The development of propagules is the serious stage for the communication of both the phytopathogenic fungus *S.vesicarium* and *S. eturmiunum*. However, the formation of such propagules is structured by such factors which remains to be fully understood.

Poultry litter biochar significantly ($p < 0.05$) improved the leaf length and width of tested cultivars compared to the control treatment. Phulkara cultivar with poultry litter biochar observed the highest leaf length (46.19 and 48.77 cm during 2018–19 and 2019–20, respectively), while wheat straw and cotton stick biochars resulted in less improvement of these traits (Fig. 3a and 3b).

Different biochars had a positive ($p < 0.05$) impact on leaf width of tested onion cultivars. The highest increase in leaf width was noted for Phulkara cultivar with poultry litter biochar (Fig. 5). Wheat straw had a moderate impact on leaf width of all cultivars during both years of study. The lowest leaf width of all three cultivars was recorded for control treatment (Fig. 3c and 3d).

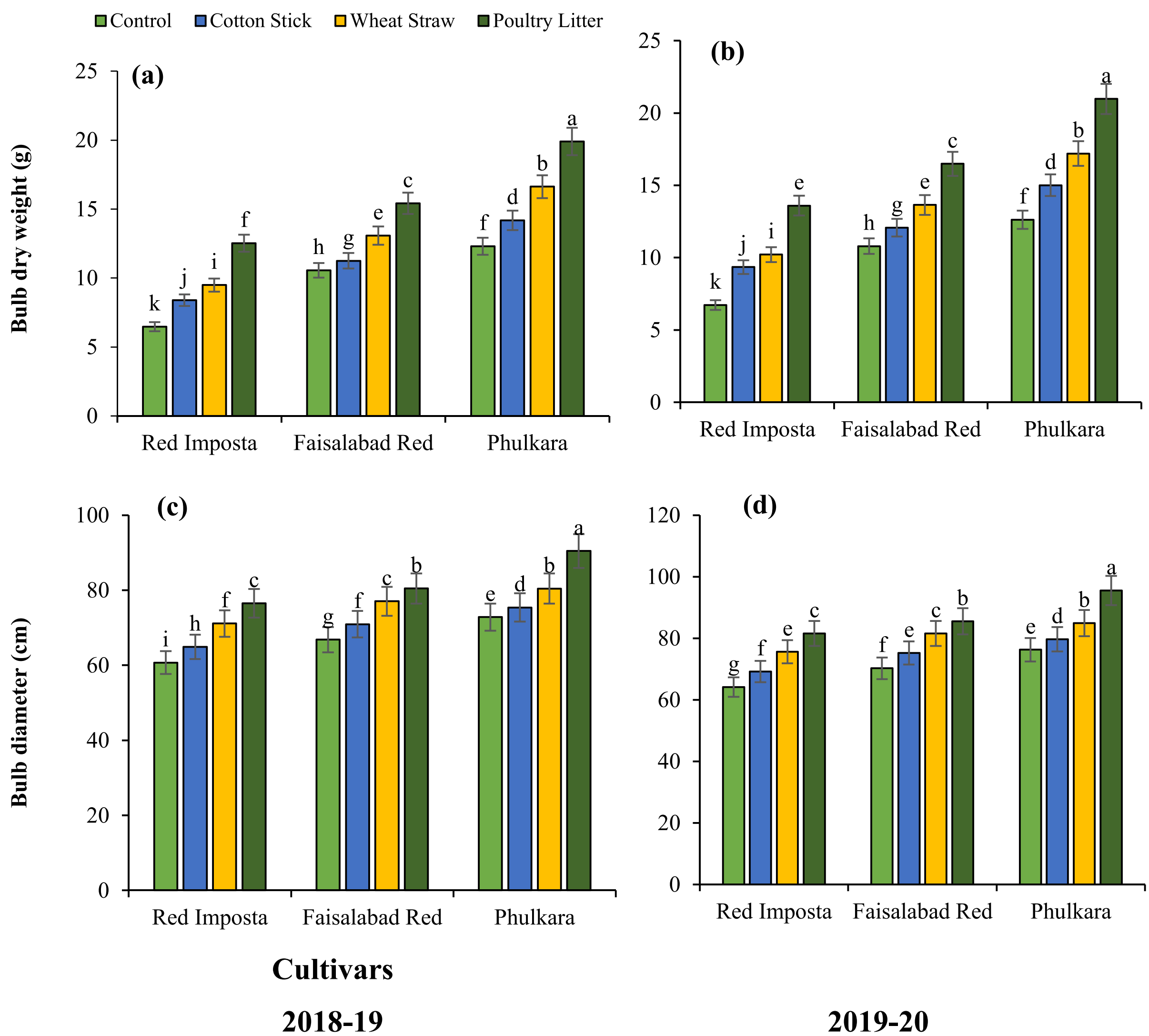

Fig. 5. The impact of various biochar substrates on bulb dry weight (a and b) and bulb diameter (cm) of different onion cultivars during 2018–19 and 2019–20.

Different biochar substrates significantly ($p < 0.05$) altered leaf area of all cultivars. Poultry litter biochar resulted in the highest leaf area of Phulkara cultivar (1982.12 cm^2 in 2018 and 2220.77 cm^2 in 2019) followed by Faisalabad Red (1528.70 cm^2 in 2018 and 1738.80 cm^2 in 2019) and Red Imposta cultivars (1246.35 cm^2 in 2018 and 1436.91 cm^2). The lowest values of leaf area were measured for all cultivars with control treatment of the study (Fig. 4a and 4b).

Different biochars had significant ($p < 0.05$) impact on root length of tested onion cultivars. Phulkara cultivar with poultry litter biochar outperformed rest of the cultivars with the highest root length (23.72 and 25.21 cm during 1st and 2nd year, respectively) during both years. Wheat straw biochar resulted in the second highest improvement in root length of tested cultivars, while the smallest root length of all cultivars was observed in control treatment (Fig. 4c and 4d).

Bulb dry weight, neck diameter and bulb diameter were measured after harvesting during both years. Bulb drying has significant relationship with reduction in sugar and amino acid contents in onions, which ultimately affects overall yield. It was observed that poultry litter significantly improved bulb dry weight and diameter and neck diameter of all cultivars (Fig. 5a, 5b, 5c, 5d, 6a and 6b). The highest improvement was recorded for Phulkara cultivar during both years of study. The remaining biochars had a moderate impact on these traits. It was interesting that wheat straw and cotton sticks resulted similar improvement in these traits, while poultry litter biochar resulted in a higher improvement of these traits. Nonetheless, the lowest values of these traits were noted for all cultivars with control treatment (Fig. 5a, 5b, 5c, 5d, Fig. 6a and 6b).

Bulb yield of different onion cultivars was significantly ($p < 0.05$) affected by various biochars included in the study. All tested cultivars produced the highest bulb yield with poultry biochar (Phulkara 14.86 ha^{-1}, Faisalabad Red 12.22 ha^{-1}, Red Imposta 11.20 ha^{-1} during 2018–19, while Phulkara 15.95 ha^{-1}, Faisalabad Red 13.31 ha^{-1}, Red Imposta 12.29 ha^{-1} during 2019–20) than rest of the biochar substrates. The other biochars also resulted in a moderate improvement in bulb yield; however, remained less effective than poultry litter biochar. The effectiveness of these biochar substrates was the highest during 2nd year. The highest yield was recorded for Phulkara cultivar (15.95 ha^{-1}) with poultry litter biochar. The remaining cultivars Red Imposta and Faisalabad Red had less yield than Phulkara. The lowest bulb yield of all onion cultivars was recorded with in control treatment (Fig. 6c and 6d).

The main objective of the study was to check the impact of different biochars on SLB disease severity/suppression. Interestingly,

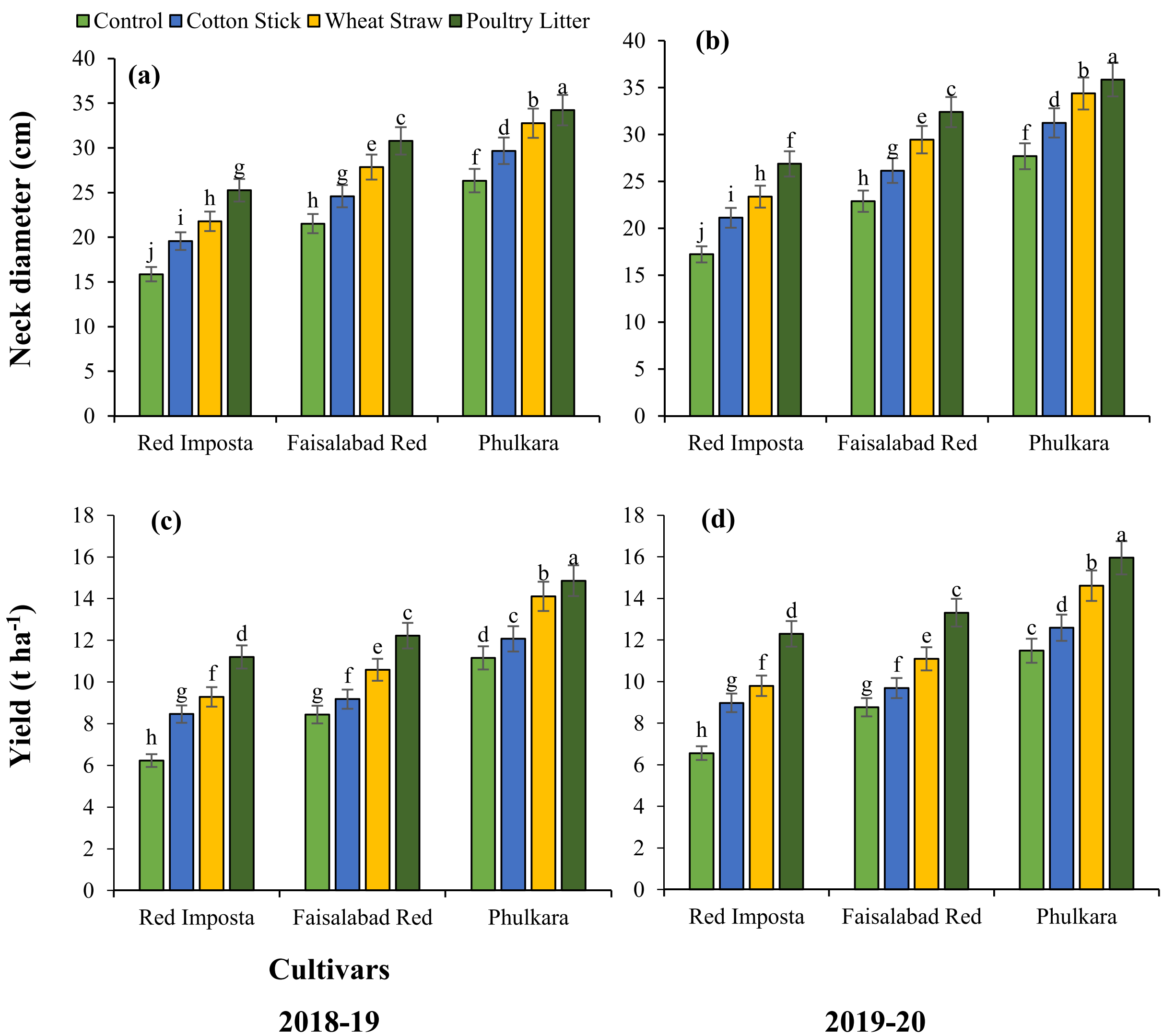

Fig. 6. The impact of various biochar substrates on neck diameter (a and b) and yield (c and d) of different onion cultivars during 2018–19 and 2019–20.

all of the tested biochars significantly ($p < 0.05$) lowered disease severity index of SLB. The poultry litter significantly lowered disease severity in all cultivars (Phulkara 3.11%, Faisalabad Red 10.85%, Red Imposta 20.87% during 1st year and Phulkara 0.72%, Faisalabad Red 8.40%, Red Imposta 18.42% during 2nd year of study), while other biochars were less effective in reducing the severity of SLB. The highest disease severity index was noted for control treatment (Fig. 7).

4. Discussion

Allometric and yield related traits of onion cultivars were significantly improved by different biochars as hypothesized. Similarly, biochars suppressed SLB compared to the control treatment. However, significant differences were noted among tested biochars and poultry litter biochar proved most effective in reducing SLB severity and improving allometric and yield-related traits. Nonetheless, the tested cultivars also significantly differed for the measured traits and Phulkara proved a promising cultivar with higher yield and less disease severity compared to the rest of the treatments. The differences in biochars are owed to their chemical properties, while differences among tested cultivars can be explained with the differences in their genetic makeup.

Fungal diseases affecting onion are managed only by fungicides throughout the world; however, their usage have long lasting adverse effects on consumable onions and environment. Keeping in view the significant losses caused by fungal diseases in onion, it is recommended that these diseases should be managed by some eco-friendly tactics. From these eco-friendly tactics, soil solarization has become an emerging method to control the soil borne pathogens. By this method, soil is concealed with the polythene sheet which enable the soil temperature to rise at high level which disable the colonization of soil pathogens and all such pathogens are killed by this method (Shahnaz et al., 2018). It was concluded that use of straw mulch significantly increased onion yield and successfully managed the insect pests. The application of such cultural practices to manage the soil borne diseases of onion might be helpful (Alyokhin et al., 2020, Quintanilla-Tornel et al., 2016).

The severity of SLB disease can be seen much higher in crops sown via seed than crops sown via bulb. In Asian countries, the majority of farmers use seed for nursery raising of onion, so chances of disease development are much high. Many management tactics, including resistant source, field sanitation, proper cultural measures and biological control methods are recommended. From the above mentioned tactics, the use of resistant source against SLB can be most effective to control this disease in

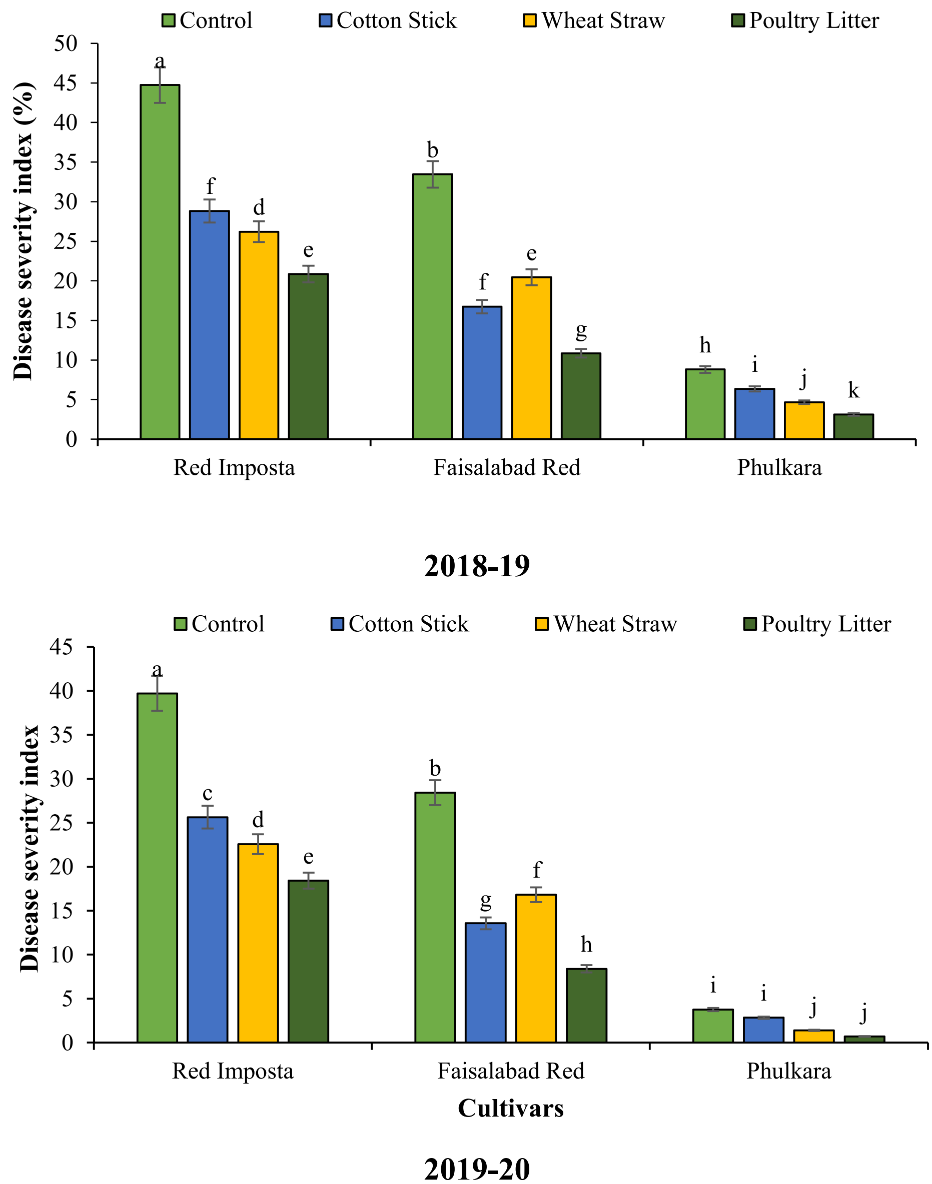

Fig. 7. The impact of various biochar substrates on disease severity index of different onion cultivars during 2018–19 and 2019–20.

onion but no significant resistant source have been recognized in common onion (Lee et al., 2013; Mahlein et al., 2012).

Different biochar substrates and rhizospheric microorganism have significant ability in terms of improving the plant growth with several enzymes and secondary metabolites, antibiosis and parasitism (Taha et al., 2020). The biochar has got a significant consideration in the recent era and is frequently applying as soil amendment to improve plant growth under various environmental conditions (Azhar et al., 2019; Rizwan et al., 2016). Biochar has a strong potential to increase crop production, sequester carbon and improve the soil fertility in various soils for a long period of time (Lehmann et al., 2011; Rehman et al., 2016; Rizwan et al., 2019). Biochars can act as bio-stimulants and bio-fertilizer for several vegetable and commercial crops. Application of biochars can be helpful in reducing the residual effects of pesticides and synthetic fertilizers (Atieno et al., 2020; Barros-Rodríguez et al., 2020). Nonetheless, biochar improves growth, development and yield of different crops by improving soil properties (Abbas et al., 2017; Beesley et al., 2010). Application of 2% farmyard manure (FYM) increased dry biomass, gas exchange, chlorophyll contents and plant height in maize crop grown on metal contaminated soil (ur Rehman et al., 2017). Similarly, cotton sticks biochar enhanced photosynthesis rate, dry biomass and growth of spinach by constraining the entry of cadmium (Cd) (Younis et al., 2016). The yield improvement in the current study is owed to increased allometric traits, which ultimately improved growth and better portioning of assimilates than control treatment. The increase in is also owed to the movement of self-proactive enzymes in leaves, which improved allometric traits (Cong et al., 2019).

Rafique et al. (2019) studied the impact of different biochars having soil microbes in P-limited soil and differentially textured soils for root colonization, nutrient uptake and P accessibility. Two biochars and microbial inoculant in differentially textured soils were used for sowing of onion. Plant biomass and nutrient uptake were enhanced by biochars even without microbial inoculation. The combination of mycorrhizae inoculation and biochar improved root colonization. Soil type and biochar association can develop an exceptional behavior of root colonization, root attributes, plant growth and nutrient uptake. The mycorrhizal inoculation with biochar can serve as unique sustainable source of P for plants (Ali et al., 2019; Rafique et al., 2019). Different biochars are rich source of P and their physio-chemical properties have the potential to mend the nutrients availability.

It is reported that once SLB disease appeared in onion, it is much difficult to control like other fungal diseases. In such scenario, use of fungicides, insecticides, biological control agents and plant extracts can significantly reduce the disease. The use of chemicals to manage this disease is much advantageous and quick (Mishra and Singh, 2017). It was revealed that onion bulbs obtained after the use of fungicides were 33–40% longer in New York (Hoepting, 2018).

Numerous combinations of soil amendments such as biochars are being used to improve plant growth and defense mechanism against soil borne phytopathogens. The results of this study revealed that animal-based manures like poultry litter biochar have strong potential to boost the resistance mechanism against SLB disease. Meanwhile plant-based biochars also have significant impact on SLB suppression.

The combination of different biochars and beneficial microorganisms like *Trichoderma* can impede the multiplication of plant pathogens in soil by various ways, including improving soil heath and stimulating plant growth. These sustainable approaches have significant ability to activate the competition for nutrients, mycoparasitism, antibiotics synthetization and space against damaging plant pathogens (Taha et al., 2020). Application of different biochars can play a positive role in bio-remediation, bio-fortification against devastating pathogens of vegetables. The rhizospheric microorganisms have strong ability to sustenance the plants by activating certain plant defense mechanisms against plant invaders and environmental stresses. These advantageous rhizospheric microorganisms have strong potential to improve soil quality. These beneficial microorganisms also play their significant part in uptake of nutrients, soil organic matter decomposition and recycling of plant nutrients and availability (Alami et al., 2020, Tripathi et al., 2020).

Cong et al. (2019) revealed that application of diversified culture fermentation of *T. pseudokoningii* and *Rhizopus nigricans* successfully managed cucumber wilt caused by *Fusarium oxysporum*. The usage of organic amendments has become an innovative approach to control the soil borne pathogens; however, this strategy didn't get full attention of researchers because of increasing demand of molecular work (Bonanomi et al., 2010). It is interestingly noted that crop residues and combination of composts response against the phytopathogens leads to significant control of soil borne pathogens. These crop residues and compost combination not only reduce the disease severity but also play a positive role in crop growth and development and ultimately leads to higher yield of crop. Moreover, it is very tough to know the exact predictors which play their role in crop development and disease suppression (Bonanomi et al., 2010).

5. Conclusions

Different plant residues and animal manure-based biochars had significant impact on growth, allometry, yield-related traits and SLB suppression in onion. Poultry litter biochar effectively suppressed SLB and improved yield and related traits of all tested cultivars. Although, several commercial fungicides are being applied to manage SLB, residual effects of such fungicides negatively affect human health and environment. Therefore, it is necessary to minimize chemical use and develop environment-friendly methods for SLB management. Poultry litter biochar seems a viable eco-friendly approach to suppress SLB and improve onion productivity. Therefore, it is recommended to use poultry litter biochar for SLB suppression and higher economic returns of onion.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abbas, T., Rizwan, M., Ali, S., Zia-ur-Rehman, M., Farooq Qayyum, M., Abbas, F., Hannan, F., Rinklebe, J., Sik Ok, Y., 2017. Effect of biochar on cadmium bioavailability and uptake in wheat (Triticum aestivum L.) grown in a soil with aged contamination. Ecotoxicol. Environ. Saf. 140, 37–47.
Abdel-Hafez, S.I., Abo-Elyousr, K.A., Abdel-Rahim, I.R., 2014. Effectiveness of plant extracts to control purple blotch and Stemphylium blight diseases of onion (Allium cepa L.) in Assiut, Egypt. Archiv. Phytopathol. Plant Protect. 47 (3), 377–387.
Abo-Elyous, K.A., Abdel-Hafe, S.I., Abdel-Rahi, I.R., 2017. Control of stemphylium leaf blight disease of onion and elevation of seed production using certain bioagents. Int. J. Plant Pathol. 8 (1), 1–7.
Ahmad, M.N., Büker, P., Khalid, S., Van Den Berg, L., Shah, H.U., Wahid, A., Emberson, L., Power, S.A., Ashmore, M., 2013. Effects of ozone on crops in north-west Pakistan. Environ. Pollut. 174, 244–249.
Alami, M.M., Xue, J., Ma, Y., Zhu, D., Abbas, A., Gong, Z., Wang, X., 2020. Structure, function, diversity, and composition of fungal communities in Rhizospheric soil of Coptis chinensis Franch under a successive cropping system. Plants. 9 (2), 244.
Ali, S., Rizwan, M., Noureen, S., Anwar, S., Ali, B., Naveed, M., Abd_Allah, E.F., Alqarawi, A.A., Ahmad, P., 2019. Combined use of biochar and zinc oxide nanoparticle foliar spray improved the plant growth and decreased the cadmium accumulation in rice (Oryza sativa L.) plant. Environ. Sci. Pollut. Res. 26 (11), 11288–11299.
Alyokhin, A., Nault, B., Brown, B., 2020. Soil conservation practices for insect pest management in highly disturbed agroecosystems–a review. Entomologia Experimentalis et Applicata. 168 (1), 7–27.
Arif, M., Atta, S., Bashir, M.A., Khan, M.I., Hussain, A., Shahjahan, M., Alwahibi, M.S., Elshikh, M.S., Farooq, S., 2021. The impact of Fosetyl-Aluminium application timing on Karnal bunt suppression and economic returns of bread wheat (*Triticum aestivum* L.). Plos one 16 (1), e0244931.
Atieno, M., Herrmann, L., Nguyen, H.T., Phan, H.T., Nguyen, N.K., Srean, P., Than, M. M., Zhiyong, R., Tittabutr, P., Shutsrirung, A., Bräu, L., Lesueur, D., 2020. Assessment of biofertilizer use for sustainable agriculture in the Great Mekong Region. J. Environ. Manage. 275, 111300.
Azhar, M., Zia ur Rehman, M., Ali, S., Qayyum, M.F., Naeem, A., Ayub, M.A., Anwar ul Haq, M., Iqbal, A., Rizwan, M., 2019. Comparative effectiveness of different biochars and conventional organic materials on growth, photosynthesis and cadmium accumulation in cereals. Chemosphere 227, 72–81.
Barros-Rodríguez, A., Rangseekaew, P., Lasudee, K., Pathom-aree, W., Manzanera, M., 2020. Regulatory risks associated with bacteria as biostimulants and biofertilizers in the frame of the European Regulation (EU) 2019/1009. Sci. Total Environ. 740, 140239.
Beesley, L., Moreno-Jiménez, E., Gomez-Eyles, J.L., 2010. Effects of biochar and greenwaste compost amendments on mobility, bioavailability and toxicity of inorganic and organic contaminants in a multi-element polluted soil. Environ. Pollut. 158 (6), 2282–2287.
Bonanomi, G., Antignani, V., Capodilupo, M., Scala, F., 2010. Identifying the characteristics of organic soil amendments that suppress soilborne plant diseases. Soil Biol. Biochem. 42 (2), 136–144.
Cong, Y., Fan, H., Ma, Q., Lu, Y., Xu, L., Zhang, P., Chen, K., 2019. Mixed culture fermentation between Rhizopus nigricans and Trichoderma pseudokoningii to control cucumber Fusarium wilt. Crop Prot. 124, 104857.
Fitiwy, I., Gebretsadkan, A., Ayimut, K.-M., 2015. Evaluation of botanicals for onion thrips, Thrips tabaci Lindeman, (Thysanoptera: Thripidae) control at Gum Selassa, South Tigray, Ethiopia. Momona Ethiopian J. Sci. 7, 32–45.
Gebretsadkan, A., Araya, A., Fitiwy, I., Yohannes, T., Kalayu, Z., 2020. Effect of pesticidal weed extracts and soil solarization on soil health and management of onion white rot (Sclerotium cepivorus). Archiv. Phytopathol. Plant Protect. 53 (13-14), 625–639.
Gedefaw, Y., Gezahegn, A., Fekadu, A., Mehari, Z., 2019. First report of Stemphylium vesicarium causing onion Stemphylium leaf blight in Ethiopia. Agricultural Sci. 10, 1104.
Hay, F.S., Sharma, S., Hoepting, C., Strickland, D., Luong, K., Pethybridge, S.J., 2019. Emergence of Stemphylium Leaf Blight of Onion in New York Associated With Fungicide Resistance. Plant Dis. 103 (12), 3083–3092.

Hoepting, C., 2018. Effect of fungicide programs for control of Stemphylium leaf blight on onion, 2017. Plant Dis. Manage Rep. 12, V144.
Hussein, M., Hassan, M., Allam, A., Abo-Elyousr, K., 2007. Management of Stemphylium blight of onion by using biological agents and resistance inducers. Egypt J Phytopathol. 35, 49–60.
Leach, A., Hay, F., Harding, R., Damann, K.C., Nault, B., 2020. Relationship between onion thrips (Thrips tabaci) and Stemphylium vesicarium in the development of Stemphylium leaf blight in onion. Ann. Appl. Biol. 176, 55–64.
Lee, R., Baldwin, S., Kenel, F., McCallum, J., Macknight, R., 2013. FLOWERING LOCUS T genes control onion bulb formation and flowering. Nat. Commun. 4, 1–9.
Lehmann, J., Rillig, M.C., Thies, J., Masiello, C.A., Hockaday, W.C., Crowley, D., 2011. Biochar effects on soil biota–a review. Soil Biol. Biochem. 43 (9), 1812–1836.
Mahlein, A.-K., Oerke, E.-C., Steiner, U., Dehne, H.-W., 2012. Recent advances in sensing plant diseases for precision crop protection. Eur. J. Plant Pathol. 133 (1), 197–209.
Marcuzzo, L.L., Haveroth, R., 2016. Development of a weather-based model for Botrytis leaf blight of onion. Summa Phytopathologica. 42 (1), 92–93.
Mishra, B., Singh, R.P., 2017. Fungicidal management of Stemphylium Blight of Onion caused by Stemphylium Vesicarium (Wallr.) Simmons. Biosci. Biotechnol. Res. Asia 14 (3), 1043–1049.
Quintanilla-Tornel, M.A., Wang, K.-H., Tavares, J., Hooks, C.R.R., 2016. Effects of mulching on above and below ground pests and beneficials in a green onion agroecosystem. Agric. Ecosyst. Environ. 224, 75–85.
Rafique, M., Ortas, I., Ahmed, I.A.M., Rizwan, M., Afridi, M.S., Sultan, T., Chaudhary, H.J., 2019. Potential impact of biochar types and microbial inoculants on growth of onion plant in differently textured and phosphorus limited soils. J. Environ. Manage. 247, 672–680.
Rehman, M.Z.-u., Rizwan, M., Ali, S., Fatima, N., Yousaf, B., Naeem, A., et al., 2016. Contrasting effects of biochar, compost and farm manure on alleviation of nickel toxicity in maize (Zea mays L.) in relation to plant growth, photosynthesis and metal uptake. Ecotoxicol. Environ. Saf. 133, 218–225.
Riaz, M., Mahmood, R., Khan, S.N., Haider, M.S., Ramzan, S., 2020. Onion tip burn: significance, and response to amount and form of nitrogen. Scientia Horticulturae. 261, 108773. https://doi.org/10.1016/j.scienta.2019.108773.
Rizwan, M., Ali, S., Qayyum, M.F., Ibrahim, M., Zia-ur-Rehman, M., Abbas, T., Ok, Y.S., 2016. Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: a critical review. Environ. Sci. Pollut. Res. 23 (3), 2230–2248.
Rizwan, M., Ali, S., Zia ur Rehman, M., Adrees, M., Arshad, M., Qayyum, M.F., Ali, L., Hussain, A., Chatha, S.A.S., Imran, M., 2019. Alleviation of cadmium accumulation in maize (Zea mays L.) by foliar spray of zinc oxide nanoparticles and biochar to contaminated soil. Environ. Pollut. 248, 358–367.
Selvaraj, T., Tadele, S., Amin, M., 2014. White rot (Sclerotium cepivorum Berk)-an aggressive pest of onion and garlic in Ethiopia: An overview. J. Agricultural Biotechnol. Sustain. Develop. 6 (1), 6–15.
Shahnaz, E., Razdan, V., Banday, S., 2018. Effect of soil solarization on the growth of onion (Aliium cepa L.) and onion blight disease. J. Pharmacognosy Phytochem. 7, 417–421.
Taha, N., Kamel, S., Elsakhawy, T., Bayoumi, Y., Omara, A.E.-D., El-Ramady, H.R., 2020. Sustainable approaches of Trichoderma under changing environments for vegetable production. Environ., Biodiversity Soil Security. 4, 291–311.
Tripathi, A., Meena, B., Pande Tayviah y, K., Singh, J., 2020. In: Microbial Bioagents in Agriculture: Current Status and Prospects. New Frontiers in Stress Management for Durable Agriculture. Springer, pp. 331–368.
ur Rehman, M.Z., Khalid, H., Akmal, F., Ali, S., Rizwan, M., Qayyum, M.F., Iqbal, M., Khalid, M.U., Azhar, M., 2017. Effect of limestone, lignite and biochar applied alone and combined on cadmium uptake in wheat and rice under rotation in an effluent irrigated field. Environ. Pollut. 227, 560–568.
Vitale, S., Luongo, L., Galli, M., Belisario, A., 2017. First report of Stemphylium vesicarium on chilli pepper in Italy. New Disease Reports 35, 36.
Younis, U., Malik, S.A., Rizwan, M., Qayyum, M.F., Ok, Y.S., Shah, M.H.R., Rehman, R. A., Ahmad, N., 2016. Biochar enhances the cadmium tolerance in spinach (Spinacia oleracea) through modification of Cd uptake and physiological and biochemical attributes. Environ. Sci. Pollut. Res. 23 (21), 21385–21394.