Effect of different tillage practices and biochar treatments on soil carbon contents and on yield of wheat (*Triticum aestivum L.*) under rainfed condition

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Abstract

Wheat is the crop which is most commonly consumed worldwide. Wheat has countless varieties throughout the world and it comes from a grass type Triticum. Tillage provides favorable condition for wheat growth. Soil tillage consist of breaking the hard pan of the soil and make it feasible for better penetration of roots of the wheat crop. The large carbon storage source in soil is biochar. Biochar have the capability to absorb CO_2 from air and it can retain this CO_2 for hundred of years. Biochar have also the property to enhance soil physical and chemical characteristics. The present study aimed to determine the influence of tillage practices and biochar treatments on soil carbon contents and on yield of wheat crop. Arrangement of treatments performed in a factorial randomized block design which include three replications. Tillage treatments includes three levels; T_1= 6 tillage operation with cultivator (farmer practice), T_2 (minimum tillage), T_3 (2 cultivation with cultivator + mold board plough). The biochar treatments consist of four levels; B_1=0, B_2=10, B_3=15, and B_4=20 t ha^{-1}. The interaction effect of biochar treatments and tillage practices was observed on CO_2 emission, dissolved organic carbon, soil organic carbon and on yield and yield components of wheat. Biochar applied @ 15 t ha^{-1} in combination with minimum tillage gave significant results on soil health in terms of CO_2 emission, dissolved organic carbon and on soil organic carbon. In addition to this, biochar @15 t ha^{-1} combined with minimum tillage practices also gave significant differences on yield and yield components on wheat.

Key Words: Tillage, Biochar, Soil carbon, Organic carbon, Wheat

Introduction

Wheat (*Triticum aestivum* L.) is the crop which belongs to the family Poaceae. It also contributes a lot as a major portion of staple food for the world's increasing population. The total cultivated area of this crop is about 9.21 million hectares with production of 24.03 million tons during the year 2018-2019. It's addition in agriculture is 14.4 % and 3 % to the gross domestic production of Pakistan (GOP, 2019). Mainly under irrigated conditions this crop is grown, and its water requirement ranges from about 18-22 inches per acre. In human nutrition wheat is a basic major source of carbohydrates. In top wheat producing countries Pakistan ranks ten but due to some adverse factors such as shortage of water, changing climates and reduction of land resources its production in Pakistan has not exceeded beyond 25-35% (Sarwar and Nawaz, 2017). By the use of better inputs, proper production technology and by proper tillage techniques wheat production can be enhanced. Because of these factors yield of wheat is affected, as they effect the chemical and physical characteristics of the soil and water (Bonfil et al., 2016). Tillage contributes up to 20 % among different production factors of wheat (Ahmad et el., 2016). Soil is going to degrade day by day due to use of intensive and unnecessary conventional tillage operations. Therefore, to enhance the water use efficiency of crops, controlling erosion process and increasing crop production interest emphasis on the shift to the reduced and zero-tillage is under high consideration (Dawelbeit and Babiker, 2013). To prevent late sowing of wheat now work on zero tillage technology has been under serious consideration. It enables wheat sowing at proper time with good crop establishment. Zero and minimum tillage practices also saves the cost of water and preparation of seedbed up to 30% (Aslam and Gill, 2015). Zero and minimum tillage practices can give better results as compared to other tillage practice because it is very cheap as compared to other tillage systems (Nagarajan et al, 2020). Deep tillage can demolish the plough pan layer, increase run-off and deep percolation of nutrients which become unavailable to plants (Higashida and Yamagami, 2019).

Biochar is known as large carbon source in the soil and can retain up to hundred of years (Kuzyakov *et al*., 2014). It plays very crucial role in different phenomenon such as, in helping degraded land and in sequestering atmospheric carbon dioxide (Barrow, 2012). Therefore, black carbon (C) or more often known as biochar may overcome some limitations in carbon management and thus improving soil quality (Sohi *et al.* 2010). Herath *et al*. (2013) discussed that biochar has high porosity and large inner surface area therefore, physical-chemical processes might be important for crop production. Itself biochar is not an organic fertilizer, because it cannot add nutrients into the soil but it has a high capability for nutrients and persistent in the soil as well as increase cation exchange capacity (Barrow 2012). He et al. (2016) described that biochar amendment can enhance soil nitrification activity in soils. Biochar has characteristics to improve soil structure and aeration due to its high porosity and low bulk density (Joseph et al., 2010). Fungo et al (2017) reported that preserved biochar promotes a movement of native soil organic carbon from larger-size aggregates to the smaller fraction in the short term (2 years). Busscher et al. (2010) also described that biochar combined with tillage operations, especially with minimum tillage enhance infiltration and water holding capacity of the soil. Busari et al. (2015) found that conservation tillage including zero tillage and minimum tillage aiming in reducing the potential soil breakdowns led to better soil environments and crop yield with the less effect on the environments. If no emphasis is taken on soil water content and frequent tillage practices continues than with the passage of time soil structure becomes degraded (Darusman, 2018). If excessive granules destruction may be continued than this may cause soil granules size reduction and smoothness which may result the poor soil porosity, reduce soil aeration and drainage properties. The problems of soil caused by tillage operations could be prevented by the use of biochar in proper quantity that may increase of soil bulk density, moisture retention and good soil aeration. The other advantages of biochar reported by Barrow (2020) are; biochar may overcome the need for fertilizer/ manure /compost and can enhance moisture retention thus reduce the requirement for irrigation water and make crops more productive and secure. The purpose of this research was to find whether the provision of biochar and different tillage practices might influence the soil carbon contents and yield of wheat. Our hypothesis was the application of biochar and tillage practices under field condition could affect soil carbon contents such as soil carbon emission, soil organic carbon, dissolved organic carbon and effect of the interaction of different tillage practices and biochar applications on yield and yield parameters of wheat.

Material and Methods

A field experiment was performed during June 2019 till May 2021 at Hazara university Mansehra, Pakistan to determine the effect of different tillage practices and biochar treatments on soil carbon dynamics and on yield of wheat (*Triticum aestivum L.*) The soil of the studied area was clayey to clayey loam with pH ranged from 7 – 8. A factorial Randomized Block Design consisting of two factors was used with three replications having a plot size of 4 × 6 m^2. The first factor was the tillage practices consisting of three levels; T_1: Control (6 cultivations with cultivator), T_2: minimum tillage (2 tillage) with cultivator and T_3: 1 Mold board plough + 2 cultivations with cultivator and the second factor was the provision of biochar consist of four levels: The biochar treatments consist of four levels; B_1=0, B_2=10, B_3=15, and

B_4=20 t ha^{-1} .Wheat was sown @ 120 Kg ha^{-1} with row spacing of 12 cm apart. The NPK fertilizer was applied @ 35-40-20 kg ha^{-1} form Urea, Diammonium Phosphate (DAP) and Potassium Sulphate sources, respectively. Seeds were sown by using drill. All fertilizers were applied as basal dose at sowing time with no subsequent application of fertilizer during whole the growing period of wheat crop. Biochar was applied before the onset of monsoon rains and no subsequent doses of biochar were applied during the growing season of wheat. In tillage treatment (T_1), 6 cultivations were performed by using cultivator. After each ploughing, planker was used for land levelling. Two tillage operations were performed before the onset of monsoon and other four practices were performed before sowing. Whereas, in tillage treatment (T_2), one cultivation was done using mould board plough before onset of monsoon and other was applied before sowing of wheat. In T_3 before onset of monsoon one chisel ploughing was applied and other one was used before sowing.

SOIL SAMPLING

Soil samples were taken at a depth of 0-15 cm before sowing and after each tillage practice during both the study years. The samples were dried, ground and sieved through 2 mm stainless steel sieve and then stored in plastic jars. Data including soil organic carbon, dissolved organic carbon and carbon emission were recorded after each tillage practice.

Carbon Emission

The soil CO_2 emission was calculated using static chamber method through CO_2 meter (Lutron GC-2028). A chamber rim was fixed into groove of a collar placed in field at random determination of gas flux. Gas samples were measured after 30 days interval. Flux was determined by transformation in headspace concentration over a measured period using the formula:

$$Flux = \left(\frac{dGas}{dt}\right) x\ 10^{-6}\ x\ \left(\frac{(V_{chanmber}\ x\ P\ x\ 100\ x\ MW)}{R\ x\ T\ x\ A}\right) x\ 10^{-6}$$

$\frac{dGas}{dt}$ denotes the change in concentration over time and measured in ppm h^{-1}; $V_{chamber}$ is the volume of the chamber; p is atmospheric pressure; *MW* is the molecular weight; R is a gas constant, 8314 J mol^{-1} K^{-1}; *T* is temperature taken in Kelvin and *A* is the chamber area. The flux of CO_2 gas was taken over a hectare and converted to kg CO_2-C ha^{-1} h^{-1} (Zhang *et al*., 2010).

Dissolved Organic Carbon

Dissolved organic carbon (DOC) was determined by using Shimadzu TOC-TN analyzer (Shimadzu Corp., Kyoto, Japan).

Soil Organic Carbon

Soil organic carbon (SOC) was measured by taking 1gram soil in a 500 mL beaker. Then ten mL of 1N potassium dichromate solution and 20 mL of conc. H_2SO_4 was added in flask and swirled to mix the suspension. The suspension was then set for 30 minutes. After that 200 mL distilled water was added following the addition of 10 mL of H_3PO_3 to the suspension. Then 10 drops of diphenylamine indicator were added and the solution was titrated against 0.5 N ferrous ammonium sulphate solution till the color changed from blue to sharp green (Nelson and Sommers, 1982).

% Total Organic Carbon (w/w) = 1.334 × Oxidizable Organic Carbon

Plant data

Height of the wheat plant was determined by selecting 10 plants randomly from each plot and average was determined**.** Spike length, number of spikelets per spike, 1000 grain weight were determined by selecting 10 plants randomly from each plot. Whereas, number of tillers per unit area was calculated by placing the quadrat of $1m^2$ at different places of each plot. Biological yield was determined by weighing above ground biomass of all wheat plants from each plot and total biomass was taken. Grain yield was taken by removing grains from each spike in kg ha^{-1}. Harvest index was determined by dividing the grain yield of the wheat crop with biological yield and then multiplied with 100 to calculate harvest index in percentage.

$$HI\ (\%) = \left(\frac{Grain\ yield}{Biological\ yield}\right)\ x\ 100$$

The data was analyzed statistically for difference between the treatments by using SPSS software v. 1.7. The least significant difference within treatment was determined at $P = 0.05$.

RESULTS

Results of different tillage practices and biochar treatments on soil carbon contents and on yield of wheat showed that at soil depth (0-15 cm) from sowing till harvesting of wheat, interaction of tillage practice T_1 (Control) and biochar treatment B_1 (0 t/ha^{-1}) CO_2 emission was 48.21 kg CO_2-C ha^{-1} h^{-1} during the first year and 51.35 kg CO_2-C ha^{-1} h^{-1} during the second year, that was maximum among all treatments (Figure 1A,1D). Interaction of tillage practice T_2 (minimum tillage + 2 cultivations) and biochar treatment B_3 (15 t/ha^{-1}) showed lowest CO_2 emission rate that was about 25.43 CO_2-C ha^{-1} h^{-1} during the first year and 31.12 CO_2-C ha^{-1} h^{-1} during the second year (Figure 1A,1D). Interaction of tillage treatment T_{2*} B_3 produced 43.21 % less CO_2 in comparison to T_{1*} B_1 (Figure 1A,1D). Results of the study also revealed that dissolved organic carbon (DOC) was lowest in interaction of T_{1*} B_1 that was about 3.11 g C kg^{-1} during the first year and 3.56 g C kg^{-1} during the second year whereas, interaction of T_{2*} B_3 showed highest DOC 4.8 g C kg^{-1} during the first year and 4.9 g C kg^{-1} during the second year (Figure 1B,1E). Interaction of T_{1*} B_1 gave 31.34 % less DOC in comparison to T_{2*} B_3 (Figure 1B,1D). Interaction of T_{2*} B_4 and T_{3*} B_4 showed at par values with each other. Data regarding soil organic carbon (SOC) revealed that T_{1*} B_1 gave 2.56 g C kg^{-1} of SOC during the first year and 3.56 g C kg^{-1} During the second year (Figure 1C,1F). Interaction of T_{2*} B_3 gave 7.88 g C kg^{-1} SOC during first year and 7.97 g C kg^{-1} during second year. Interaction of T_{2*} B_3 gave 61.36 % more SOC than T_{1*} B_1 (Figure 1C,1F).

Yield parameters of wheat were analyzed to evaluate the effect of tillage practices and different biochar treatments. Data revealed that that maximum 92.55 cm plant height was observed in interaction T_{2*} B_3 and minimum 80.55 cm height was obtained in T_{1*} B_1 during both the study years (Figure 2A,2E). T_{1*} B_1 and T_{1*} B_4 gave at par results with each other. Interaction T_{2*} B_3 gave 12.96 % more plant height as compared to T_{1*} B_1 (Figure 2A,2E). Spike length was taken by selecting 10 plants randomly from each plot at maturity stage. During both the years on average basis maximum spike length was observed in T_{2*} B_3 i.e.11.99 cm and minimum was observed in T_{1*} $B_{1,}$ which was 8.49 cm (Figure 2B,2F). Number of spikelets/spike were maximum during both the study years in T_{2*} B_3 i.e. 20.54 and minimum was attained in T_{2*} B_3 which was 16.62 (Figure 2C,2G). T_{2*} B_3 interaction gave 19.08 % more spikelets/spike than T_{1*} $B_{1.}$ Number of tillers per unit area were calculated by selecting 10 plants randomly from each plot. Results showed that during both the study years minimum number of tillers per unit area gave by the interaction of T_{1*} B_1 which was 216.26 and maximum gave by T_{2*} B_3 which was 281.29 (Figure 2D,2H). T_{1*} B_4 and T_{2*} B_4 were at par with each other. Maximum value of 1000 grain weight during both the study years was 51.14 g which was showed by the interaction of T_{2*} B_3 and minimum value gave by T_{1*} $B_{1,}$ which was 40.58 g

(Figure 3A,3E). Difference between these two interactions was 20.64 %. Biological yield was calculated by taking above ground biomass of wheat plants from each plot and then mean values were calculated. It is evident from Figures 3B and 3F that during both the study years interaction of $T_2 * B_3$ gave the maximum biological yield which was 8156.62 kg/ha whereas, minimum biological yield gave by $T_1 * B_1$, which was 7440.82 kg/ha (Figure 3B,3F). Interaction of $T_2 * B_3$ gave 8.77 % more biological yield as compared to $T_1 * B_1$. Grain yield of wheat was taken when plants were fully dried and attained light brown colour. Results revealed that on average basis of both the years interaction $T_2 * B_3$ showed significant difference than rest of interactions. Maximum grain yield of interaction $T_2 * B_3$ was 3006.62 kg/ha and minimum gave by $T_1 * B_1$ which was 2507.30 kg/ha (Figure 3C,3G). Values of interactions $T_1 * B_4$ and $T_2 * B_1$ found at par with each other (Figure 3C,3G). Values of harvest index revealed that $T_2 * B_3$ interaction gave maximum harvest index percentage during both the study years. $T_2 * B_3$ gave 36.86 % harvest index while minimum showed by $T_1 * B_1$, which was 33.69 % (Figure 3D,3H). Interactions $T_1 * B_4$ and $T_2 * B_1$ were at par with each other, whereas interaction $T_1 * B_1$ and $T_1 * B_2$ also showed values which were at par with each other during both the years (Figure 3D,3H).

DISCUSSION

By the use of heavy tillage practices soil structure not only degrade but also large amount of carbon emitted from the soil which is very hazardous for our environment (Abdollahi and Munkholm, 2019). In our experiment soil carbon emission was higher in T_1 (Control) that may be due to disturbance of soil by the use of large number of tillage practices which not only degrade the soil but also cause carbon emission from the biochar. Moreover, reduction in yield of wheat also occurred in interaction of (T_1*B_1) might be due to no availability of biochar, as biochar is a rich source of carbon. Tillage treatment T_2 along with biochar treatment B_3 (15 t ha^{-1}) gave more dissolved organic carbon (DOC) that may be due to a smaller number of tillage practices as compared to control treatment. Adekiya et al., (2019) also reported that less number of tillage practices and by the use of proper amount of biochar cause less damage to the soil and prevent carbon emission. Deep and more tillage practices and less or no use of biochar can reduce the soil dissolved organic carbon (DOC) (Agbede, 2017). That might be the reason that in our study (T_1*B_1) interaction i.e. more tillage practices and no use of biochar preserved less amount of carbon. The soil organic carbon (SOC) found higher in T_2 (minimum tillage) and B_3 (15 t ha^{-1}) interaction as compared to other tillage practices and biochar treatments, that may be due to less disturbance to soil and the use of biochar which is a good source of carbon. as compared to rest of tillage treatments. Agbede and Adekiya (2018) also discussed that carbon contents in soil are higher where less tillage practices are performed and use of biochar is frequent. Soils on which frequent use of tillage practices are performed have poor structure and more organic carbon loss (Alburquerque *et al.*, 2021).

Interaction $T_2 * B_3$ gave maximum wheat plant height as compared to rest of tillage practices and biochar treatments, this may be due to minimum tillage practice which conserve the soil moisture that may be lost due to heavy tillage practices. Biochar dose (15t ha^{-1}) also provide proper amount of carbon and minerals to plant, due to this plants attained maximum height. Minimum tillage practices along with the use of proper biochar conserve soil moisture and enhance soil porosity which helps in better growth of plant (Blanco-Canqui *et al.*, 2017). Briones and Schmidt (2020) found that conventional tillage practices and poor application of nutrients and carbon media such as biochar leads towards degradation of land and poor crop stand, especially its reproductive organs. In our experiment also the conventional tillage T_1 and no application of biochar B_1 gave retarded spike length whereas, $T_2 * B_3$ interaction gave better spike length in which we used minimum tillage practices and biochar dose of (15 t ha^{-1}) as compared to rest of tillage and biochar interactions. Number of spikelets/spike were found maximum in $T_2 * B_3$ and minimum found in $T_1 * B_1$, this may be due to large number of tillage practices lost the soil moisture and it becomes unavailable to the plants due to this number of spikelets/spike of wheat reduced in conventional tillage. Le Bissonnais, (2016) also described that if heavy tillage practices were used for longer period of time and no use of biochar and other nutrient media then soil degradation occur which cause poor plant growth. Number of tillers per unit area were calculated and was found that tillers depends upon soil fertility and healthy plant stand, which was poor in T_1*B_1 as compared to other interactions. Deep and frequent tillage practices and poor and excess amount of biochar reduced the soil moisture contents and nutrients, that is the reason of poor stand of plants and ultimately number of tillers (Lehmann and Joseph, 2020). Interaction T_2*B_3 gave maximum 1000 grain weight as compared to other interactions, this might be due to the biochar enhanced soil organic carbon and nutrients and minimum number of tillage practices conserved moisture, which provides better crop stand and ultimately better grain yield. Lou, (2016) also reported that less disturbance to soil and proper amount of biochar can develop better gain, but if excess amount of tillage and biochar was applied that soil nutrient balance may disturbed. Biological yield of a crop depends upon soil health and better crop stand of plant (Nguyen *et al.*, 2017). Proper amount of biochar application is very essential for getting good crop stand because if excess amount is applied then root degradation may occur which cause less biological yield (Obour *et al.*, 2018). Results of our study also revealed interaction of T_2*B_3 gave maximum biological yield as compared to other interactions, this might be due to improper application of biochar and tillage practices. Grain yield of wheat was taken when plants get fully dried. Grain yield of a crop would be better crop plants are healthy and this is possible only if nutrients and moisture are at required level (Salem *et al.*, 2019). Grain yield of wheat in our experiment was higher in T_2*B_3, may be due to better moisture level because of minimum tillage practice during monsoon and biochar effect which make the soil porous for better crop growth. Interaction T1*B_1 and other gave poor grain yield, might be due to poor soil moisture and inappropriate application of biochar. Harvest Index (HI) was also calculated, and found that interaction T_2*B_3 gave maximum values, this may be due to better biological and grain yield of the T_2*B_3 interaction. Better moisture conservation and nutrient retention due to application of biochar during monsoon gave better harvest index as compared to conventional tillage practices which causes loss of moisture and nutrients during monsoon. Zukaitis and Liaudanskiene, (2020) discussed that deep tillage practices can conserve moisture and nutrients under rainfed condition but if these practices and biochar were used inappropriately than this leads towards poor biological and grain yield of a crop and ultimately poor harvest index obtained. This is very important that biochar should be applied at proper amount with the combination of best tillage operation which will not be hazardous to soil nutrients, so that maximum harvest index can be achieved (Tavares *et al.*, 2018).

CONCLUSION

Results of the study revealed that interaction of tillage practices along with biochar treatments played significant role on soil carbon contents and on yield of wheat. Soil carbon contents are very important for crops growth. Excess carbon emission from soil by the use of heavy tillage practices pollutes the environment. To reduce the emission of carbon from soil and to enhance wheat yield we used different tillage practices and biochar treatments. Findings of our experiment suggest that if minimum tillage (2 tillage with cultivator) and biochar application (15 t ha^{-1}) used together then we can reduce the carbon emission from soil and can enhance wheat yield.

References:

Abdollahi, L., Munkholm, L.J., 2019. Tillage system and cover crop effects on soil quality: I. Chemical, mechanical, and biological properties. Soil Sci. Soc. Am. J. 78 (1), 262–270.

Adekiya, A.O., Agbede, T.M., Aboyeji, C.M., Dunsin, O., Simeon, V.T., 2019. Effects of biochar and poultry manure on soil characteristics and the yield of radish. Sci. Hortic. 243, 457–463.

Agbede, T.M., Adekiya, A.O., 2018. The effect of tillage on soil physical and chemical properties and yield of ginger. Agric. Conspectus Sci. 83 (4), 315–320.

Agbede, T.M., Adekiya, A.O., Eifediyi, E.K., 2017. Impact of poultry manure and NPK fertilizer on soil physical properties and growth and yield of carrot. J. Hortic. Res. 25 (1), 81–88.

Alburquerque, J.A., Salazar, P., Barr_on, V., Torrent, J., del Campillo, M.C., Gallardo, A., Villar, R., 2021. Enhanced wheat yield by biochar addition under different mineral

Barrow, C.J. 2020. Biochar: Potential for countering land degradation and improving agriculture. Applied Geography 34.21-28.

Blanco-Canqui, H., Wienhold, B.J., Jin, V.L., Schmer, M.R., Kibet, L.C., 2017. Long-term activation effects on sorption of phosphate on pine sawdust biochars in aqueous solutions. Chem. Speciat. Bioavailab. 28 (1-4), 42–50.

Briones, M.J.I., Schmidt, O., 2020. Conventional tillage decreases the abundance and biomass of earthworms and alters their community structure in a global metaanalysis. Global Change Biol. 23, 4396–4419.

Busari, M.A., Kukal, S.S, Kaur, A., Bhatt, R. and Dulazi, A.A. 2015. Conservation tillage impacts on soil, crop and the environment. Intternational soil and water conservation research. 3 (2015) pp. 119- 129. fertilization levels. Agron. Sustain. Dev. 33 (3), 475–484.

D.J. Bonfil, I. Mufradi, S. Klitman, S. Asido, Wheat grain yield and soil arofile water distribution in a no till arid environment Agronomy Journal, Vol, 91, 368-373, 2016.

Darusman, L.R. Stone, Whitney, D.A., Janssen, K.A. and Long. J.H. 2018. Soil properties after twenty years of fertilization with different nitrogen sources. Soil Sci. Soc. Am. J. 55:1097-1100.

Fungo, B., Lehmann, J. Kalbitz, K., Thionġo, M., Okeyo, I.,Tenywa, M. and Neufeldt. H. 2017. G. Sarwar, Q. Nawaz. Studies on the efficacy of different post emergence herbicides for the control of weeds and their effect on yield of wheat. Sarhad Journal of Agriculture, Vol.1, 251-259, 2017.

Geoderma 237–238, 60–70.

GOP, Economic survey of Pakistan. Finance and Economic Affairs Division, Islamabad, 2019.

He L., Zhao, X., Wang, S.Q, Xing.G.X. 2016. The effects of rice-straw biochar addition on nitrification activity and nitrous oxide emissions in two oxisols. Soil & Tillage Research 164. 52-62.

Joseph, S.D., Camps-Arbestain, M., Lin, Y., Munroe, P., Chia, C.H., Hook, J., van Zwieten, L., Kimber, S., Cowie, A., Singh, B.P., Lehmann, J., Foidl, N., Smernik, R.J and

Amonette, J.E. 2010. An Investigation into the reactions of Biochar in soil. Soil Res. 48, 501-515.

Kuzyakov, Y., Subbotina, I., Chen, H. Bogomolova, I. and Xu, X. 2014. Black carbon decomposition and incorporation into soil microbial biomass estimated by *C*-14 labeling. *Soil Biol. Biochem.*, 41, pp. 210–219.

Le Bissonnais, Y., 2016. Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. Eur. J. Soil Sci. 67 (1), 11–21.

Lehmann, J., Joseph, S., 2021. Biochar for Environmental Management: Science, Technology and Implementation. Earthscan, London, UK.

Lou, K., Rajapaksha, A.U., Ok, Y.S., Chang, S.X., 2016. Pyrolysis temperature and steam

M. Aslam, A. Majid M.A. Gill, Zero tillage wheat production technology prospects and threats, Science and Technology Development International Journal, Vol.1, 15-19, 2015.

M.I. Dawelbeit, E.A. Babiker, Effect of tillage and sowing method on growth and yield of wheat, Soil and Tillage Research, Vol.42, 127–32, 2013.

N. Ahmad, M. Rashid, A.G. Vaes, Fertilizer and their use in Pakistan, NFDC. Publication, No. 4/96, 2nd Ed, Islamabad. 2016.

Nguyen, T.T.N., Xu, C.Y., Tahmasbian, I., Che, R., Xu, Z., Zhou, X., et al., 2017. Effects of biochar on soil available inorganic nitrogen: a review and meta-analysis. Geoderma 288, 79–96.

Obour, A.K., Chen, C., Sintim, H.Y., McVay, K., Lamb, P., Obeng, E., et al., 2018. Camelina

R.S. Grey, J.S. Taylor, W.J. Brown, Economic factors contributing to the adoption of reduced tillage technologies in central Saskatchewan, Canadian Journal of Plant Sciences, Vol. 76, 661-668. 2016.

S. Higashida, M. Yamagami, Effects of deep ploughing with concomitant application of farm manure on the productivity of arable crops, Bulletin of Hokkaido-Prefectural Agricultural Experiment Stations, Vol.84: 55-64. 2019.

S. Nagarajan, A. Singh, R. Singh, S. Singh. Impact Evaluation of zero-Tillage in Wheat Through Farmer's Participatory mode. Paper for international workshop on herbicide resistance management & Zero tillage in rice-wheat cropping system, Department of Agronomy, CCS Haryana Agricultural University, 2020.

Salem, H.M., Valero, C., Angel, M., Gil, M., Silva, L.L., 2019. Short-term effects of four sativa as a fallow replacement crop in wheat-based crop production systems in the US Great Plains. Ind. Crop. Prod. 111, 22–29.

Sohi, S.P., Krull, E., Lopez-Capel, E. and Bol, R. 2010. A review of biochar and its use and function in soil. Advances in Agronomy, 105, pp. 47–82.

Tavares, A.C., Goncalves, M.J., Cavaleiro, C., Cruz, M.T., Lopes, M.C., Canhoto, J., Salgueiro, L.R., 2018. Essential oil of Daucus carota subsp. halophilus: composition, antifungal activity and Cytotoxicity. J. Ethnopharmacol. 119, 129–134.

Zhang M, et al. (2010). Creation of a hyperpermeable yeast strain to genotoxic agents through combined inactivation of PDR and CWP genes. Toxicol Sci 113(2):401-411.

Zukaitis, T., Liaudanskiene, I., 2020. The impact of reduced tillage on some chemical properties of a clay loamy soil. Soil Sci. Annu. 71 (2), 37–42.

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Figures:

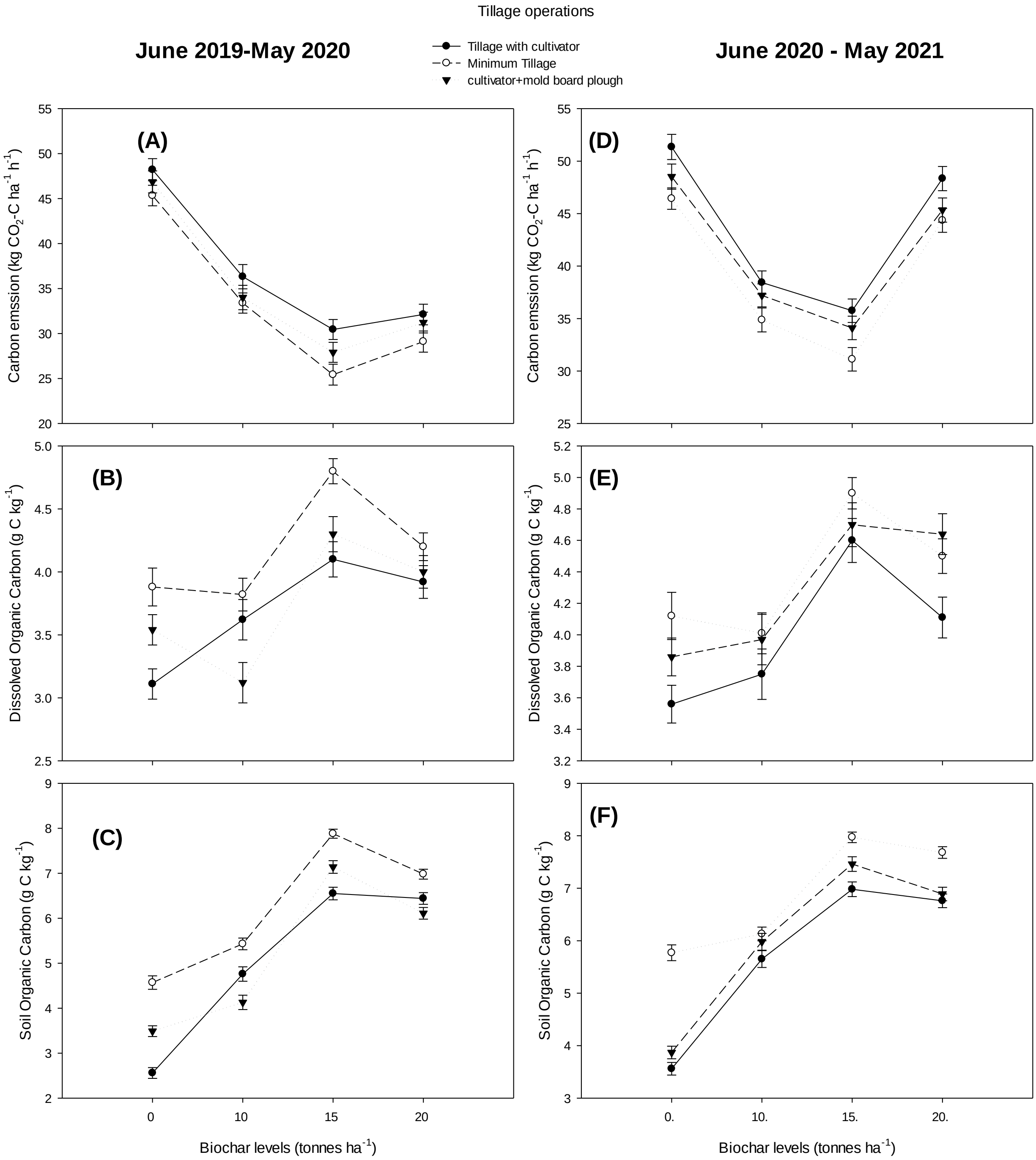

Fig 1: Soil Attributes

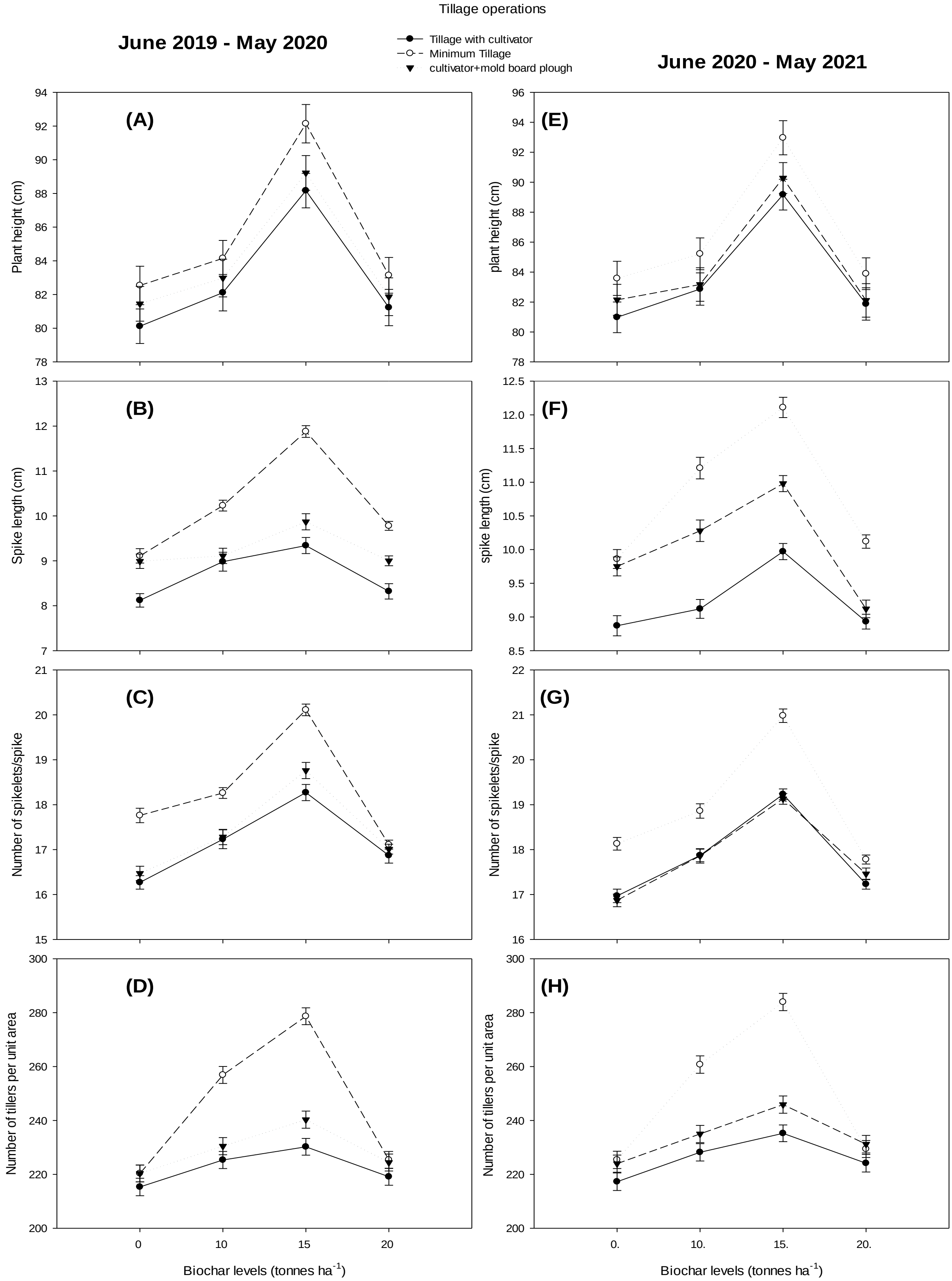

Fig 2: Growth Attributes of Wheat

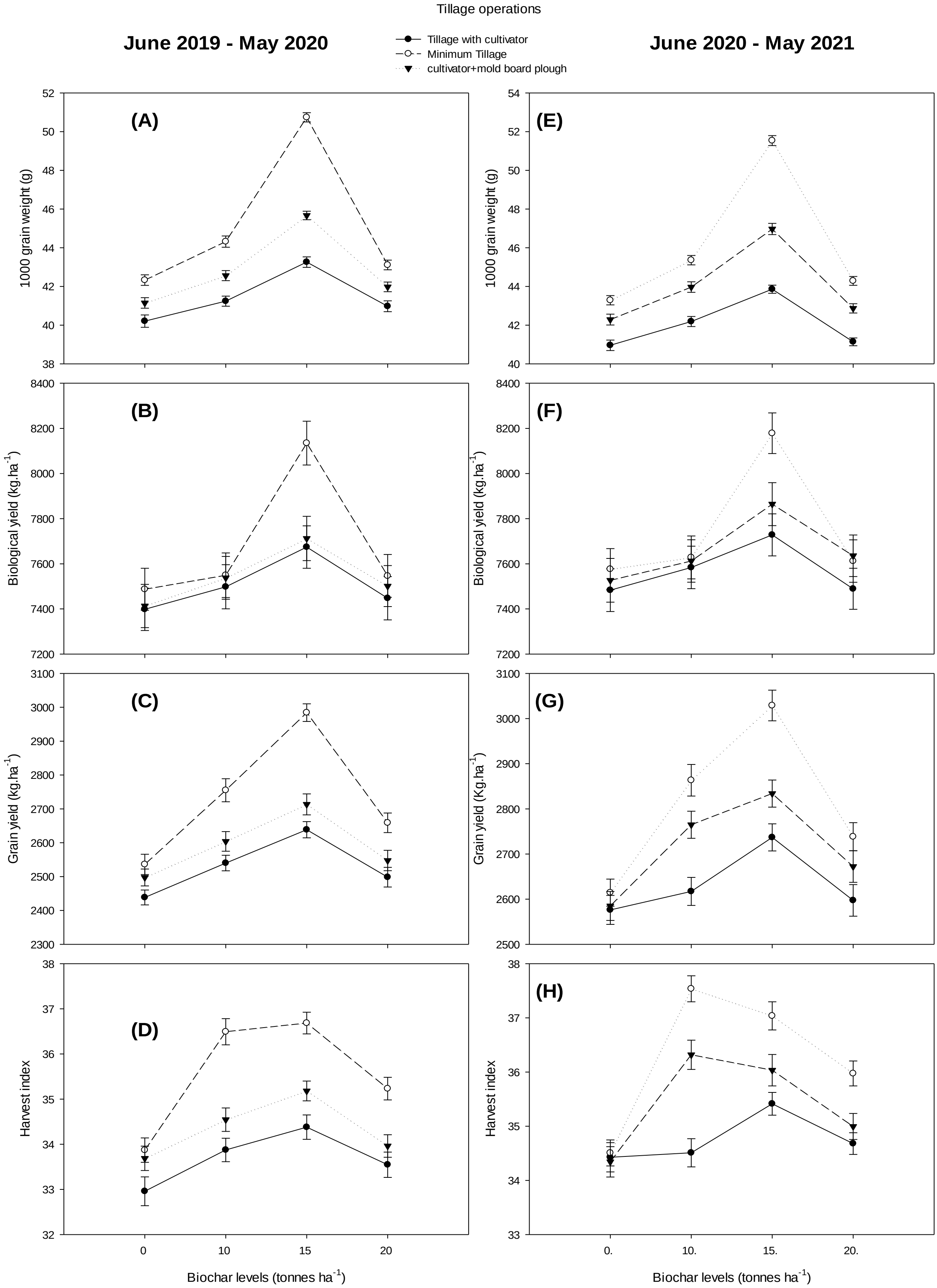

Fig 3: Yield Attributes of Wheat