EFFECT OF BIOCHAR, FARMYARD MANURE AND NITROGEN FERTILIZER ON YIELD AND YIELD COMPONENTS OF BREAD WHEAT (*TRITICUM AESTIVUM* L.) IN SINANA DISTRICT, SOUTH EASTERN OROMIA, ETHIOPIA

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ABSTRACT

Bread wheat is an important food security and cash crop in country, particularly in the Bale and Arsi high land. However, the yield of the crop is constrained by poor soil fertility management practices. Therefore, a field experiment was conducted at Selka Kebele of Sinana District in Bale zone of Oromia Regional State, with the objective of investigating the influence of biochar, farmyard manure, and mineral nitrogen fertilizer on yield, and yield components of bread wheat. The treatments consisted of two levels of farmyard manure (0 and 6 tons ha^{-1}), three levels of biochar (0, 5, and 10 tons ha^{-1}) and three levels of nitrogen (0, 23 and 46 kg N ha^{-1}). The results revealed that the interaction effects of biochar, farmyard manure, and mineral nitrogen fertilizer significantly (P<0.001) influenced the highest adjusted grain yield of 6324.90 kg ha^{-1} was recorded in response to the combined application of 10 t biochar ha^{-1} +6 t FYM ha^{-1} +46 kg N ha^{-1}. However, the application of 5 t biochar ha^{-1} + 0 t FYM ha^{-1}+46 kg N ha^{-1} remains profitable and recommended for farmers in Sinana district and other areas with similar agro ecological condition. It could, thus, be concluded that, applying biochar at the rate of 5.0 t ha^{-1}combined with 46 kg N ha^{-1} resulted in optimum grain yield of the crop.

Key Words: Biochar, Grain yields, Chemical Fertilizer, and Organic Fertilizer

No: of Figures :1 **No: of Tables: 4** **No: of References: 35**

INTRODUCTION

Wheat is one of the most important crop plants in world. It grows under a broad range of latitudes and altitudes. It is not only the most widely cultivated crop but also the most consumed food crop all over the world. One of the most important challenges in wheat production is increasing in yield it (FAO, 2006). This is justifiable because of the fact that wheat is among the most important crops not only in Ethiopia but also worldwide. It has played a significant role in feeding a hungry world and improving global food security (Shiferaw *et al*., 2013).

According to Tekalign Mamo *et al*. (2002), many soils in the highlands of Ethiopia are poor in available plant nutrients and organic matter content. In addition to this previously, only nitrogen (N) and phosphorus (P) were considered to be the limiting nutrients in Vertisols of Ethiopia (Tekalign Mamo *et al*., 1988). Moreover, prices of chemical fertilizer escalating, have led to growing interests in the use of organic fertilizers as a source of nutrients (Satyanarayana et *al*., 2002). Likewise, most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al*., 2001).

Generally, according to Gebremedhin *et al*. (2015), the treatments which contained biochar as a soil amendment beat the other treatments which increased grain and straw yields of wheat for a biochar treatment (100 kg urea+100 kg DAP + 4 ton biochar ha^{-1}) by 15.7% and 16.5% respectively, over the lone NP application. In the same way, farmyard manure at the rate of 10 t ha^{-1} resulted in significantly higher yield components, grain yield, soil C, P and K than 5 t ha^{-1}. Similarly, Laghari *et al*.(2010) reported that fertilizer application enhanced growth, yield, and nutrient uptake of wheat. Likewise, application of 120-60-60 NPK kg ha^{-1} resulted in maximum grain yield and NPK uptake. Rastgou *et al.* (2013) reported that the highest N uptake was obtained from 200 kg N ha^{-1}(more than 20% yield increase).

The soils of Bale highlands including Sinana area are dominantly Vertisols, Cambisols and Phaeozems with poor structure, low infiltration capacity and develop deep cracks in dry seasons (Abayneh and Ashenafi, 2006). Therefore, it is generally accepted that improved soil conditions associated with manure, biochar and nitrogen fertilizers application lead to changes in soil and nutrient availability which enhance yield of bread wheat under agro-climatic conditions of Bale highland. Therefore, this study was undertaken with the following objectives of investigate the effect of biochar, farmyard manure (FYM) and nitrogen (N) fertilizer rates on yield and yield components of Bread wheat.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted during the 2015 main cropping season at Selka Kebele of Sinana district which is located in Bale zone of Oromia Regional State, southeastern Ethiopian highland with the geographic coordinates of 07° 04' 248" N to 07° 04' 256" N and 040° 11' 137" E to 040° 11' 154" E at a distance of about 456 km Southeast of Addis Ababa and at an altitude of 2400 m above sea level (Figure 1). The area is characterized by high altitude, sub humid climate with bimodal rainfall pattern, According to Sinana Agricultural Research Center Meteorology Station records from 1993 to 2015, the long-term precipitation ranges from 710.10 to 1566.30 mm with an annual average of 1149.72 mm. The area has bimodal rainfall pattern with the first rainy season start from March and taper off in July, while the second rains fall between August and December (Figure 2). The area receives rainfall of 320.05 to 861.39 mm during the first rainy season (March to July) and 353.38 to 867.90 mm during the main season (August to December). The mean annual maximum temperature is 20.96 ^{0}C and the monthly values range between 19.39 ^{0}C in October and 22.85 ^{0}C in February (Appendix Table 3). The mean annual minimum temperature is 9.67 ^{0}C and the monthly values range between 7.93 ^{0}C in December and 10.79 ^{0}C in May. The coldest month is December whereas February is the hottest month (Figure 2).

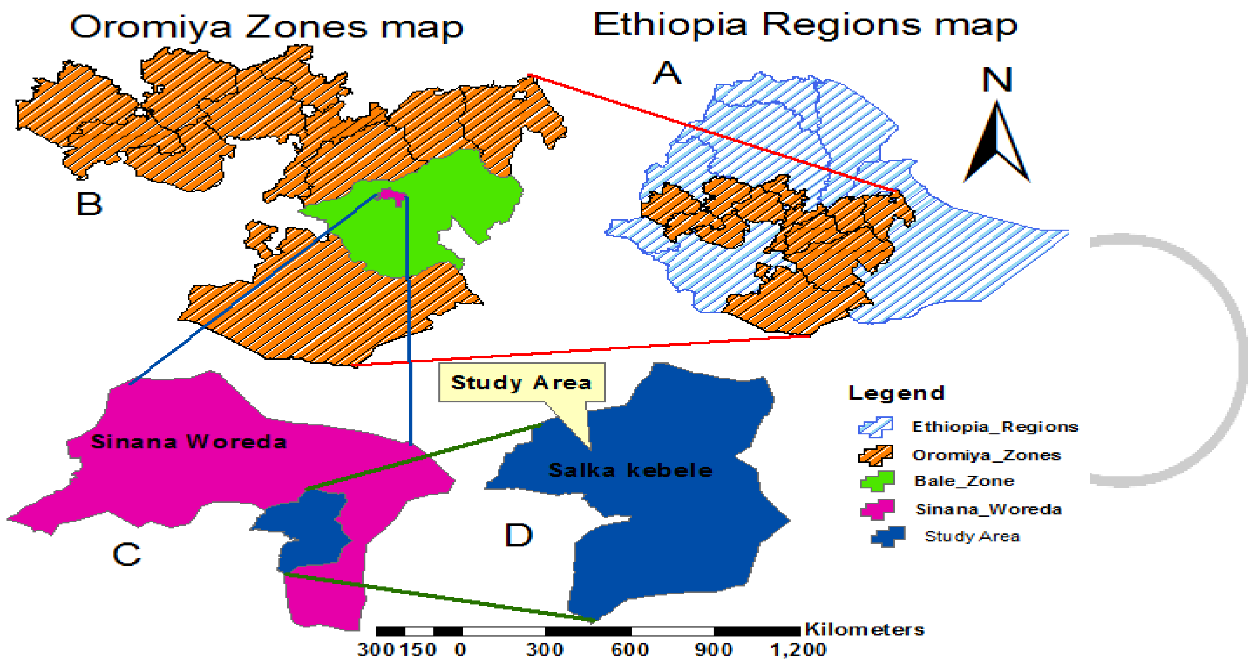

Figure 1. Maps of the study area

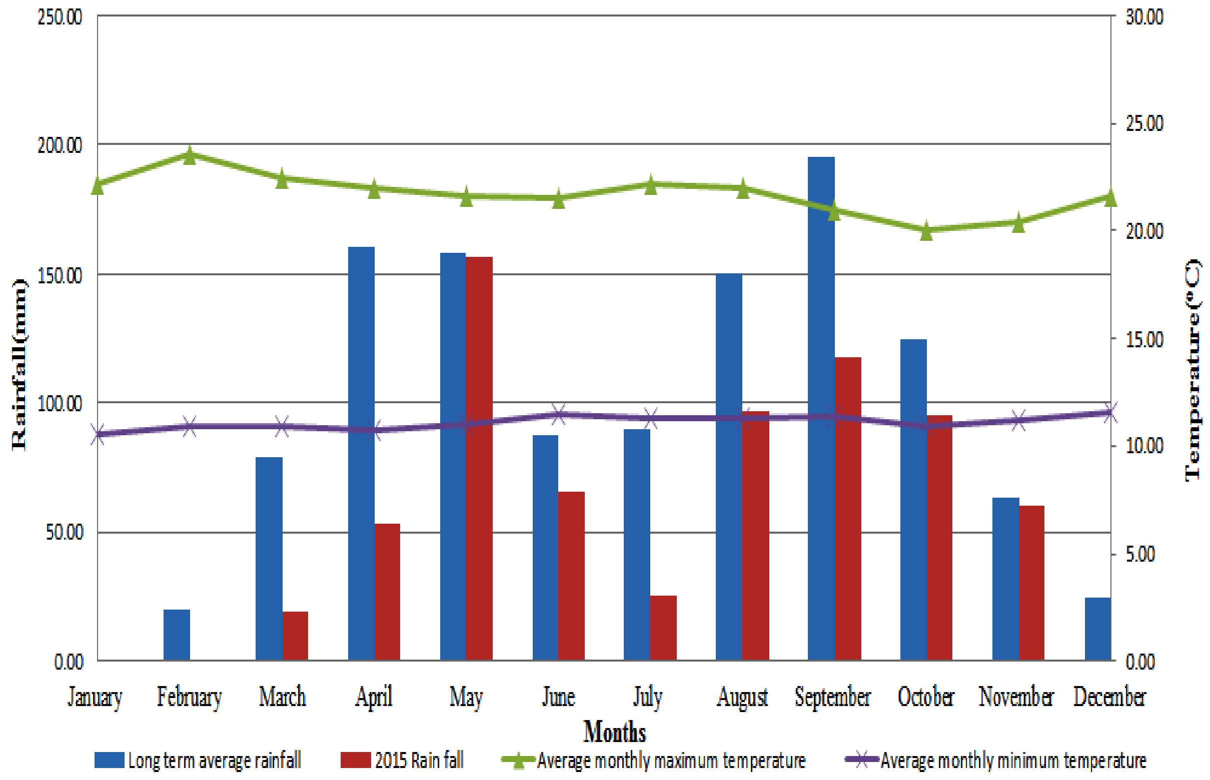

Figure 2. Monthly rainfall (2015), long term average rainfall, maximum and minimum monthly average temperature of Sinana Agricultural Research Center

Description of Experimental Materials

Bread wheat variety

The bread wheat variety Sanete (14F/HAR 1685), which was released by Sinana Agricultural Research Center (SARC) in 2014 was selected for the experiment. It is the most widely grown wheat variety in the area, with potential of about 4.4-6.7 ton ha^{-1}. The variety has high disease resistance relative to other bread wheat varieties and the adaptation area in the highlands of Bale and similar agro ecology with altitudes ranging between 2300-2600 meters above sea level and rainfall of 750-1500 mm. The seeding rate of the variety is 150 kg ha^{-1} with the spacing of 20 cm between rows. The crop is usually sown from mid-June-early September.

Inorganic fertilizer materials

Urea (46% N) was used as a source of N and recommended rate of Triple Super Phosphate (TSP, 46% P2O5) was used as a source of phosphorus.

Farmyard manure

Farmyard manure was collected, air dried, properly crushed into smaller size to ensure uniform distribution over the field. Then, it was well decomposed, aged, dried and was applied to the plots uniformly a month before planting with the specified rates of 0 and 6 tons ha^{-1} according to Teklu and Hailemariam (2009).

Biochar

Biochar was prepared by pyrolysis method as described by Masulili *et al*. (2010). Moreover, the cattle manure was collected from the feedstock and it was naturally sun-dried for about 3-5 days on concrete floor with plastic sheet depending on initial moisture content. As the moisture reached 15% after drying, the bulky dung was broken by hand to meet size of 4 to 5 cm and put into the heating-drum. The drum for heating materials was sealed to limit the oxygen and subsequently combusting was started using saw-wood fuel at a certain heating temperature. It was important to push down and mix the hot material periodically to maximize charring. Biochar yield was harvested after 1-2 hours as indicated by smoky black color chars. The chars were removed from burning stove and were allowed to settle down for cooling the yield by initially spraying water thoroughly over surface of drum. The biochar prepared following the above procedure was collected; grained to 2 mm size in which they were mixed to the soils.

Treatments and Experimental Design

The treatments consisted of two levels of farmyard manure (0 and 6 tons ha^{-1}), three levels of biochar (0, 5 and 10 tons ha^{-1}), and three levels of nitrogen (0, 23 and 46 kg N ha^{-1}). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement fashion with three replications. Accordingly, the treatments and treatment combinations including the control treatment were assigned randomly to the experimental units within a block. Each plot consisted of 7 rows of 3 m length, spaced 20 cm apart. The adjacent blocks and plots were separated by 1m wide-open space and 0.5 m blank rows, respectively. The plot size was 3m × 1.4m (4.2m^2).

Experimental Procedures and Cultural Practices

The experimental land was prepared by ploughing. Biochar and farmyard manure were applied to the plots uniformly a month before planting with proper care to ensure uniform distribution over the plots and nitrogen fertilizer was applied at the planting time using all cultural practices with recommended production practices for wheat. Weeds were removed by hand when required. Rouging of lately emerging grasses and off-type plants was done to avoid interference with the wheat cultivars. The bread wheat variety was sown on 1 August 2015 at the recommended seed rate of 150 kg ha^{-1}. Planting was done by uniformly drilling the seeds into rows made by hand hoes at row spacing of 20 cm. Yellow rust disease was controlled by spraying the fungicide (Redomil) at the rate of 0.5 Liter ha^{-1} immediately at appearance of the symptom of the disease. Meanwhile, harvesting was done on 29 December 2015. After harvesting the crop, threshing and winnowing was done; the yield was recorded

Data Collection

Agronomic data collection

At physiological maturity, date of maturity, plant height, number of fertile tillers per plant, spike length and Seeds per spike were collected on the basis of 10 randomly tagged plants in the five rows from seven rows of each plot. Kernel weight was determined on the basis of weight of 1000 seeds randomly sampled from the grain yields of the crop under each treatment. To achieve this, seeds were counted by electric seed counter and their weights were measured with sensitive balance. The data on biological yields was collected in such a way that the whole crop above the ground surface was cut very close to the ground surface in a five rows among seven rows from each plot at harvesting stage. The whole biological yields (biomass) and grain yields after the spikes of the wheat were cut and threshed then the grain yield were weighted with sensitive balance. The weight of the straw was calculated by subtracting the grain yield from the biological yields.

Statistical data analysis

The effects of treatments on soil physical and chemical properties, availability of plant nutrient after a month of planting, post-harvest and agronomical traits of bread wheat were subjected to analysis of variance (ANOVA) using general linear model (GLM) procedures of statistical analysis system of computer software (SAS, 2004. Version 9.1.2) and significantly differing means were separated using the Duncan`s multiple range test (DMRT). Least significant difference (LSD) test was involved to compare among means separated by DMRT. A simple correlation was conducted to test the relationship between soil chemical properties and agronomic traits of bread wheat.

Economic feasibility of the treatments were analyzed using partial budgeting, dominance analysis and marginal analysis using the average yield for wheat and official prices of N fertilizers, local price of farmyard manure and labor cost for all treatments. In additions, ANOVA analysis was conducted on the profit levels of treatments to identify the presence of significant profit difference across mean profits of each treatments levels difference.

RESULTS AND DISCUSSIONS

Seed per Spike, Spike Length and Maturity Date

Analysis of variance revealed that the interaction effects of farmyard manure, biochar and nitrogen levels on spike lengths were highly significant ($p< 0.05$). However, the interaction effect of farmyard manure and biochar levels and that of farmyard manure and nitrogen levels as well as biochar and nitrogen levels on spike lengths were non-significant.

As the results revealed that the effect of biochar and farmyard manure levels on the spike length was not linearly increased to the levels of treatment; but, the effect of nitrogen levels on the spike length shows that with the increase in nitrogen levels (0, 23 and 46 kg ha^{-1}) spike length also increase by 3.27 % and 7.93 % over the control treatment respectively. These may also be attributed to the commonly established fact that the combination of organic and inorganic fertilizer increases synchrony and reduces losses by converting inorganic nitrogen into organic forms (Kramer *et al.*, 2002). Similarly it was supported by Gurmessa (2002) who claimed that spike length increased significantly with nitrogen.

Analysis of variance revealed that the interaction effects of farmyard manure, biochar and nitrogen levels and that of farmyard manure and nitrogen levels as well as biochar and nitrogen levels on maturity date were non-significant. However, that of farmyard manure and biochar on maturity date was significant ($p < 0.05$) (Table 13).

The results of main effects revealed that the effect of biochar and farmyard manure levels on the maturity date was not linearly increased to the levels of treatment; however, that of nitrogen levels on the maturity date shows that with the increase in nitrogen levels (0, 23 and 46 kg ha^{-1}) maturity also increase by 2.96 % and 5.17 % more duration to reach 90% physiological maturity than wheat plants grown in the control plots respectively. This might be due to prolonged time period required by the plants to reach maturity at higher levels of nitrogen may be attributed to the increase in leaf area duration, increased vegetative growth and increased light use efficiency. The result is supported by the findings of Deldon (2001) who reported that higher nitrogen levels resulted in delayed leaf senescence, sustained leaf photosynthesis and extended days to maturity. Similarly, according to Uzoma *et al.*(2011) reported that biochar amended soils resulted in better crop establishment and positively increased crop growth rate and net assimilation rate which resulted in higher corn productivity.

Table 13. The main effect of farmyard manure, biochar and urea rate on seed per spike, spike length and maturity date of bread wheat

FYM (ton ha^{-1})	Seed per spike	Spike length (cm)	Maturity date
0	45.93	6.92^{a}	142.85^{a}
6	45.14	6.60^{b}	141.78^{b}
LSD $_{(0.05)}$	NS	0.18	1.07
Biochar (ton ha^{-1})			
0	45.32	6.77	142.22^{ab}
5	46.74	6.97	143.50^{a}
10	44.53	6.53	141.22^{b}
LSD$_{(0.05)}$	NS	0.23	1.31
Nitrogen (kg N ha^{-1})			
0	44.40	6.50^{b}	138.39c
23	45.87	6.72^{b}	142.61^{a}
46	46.33	7.06^{a}	145.94^{a}
LSD$_{(0.05)}$	NS	0.24	1.38
CV (%)	8.91	4.93	1.36

Means followed by the same letter with in the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test, FYM = Farmyard manure, CV = Coefficient of variation, Least Significant differences, N = Nitrogen from Urea, NS = not Significant.

Plant Height, Fertile Tiller per Plants and Grain Yield

The analysis of variance revealed that the interaction effects of farmyard manure, biochar and nitrogen levels and that of farmyard manure and nitrogen levels on plant height were non-significant. However, that of biochar and nitrogen levels on plant height was significant ($P < 0.05$) as well as farmyard manure and biochar levels on plant height was highly significant ($P < 0.001$) (Table 14).

As the results show that plant height of bread wheat increase with the interaction mean of biochar (0, 5 and 10 ton ha^{-1}) and farmyard manure rate (0 and 6 ton ha^{-1}). This might be because of the ability of manure to supply numerous plant nutrients and in creating suitable plant growing environment by improving moisture and nutrient status of the soil which enhance growth and general performance of the plants. Likewise, Hader (1986) reported that organic fertilizers compensate for both the deficit and the excess of elements in the soil, which can take place with mineral fertilization. In general, the enhanced heights of the wheat plants in response to the combined application of the fertilizers may be attributed to the synergistic effects of macro-and micro-nutrients.

The analysis of variance revealed that the interaction effects of farmyard manure, biochar and nitrogen levels and that of farmyard manure and nitrogen levels as well as biochar and nitrogen on fertile tiller per plant were non- significant. However, the interaction effect of farmyard manure and biochar levels on fertile tiller per plant were significant ($P < 0.05$). Moreover, the main effect of farmyard manure and biochar levels on fertile tiller per plant was significant ($P < 0.05$) and that of nitrogen levels on fertile tiller per plant was highly significant ($P < 0.001$)(Table 14).

As the result of interaction mean show that fertile tillers of bread wheat increase with respect to farmyard manure levels (0 and 6 ton ha^{-1}); however, not regular increments with respect to biochar levels(0, 5 and 10 ton ha^{-1}). This findings similar with Hossain *et al*. (2002) implying that the combined application of organic and mineral fertilizers improved early establishment of wheat through increased fertile spikes per meter square, which may be attributed to the increased availability of macro-and micronutrients as well as improved soil physical characteristics such as water holding capacity, aggregate stability, and reduction in the loss of the nitrogenous fertilizer.

As the results of interaction mean revealed that the effects of farmyard manure, biochar and nitrogen levels and that of biochar and nitrogen levels as well as farmyard manure and nitrogen levels on grain yields were non- significantly. However, that of farmyard manure and biochar levels on grain yields was significant ($P < 0.05$). Likewise, The main effect of farmyard manure and biochar levels on grain yields were significant (P<

0.05) and that of nitrogen levels on grain yields were highly significant ($P< 0.001$).
As the results show that grain yields of bread wheat increase with the interaction mean of biochar (0, 5 and 10 ton ha^{-1}) and farmyard manure levels (0 and 6 ton ha^{-1}). This finding in line with Yaduvanshi and Sharma (2008), found that application farmyard manure with chemical amendment increased wheat yield and N, P and K uptake in grain yield. Similarly, Ali M. *et al.,* 2015 the application of BC at the rate of 25 ton ha^{-1}, FYM at 10 ton ha^{-1} and N at 120 kg ha^{-1} improved wheat grain yield by 9.96, 7 and 11% over no BC, 5 ton FYM ha^{-1} and 60 kg N ha^{-1} respectively.

Table 14. The interaction effect of farmyard manure and biochar on plant height, fertile tiller per plants and grain yield of bread wheat

	Plant height (cm)			Fertile tiller per plants			Grain yield (ton ha^{-1})		
	Biochar (ton ha^{-1})								
FYM (ton ha^{-1})	0	5	10	0	5	10	0	5	10
0	97.49a	101.22^{b}	100.33^{b}	4.96^{a}	5.69^{ab}	5.00^{a}	4.35^{a}	4.84^{b}	4.91^{b}
6	100.91 b	101.76^{b}	106.07^{b}	5.36^{ab}	6.02^{bc}	6.44^{c}	4.86^{b}	4.87^{b}	5.79^{d}
SE±		1.48			0.72			4.990	
$LSD_{(0.05)}$		1.42			0.69			4.781	
CV (%)		1.50			12.8			10.10	

Means followed by the same letter with in the same column of the respective treatment are not significantly different (P ≤ 0.05) according to Duncan's Multiple Range Test, FYM = Farmyard manure, SE = Standard error, CV = Coefficient of variation, Least Significant differences, NS=not Significant

Biological Yield, Straw Yield and Thousand Kernel Weight

The analysis of variance showed that none of the interaction effect of the treatments was significant on the biological yield, straw yield and thousand kernel weight of bread wheat. However, the main effects of farmyard manure and biochar levels on the biological yields and straw yields were significant ($P < 0.05$) and that of nitrogen levels on the biological yield and straw yield were highly significant ($P < 0.001$) (Appendix table 22). But, that of farmyard manure levels, biochar levels and nitrogen levels on thousand kernel weight were non-significant (table 15).

As the result of mean of main effects revealed that the biological yields of bread wheat increase with the increase levels of biochar (0, 5 and 10 ton ha^{-1}) by 5.81 and13.97% respectively over control treatments. likewise, farmyard manure (0 and 6 ton ha^{-1}) by 10.58 % and that of nitrogen fertilizer (0, 23 and 46 kg ha^{-1}) by 10.59 and 21.04 % respectively over the control treatment; In addition to this the straw yields of bread wheat also increase with the increase levels of biochar (0, 5 and 10 ton ha^{-1}) by 6.20 and 14.03 % respectively over control treatment, farmyard manure (0 and 6 ton ha^{-1}) by 11.35 % as well as nitrogen fertilizer (0, 23 and 46 kg ha^{-1}) by 10.65 and 19.63 % respectively over the control treatment. This study in line with Shah and Ahmad (2006) the increased uptake of N in leaf, stem, straw and grain in higher FYM incorporated plots might be associated with the mineralization of FYM throughout the growing season that ensured its availability to wheat crop. Similarly, according to Ali M. *et al.*(2015) higher straw yield (15.36%) was recorded in plots treated with 25 t BC ha^{-1} as compared to no BC plots or 50 t ha^{-1} BC plots.

Table 15. The main effect of farmyard manure, biochar and nitrogen levels on biological yield, straw yield and thousand kernel weight of bread wheat

FYM(tons ha^{-1})	Biological yields (tons ha^{-1})	Straw yields (tons ha^{-1})	Thousand kernel weight
0	12.51^{b}	7.81^{b}	42.35
6	13.99^{a}	8.81^{a}	42.64
$LSD_{(0.05)}$	0.71	0.53	NS
Biochar (tons ha^{-1})			
0	12.32^{b}	7.72^{b}	42.35
5	13.08^{b}	8.23^{b}	42.39
10	14.32^{a}	8.98^{a}	42.75
LSD(0.05)	0.87	0.65	NS
Nitrogen (kg N ha^{-1})			
0	11.74^{c}	7.41^{c}	42.20
23	13.13^{b}	8.29^{b}	42.33
46	14.87^{a}	9.22^{a}	42.96
$LSD_{(0.05)}$	0.87	0.65	NS
CV (%)	9.69	11.64	3.88

Means followed by the same letter with in the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test, FYM = Farmyard manure, CV = Coefficient of variation, Least Significant differences, NS = not Significant

CONCLUSION

Maturity date of bread wheat increase with nitrogen levels (0, 23 and 46 kg ha^{-1}) by 2.96 % and 5.17 % more duration to reach 90% physiological maturity than in the control plots respectively. Likewise, the plant height of bread wheat increase with the interaction of biochar (0, 5 and 10 ton ha^{-1}) and farmyard manure levels (0 and 6 ton ha^{-1}). Similarly, the grain yields of bread wheat increase with the interaction effect of biochar levels (0, 5 and 10 ton ha^{-1}) and farmyard manure levels (0 and 6 ton ha^{-1}) increase.

The highest bread wheat yield (7027.67 kg ha^{-1}) was recorded at 10 t biochar ha^{-1} + 6 t farmyard manure ha^{-1} + 46 kg N ha^{-1} which was followed by 5 t biochar ha^{-1} + 6 t farmyard manure ha^{-1} + 46 kg N ha^{-1}. However, the application of 5 ton BC ha^{-1} + 0 ton FYM ha^{-1} + 46 kg N ha^{-1} remains profitable and recommended for farmers in Sinana district and with similar agro ecological condition.

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Generally recommendations: Farmers are advised to add small amount of mineral fertilizer to farmyard manure and biochar to improve soil properties and enhance soil productivity and quality. The study could be repeated for a longer period to ascertain the lasting impact of farmyard manure and biochar on soil properties. The time of application of farmyard manure and biochar should be early as much as possible per cropping season; this is to increase the decomposition rate of organic materials and to avail nutrient for plants growth and development. The levels of farmyard manure and biochar should be increased to increase the availability of plant nutrient by keeping inorganic fertilizer constant or decrease levels for the reduction of their environmental and economic impacts.

ACKNOWLEDGEMENTS

The authors would like to thank all staffs of Soil Fertility Improvement and Soil and Water Conservation team of Sinana Agricultural Research Center, for their contribution towards implementation of the study, and Sinana Agricultural Research Centre for providing necessary logistic support in the course of the study. The generous financial assistance from Oromia Agricultural Research Institute is also gratefully acknowledge

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