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Effects of biochar and nps fertilizers on growthand yield of Swiss chard (*Beta vulgaris* var. *cicla* L.) in north ARI, south omo zone, southern Ethiopia

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ABSTRACT

Aim: The aim of this study was to assess the effect of biochar and NPS fertilizer on growth and yield of Swiss chardand soil properties in North Ari, Southern Ethiopia.
Materials and Methods: Field experiment was conducted to assess the effects of biochar (10,20 and 30 t/ha) and NPS fertilizer rate (0, 50, 100,150 and 200 kg N ha-1) on growth and yield components of Swiss chard. The experiment was laid out in a randomized complete block design (RCBD) of factorial arrangement with three replications where, Ford Hook Giant variety of Swiss chard was used as a test crop.
Results: Results indicated that biochar and NPS fertilizer significantly ($P < 0.05$) influenced days to first harvest of Swiss chard in their main effects. The interaction effects of biochar and NPS fertilizer influenced plant height, leaf number and leaf fresh weight of Swiss chard highly significantly ($P < 0.01$).
Conclusion: It was concluded that the tested growth, yield components and yield of Swiss chard, were significantly influenced by the main as well as the interaction effects of biochar and NPS fertilizer rates.

Keywords: Biochar, Ford hook Giant, leaf fresh yield, Marketable yield, NPS fertilizer, Swiss chard.

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Introduction

Swiss chard (*Beta vulgaris* var. *cicla* L.), also known as spinach beet, sliver beet, seakale beet, chard leaf beet and spinach in various parts of the world, belongs to family Chenopodiaceae (Swiader *et al.,* 1992 and Smith *et al.,* 2001). It's a biennial plant with large dark leaves, belongs to same family as beetroot. Unlike beetroot, Swiss chard lacks large bulbous tape root (Dlamini *et al.,* 2020). It has been producing around urban and peri-urban areas compared to lettuce and cabbage (Gebremedhin and Awgchew, 2019). According to CSA (2020), in country Swiss chard covered 226.80 ha of cultivated land, from which 662.30 tons production was obtained with an average productivity of 2.92 tons ha^{-1}. It ranked fourth among cool season leaf vegetables based on area of production and production in quintals next to Ethiopian cabbage, head cabbage and lettuce (CSA, 2020).

Besides its importance, little research effort was made before on this vegetable to enhance its productivity (Gebremedhin and Awgchew, 2019). However, this vegetable has nutritional advantages that can contribute significant positive impact on improving food security, especially on reducing malnutrition.

The quality and yield of Swiss chard are strongly influenced by the amount, frequency, type, and method of fertilization (Libuttiet *al.,* 2020).Hence, fertilizer use is the most practical and effective agronomic practice that improves yield and nutritional quality of many vegetable crops for human consumption (Anjanaet *al.,* 2007).This has so far been checked by the application of plant nutrients to the soil either the organic or inorganic types as well as both.

Severe soil fertility depletion and declining agricultural productivity due to a reduction of soil organic matter (SOM) and nutrient imbalances are major constraints in most tropical agricultural soils (Sanchez, 2002; Pender, 2009). Soil nutrient depletion is an important concern, directly linked to food insecurity due to unsustainable intensified land use (Henao and Baanante, 1999). As such, most farmers adopt intensive use of synthetic chemical fertilizers, which can be detrimental to the environment, ecological system, and the health of life forms. The use of organic amendments such as biochar for both field and controlled-environment production is acknowledged as sustainable clean technology (Abbey *et al.,* 2020).

Many studies have shown that biochar can enhance the biological, physical, and chemical properties of growing media. These include improvements in soil structure, slow release of nutrients, sequestration of carbon, cation exchange capacity, sorption capacity, water-holding capacity, and soil fertility (Agegnehu *et al.,* 2015; Khan *et al.,* 2016). Biochar soil amendment also significantly increased plant growth and nutrition and improved the efficiency of added N and other fertilizers (Steiner *et al.,* 2008). Plant growth and yield increases with biochar additions have, in most cases, been attributed to optimization of the availability of plant nutrients (Gaskin *et al.,* 2010; Agegnehu *et al.,* 2016a), increase in soil microbial biomass and activity (Lehmann *et al.,* 2011) and reduction of exchangeable Al^{3+} (Qian *et al.,* 2013). However, it is worth noting that the benefit of biochar is dependent on the rate of application, supplementing it with mineral fertilizers like N, P and S, the genotype of the plant and others.

Biochar, when used in conjunction with inorganic fertilizers like N, P and S, can improve the efficient utilization of nutrients and facilitate sustainable crop production in degraded soils.Various studies have shown that the use efficiency of inorganic fertilizer is enhanced by the co-application of biochar and chemical fertilizers (Steiner *et al.,* 2008; Alburquerque *et al.,* 2013). So, balanced fertilization is the key to sustainable vegetablecrop production and maintenance of soil health which has both economic and environmental consideration. Research efforts on how to use the resources and use of biochar together with mineral fertilizers could be an alternative solution for sustainable fertility management and promote food self-sufficiency. In general, the role of biochar supplemented with mineral fertilizer and its effect on Swiss chard growth and yield as well as on soil properties has not been studied in study area. Hence the study was initiated with the objective of determining effect of Biochar and NPS fertilizer on growth and yields of Swiss chard (*Beta vulgaris* var. *cicla* L.) and soil chemical properties inNorth Ari, South Omo zone, Southern Ethiopia.

Materials and Methods

The study was conducted at Gelila North Ari Woreda of South Omo Zone, Southern Ethiopia. Geographically, the area was located at 6°19' 0'' N latitude and 37°35'0''E longitude with altitude of 3007 m.a.s.l and about 900 km south of Addis Ababa. The district was categorized under Omo highlands Enset, wheat and barley livelihood zone and currently known for its high apple fruit production. The total annual rainfall of the study area was within range of 1100-1600 mm/annum. The mean minimum temperatures from December to February and maximum temperatures from July to September of the Gelila area are 12°C and 23°C, respectively. The soil of Gelila was clay loam in texture with 77% Aluminium (Al) saturation. It has a weak medium sub angular blocky structure with consistence that is friable when moist and sticky/slightly plastic under wet condition with the pH value of 4.8. The topography of the area was hilly, with slope of 13% (Biniam *et al.,* 2021).

Experimental Materials: The experimental materials used in this study were organic fertilizer biochar and mineral NPS fertilizer. The Swiss chard variety namely 'Ford Hook Giant' was used as the test crop variety. The variety is a widely known and well adapted to Ethiopian cool highlands and it has darker green leaves and broader leaf stalks (Semagn and Fentahun, 2010).

Soil Sampling and Analysis: Before land preparation, soil samples were randomly taken from the experimental site in zigzag manner from ten spots at a depth of 0-30 cm using an auger as described by Munson and Nelson (1993), and the samples were mixed thoroughly to produce 1.0 kg of a representative composite sample. Similarly, surface soil samples of the same depth were collected after harvest from each plot by taking samples from three points within each plot and composited to yield one representative sample per treatment for analysis. The soil samples were air dried, grounded using a pestle and mortar, and allowed to pass through a 2 mm sieve. However, for total nitrogen (N) and soil organic carbon (SOC) content analyses the soil sample was prepared by passing through 0.5 mm sieve. The composite samples were put in polythene bag and taken to WolaitaSodo Soil Testing Laboratory for analysis of pH, SOC (%), total N (%), available phosphorus (P), sulfur (S) (mg kg^{-1}), cation exchange capacity (CEC) [cmol (+) kg^{-1}] and soil texture.

Chemical Analysis forBiochar Characterization: Determination of the nutrient content of biochar is very essential point to know nutrient concentration of biochar and also to make treatment arrangement. Total N in biochar sample was estimated by semi-micro Kjeldahl method as described in section 2.3. But, 0.1 g oven dried sample was digested instead of 1 g soil sample for biochar analysis. The P, pH, OM content and CEC were determined by using procedures stated for soil analysis above in section 2.3.

Treatments and Experimental Design: The experiment was consist of two factors, namely three levels of biochar (10, 20and 30 ton ha^{-1}) and inorganic NPS fertilizer at five rates (0, 50, 100, 150 and 200NPS ha^{-1}), making a total of fifteen treatment combination sfactorially arranged in randomized complete block design (RCBD) with three replications.

Seeds were normally drilled directly into the soil in rows spaced 40 cm apart and later thinned to a spacing of 30 cm within the row. The plot size was 3.6 m × 2 m (7.2 m^2).

Experimental Procedure and Plot Management: The experimental field was ploughed, disked and pulverized to a fine tilth by oxen or man power. After layout, plots were levelled manually; treatments were assigned randomly each to experimental plots within a block. Biochar from locally available feedstock was prepared using traditional earth-mound (earth kiln) technology (Srinivasarao *et al.,* 2013). After pyrolysis process, biochar was grounded to small granules and passed through 2 mm sieve in order to have same particle size as that of soil. Biochar was mixed thoroughly, weighed for each plot, spread evenly, and incorporated into the plots manually 30 days before sowing accordingly to rates. The levels of each blended fertilizer formulations (NPS) (0, 50, 100,150and 200 kg ha^{-1}) were applied with full dose of basal application based on treatments. All other agronomic practices were followed as per the recommendations for the crop.

Data Collection and Measurement:

Crop phenologicaland vegetative growth parameters:

Days to first harvest: Swiss chard leaves are ready for harvesting when they are turgid and dark-green in color with white or red midrib and petiole depending on the variety (Maria *et' al*, 2012). Moreover, harvested leaves together with petioles shall be at least 15 cm long (Maboko and Plooy, 2013). Accordingly, days to first harvest was obtained by counting the number of days elapsed from the date of planting up to the date when 50% of the plants in the plot contain at least one harvest-matured leaf and the mean values were computed and used for further analysis.

Plant height (cm): The plant heights of six randomly taken and tagged plants grown in the net plot area were measured from the ground level to the topmost growth point using rulers at ten days interval up to first harvest and the mean values were computed and used for analysis.

Number of leaves per plant: Number of harvested leaves of six randomly taken and tagged plants grown in the net plot area was counted at each harvest and every visible leaves including the new once were counted at the last harvest and the mean values were computed and used for analysis.

Length of leaf (cm): The leaf lengths of six randomly taken leaves harvested from the net plot area at each harvest were measured from the base (end of sheath) to the tip of the leaf and the mean values were computed and used for analysis.

Total number of leaves harvested per plant (count): At each harvest the numbers of leaves harvested from six randomly taken and tagged plants were counted and the mean values were computed and used for analysis.

Yield and yield related parameters of Swiss chard

Average leaf fresh weight (g): The leaf fresh weights of six randomly taken leaves harvested from the net plot area were weighted using sensitive balance at each harvest and the mean values were computed and used for analysis.

Marketable leaf fresh yield (t/ha): Leaves that are at least 15cm long (Maboko and Plooy, 2013) and free of decayed, bruises and damages and dark green are considered as marketable (Miceli and Miceli, 2014). Such leaves harvested from the net plot area at each harvest were weighed in sensitive balance and mean values of each harvest was then changed to hectare basis and expressed in t ha^{-1}.

Unmarketable leaves (%): Leaves that are soiled and decayed, small in size and yellow in color, damaged and bruised are considered as unmarketable (Miceli and Miceli, 2014). The weight proportion of such leaves to that of total leaf fresh yield were computed and expressed in percentage.

Total leaf fresh yield (t/ha): It was obtained by summation of marketable and unmarketable yields and then converted to hectare basis and expressed in t ha-1.

Statistical Data Analysis

Data collected was subjected to analysis of variance (ANOVA) appropriate to two-factor factorial experiment in RCBD according to the General Linear Model (GLM) of GenStat 16th edition (GenStat, 2012) and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found to be significant, the means was compared using least significance difference (LSD) at 0.05 probability level.

Results and Discussion

Results were observed as follows:

Soil physical and chemical properties of the experimental site:

Table 1: Chemical Analysis of Biochar used for experiment

pH	Al cmol(+) kg^{-1}	Cacmol(+) kg^{-1}	K cmol(+) kg^{-1}	Mgcmol(+) kg^{-1}	Na cmol(+) kg^{-1}	CEC cmol(+) kg^{-1}	Total N%	Total C%	CaCo3%
5.8	<0.12	6	0.24	1.0	0.92	8.8	0.46	47	30

Table 2. Pre planting soil physico-chemical properties of the experimental site

Parameters	**Value**	**Methods**
Clay: Silt: Sand (%)	27: 37: 30	Hydrometer
Texture class	Clay loam	
pH (1:2.5 soil to water)	5.9	
Organic matter (%)	1.7	Walkley and Black
Total N (%)	0.08	Kjeldahl
C:N ratio	9	
Available P (ppm)	9.3	Olsen
CEC (cmol(+) kg^{-1})	25.5	
Base saturation (%)	90	
Exchangeable Na(cmolc kg-1)	0.02	Ammonium acetate
Exchangeable K(cmolc kg-1)	0.71	
Exchangeable Ca(cmolc kg-1)	18.79	
Exchangeable Mg(cmolc kg-1)	3.30	

Phenology and Growth Parameters of Swiss chard as Affected by Biochar and NPS Fertilizer

Days to first harvest (days): Analysis of variance revealed that the main effects of NPS was highly significantly ($P<0.01$) and biochar significantly ($P<0.05$) affected days to first harvest of Swiss chard. However, the interaction effect of both factors did not affect days to first harvest of Swiss chard.

Increasing the rate of NPS from 0 to 200 kg ha^{-1} was resulted the lowest number of days to reach maturity of Swiss chard from 68.33 to 63.11 days. The earliest days to maturity (63.11 days) was observed at higher NPS fertilizer rate (200 kg ha-1), whereas the longest days to maturity (68.33 days) was recorded at zero application. Similarly, increasing the biochar further from 10 to 30 t/ha also decreased days to maturity of Swiss chard plants significantly. The earliest harvest-maturity of Swiss chard leaves was observed at highest of 30 t/ha (64.46 days) while the longest maturity date (66.66 days) was observed at the lower biochar application of 10 t/ha (Table 3).

The decrease in days to maturity with the addition of higher NPS fertilizer level could be attributed to more availability of the nutrient which boosts protein synthesis which lead to increased accumulation of carbohydrates and this in turn, may have resulted in increased plant vegetative growth such as leaf length and tenderness of the leaves. This result is consistent with the findings of AberaJaleta, (2020) who reported that cabbage plant maturity significantly decreased as nitrogen fertilizer rates increased.

These findings were in agreement with Khatiwada, (2001) on cabbage plants and Turbin *et al.*, (2014) on Brussels sprouts reported that wider rather than narrower spacing lowers the number of days to reach maturity, showing that narrower spacing leads to stiffer competition among plants for growth factors, causing reduced growth.

Table 3. Effects of biochar and NPS fertilizer on days to first harvests of Swiss chard

Rate of NPS (kg/ha)	Days to first harvest
0	71.33[a]
50	72.11[ab]
100	72.11[ab]
150	70.44[bc]
200	69.11[c]
Sig. Level	**
SE ±	1.09
Rate of Biochar(t/ha)	
10	66.66[a]
20	65.73[ab]
30	64.46[b]
Mean	65.62
SE ±	0.85
CV (%)	3.55
Sig. Level	*

Where; ** = highly significant at (P≤0.01); * = significantly at (P≤0.05); treatment means followed by the same letter(s) within the same column are not significantly different, CV = Coefficient of variation, SE= Standard error

Plant height (cm): The analysis of variance revealed that main effect of biocchar and NPS fertilizer rates and their interaction effect had significant (P < 0.01) effects on the plant heights of Swiss chard plants.

Increasing rate of NPS fertilizer as well as higher rate of biochra generally increased the heights of Swiss chard plants. In the interaction effect, the results showed that, increasing plant biochar significantly increased Swiss chard plant height per plant across the increasing rate of the NPS fertilizer. Thus, the highest Swiss chard plant height (42.66 cm) was observed by the treatment combination of 200 kg ha-1 NPS fertilizer and 30 t/ha biochar, which was statistically similar with plant heights, recorded from treatment combination of 20 t/ha biochar x 200 kg ha-1 NPS (39.66 cm) and 30 t/ha biochar x 150 kg ha-1 N (39.33 cm).

The highest plant height of Swiss chard at highest rates of NPS and higher rate of biochar recorded in the current study might be due to the presence of production of new shoots and enhancement of vegetative growth, which is directly related to the increase in plant height. The results of this study was in agreement with those of Ahmad, (2014) on cauliflower and Rashid *et al*., (2016) on tomato plants who reported that with the application of high nitrogen level combined at recorded the highest plant height.

Table 4. Effect of biochar and NPS fertilizer on plant height

Rate of Biochar(t/ha)	Rate NPS(kg/ha)	Plant height (cm)
10	0	25[e]
	50	25.33[e]
	100	35[d]
	150	35[d]
	200	40[c]
20	0	15.33[e]
	50	25[d]
	100	31.66[c]
	150	37[b]
	200	39.66[ab]
30	0	18.33[e]
	50	23.66[d]
	100	39[ab]
	150	39[ab]
	200	42.66[a]
Mean		28.13
SE ±		2.20
CV (%)		9.58
Sig. Level		**

Leaf length (cm): The results of analysis of variance indicated that the main effects of NPS fertilizer and biochar as well as their interaction highly significantly (P<0.01) influenced leaf lengths of Swiss chard. Relatively, increasing the rates of NPS as well as increasing the rate of biochar generally increased leaf lengths of Swiss chard plants (Table 5).

In the interaction effect, the highest leaf length (67.30 cm) was recorded at applications of 100 kg ha-1 NPS combined with 30 t/ha biochar which was statically similar with the interaction effects of 150 kg ha-1 N x 30 t/ha (63.63 cm) and 200 kg ha-1 NPS x 30 t/ha (66.96 cm). The shortest leaf length was obtained from plants grown at 20 t/ha biochar and without NPS fertilizer application. The increase in leaf length at the medium NPS fertilizer combined with higher amount of biochar may be due to increased amount of nutrient requirement for the growth factors which may lead to better growth and significantly taller leaf length compared to lower levels of NPS fertilizer. However, increasing the rate of NPS fertilizer beyond 100 kg ha-1 did not change leaf length, indicating that too much NPS beyond the potential of the plant would have no added values for leaf length. This finding agrees with results of Hasan*et al*., (2017);

BewuketGashaw and Shewaye Haile, (2020), who reported that wider rather than narrower intra-row spacing interacted with excess nitrogen, produced longest lettuce plants, showing that narrower spacing leads to stiffer competition among plants for growth factors, causing reduced growth.

Number of leaves per plant: The analysis of variance revealed that main effects of biochar and NPS fertilizer rates and their interaction effect had significant ($P < 0.01$) effects on the number of leaves per plant of Swiss chard. Increasing rate of NPS fertilizer as well as higher biochar generally increased the number leaves per plants of Swiss chard. In the interaction effect, the result revealed that significantly highest numbers of leaves per plant (14.83) were produced in response to the applications of highest levels of NPS fertilizer (200 kg ha-1) combined with high amount of biochar rate (30 t/ha) which was statistically similar with the number leaves produced from the interaction effects of 100 kg ha-1 x 30 t/ha (14.13) and 150 kg ha-1 x 30 t/ha (14.16). On the other hand, plants with the lowest number of leaves per plant (5.83) were produced in response to the plot applied with 20 t/ha biochar with nil rate of the NPS fertilizer (Table 5).

Obtaining the highest number of leaves per plant of Swiss chard in treatment combination of higher biochar (30 t/ha) and higher NPS fertilization (200 kg N ha-1) might be due to blended fertilizer mainly related to production of new shoots and vigor in vegetative growth of Swiss chard, thus directly responsible for the increasing of leaf number. Therefore, there is moderate amount of nutrients, moisture and light among the plants to achieve the required nutrition for their growth. This result was in agreement with the findings of Gebremedhin Hailay and Awgchew Haymanot (2019) who reported that the highest number of leaves per plant (28.38) was obtained from 150 kg N ha-1combined. Similarly Ahmad, (2014) on cauliflower and Hasan *et al*. (2017) on lettuce plants showed increasing trends of leaf numbers with increasing of nitrogen fertilizer interactions.

Total number of leaves harvested per plant: Total number of leaves harvested per plant of Swiss chard was significantly ($P < 0.01$) influenced by the main effects of both biochar and NPS fertilizer application as well as by their interaction. Increasing rate of biochar and NPS fertilizer generally increased total number of leaves harvested plants of Swiss chard (Table 5). In interaction effect, the results revealed that significantly highest total numbers of leaves harvested per plant (12) of Swiss chard were obtained from plants treated with NPS fertilizer at the rates of 200 kg ha-1 and biochar rate of 30 t/ha. However, the lowest total number of leaves harvested per plant (2.36) was recorded on Swiss chard plants grown at 20 t/ha biochar combined without NPS fertilizer.

It might be due to reason that NPS fertilizer promotes vegetative growth and development of new shoots by its simulative effect on cell division and cell enlargement and an increase in biochar rate increase soil properties that boosted soil nutrients, thus, directly responsible for increasing of total number of leaf numbers of Swiss chard. The results of present study were conformed by findings of Ahmad (2014) on cauliflower and Bewuket Gashaw and Shewaye Haile (2020) on lettuce plants also shown an increase in total leaf number while increasing in intra-row spacing combined with wider intra-row spacing.

Table 5: Effect of Biochar and NPS fertilizer on leaf length, number of leaf per plant, total number of leaves harvested per plant

Rate of Biochar(t/ha)	Rate NPS(kh/ha)	LL	NLPP	TNLHPP
10	0	35.96^{e}	5.83^{g}	2.36^{j}
	50	36.63^{e}	6.76^{fg}	3.36^{hij}
	100	49.30^{d}	6.93^{efg}	2.86^{ij}
	150	60.63^{ab}	7.30^{efg}	3.96^{fghi}
	200	52.63^{cd}	9.16^{bcd}	5.03^{def}
20	0	36.63^{e}	9.96^{efg}	4.10^{efgh}
	50	50.30^{d}	8.26^{def}	4.76^{efg}
	100	58.96^{bc}	8.50^{cde}	5.00^{def}
	150	57.96^{bc}	10.03^{bc}	6.20^{dc}
	200	66.30^{a}	10.60^{b}	6.60^{c}
30	0	45.63^{d}	7.10^{efg}	3.60^{ghi}
	50	49.63^{d}	9.20^{cbd}	5.20^{de}
	100	67.30^{a}	14.13^{a}	9.96^{b}
	150	63.63^{ab}	14.16^{a}	9.30^{b}
	200	42.66^{a}	14.83^{a}	12.00^{a}
Mean		53.23	9.32	5.62
SE ±		3.45	0.78	0.59
CV (%)		7.93	10.27	12.96
Sig. Level		**	**	**

Where; ** =highly significant at ($P \leq 0.01$); LL=Leaf length; NLPP= number of leaves per plant and TNLHPP=total number of leaves harvested per plant: treatment means followed by the same letter(s) within the same column are not significantly different, CV = Coefficient of variation, SE= Standard error

Yield and yield component parameters

Average leaf fresh weight (g)

The study revealed that the main effects of NPS fertilizer rate and biochar as well as their interaction effect very highly significantly (P<0.001) influenced average leaf fresh weight of Swiss chard. Increasing rate of NPS fertilizer as well as increasing rate of biochar generally increased the average leaf fresh weight of Swiss chard (Table 6).

In interaction effect, result revealed that significantly the highest average leaf fresh weight of Swiss chard (93.37g) was recorded at 200 kg ha-1 NPS combined with 30 t/ha which was statistically similar with the highest average leaf fresh weight obtained from the interaction effects of 150 kg ha-1 NPS x 30 t/ha (92.09 g). However, plants treated with null kg NPS ha-1 and spaced 20 t/ha apart produced the lowest (38.91g) average leaf fresh weight. The highest average leaf fresh weight production of Swiss chard shoots at 40 cm plant spacing combined with 200 kg N ha-1 might be due to higher N availability in the soil that can be absorbed by the plant which ensure favourable condition for the growth of plant with optimum vegetative growth and ultimately increase the leaf fresh weight of Swiss chard. The present results are in agreement with the findings of Miceli and Miceli, (2013), Echer*et al*. (2012) and GebiremedhinHailay and AwgchewHaymanot (2019) who reported that application of inorganic fertilizer rate affects leaf fresh weight of Swiss chard plants. Similarly Hasan*et al*. (2017) and TamiruFikru*et al*. (2017) also reported an increase in NPS rate and application of biochar increase the leaf fresh weight of lettuce and beet root respectively.

Marketable leaf fresh yield (t/ha)

The results of analysis of variance indicated that the main effects of NPS fertilizer and biochar as well as their interaction significantly (P<0.01) influenced marketable leaf fresh yield of Swiss chard. Increasing rate of biochar consistently increased marketable leaf fresh yields of Swiss chard. Similarly, increasing the rate of NPS fertilizer up to a certain level has increased marketable leaf fresh yields of Swiss chard plant.

In the interaction effect, the result revealed that significantly highest marketable leaf fresh yield (36.54 t ha-1) of Swiss chard was obtained from plants spaced at 30 t/ha and supplied with 100 kg ha-1 NPS, which was statistically similar with that of plants grown in the treatment combinations of 150 kg ha-1 NPS × 30 t/ha (36.02 t ha-1) biochar. On the other hand, the lowest (12.98 t ha-1) marketable leaf fresh yield was recorded when Swiss chard plants were grown at 20 t/ha biochar without NPS fertilizer.

The highest marketable leaf fresh yield of Swiss chard obtained at treatment combination of 30 t/ha biochar and 100 kg NPS ha-1 might be attributed to optimum utilization of nutrients per unit area and optimum amounts of NPS fertilizer which leads to highest marketable leaf yields. Generally, application of NPS fertilizer up to a certain level were at higher rate of biochar increased vegetative growth which in turn may develop relatively healthy and attractive leaves which were acceptable for markets. These results of the current study are consistent with the findings of Tahsin (2010) who reported that yields in leafy vegetables for any crop may be increased up to 25% by using optimum spacing. On the other hand treatments with higher levels of nitrogen fertilizer combined with narrow intra row spacing produced high proportion of unfit leaves that were infected and damaged by diseases. Narrow intra-row spacing favors disease proliferation at the lower leaves of Swiss chard plants (Echer *et al*., 2012). Excess N increases the susceptibility of plants to disease, reducing quantity and quality of the harvested product (Echer *et al*., 2012). These results are also in line with the findings of Kołota *et al*., (2017) and GeberemedhinHailay and Awgchew Haymanot (2019) who reported that the optimum marketable leaf fresh yield of Swiss chard was attained at 100 kg N ha-1combined with 40 cm intra-row spacing.

Unmarketable leaf yield (%)

The analysis of variance reviled that unmarketable leaves of Swiss chard plants was affected significantly (P < 0.05) by NPS fertilizer rates and biochar in their main effects as well as in their interaction effects (Appendix Table 5). Relatively highest rates of NPS fertilizer as well as low rate of biochar generally increased unmarketable leaf yields of Swiss chard (Table 6).

In the interaction effect, the result revealed that significantly highest unmarketable leaf yield (1.56 t ha-1) of Swiss chard plants was obtained from plot received of 20 t/ha biochar and supplied with 200 kg ha-1 NPS fertilizer, followed by 30 t/ha combined with 200 kg NPS ha-1. However, the least unmarketable leaf yield (0.75 t ha-1) of Swiss chard was obtained with the interaction effect of 30 t/ha biochar and 0 kg ha-1 NPS fertilizer. Thus, application of 200 kg ha-1 NPS fertilizer for plants spaced at 20 t/ha of biochar increased unmarketable leaf yield by 108% compared with the treatment combination of 100 kg ha-1 NPS fertilizer and 30 t/ha biochar.

Total leaf fresh yield (t/ha)

The main effects of NPS fertilizer as well as biochar significantly (P < 0.01) influenced total leaf fresh yield of Swiss chard. Similarly, the two factors also interacted to influence significantly (P <0.01) the same parameter. Increasing rate of NPS up to certain level as well as increasing rate of biochar generally increased the total leaf fresh yield of Swiss chard (Table 6).

In the interaction effect, the result revealed that significantly highest total leaf fresh yield of Swiss chard (37.31 t ha-1) was attained from at 100 kg ha-1 NPS combined with 30 t/ha biochar. But, total leaf fresh yield of Swiss at this biochar level (30 t/ha) did not show significant difference as further increase in NPS rate from 100 to 200 kg ha-1. On the other hand, the lowest (13.88 t ha^{-1}) total leaf fresh yield of Swiss chard was recorded for plants spaced at 20 t/ha biochar that received the NPS rates of 0 kg ha^{-1}. For example, comparing the total leaf fresh yield of Swiss chard, the treatment combination 100 kg NPS ha-1and 30 t/ha increased the total leaf fresh yield of Swiss by 62.8% as compared to the treatment received of 20 t/ha and nil NPS fertilizer application.

Table 6. Interaction effects of biochar and NPS fertilizer on yield components of Swiss chard

Rate of Biochar(t/ha)	Rate NPS(kh/ha)	ALFW (g)	MLFY t/ha	UML t/ha	UML (%)	TLFY t/ha
10	0	38.91^{i}	12.98^{j}	0.89^{cd}	6.4	13.88h
	50	41.91^{hi}	29.56^{ef}	0.85^{def}	2.8	30.41c
	100	57.20^{efg}	29.53^{ef}	0.86^{ed}	2.8	30.39cd
	150	60.36^{de}	30.52^{d}	0.99^{b}	3.1	31.52b
	200	61.32^{cd}	18.42^{i}	1.56^{a}	8.0	19.58g
20	0	42.69^{h}	26.16^{h}	0.78^{ef}	2.9	26.94f
	50	56.75^{g}	29.85^{e}	0.82^{def}	2.7	30.67c
	100	60.23^{def}	31.21^{c}	0.81^{def}	2.5	32.03b
	150	64.04^{c}	29.47^{ef}	0.98^{bc}	3.2	30.45c
	200	69.08^{b}	27.91^{g}	1.10^{a}	3.8	29.00e
30	0	57.03^{fg}	28.99^{f}	0.75^{f}	2.5	29.74d
	50	61.09^{cd}	29.77^{e}	0.78^{ef}	2.6	30.56c
	100	72.03^{b}	36.54^{a}	0.76^{ef}	2.0	37.31a
	150	92.09^{a}	36.02^{ab}	0.84^{def}	2.3	36.86a
	200	93.37^{a}	35.79^{b}	0.86^{de}	2.3	36.65a
Mean		61.88	28.85	0.88		29.73
SE ±		1.58	0.33	0.05	0.05	0.33
CV (%)		3.14	1.38	6.73	6.73	1.35
Sig. Level		**	**	*		**

Where; *** = very highly significant at (P≤0.001); ** = highly significant at (P≤0.01); * = significant at (P≤0.05); leaf fresh weight (LFW); marketable leaf fresh yield (MLFY); unmarketable leaf (UML); total leaf fresh yield (TLFY); treatment means followed by the same letter(s) within the same column are not significantly different, CV = Coefficient of variation, SE= Standard error

It was revealed that with the increases of biochar and NPS level, individual leaf fresh weight per plant increase. The significant impact on total leaf fresh weight of the Swiss chard on higher biochar and in increasing NPS rate might be due to the fact that NPS is acomponent of chlorophyll, nucleic acids, nucleotides, coenzymes, phytohormonesandcytokinins and hence, its suboptimal amount inhibits emission of new cells and plant organs. So, optimum NPS fertilizer and higher biochar rate ensure the highest total leaf fresh yield with maximum vegetative growth. These results agreed with those obtained by GebremedhinHailay and AwgchewHaymanot, (2019) as the highest total plant fresh weight of Swiss chard had Shown in treatment combinations of 30 t/ha x 100 kg NPS ha-1, while the lowest values were recorded from the treatment combination of 20 t/ha biochar and 0 kg ha-1 NPS .

Conclusions

It was concluded that results of the present study clearly showed that, almost all the tested growth, yield components and yield of Swiss chard, were significantly influenced by the main as well as the interaction effects of biocharand NPS fertilizer rates.

Application of NPS at the rate of 100 kg ha^{-1} and 30 t/ha biocharfor Swiss recorded the highest total leaf fresh yield (37.31 t ha^{-1}) and marketable leaf yield (36.54 t ha^{-1}).

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