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BIOCHAR OPTIMIZES GROWTH, YIELD AND QUALITY OF WHEAT WITH NITROGEN UPTAKE IN LOW CALCAREOUS FERTILITY SOIL TREATED WITH MINERAL NITROGEN AND ORGANIC SOURCES

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ABSTRACT

Nutrient uptake and crop quality are significantly inclined by fertilization efforts and their supplied rates. Biochar enhanced crop productivity and their nutrient uptake of wheat, however its collaboration with organic amendments and mineral fertilizers not fully explored to these amendments to understand their role for enhancing wheat productivity and nutrient uptake. Therefore, we conducted two years research study to inspect the role of biochar with organic and mineral amendments. The experiment comprised with forms of organic sources (biochar and crop residues), Organic sources (Cowpea, Parthinium hysterphorus and Eucalyptus camaldulensis) added five tons ha^{-1} and thrice N doses (100, 120 and 140 kg ha^{-1}) respectively along with one control treatment in two years of field experiment. The application of 5 tons biochar of cowpea source along with 140 kg N ha^{-1} as mineral fertilizer positively enhanced growth, yield and nitrogen uptake i.e. 30% improvement in leaf area tiller^{-1}, 37% increase in leaf area index, thousand seed weight (13%) and grain yield (29%) while their N uptake by grains and straw 12.6% and 20% respectively, total N uptake 39.2% and protein 12% was improved over treatments where no any amendments done crosswise both years. Whereas the influence was more auspicious at second year (2021-22) afterward amended of biochar with organic and synthetic amendments compared with 1st year. Therefore, for better crop growth and yield, quality and N uptake biochar of organic source as cowpea along with 140 kg N ha^{-1} is recommended in semi-arid calcareous soils agro-climatic condition of the study area.

Keywords; *Biochar, protein, nitrogen uptake, organic amendments, mineral nitrogen.*

INTRODUCTION

Pakistan's economy is largely agrarian, with a significant portion of the people reliant on agriculture for their livelihoods (Ahmad et al., 2020). The overreliance on a few major crops, such as wheat and rice, poses a risk to food security (Baloch et al., 2020). Ensuring food security involves not only sufficient food production but also accessibility, affordability, and nutritional quality of food for all segments of the population (Chen et al. 2018; Rizwan et al., 2017).

Wheat (*Triticum aestivum L.*) is a dynamic crop in cereals and an significant portion of the daily nutrition of more than 70% of the world's population (Rizwan et al., 2017). It is cultivated on about 200 million hectares in various regions and delivers almost 9% of the food desires of the world (Saikia et al., 2015). Hence, worldwide wheat productivity essential to endure and rise to meet collective demand from increasing population (Singh and Sidhu. 2014). Pakistan ranks 8th in wheat productivity (Muhammad et al., 2013), which is full-grown on more than 42% of Pakistan's agricultural land-living. Wheat is growing in a diverse kind of environments, from temperate to subtropical regions (Tariq et al., 2017). Major wheat-producing regions include China, India, Russia, USA, France and Pakistan. Wheat is a rich source of carbohydrates, providing essential energy (Upendra et al., 2019). It also comprises proteins, dietary fiber, vitamins (such as B vitamins), and minerals together with iron and magnesium (Shah et al., 2017). Whole wheat products, retaining the bran and germ layers, are chiefly nutritious (Sarwar et al., 2008). Wheat has multipurpose usages, with its prime products being flour and numerous wheat-based food items (Wang et al., 2015). These contain bread, pasta, pastries, cereals, and more. Wheat straw, the plant's residue after harvest, is also used for animal fodder, bedding, and in some gears, biofuel production. Wheat is a main commodity in international trade, paying meaningfully to the global economy (Yasin et al., 2010). Its reputation spreads beyond direct feeding, as it serves as a key ingredient in various processed foods (Shah et al. 2017).

Biochar can absolutely impact soil microbial communities. It delivers a habitat for beneficial microorganisms, endorsing their growth and activity (Murtaza et al., 2021; Rodríguez-Vila et al. 2022). This property helps avoid nutrient leaching, guaranteeing that imperative elements like nitrogen, phosphorus, and potassium remain accessible to wheat plants for a more prolonged period (Premalatha et al. 2023; Rodríguez-Vila et al., 2022). Incorporating biochar into the soil contributes to carbon sequestration, serving to mitigate climate change (Rombola et al., 2022: Schmidt et al. 2021). The constant carbon structure of biochar performs as a long-term pool for carbon, reducing the net emissions from the soil (Abbruzzini et al. 2019; Cha et al., 2016). Healthy soil microbial societies contribute to nutrient cycling, disease suppression, and overall soil health. In regions with acidic soils, biochar can help neutralize soil pH (Premalatha et al., 2023). The liming outcome of certain types of biochar can contribute to generating a more neutral pH, which is advantageous for wheat cultivation as wheat (Chintala et al. 2014).

Crop residues, the leftover plant resources after harvesting, offer numerous aids in agriculture (Usman et al., 2018). These residues can be used in several ways to enhance soil health, improve crop productivity, and their contribution to sustainable agricultural practices. Here are some key benefits of employing crop residues in agriculture (Zhai et al., 2015). Crop residues are rich in organic matter. This boosts the overall health and fertility of the soil. Crop residues comprise important nutrients such as nitrogen, phosphorus, and potassium (Zhang et al., 2014). Returning these residues to the soil agrees for nutrient recycling, reducing the need for synthetic fertilizers. This helps preserve or enhance soil fertility and provisions healthy plant growth (Gabhane et al., 2012; Casado and Abril. 2013). This defensive cover helps avert the loss of valued topsoil and protects against the negative influences of severe weather events (Celik et al., 2017). Incorporating cowpea residues into the soil contributes to carbon sequestration (Kinoshita et al., 2017). This process helps build soil organic carbon, enhancing soil fertility and providing a stable source of organic matter for wheat crops (Machado et al. 2015). This is particularly beneficial in regions with limited water availability, helping wheat crops handle with water stress (Gupta et al., 2014). Farmers often implement preservation agriculture practices, such as minimal tillage or no-till farming, to make best use of the benefits of crop residues in sustainable wheat production (Stewart et al. 2018).

MATERIALS & METHODS

DESCRIPTION OF STUDY AREA

A two years experiment in field was carried out at the Research farm of Agronomy, Agriculture University Peshawar Pakistan for two consecutive years 2020-21 & 2021-22. The experimental site is located at 34.01° N latitude, 71.35° E longitude, at an altitude of 359 m above sea level in Peshawar valley. Soil is clay loam, low in organic matter, phosphorus, potassium, alkaline and calcareous in nature. The climate of the area is semiarid and weather data (mean rainfall, temperature and relative humidity) of the growing season are given in (Figure 1 & 2). The fields of research farm is irrigated by canals of warsak from Kabul River. Physico-chemical properties of the experimental site are shown in (Table 1).

Table 1. Pre-sowing soil physico-chemical properties of the experimental site (0-30 cm depth).

Soil properties	Unit	Value
Clay	%	12.7
Silt	%	50.0
Sand	%	37.3
Textural class	-	Sandy loam
pH	-	7.67
EC	d S m^{-1}	0.15
Organic matter	%	0.81
Total nitrogen	%	0.07
Phosphorus	mg kg^{-1}	2.31
Potassium	mg kg^{-1}	105.9

EXPERIMENTAL INPUTS

For biochar, whole plants of Parthenium hysterophorus, leaves and branches of *Eucalyptus camaldulensis* and *Vigna unguiculata* was chopped in to small pieces and their biochar was arranged through preparation technique of previously described of Arif et al. (2021). For plants residues, whole plants of *Parthenium hysterophorus,* leaves and branches of *Eucalyptus camaldulensis* and *Vigna unguiculata* was chopped in to small pieces and applied two weeks before sowing of wheat crop. For mineral nitrogen, nitrogen doses were prepared and applied in split doses whereas urea was used as source for mineral nitrogen. Similar field layout and experimental treatments were used for second year experiment.

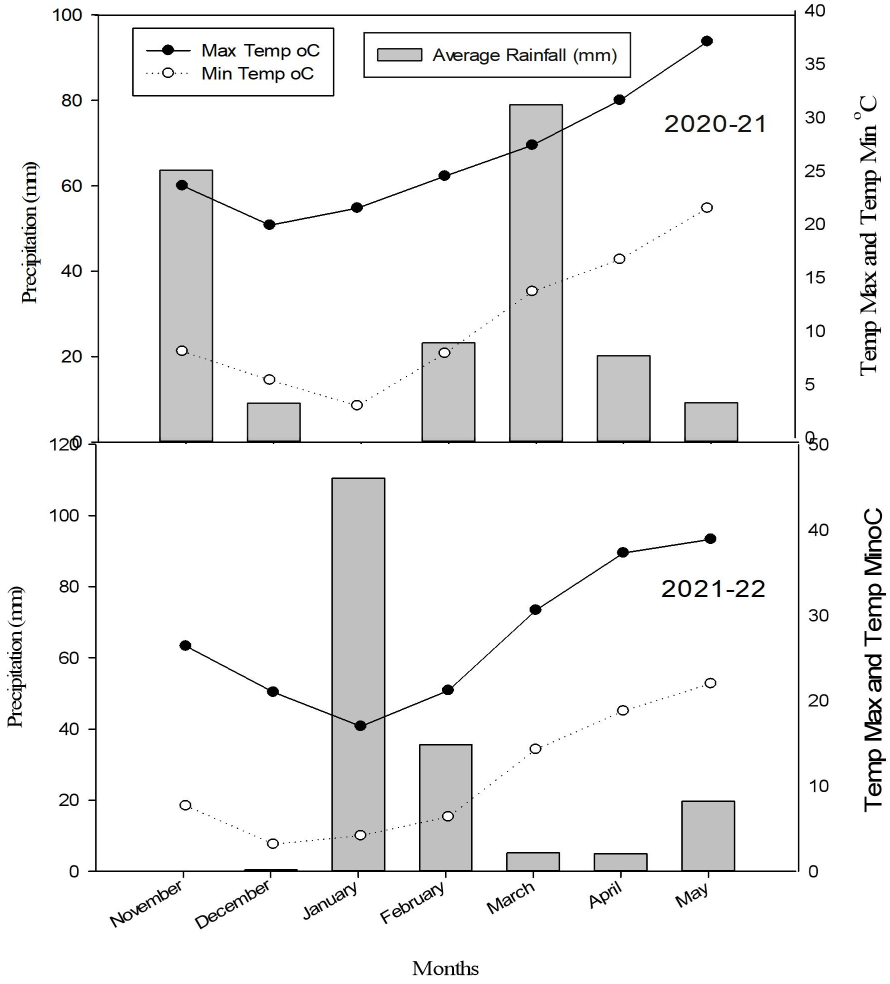


Fig. 1. Monthly average maximum and minimum temperature and rainfall (mm) during both Rabi seasons 2020-21 and 2021-22 at study area. (Pakistan meteorological department Peshawar).

EXPERIMENTAL DESIGN AND TREATMENTS

The field trial was laid out as factorial experiment with randomized complete blocks design along with three replications. The experimental factors comprised with three factors i.e. Forms of organic sources (biochar and crop residues), Organic sources (Cowpea, Parthinium hysterphorus and Eucalyptus camaldulensis) applied at the rate of five tons ha^{-1} and N doses (100, 120 and 140 kg ha^{-1}) respectively. Field was properly ploughed through common cultivator. Experimental treatments were allotted to the respective plots two weeks before sowing the crop. The plots size of each treatment was 4 x 2.4 m, having 8 rows 30 cm separately, 4 m long. Variety Pirsabak-2015 sown with seed rate of 120 kg ha^{-1}. Sources of biochar and residues applied 5 tons ha^{-1} two weeks before sowing. Treatments of N was added in different three split dosages i.e. sowing time, initial irrigation and tillering stage. Different agronomic practices was carried out uniformly for all treatments.

PROCEDURE FOR RECORDED OBSERVATIONS

Leaf area tiller^{-1}

LA tiller^{-1} was calculated by from the leaves of randomized selection of five tillers in each experimental unit at anthesis stage, the leaf area of all leaves were measured and calculate through using following formula.

LA tiller^{-1} = average length and width of leaf x leaves numbers x 0.75

Leaf area index

LAI for wheat crop was noted by distributing mean data of LA tiller^{-1} and tillers m^{-2} numbers to ground area through following formula:

$$LAI = \frac{\text{LA tiller}^{-1}\ (cm^2) \times \text{tillers } m^{-2} \text{ numbers}}{10000\ cm^2}$$

Thousands seeds weight (g)

For grains of thousands seeds weight of wheat, grains were taken and counted randomly from each seed lot and noted their weight.

Economic yield (kg ha^{-1})

Economic yield of wheat was observed after separating seeds of the reaped central four rows of every treatment, seeds then converted by the following:

$$\text{Economic production (kg ha}^{-1}\text{,)} = \frac{\text{economic production in three rows,}}{\text{R-R distance (m), x Row length (m), x No. of rows,}} \times 1000\ (m^{-2})$$

Wheat seed protein content (%)

Protein contents of wheat seeds achieved by multiplying the calculated grain N concentration with 6.25 as described by Kjeldahl method as showed in formula (AOAC. 1990):

Protein (%) = grain N content (%) x 6.25

Nitrogen uptake by seeds, straw and total N, Uptake (kg ha^{-1},)

Straw and grain N uptake (kg ha^{-1}) was measured by the formulas:

N, uptake by grains, (kg ha^{-1}) = grain N, (g kg^{-1}) x Grain yield (kg ha^{-1})/1000

Straw N uptake (kg ha^{-1}) = (Straw N (g kg^{-1}) x Straw yield (kg ha^{-1})/1000

Total N uptake was worked out as the sum of amount of straw and seeds N uptake.

Statistical Analysis

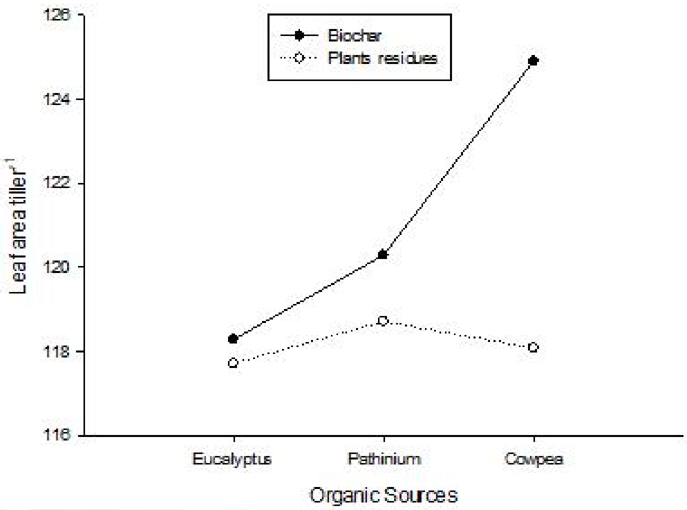
Statistical analysis of the recorded observation were carried out for ANOVA method appropriated for RCB factorial design as described by (Jan et al., 2009) at 5% level of significance for comparison of (LSD).

RESULTS

Leaf area tiller^{-1} (cm^2)

Among different organic sources, cowpea produced higher (121.5 cm^2) leaf area tiller^{-1} followed by parthenium application (Table 3). Parthenium residues application produced lower leaf area tiller^{-1} (119.5 cm^2) which were statistically similar with eucalyptus residues application (118 cm^2). Leaf area tiller^{-1} were observed higher in those plots where organic sources was applied in form of biochar. Biochar treated plots produced higher (121.2 cm^2) leaf area tiller^{-1} whereas lower (118.2 cm^2) was noticed in crop residues treated plots. When comparing treatments with nitrogen, nitrogen applied at 140 kg ha^{-1} with a higher level of application, plants recorded higher leaf area tiller^{-1} (122.3 cm2), that is statistically alike to plots treated with N added at rate of 120 kg ha^{-1} (120.8 cm2). Conversely, lower leaf area tiller^{-1} (115.9 cm2) was noticed where N were used at rate of 100 kg ha^{-1}. The integrated effect of forms and sources showed (Fig 2) that organic source cowpea applied in form of biochar respond maximum leaf area tiller^{-1} as compared to organic sources applied in form of plants residues. Similarly, the cooperative effect of years and control vs rest showed that year second showed more response in leaf area tiller^{-1} than year first in rest plots as compared to control plots.

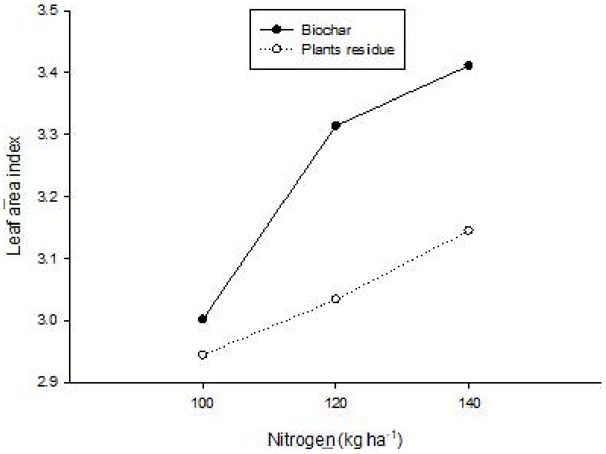
Fig 2. Integrated influence of organic sources with forms on LA tiller^{-1} of wheat.



Leaf area index

Analysis of the LAI statistical data demonstrated the significant effect of different organic sources, their forms and varying nitrogen concentrations (Table 3). Regarding interactive effect, except for F x N (Figure 4), all potential interactions between distinct organic sources, their forms, and varying quantities of nitrogen were found non-significant. The leaf area index of wheat increased with the addition of cowpea residues, followed by parthenium. While minimum was recorded with the application of eucalyptus residues. Cowpea residues produced higher leaf area index (3.27) while lower leaf area index was observed with eucalyptus residues application (3.01). Regarding forms application, plots treated with organic sources in form of biochar recorded more leaf area index than plots treated with crop residues. As with nitrogen levels, higher dose of N addition at 140 kg ha^{-1} created the highest LAI (3.28), followed by N used at a rate of 120 kg ha^{-1}, while a less rate of nitrogen application 100 kg ha^{-1} produced a lower LAI (2.97). When comparing biochar-treated plots treated with different plant residues, the interactive effect of forms and nitrogen revealed that the leaf area index rise with increasing nitrogen levels up to 140 kg ha^{-1} (Fig 3)

Fig 3. Integrated effect of nitrogen & organic sources forms on LAI of wheat.



Thousand grains weight (g)

The statistical data means analysis showed that adding organic sources of plants residues, such as cowpea application recorded maximum grains weight (44 g) followed by parthenium residues (41.1 g), whereas eucalyptus residues treated plots produced light grains (39.8 g). Organic source applied as biochar form produced heavier grains (42.9 g) as compared to organic source applied in form of plants residues (40.4 g). Regarding inorganic nitrogen levels, it was observed that thousand grains weight increased with increasing nitrogen dose. Heavier grains (43.5 g) were recorded from those treatments where nitrogen was supplied at a greater dose (140 kg N ha^{-1} tailed by N added at dose of 120 kg ha^{-1}) whereas less grains weight (39.7 g) were observed in treatments that received a lower dose of nitrogen (100 kg N ha^{-1}). The mean values of years indicated that heavier grains (42.0 g) were noted in second year as linked to year one. The average control vs. rest effect comparison exposed that fertilized treatments generated heavier grains than control plots. The interactive effect of organic sources and forms showed that all organic sources applied in form of biochar recorded better respond as compared to organic sources applied in form plants residues (Fig 4).

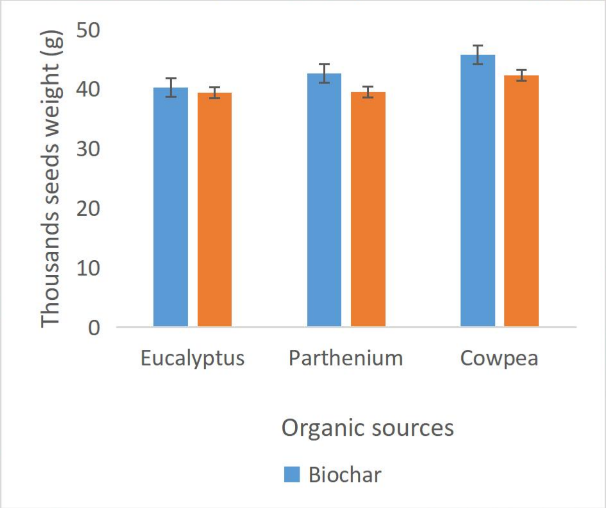


Fig 4. Integrated effect of organic sources and forms of organic sources on thousands seeds weight of wheat.

Grain yield (kg ha^{-1})

The mean values of the various organic plant sources indicated that adding cowpea residues increased wheat grain yield (3663 kg ha^{-1}), followed by parthenium residues. Adding eucalyptus residues formed the lowest wheat grain yield (3346 kg ha^{-1}). Regarding forms of organic sources, the economic yield of wheat was more (3641 kg ha^{-1}) when organic sources was applied in form of biochar while lowers grain yield (3344 kg ha^{-1}) was measured with organic sources applied in form of residues. When different amounts of inorganic nitrogen were applied, it was found that the wheat grain productivity increased with the highest nitrogen application dose. The highest economic yield of wheat (3852 kg ha^{-1}) was set up by applying N at dose of 140 kg ha^{-1}, tailed by 120 kg N ha^{-1} whereas minimum grain yield of wheat (3163 kg ha^{-1}) were produced by applying a lower dose of nitrogen i.e. 100 kg ha^{-1}

Table 2. LA tiller^{-1}, LAI, Thousand seeds weight (g) and economic yield, (kg ha^{-1},) of wheat as influenced by biochar, organic sources and mineral N.

Treatments	Leaf area tiller^{-1}	Leaf area index	Thousand grains weight (g)	Economic yield (kg ha^{-1})
Sources (S)				
Cowpea	121.5 a	3.27 a	44.00 a	3663 a
Parthinium	119.5 b	3.14 b	41.07 b	3469 b
Eucalyptus	118.0 b	3.01 c	39.84 c	3346 c
LSD for S	1.8	0.09	0.86	103
Forms (F)				
Biochar	121.2 a	3.24 a	42.88 a	3641 a
Plants residue	118.2 b	3.04 b	40.39 b	3344 b
LSD for F	1.5	0.07	0.70	84
N Levels (kg ha^{-1})				
100	115.9 b	2.97 c	39.71 c	3163 c
120	120.8 a	3.17 b	41.75 b	3463 b
140	122.3 a	3.28 a	43.45 a	3852 a
LSD for N	1.8	0.09	0.86	103
Years				
2020-21	119.4	3.13	41.26 b	3356 b
2021-22	119.9	3.15	42.01 a	3629 a
Significance	Ns	Ns	*	*
Contrast				
Control	93.2 b	2.36 b	37.77 b	2807 b
Rest	119.7 a	3.14 a	41.64 a	3493 a
Significance	*	*	*	*

Nitrogen uptake by grain (kg ha^{-1})

According to statistical analyzed of the data, mean values of the data represent that cowpea residues addition recorded higher (84.2 kg ha^{-1}) grain nitrogen uptake of wheat followed by parthenium residues while lower grain nitrogen uptake of wheat was recorded with addition of eucalyptus residues (74.4 kg ha^{-1}). In case of forms, organic sources applied in the form of biochar produced more grain nitrogen uptake (84.5 kg ha^{-1}) of wheat as compared to organic sources in form of residues application. In terms of inorganic nitrogen levels, the treatments with the highest grain nitrogen uptake (89.1 kg ha^{-1}) of wheat applied a higher dose of nitrogen (140 kg ha^{-1}), tracked by nitrogen applied at dose of 120 kg ha^{-1}. In contrast, the plots with lower grain N uptake (69.6 kg ha^{-1}) were recorded to addition of lower level of N (100 kg ha^{-1}). Nitrogen uptake by wheat grain was noted maximum for year second than in year first. It was also observed that in fertilized plots grain nitrogen uptake was recorded maximum than control plots.

Nitrogen uptake by straw (kg ha^{-1})

Means of the statistical analyzed data revealed that maximum nitrogen uptake by wheat straw (41.7 kg ha^{-1}) were recorded with application of cowpea residues as organic source followed by parthenium plant residues which was statistically similar with eucalyptus residues (36.3 kg ha^{-1}) as given in (Table 3). Considering forms, biochar applied form of plants residues produced higher (41 kg ha^{-1}) wheat straw nitrogen uptake as compared to form of plants residues. In terms of inorganic nitrogen application, the highest nitrogen uptake (44.4 kg ha^{-1}) was recorded for wheat straw when a higher rate of N was added at dose of 140 kg ha^{-1}, trailed by N at 120 kg ha^{-1}. In contrast, the lower nitrogen uptake (34 kg ha^{-1}) was observed for wheat straw in plots where lower rate of N (100 kg ha^{-1}) was used. Control vs rest data indicated that nitrogen uptake by wheat straw was maximum in fertilized treatments as compared with control plots. Mean values of the data for year as a source of variation shows that wheat straw nitrogen uptake of wheat was recorded higher in year second as compared with year first.

Total nitrogen uptake (kg ha^{-1})

Data indicating that different organic sources of plant residues, form and inorganic nitrogen levels significantly affect wheat's total nitrogen uptake are showed at (Table 3). Analysis of the observations shows that total nitrogen uptake of wheat was recorded maximum (126 kg ha^{-1}) for cowpea residues application followed by parthenium residues whereas minimum (110.7 kg ha^{-1}) total N uptake were recorded with incorporation of eucalyptus residues. Considering forms of organic sources, total N uptake were noticed maximum (125.5 kg ha^{-1},) when applied in form of biochar as compared to application in form of crop residues. Regarding inorganic nitrogen application, the highest total nitrogen uptake (133.5 kg ha^{-1}) were noted for 140 kg ha^{-1} nitrogen addition, followed by 120 kg ha^{-1}. In comparison, the lowest total N uptake (103.5 kg ha^{-1}) was recorded for 100 kg ha^{-1} N addition. Compared to the first year, the total nitrogen intake of wheat in the second year was reported at a maximum of 122.5 kg ha^{-1}. It was also observed that fertilized plots were recorded maximum for total nitrogen uptake as compared to control treatments.

Grain protein content (%)

Regarding data on grain protein content of wheat, different organic sources, their forms and amounts of inorganic nitrogen significantly affected wheat grain protein content (Table. 4). Analyzed statistical data showed that applying cowpea residues as an organic source of plant residues increased (14.3%) the protein content of wheat seeds, followed by parthenium residues while applying eucalyptus residues resulted in the lower (13.9%) grain protein content. When organic sources was applied in form of biochar, wheat grains protein content was recorded higher (14.5%) than organic sources in form plant residues. Considering different levels of inorganic nitrogen application, nitrogen applied at 140 kg ha^{-1} produced significantly higher (14.4 %) wheat grain protein content as compared to other levels which is followed by nitrogen applied at 120 kg ha^{-1} whereas inorganic N added at 100 kg ha^{-1} noted lower (13.7 %) wheat grain protein content. Fertilized plots were observed high in grain protein content of wheat as compared with control treatments while wheat grain protein content was recorded higher in year second as compared with year first.

Table 3. N uptake by straw, N uptake by grains, TNU (kg ha^{-1}) Protein (%) of wheat as influenced by biochar, organic sources & mineral N.

Treatments	straw N uptake,(kg ha^{-1})	grains N uptake, (kg ha^{-1},)	T.N uptake (kg ha^{-1},)	Protein (%)
Sources (S)				
Cowpea	41.7 a	84.2 a	126.0 a	14.31 a
Parthinium	38.6 b	78.4 b	117.0 b	14.10 b
Eucalyptus	36.3 b	74.4 c	110.7 c	13.85 c
LSD for S	2.2	2.7	4.3	0.21
Forms (F)				
Biochar	41.0 a	84.5 a	125.5 a	14.47 a
Plants residue	36.7 b	73.5 b	110.3 b	13.71 b
LSD for F	1.8	2.2	3.5	0.17
N Levels (kg ha^{-1})				
100	34.0 c	69.6 c	103.5 c	13.72 c
120	38.3 b	78.4 b	116.6 b	14.11 b
140	44.4 a	89.1 a	133.5 a	14.43 a
LSD for N	2.2	2.7	4.3	0.21

Years				
2020-21	37.7 b	75.6 b	113.2 b	14.02
2021-22	40.1 a	82.5 a	122.5 a	14.15
Significance	*	*	*	NS
Contrast				
Control	31.5 b	57.8 b	90.1 b	12.86 b
Rest	38.9 a	79.0 a	118.0 a	14.09 a
Significance	*	*	*	*

DISCUSSION

Wheat growth and yield as influenced by biochar and nitrogen

Biochar applied from different organic sources, compared to plants residues, biochar applied to wheat produced high leaf area tiller^{-1} and greater LAI, thousands grains weight and grain yield of wheat. The effects were most noticeable when biochar from organic sources, cowpea, parthenium and eucalyptus was mixed with 140 kg N ha^{-1}. In the 2020–21 and 2021–22 growing seasons, inorganic nitrogen, organic sources, and biochar amendments significantly increased wheat yield and yield-related components. Comparing organic sources, the addition of biochar derived from cowpea residues along with 140 kg ha^{-1} N application resulted in a 30% improvement in leaf area tiller^{-1}, 37% increase in leaf area index thousand seed weight (13%) and grain yield (29%) as compared to control treatments. This increase in wheat growth and yield with the amendments of biochar treatments, the reason maybe because of nutritious status of biochar which supplements its crucial elements and added in soil for long turn, reducing nutrient loss and finally boost the soil status of fertility. One possible explanation for the enhanced crop growth and yield could be the result of a collective application of organic and inorganic nitrogen, which made a significant amount of nutrients available to the crop for its whole life. This would allow optimal nutrient uptake and increased biomass output (Zhang et al., 2017; Wei et al., 2018). Our findings support Lehmann et al. (2006) and Arif et al. (2021), they suggested that nutrients in biochar additions may cause the observed short-term rise in crop yields. Long lasting impacts of BC, related to elements obtainability is attributed a rise in CEC, oxidation of surface, where it strengthens over many times and results in better retention of nutrients in soil. according to Cheng et al. (2006) and Liang et al. (2006). The influence of biochar on soil physio-chemical properties, such as boosted holding capacity of water, enhaced CEC and giving support as pathway for nutrients and elements engagement by enlightening circumstances for microbial activity in soil flora are potential clarifications for the intensification in wheat growth and productivity in amended of biochar treatments (Chan et al., 2007; Sohi et al., 2009). According to Zhang et al. (2019) and Arif et al. (2017), BC boosts crop yield by enhancing fertilization and fertility status of soil, particularly N fertilizers. When nitrogen was applied, Ali et al. (2019) observed higher plants and a greater LAI in treated treatments comparing with control one. In a similar way, Khan et al. (2022) found that applying organic nitrogen or synthetic nitrogen (urea) boosted the leaf area index, leaf area, and plant height of wheat. Nitrogen addition increased plant height and leaf area because it enhanced photosynthetic activity (Reis et al., 2016) and nutrient uptake (Eid et al., 2020; Akhtar et al., 2019). According to Anas et al. (2020), organic sources are an excellent source of several macro and micronutrients, particularly nitrogen. Song et al. (2018) reported increased in economic yield of wheat in biochar treated plots, whereas Purakayastha et al. (2016) reported high stover production of maize. The biomass productivity of maize in biochar amended treatments showed comparable improvements, as stated by Song et al. (2018) and Purakayastha et al. (2016). Alburquerque et al. (2014) and Ahmad et al. (2022) also noted that sunflower had the maximum dry biomass with amendment of high dose of BC produced with cutting olive trees; this was primarily because the soil used for the experiment was not fertile and the sunflower was nutritious. According to Lehmann et al. (2009) and Liu et al. (2017), BC incorporation may have an subsidiary effect by decreasing nutrient leaching and improving fertilizer use efficiency, which could lead to an increase in wheat growth and yield. Comparably, Thomazini et al. (2015) found that applying BC enhanced cereal production and its components.

Protein and total nitrogen uptake by wheat straw and grain as influenced by biochar and nitrogen

Along with raising yield and output, the most crucial goal is to improve wheat quality. Increasing the protein concentration in grains is preferable since more protein might result in more robust and higher-quality dough. The biochar-incorporated treatments showed increases in grain and straw nitrogen uptake, seed protein content, and total N uptake of 12.6%, 20%, 12%, and 39.2%, respectively, compared to the control plots. Similarly, compared to control treatments, nitrogen fertilization showed a 48% increase in total nitrogen uptake and an 11.6% rise in grain protein concentration. The rationale might be that biochar incorporated plots have better nutrient availability, further enhancing quality features in plants because of N uptake in high amount. Additionally, Ali et al. (2015) reported that applying biochar improved the nitrogen content of grains by 56%. Dai et al. (2017) reported that adding BC increased N in maize grains. However, Slavich et al. (2013) reported that adding biochar significantly increased wheat seed nitrogen content (24%). Ouyang et al. (2014) too noticed that plots with biochar added at 20 t ha^{-1} had better grain protein content, higher nitrogen uptake, and higher nitrogen content in the seeds. In contrast to our findings, Deluca et al. (2009) reported that adding BC increased the amount of N in plants, boosting the plant's ability to use N. The study found that the application of biochar from different organic sources considerably increased the protein content of wheat grains. Because BC retains ammonium ions and prevents bacteria from converting them into NO3, so the longer half-life of NH4+ ions in the soil may be the reason. Additionally, biochar significantly reduces N losses from volatilization and leaching in soil. Tan et al. (2015) confirmed these findings by observing that applying biochar significantly increased the uptake of nitrogen (N) in maize and wheat. This impact was attributed to either direct adsorption or indirect microbial immobilization caused by the biochar. Lehmann et al. (2006) found that adding biochar-amended urea to wheat grains increased their percentage of nitrogen content, which significantly increased status of protein in wheat seeds (Yuan et al., 2013; Abbruzzini et all., 2019). Additionally, Ali et al. (2015) found that applying biochar to wheat resulted in a 20% increased grain protein content. Increased nitrogen uptake in wheat straw and grains with biochar-altered treatments demonstrated the beneficial influence of biochar in improving manures usage proficiency, specially when N loss is a primary agronomic and environmental concern. The issue of nutrients from BC, primarily nitrogen (N), as well as its ability to reduce nutrient leaching also moisture retention (Rodríguez et al., 2022; Murtaza et al., 2021). According to Abukari et al. (2018), biochar is a binding material that lowers N losses. As a result, BC's improved capacity to hold nutrients leads to increased dry matter production and nutrient uptake. Murtaza et al. 2021; Rombola et al. 2022 and Premalatha et al. (2023) also reported greater nutritional uptake of N in the roots and shoots of wheat in biochar treated plots with similar results.

CONCLUSION & RECOMMENDATION

The application of 5 tons biochar of cowpea source and also 140 kg N ha^{-1} as mineral fertilizer meaningfully enhanced wheat growth, yield and nitrogen uptake i.e. 30% improvement in leaf area tiller^{-1}, 37% increase in leaf area index, thousand seed weight (13%) and grain yield (29%) while their N uptake by grains and straw 12.6% and 20% respectively, total N uptake 39.2% and protein 12% was improved over absolute control when averaged across the year. When compared year's means, the addition of biochar of cowpea source along with mineral N was more pronounced and impactful during 2nd years. Henceforth the applied 5 tons biochar of cowpea source also with 140 kg ha^{-1} N as mineral fertilizer recommended and a auspicious option for enhancing wheat yield uptake of nutrient and crop superiority in semi-arid agro- climatic condition under calcareous soils.

CONFLICT OF INTEREST

The authors declared that they have no any conflict of interest regarding this research study

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Junaid Ahmad: Executed the experiment, recorded all observation and analysis. Shazma Anwar: supervision of research and data analysis.

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