Vol. 10(9), pp. 135-142, October 2018
DOI: 10.5897/JHF2018.0543
Article Number: 7206CE358909
ISSN: 2006-9782

http://www.academicjournals.org/JHF

Journal of Horticulture and Forestry

Full Length Research Paper

Effect of manure and nitrogen rates on growth and yield of garlic (*Allium sativum* L.) at Haramaya, Eastern Ethiopia

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Received 30 July, 2018; Accepted 6 September, 2018

An experiment was conducted at Haramaya University, Horticulture Research Field, Haramaya during the period from 13 August, 2010 to 17 January, 2011 to investigate the effect of manure and different levels of nitrogen on yield and yield attributed traits. A local garlic cultivar was used for the study. The treatments consisted of four levels of nitrogen (0, 50,100 and 150 kg/ha) and three levels of goat manure (0, 10 and 20 t/ha). The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times. The results revealed that interaction effects of nitrogen and manure significantly (P<0.05) influenced plant height, mean fresh bulb weight, mean clove weight, total bulb yield, fresh biomass yield, percent bulb dry matter yield and harvest index. While neither the combined nor the main effects of manure and nitrogen had significant effect (P>0.05) on leaf number. However, the combined application of 50 kg/ha N and 10 t/ha manure significantly (P<0.05) increased mean fresh bulb weight, mean clove weight, total bulb yield, and harvest index. Maximum yield (27.8 t/ha) was recorded at the combined application of 50 kg/ ha N and 10 t/ha manure. It can, thus, be concluded that for short term garlic production, smallholder farmers could not only get optimum yield of garlic from the combined application of 50 kg/ha N plus 10 t manure/ha but also could save considerably on inorganic fertilizers that can be used for increasing yield of other crops to enhance food security and income.

Key words: *Allium sativum*, garlic, goat manure, nitrogen, yield.

INTRODUCTION

Garlic (*Allium sativium* L.) belongs to the family Alliaceae and is the second most widely used *Allium* next to onion (Yadav et al., 2017). Garlic is produced for fresh market, dehydrated as ingredient for food processing and food supplement output like dehydrated powder, essential oil, oil macerate, powder and aged garlic extract (Wiczkowski, 2011). In Ethiopia, garlic is one of the important bulb crops produced for home consumption as spice or condiment in the preparation of soup, pickle and other preservatives as well as a source of income to

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Table 1. Soil physico-chemical lab analysis of the experimental site.

S/N	Parameter	Result	Remark
1	pH	8.0	-
2	Texture	Sandy loam	With sand, silt, and clay contents of 63, 20, and 17%
3	Organic carbon content (%)	1.15	-
4	Total nitrogen (%)	0.11	-
5	Available phosphorus (mg/kg)	18.2	-
6	Exchangeable potassium ($cmol_c$ $cmol_c$ /kg soil)	0.65	255 mg K/kg soil

many rural farmers in many parts of the country (Alemu et al., 2016). Despite its importance, great potential for production and high market demand, the current garlic production and productivity is limited and remain seasonal. Low soil fertility is one of the factors limiting the productivity of different crops in Ethiopia mainly accounted for removal of surface soil by erosion, nutrients removal by crops from the soil, complete removal of plant residue from farmland and lack of crop rotation system on the farm land resulting in lower crop yields (Abay, 2016; Belay, 2015).

To mitigate these problems, Ethiopian farmers have a tradition to maintain or improve the fertility of the soil using fallowing, farmyard manure, intercropping and crop rotation systems (Befekadu et al., 2017). Application of manure enhances soil fertility and increase the productivity of garlic by improving soil properties and nutrient status. Similarly, Shivananda (2002) reported that application of organic materials like farm yard manure, compost or green manure in combination with inorganic fertilizer improved soil physical properties and the author indicated that the uptake of nitrogen, phosphorus, potassium, zinc, manganese, copper and iron were increased significantly by crops when 50% of organic fertilizers in combination with 50% inorganic fertilizers were applied.

Inorganic fertilizer application is taken as alternative solution to increase productivity of crops. Because, inorganic fertilizers of balanced doses could increase the leaf area, photosynthetic productivity and yield of garlic (Pradesh et al., 2013). But due to escalating costs of inorganic fertilizers and shifts in policies with respect to subsidizing fertilizer costs, the use of inorganic fertilizer by the small-scale producers is becoming unaffordable (Driba, 2016). Application of all needed nutrients through chemical fertilizers is also known to have deleterious effect on soil fertility leading to unsustainable yields, while integration of chemical fertilizers with organic manures is able to maintain the health, productivity and fertility of soil (Yadav et al., 2017). Optimized use of fertilizers through judicious combination of organic resources and mineral fertilizers at levels sufficient to replenish soil nutrients removed by the crops is crucial so as to enhance productivity and keeping wellbeing of the environment (Ouedrago et al., 2002). Consequently, there is a paradigm shift to integrate mineral fertilizer and organic fertilizers for different reasons. Integrated nutrient application not only ensures the supply of essential nutrients to plants but also has some positive interactions to increase nutrient use efficiency and thereby reduce environmental hazards (Bewuket et al., 2017).

Therefore, a systematic investigation into the effect of manure and inorganic fertilizers on garlic is important for optimizing the application of manure and N mineral fertilizer for higher yield and quality of the crop. Hence, the present study was initiated to investigate the effect of combined application of different rates of manure and nitrogen on yield and yield components of garlic.

MATERIALS AND METHODS

Description of experimental sites

The study was conducted under rain-fed condition during the 2010-2011 main cropping season at Haramaya University main campus field research station, Eastern Ethiopia. The area is located at 9°24'N latitude and 42°03'E longitude. The altitude of the site is about 1980 m above sea level.

The soil of the experimental site is fluvisol. Soil chemical and physical characteristics were determined before conducting the experiment (Table 1).

Based on these results, the soil of the experimental site is very low in organic matter, low in total nitrogen, medium in available phosphorus, high in exchangeable potassium and alkaline in reaction (Hillette et al., 2015).

Weather condition of the experimental site

The site has a bimodal rainfall distribution and is representative of a sub-humid mid altitude agro-climatic zone. The short rainy season extends from March to April and constitutes about 25% of the annual rainfall whereas the long rainy season extends from June to October and accounts for about 75% of the total rainfall (Belay et al., 1998). The mean annual rainfall and temperature are 760 mm and 17°C, respectively.

Description of experimental materials

The experiment was conducted with garlic (*A. sativum* L.) local variety. The cloves were obtained locally from farmers which are widely cultivated in Eastern Ethiopia. Medium sized cloves were prepared for planting.

Table 2. The interaction effect of manure and nitrogen on plant height (cm).

Treatment	Plant height (cm)			
	Manure (t ha^{-1})			
Nitrogen (kg ha^{-1})	0	10	20	Mean
0	35^{c}	49^{ab}	50^{ab}	45
50	50^{ab}	48^{b}	47^{b}	48
100	51^{ab}	49^{ab}	48^{b}	49
150	52^{a}	52^{a}	49^{ab}	51
Mean	47	50	48	-
LSD (0.05)	3.3	-	-	-
CV (%)	4.03	-	-	-

Treatments and experimental design

The treatments consisted of four levels (0, 50, 100, and 150 kg/ha N and three levels (0, 10, and 20 t/ha) goat manure. The fertilizer sources were Urea (CO ([NH_2]$_2$) 46% N) as a source of nitrogen and manure from the heap. Tri-superphosphate (CaH_2PO_4)$_2$, which constitutes 46% P_2O_5 was used as a source of phosphate. Manure was obtained from Haramaya University main campus goat farm which was well composted as a heap. The treatments were laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. The size of each plot was 2.10 m × 1.80 m =3.78 m^2 with a net plot area of 1.62 m^2. A distance of 0.6 m was maintained between the plots and 1 m between the blocks. There were 6 rows per plot having 21 plants per row with the spacing of 30 × 10 cm.

Management of the experiment

The experimental plots were planted with the cloves at the depth of 3 to 4 cm by sticking the cloves into the bed and covering them lightly with the soil. Urea was applied in split application, 1/3 during planting, 1/3 six weeks after plant emergence (active stage of vegetative growth) and the other 1/3 was applied twelve weeks after plants had emerged (just at the start of bulbing). Phosphorus in the form of Tri-super phosphate (TSP, 46% P_2 O_5) was applied at the rate of 92 kg/ha at the time of planting to all plots uniformly. Manure was incorporated into the experimental plots one month before planting the cloves. The manure was applied in trenches of about 15 cm depth and thoroughly mixed with the soil and buried. Cultivation, weeding and harvesting were done at the appropriate time. Supplemental irrigation was used as required. Harvesting was done when 70% of the leaves senesced or fell over gently; cloves were harvested by pulling up individual plants by hand. The harvested bulbs were cured under a shade for a week under ambient situation. Yields obtained from the four central rows from each plot were used to record data on various parameters.

Data collection and measurements

Growth parameters

Leaf number per plant: was determined by counting healthy leaves per plot from randomly sampled plants at physiological maturity.

Plant height (cm): was measured by taking randomly sampled plants per plot as the distance in cm from the soil surface to the top most growth point of aboveground at physiological maturity (50% leaf fall).

Yield parameters

Total fresh biomass yield (g): was determined by taking the total weight of sampled plants from the four central rows of fresh bulbs, leaves, stems and roots.

Mean bulb weight (g): was measured by weighing and dividing the total weight of bulbs to the total number of bulbs.

Mean clove weight (g): was determined by dividing the total weight of cloves to the total number of bulbs.

Total bulb yield (t): was recorded by weighing the total yield of the four central rows of harvested bulbs.

Bulb dry matter (%): was calculated by dividing the dry weight of bulbs to the fresh weight bulbs and multiplied by 100.

Harvest index (%): was determined as the ratio of the dry matter yield of total bulb per dry matter yield of total biomass and multiplied by 100.

Data analysis

The data were subjected to analysis of variance (ANOVA) using the general linear model of SAS (SAS, 2002) version 9.1. All significant pairs of treatment means were compared using the Least Significant Difference (LSD) test at 5% level of significance. Simple linear correlation was employed for determination of associations between yield and yield related traits.

RESULTS AND DISCUSSION

Growth parameters

Plant height

Compared to plants obtained from the untreated plots, plants grown in plots treated with the fertilizers had significantly increased heights (Table 2). The maximum plant heights of garlic were recorded from plots that

Table 3. Interaction effect of manure and nitrogen on fresh biomass yield (g).

Treatment	Fresh biomass yield (g) Manure (t/ha)			
Nitrogen (kg/ha)	0	10	20	Mean
0	5615.3[c]	7592.5[ab]	8763.2[a]	7323.7
50	6617.4[b]	7561.8[ab]	6740.6[b]	6973.3
100	7516.8[ab]	5982.0[b]	6892.2[b]	6797.0
150	7401.6[ab]	6626.1[b]	7022.0[b]	7016.6
Mean	6787.8	6940.6	7354.5	-
LSD (0.05)	1669.1	-	-	-
CV (%)	14.02	-	-	-

Means with similar or no superscripts within a column are not significantly different at 0.05 probability level.

received either 150 kg/ha N alone or 150 kg/ha N in combination with 10 t/ha manure, which were in statistical parity with the heights of plants recorded at the treatment combinations of 0 t/ha manure and 50 kg/ha N, 0 t/ha manure and 100 kg/ha N, 10 t/ha manure and 0 kg/ha N, 10 t/ha manure and 50 kg/ha N, 10 t/ha manure and 100 kg/ha N, 20 t/ha manure and 0 kg/ha N, 20 t/ha manure and 100 kg/ha N, 20 t/ha manure and 150 kg/ha N. The lowest plant height was recorded at the combination of 0 kg/ha N and 0 kg/ha manure.

Although inconsistent, the results of the interaction effect on plant height indicate that increasing the combined rates of nitrogen and manure or increasing the rate of either manure or nitrogen promotes growth of plants in height. This may be attributed to the fact that manure contains carbon, nitrogen as well as other nutrients which may have synergy with the inorganic nitrogen supply in promoting plant growth. This hypothesis is supported by the findings of Alemu et al. (2016) who reported that organic manure and inorganic fertilizer supplied all the essential nutrients resulting in increase of measured variables like plant height. Generally, it was observed that treatments that received both organic and inorganic fertilizer produced plants with more height as compared to plants in unfertilized plot. This study is also in parity with Kokobe et al. (2013) who documented that effect of farmyard manure and nitrogen fertilizer rates on increased plant height of onion.

Leaf number

Neither the main nor the interaction effects of the two fertilizers were significant (P>0.05) on the number of leaves produced by the garlic plant.

Yield parameters

Fresh biomass yield (g)

The interaction effect of manure and nitrogen showed significant difference (P≤0.05) on fresh biomass yield. The maximum fresh biomass yield was recorded at the application of 20 t/ha manure plus 0 nitrogen followed by 10 t/ha manure, 10 t/ha manure and 50 kg/ha N, 0 t/ha manure and 100 kg/ha N, which were in statistical parity. The minimum mean fresh biomass yield was, however, recorded from plants grown at nil manure and nitrogen. Compared to the fresh biomass yield obtained at nil manure and nitrogen, the fresh biomass yield obtained at 20 t/ha manure alone and 10 t/ha manure and 50 kg/ha N increased by about 56 and 35%, respectively (Table 3).

The results might be due to the higher tissue water content of bulbs growing optimally when nitrogen from manure and urea is sufficiently available. Consistent with this suggestion, Hassan (2015) reported that garlic yield components were affected significantly with improving growth and productivity of two garlic cultivars (*A. sativum* L.) grown under sandy soil conditions using nitrogen and bio-enriched fertilizers. Shah and Khan (2003) also credited the improved performance under the combined application of manure and urea to the immediate availability of N from urea and its delayed releases from the manure, achieving a better synchrony with crop development.

Mean fresh bulb weight

The interaction effect of manure and nitrogen showed significant difference (P<0.01) on mean fresh bulb weight (Table 4).

The result of the mean fresh bulb weight revealed that combined application of manure and nitrogen increased mean fresh bulb weight with the maximum value obtained in plots that received 50 kg/ha N plus 10 t/ha manure as well as 50 kg/ha N plus 20 t/ha manure without significant difference among them. The result also showed that nitrogen alone increased mean fresh bulb weight up to the rate of 100 kg/ha N and reduced mean fresh bulb weight by about 8% with further increment to 150 kg/ha N. In combination with manure at both levels

Table 4. Interaction effect of manure and nitrogen on mean fresh bulb weight (g).

Treatment	Mean fresh bulb weight(g)			
	Manure (t/ha)			
Nitrogen (kg/ha)	**0**	**10**	**20**	**Mean**
0	32.37^{c}	40.13^{b}	52.29^{ab}	41.6
50	46.42^{b}	55.43^{a}	55.17^{ab}	52.34
100	50.27^{ab}	45.19^{b}	45.47^{b}	46.98
150	46.54^{b}	48.46^{ab}	47.61^{b}	47.54
Mean	43.9	47.3	50.14	47.11
LSD(0.05)	7.49	-	-	-
CV (%)	9.38	-	-	-

Means with similar or no superscripts within a column are not significantly different at 0.05 probability level.

Table 5. Interaction effect of manure and nitrogen on mean clove weight (g).

Treatment	Mean clove weight (g)			
	Manure (t/ha)			
Nitrogen (kg/ha)	**0**	**10**	**20**	**Mean**
0	2.0^{c}	2.1^{c}	2.9^{b}	2.3
50	2.6^{bc}	3.7^{a}	2.5^{bc}	2.9
100	2.8^{b}	2.5^{bc}	2.7^{b}	2.7
150	2.6^{bc}	2.5^{bc}	2.6^{bc}	2.5
Mean	2.5	2.7	2.7	-
LSD (0.05)	0.5	-	-	-
CV (%)	10.82	-	-	-

Means with similar or no superscripts within a column are not significantly different at 0.05 probability level.

(10 and 20 t/ha manure), the rate of 50 kg/ha N resulted in the production of heavier bulbs with reduction in mean bulb weight with the rates of the fertilizer increased further.

It can be evidently deduced that combined application of different amounts of nitrogen and manure increased mean fresh bulb weight compared to the treatment of no combined application, the optimum combination being at 50 kg/ha N with 10 t/ha manure. This could be due to the requirement of this cultivar of garlic for nitrogen in the summation equivalent to 50 kg/ha N and the nitrogen available in 10 or 20 t/ha manure. This study is in harmony with Bewuket et al. (2017) who reported that the interaction effect of 50% RNP and 5 t/ha vermin-compost affected mean garlic bulb weight significantly. This finding is also consistent with that of Teklu et al. (2004) who stated that reducing the recommended fertilizer rate by one third did not significantly reduce yield when supplemented by 2 t/ha manure for tomato, potato and cabbage. The higher combined levels evidently led to significant reductions in mean clove weight, which could be attributed to the detrimental effect of nitrogen on bulb growth and development when supplied in excess amounts. This may stem from the occurrence that too much nitrogen leads to excessive vegetative growth at the expense of low partitioning of assimilates to bulbs. In contrast to this study, Alemu et al. (2016) documented non- significant result by combining vermicompost with nitrogen and phosphorus fertilizers.

Mean clove weight

The highest significant mean clove weight was attained at the combined application of 50 kg/ha N and 10 t/ha manure (Table 5). On the other hand, the minimum mean clove weight was recorded at the combined rates of nil manure and nitrogen, which was significantly lower than the mean clove weights, obtained at all other treatment combinations except at the combined rates of 0 kg/ha N and 10 t/ha manure. The mean clove weight obtained from plots fertilized with 50 kg/ha N plus 10 t/ha manure exceeded the mean clove weight obtained from the unfertilized plot by about 83%. The mean clove weights from plots that received nitrogen alone increased up to the rate of 100 kg/ha N and declined afterwards. In general, mean clove weights increased in response to increasing the combined rates of manure and nitrogen up

Table 6. Interaction effect of manure and nitrogen on total bulb yield (t).

Treatment	Total bulb yield (t)			
Nitrogen (kg ha^{1})	Manure (t ha^{1})			
	0	10	20	Mean
0	15.4^{f}	21.6^{cd}	24.1^{bc}	20.4
50	20.4d^{e}	27.8^{a}	19.1^{e}	22.2
100	25.3^{b}	19.8^{de}	19.8^{de}	21.6
150	21.0^{de}	23.0^{c}	21.0^{de}	21.6
Mean	20.4	22.8	21.0	-
LSD (0.05)	1.9	-	-	-
CV (%)	5.19	-	-	-

Means with similar or no superscripts within a column are not significantly different at 0.05 probability level.

to 50 kg/ha N plus 10 t/ha manure but decreased afterwards.

The initial increase in mean clove weights in response to increasing the combined rates of the two fertilizers may be ascribed to the availability of optimum nitrogen and other nutrients contained in manure that led to high mean clove weight through facilitating improved leaf growth and photosynthetic activities thereby increasing partitioning of assimilate to the storage organ. This finding is supported by work of Funda et al. (2011) who reported significant increase in onion yield components including mean clove weight with the application of optimum amounts of organic manure and mineral fertilizers. Yadav et al. (2017) in their study also documented that application of organic manure and fertilizers significantly increased the yield parameters including clove weight. The decrease in mean clove weight as the combined rates of manure and nitrogen increased further could be attributed to a possible outcome that manure releases ample nitrogen through mineralization. Consequently, this, together with the applied nitrogen, may lead to too much availability of NO_3^- or NH_4^+ for uptake by the plants. This may have led to excess vegetative growth at the expense of bulbs reducing mean clove weight through over-partitioning of dry matter to the vegetative parts.

Total bulb yield (t/ha)

Plants harvested from all plots had virtually no unmarketable bulbs; thus, all bulbs were marketable. The maximum bulb yield was recorded in plots that received 50 kg/ha N and 10 t/ha manure closely followed by the yield obtained at 100 kg/ha N alone as well as 20 t/ha manure alone (Table 6). The significantly lowest total bulb yield was recorded from plants grown in the control treatment. Compared to the bulb yields obtained from the control treatments, the increments in bulb yields obtained at 50 kg/ha N and 10 t/ha manure, 100 kg/ha N alone as well as 20 t/ha manure alone were 80, 64 and 56%, respectively. However, there was no statistical difference between the latter two treatments. When the combined rates of manure and nitrogen increased beyond 50 kg/ha N and 10 t/ha manure, bulb yield began falling significantly.

From the results, it could be observed that there were strong relationships between total bulb yield and yield related traits such as mean fresh bulb yield, mean clove weight, and harvest index which are the function of yields. Most of these parameters attained their highest magnitude at the level of 50 kg/ha N and 10 t/ha manure, above which they declined. The decline in bulb yield in response to the increased doses of manure and nitrogen above 50 kg/ha N and 10 t/ha manure may be attributed to stimulation of vigorous vegetative growth resulting in less partitioning of assimilates to the bulbs. In harmony with this study, Yadav et al. (2017) reported higher garlic yield at combined application of 50% recommended dose of NPK + 120 q/ha FYM. Similarly, Bewuket et al. (2017) also documented that 50% RNP (recommended nitrogen and phosphorus; 128: 92 kg/ha) + 5 t/ha vermicompost produced the highest total bulb yield. Gebremikael et al. (2017) on the other side stated that application of 5 t/ha vermicompost + 50% RDF (69 kg/ha N) recorded the highest marketable yield for onion. The present finding is also in line with that of Kipkosgei et al. (2003) who reported that incorporation of various rates of farmyard manure (FYM) and calcium ammonium nitrates significantly increased yields of *Solanum villosum*. Melaku (2010) on his part reported the highest total onion bulb yield was obtained with the application of 20 t/ ha manure plus 80 kg/ha N and 40 kg/ha P. In contrast, Abraha et al. (2015) reported better garlic yield by combining (130:20:21:15 kg/ha N, P, S and Zn fertilizers) compared to compost at 12,000 kg/ha alone or their combinations.

Per cent bulb dry matter

The interaction effect of manure and nitrogen showed significant difference (P<0.01) on percent bulb dry matter

Table 7. Interaction effect of manure and nitrogen on percent dry matter (%).

Treatment	Percent bulb dry matter (%)			
Nitrogen (kg/ha)	Manure (t/ha)			
	0	10	20	Mean
0	31.6[b]	27.0[b]	33.9[ab]	30.8
50	28.3[b]	25.5[b]	30.6[b]	28.1
100	28.7[b]	35.7[ab]	29.5[b]	31.3
150	40.2[a]	29.0[b]	39.0[a]	36.0
Mean	32.2	29.3	33.2	31.6
LSD(0.05)	6.5	-	-	-
CV (%)	12.08	-	-	-

Table 8. Interaction effect of manure and nitrogen on harvest index (%).

Treatment	Harvest index (%)			
Nitrogen (kg/ha)	Manure (t/ha)			
	0	10	20	Mean
0	69.4[ab]	63.1[b]	68.2[ab]	41.6
50	66.1[ab]	71.3[a]	64.2[b]	52.3
100	68.7[ab]	71.0[a]	61.2[b]	47.0
150	69.1[ab]	69.2[ab]	70.1[ab]	47.5
Mean	68.3	68.6	65.9	-
LSD (0.05)	6.1	-	-	-
CV (%)	5.32	-	-	-

Means with similar or no superscripts within a column are not significantly different at 0.05 probability level.

(Table 7). Maximum percent dry matter yields were recorded from plants grown in plots that received 150 kg/ha N without manure, 150 kg/ha N and 20 t/ha manure, and 10 t/ha manure and 100 kg/ha N. The differences between the percent bulb dry matter of plants grown in the control treatment on one hand and those grown at 150 kg/ha N without manure, 150 kg/ha N and 20 t/ha manure, and 10t/ha manure and 100 kg/ha N on the other hand, were 27 23, and 12%, respectively. Besides, there was no significant difference in percent bulb dry matter between the three combined treatments. The minimum bulb dry matter yield was recorded at the combined application of 50 kg/ha N plus 10 t/ha manure as well as the control treatment. Inconsistent results were recorded when the combined application rates of nitrogen and manure were increased further. The increment in percent dry matter due to application of 150 kg/ha N only over the combined application of 50 kg/ha N plus 10 t/ha manure amounted to 57%.

The results of the present study support the hypothesis that dry matter content is not necessarily determined by or associated with fresh yield of garlic. On the contrary, Bewuket et al. (2017) reported combined use of vermicompost and inorganic NP fertilizers increased the dry matter of crops over other plots. The results of Yadav et al. (2017) is also in conformity with the results of this study, which indicated that integration of organic manures with NPK fertilizers had significant effect on yield and physicochemical characteristics of garlic.

Harvest index

The interaction effect of manure and nitrogen showed significant difference ($P<0.05$) on harvest index (Table 8). Application of 50 kg/ha N combined with 10 t/ha manure showed maximum harvest index followed by 100 kg/ha N plus 10 t/ha manure. The minimum harvest index was recorded at the combination of 100 kg/ha N and 20 t/ha manure. Compared to the harvest index observed at the combined treatment of 100 kg/ha N along with 20 t/ha manure, the harvest index due to the application of 50 kg/ha N plus 10 t/ha manure increased by about 17%. Decreasing trends were observed as the combination of the two rates of fertilizer was increased. Moreover, statistically significant harvest indices were recorded between plots that received the combined applications of 100 kg/ha N plus 10 t/ha manure as well as plots that received the combined application of 100 kg/ha N plus 20 t /ha manure.

The finding is supported by the results of Wondimu (2009) who reported that the highest harvest index for Adama Red cultivar of onion was recorded from treatments that received N and FYM at 25 kg/ha N + 8 t/ha FYM, respectively. In contrary to this study, Alemu et al. (2016) reported that garlic harvest index was significantly affected by the interaction effects of nitrogen and phosphorus rather than their combination with the organic fertilizer. The lower harvest indices at the higher combined rates of the fertilizers could be attributed to excess vegetative growth that has a detrimental effect on partitioning of assimilates towards the bulbs. In contrary to this study, Fikru and Fikreyohannes (2018) also documented non-significant response of garlic (*A. sativum* L.) to vermicompost and mineral N fertilizer application for harvest index.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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