OPEN ACCESS

May 2018
ISSN 2006-9782
DOI: 10.5897/JHF
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

ABOUT JHF

The Journal of Horticulture and Forestry (JHF) is published monthly (one volume per year) by Academic Journals.

Journal of Horticulture and Forestry (JHF) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Arboriculture, Plant growth by hydroponic methods on straw bales, Postharvest physiology of crops, Permaculture etc.
The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JHF are peer-reviewed.

Contact Us

Editorial Office: jhf@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/JHF

Submit manuscript online http://ms.academicjournals.me/

Editors

Dr. Süleyman Korkut

Editorial Board

Journal of Horticulture and Forestry

Table of Contents: Volume 10 Number 5 May 2018

ARTICLES

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a crop of major economic importance worldwide. Potato (*Solanum tuberosum* L.) is a crop native to the central Andean area of South America, but it is now cultivated and consumed in most parts of the world, with an average consumption in 2011 of 96 g/capita/day. On a global scale, potato is the third most important food crop in the world after rice and wheat in terms of human consumption (FAO, 2014).The relatively high carbohydrate and low fat content of potato makes it an excellent energy source for human consumption (Dean, 1994).

The potato crop was introduced to Ethiopia around 1858 by Schimper, a German botanist (Pankhurst, 1964). The country has about 70% of the available agricultural land suitable for potato production (Gebremedhin et al., 2008). However, the potato sub-sector in Ethiopia is relatively undeveloped and is faced with low productivity of less than 10 t/ha (Roger, 2014).

The optimizing of plant density is one of the most important agronomic practices of potato production, because it affects seed cost, plant development, yield and quality of the crop (Bussan et al., 2007). As plant density increases, there is a marked decrease in plant size and yield per plant. This effect is due to increased inter-plant competition for water, light and nutrients (Masarirambi et al*.,* 2012). Plant density in potato affects some important plant traits such as total yield, tuber size distribution and tuber quality (Samuel et al., 2004). The blanket recommended plant spacing for all potato varieties in Ethiopia is 75 cm by 30 cm between rows and plants, respectively (MoA, 2014) but there are still many farmers who grow potatoes frequently in the area giving less regard to optimal plant population density for production of ware and seed potatoes. Moreover, tubers are often planted by smallholder farmers at narrower and erratic spacing resulting in non-optimum plant population densities that may result in low and erratic yields. The possibility of securing high yields depends on the optimum number of plants per unit area (Endale and Gebremedhin, 2001). Plant spacing should depend on type of variety, fertility status of soil, plant architecture or growth habit etc. (Girma and Niguisse, 2015). Potato varieties also differ on growth habit and other attributes. Therefore, using the same spacing for all varieties may not lead to optimum tuber yields (Lung'aho et al., 2007).

Farmers in eastern Ethiopia use much closer spacing without making any distinction between the purposes of ware potato production and seed potato production. Therefore, potato seed tuber spacing in eastern Ethiopia does not account for varietal differences as well as whether the potato production is meant for ware or seed tubers. Therefore, the current study was conducted with the objective of determining the optimum plant population density for potato varieties in relation to growth and yield.

MATERIALS AND METHODS

Description of experimental sites

The study was conducted under rain-fed conditions during the 2013 main cropping season at Haramaya and Hirna districts, in eastern and western Hararghe zones of the Oromia Regional State in Ethiopia, respectively.

Weather condition of the experimental sites

During the crop growing season, Haramaya exhibited 1171.2 mm annual rainfall and the mean maximum and the mean minimum temperatures were 24.51 and 10.20°C, respectively. However, Hirna showed 1093.5 mm annual rainfall and mean maximum and mean minimum temperatures was 26.88 and 11.91°C, respectively (Figure 1).

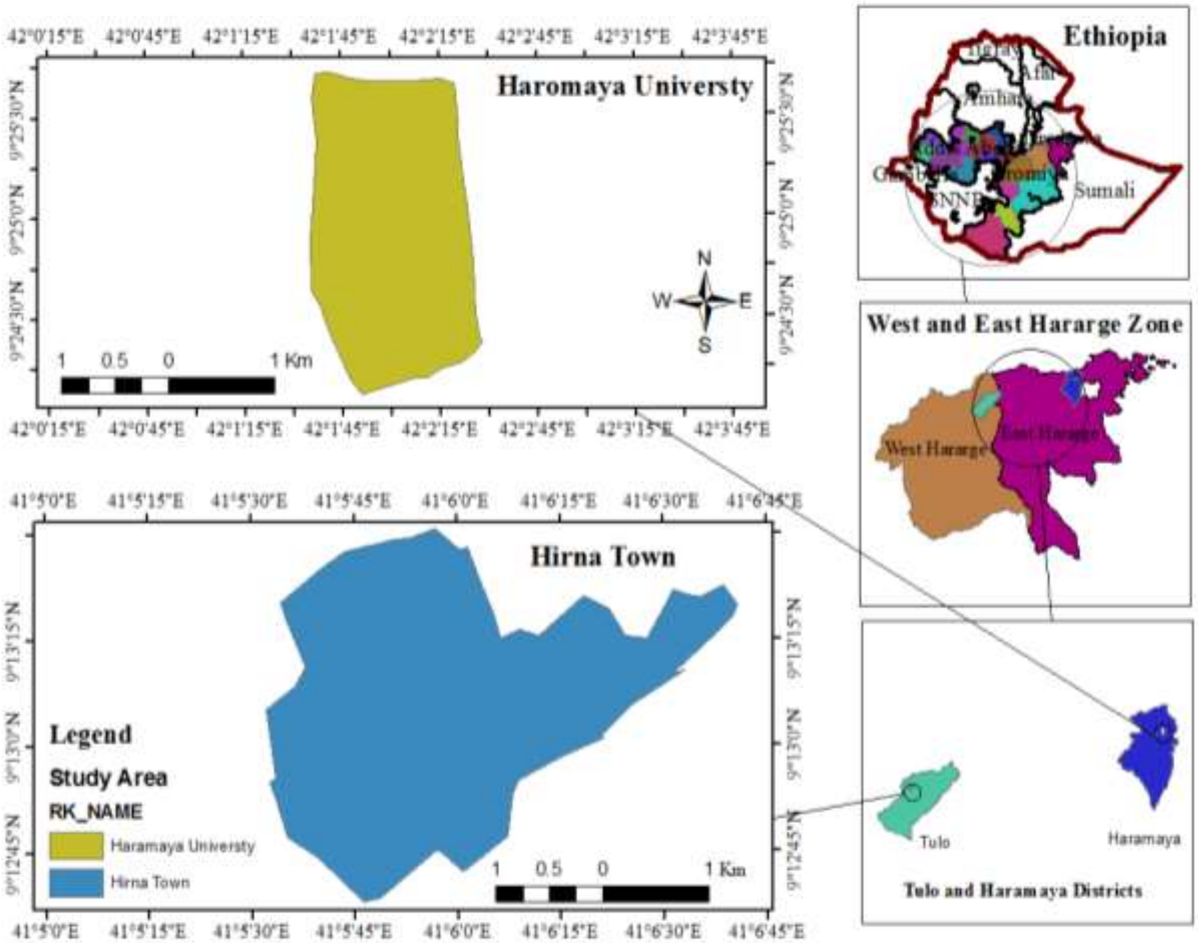

Figure 1. Geographical location of the study sites.

Description of experimental materials

The experiment was conducted with four improved potato varieties (Bubu, Badhasa, Zemen and Chiro) which are widely cultivated in eastern Ethiopia (Table 1). Well sprouted medium seed tubers sized materials were prepared for planting.

Table 1. Description of the potato varieties used for the experiment.

S/N	Variety	Year of release	Growth habit	Plant height (cm)	Area of adaptation	
					Altitude (metres above sea level)	Rainfall (mm)
2	Badhasa	2001	Erect	50-55	1700-2000	700-800
3	Zemen	2001	Erect	55-60	1700-2000	700-800
4	Chiro	1998	Semi-erect	60	1600-2000	700-800

Source: MoARD (2012).

Treatments and experimental design

The experiment consisted of four improved potato varieties (Bubu, Badhasa, Zemen and Chiro) and five seed tuber spacing between rows (ridges) and between plants (75 cm x 30 cm, 60 cm x 30 cm, 60 cm x 25 cm, 50 cm x 25 cm and 45 cm x 20 cm). The treatments were laid out as a randomized complete block design (RCBD) in a factorial arrangement and replicated three times per treatment. Gross plot size was 3.6 m x 4.0 m (14.4 m^2). The spacing between adjacent plots was 1.0 m and the spacing between adjacent blocks was 1.5 m.

Management of the experiment

The experimental fields were cultivated to a depth of 25-30 cm and then levelled after which ridges were made by hand. Well-sprouted medium sized seed tubers were planted according to the specified treatments. Cultivation, weeding and harvesting were done at the appropriate time. Untifengicidal chemical (Mancozeb 80% WP) was applied on 15 days interval at the rate of 1.5 kg ha^{-1} diluted at the rate of 40 g per 20 L to control late blight disease.

Phosphorus fertilizer was applied at the rate of 92 kg P_2O_5 ha^{-1} by banding the granules of DAP (diammonium phosphate) (18% N, 46% P_2O_5) at the depth of 10 cm below and around the seed tuber at planting. The blanket N recommendation is 111 kg N ha^{-1} (Anonymous, 2004). Thus, Urea (46% N) was applied only at the rate of 75 kg N ha^{-1} two times, that is, 1/2 at mid-stage (at about 45 days after planting), and 1/2 at the start of flowering.

Harvesting was done at physiological maturity when the leaves of the potato plants senesced. Two weeks before harvesting, the haulms of the potato plants were mowed using a sickle to toughen the periderm and avoid bruising during harvesting; harvesting was done by hand using hoes.

Data collection and measurements

Phenological and growth parameters

Days to maturity: was recorded when 50% of the plants in each plot became ready for harvest as indicated by the senescence of the haulms. The days were counted from emergence to maturity of the crop.

Plant height: was measured by taking five plants per plot as the distance in cm from the soil surface to the top most growth point of aboveground at physiological maturity.

Leaf area index: of the plants were estimated from individual leaf length using the following formula developed by Firman and Allen (1989).

$$\text{Log 10 (leaf area in cm}^2) = 2.06 \times \text{log10 (leaf length in cm)} - 0.458$$

Yield components

Average tuber number per hill: was recorded as the actual number of tubers to be collected from a matured plant at harvest.

Average tuber mass per hill (g/tuber): was obtained by dividing total weight of tubers per plant by the number of tubers.

Number of marketable and unmarketable tubers: was counted based on their size category, that is, tubers greater than or equal to 25 g, free from diseases, insect pests and other forms of damage considered marketable and tubers having less than 25 g, and with diseases, insect pests, and other forms of damage considered as unmarketable tubers.

Yield parameters

Marketable yield: All the marketable tubers which were free from diseases, insect pests and other damages as well as those greater than or equal to 25 g in weight were recorded and calculated per ha.

Non-marketable tuber yield: Unmarketable tubers included diseased, deformed tubers as well as tubers weighing less than 25 g were recorded and calculated per ha.

Total tuber yield: was recorded as the sum of marketable and unmarketable tuber yields.

Data analysis

The data were subjected to analysis of variance (ANOVA) using the General Linear Model of the SAS statistical package (SAS, 2007) version 9.1. All significant pairs of treatment means were compared using Tulkey Test at 5% level of significance. T-test was conducted to determine differences between the two locations in the performance of the potato varieties to plant spacing. F-test for homogeneity of variances showed significant differences for the parameters, thus separate analysis was done for the locations except for unmarketable tuber number.

RESULTS AND DISCUSSION

Phenological and growth parameters

Days to 50% maturity

The interaction effect of variety and plant spacing significantly affected days to 50% maturity at both Haramaya ($P < 0.01$) and Hirna ($P < 0.05$) (Table 2).

Table 2. Days to 50% maturity of potato varieties as influenced by the interaction effect of variety and seed tuber spacing at Haramaya and Hirna during the 2013 cropping season.

Variety (A)	Days to 50% maturity		
	Spacing (B)	**Haramaya**	**Hirna**
	75 cm × 30 cm	98.33^{ab}	94.67^{a}
	60 cm × 30 cm	$95.00^{a\text{-}f}$	93.67^{ab}
Bubu	60 cm × 25 cm	$92.33^{c\text{-}h}$	91.33^{abc}
	50 cm × 25cm	98.67^{a}	90.67^{bcd}
	45 cm × 20 cm	87.33^{h}	89.33^{cde}
	75 cm × 30 cm	$96.33^{a\text{-}d}$	89.33^{cde}
	60 cm × 30 cm	97.00^{abc}	89.33^{cde}
Badhasa	60 cm × 25 cm	$93.00^{b\text{-}g}$	88.67^{cde}
	50 cm × 25 cm	$91.00^{d\text{-}h}$	88.00^{cde}
	45 cm × 20 cm	$90.67^{e\text{-}h}$	86.33^{e}
	75 cm × 30 cm	$94.33^{a\text{-}g}$	90.00^{cd}
	60 cm × 30 cm	$91.67^{c\text{-}h}$	88.33^{cde}
Zemen	60 cm × 25 cm	$94.33^{a\text{-}g}$	90.00^{cd}
	50 cm × 25 cm	$93.33^{a\text{-}g}$	89.67^{cde}
	45 cm × 20 cm	$92.33^{c\text{-}h}$	87.33^{de}
	75 cm × 30 cm	$95.67^{a\text{-}e}$	88.33^{cde}
	60 cm × 30 cm	$93.00^{b\text{-}g}$	90.33^{bcd}
Chiro	60 cm × 25cm	$91.33^{d\text{-}h}$	89.67^{cde}
	50 cm × 25 cm	89.33^{gh}	89.67^{cde}
	45 cm × 20 cm	89.67^{fgh}	87.67^{de}
LSD (AXB) (0.05)		2.885	1.932
F-test		**	*
CV%		1.9	1.3

Means followed by the same letter within a column for the interaction effect of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. * = significant at 5% probability level. LSD = Least significant difference; CV = Coefficient of variation.

At Haramaya the maximum days to 50% maturity was recorded at the interaction of variety bubu with 50 cm x 25cm spacing. At Hirna the maximum number of days for 50% maturity was recorded at the interaction of variety Bubu with 75 cm × 30 cm spacing. At both locations, decreasing plant spacing hastened the time required to reach 50% maturity by the plants although the data are inconsistent. Thus, the maximum number of days for 50% maturity was required mostly by plants grown at the wider spacing of 75 cm x 30 cm and 60 cm x 30 cm whereas the minimum number was required by plants grown at the narrower spacing of 50 cm x 25 cm and 45 cm x 20 cm. Plants grown at the spacing of 60 cm x 25 cm somewhat fell in the intermediate range in terms of the time required to reach 50% maturity at both locations (Table 2). This trend of hastened maturity in response to narrowing seed tuber spacing and prolonged maturity in response to widening it is attributable to competition for growth factors, which becomes stiffer in the former case but lesser in the latter case. The results of this study are consistent with the reports of Beukema and Vander Zaag (1990) who stated that a high planting density stimulates early tuber growth and maturity in potatoes.

Plant height

Plant height responded significantly ($P < 0.01$) to the main effects of variety and plant spacing at both locations (Table 4). However, variety and spacing did not interact to influence plant height at both locations (Table 8).

Variety Bubu showed the tallest plant length (62.09 and 68.83 cm) and Badhasa gave the smallest length (40.91 and 52.67 cm) at both locations, respectively (Table 4). The difference in plant height due to variety may be attributed to genetic differences. This suggestion is consistent with that of Elfnesh et al. (2011) who found varietal difference across locations in plant height of the varieties Badhasa, Zemen and Chala at Haramaya, Kulubi and Langey in the eastern highlands of Ethiopia.

Increasing seed tuber spacing significantly increased plant height. Thus, at both locations plant heights remained high at the spacing of 75 cm x 30 cm, 60 cm x 30 cm, and 60 cm x 25 cm. However, decreasing seed tuber spacing further to 50 cm x 25 cm and 45 cm x 20 cm significantly reduced plant height. There was no significant difference between 50 cm x 25 cm and 45 cm x 20 cm for plant height at both locations (Table 4). At Haramaya and Hirna, the maximum plant height (55.18 and 68.32 cm, respectively) was recorded at relatively widest spacing 75 cm x 30 cm whereas the minimum (46.53 and 54.98 cm, respectively) was recorded at the narrowest spacing 45 cm x 20 cm. The increased plant height at wider spacing might be due to availability of more growth resources under wider spacing for better plant growth per hill than the closer spacing.

Leaf area index

At both Haramaya and Hirna, the main effects of variety and plant spacing significantly ($P < 0.01$) influenced leaf area index of potato (Table 3). However, a non-significant difference was observed due to the interaction effect of variety and plant spacing on this parameter at both locations. However, the interaction of variety and spacing did not influence leaf area index at both location (Table 8).

Table 3. Plant height and leaf area index of potato as influenced by the main effects of variety and seed tuber spacing at Haramaya and Hirna during the 2013 main cropping season.

Variety	Plant height (cm)		Leaf area index	
	Haramaya	Hirna	Haramaya	Hirna
Bubu	62.09[a]	68.83[a]	2.868[a]	3.178[a]
Badhasa	40.91[c]	52.67[c]	2.162[b]	2.953[a]
Zemen	50.82[b]	62.83[ab]	1.798[b]	2.613[ab]
Chiro	48.40[b]	59.20[bc]	1.773[b]	2.167[b]
LSD (0.05)	4.185	5.458	0.4084	0.4694
Spacing				
75 cm × 30 cm	55.18[a]	68.32[a]	1.303[b]	1.776[c]
60 cm × 30 cm	54.02[ab]	65.33[a]	1.668[b]	2.222[c]
60 cm × 25 cm	49.04[abc]	60.17[ab]	2.344[a]	2.487[bc]
50 cm × 25 cm	47.98[bc]	55.60[b]	2.476[a]	3.065[b]
45 cm × 20 cm	46.53[c]	54.98[b]	2.961[a]	4.087[a]
LSD (0.05)	4.679	6.102	0.4566	0.5248
F-test	**	**	**	**
CV%	11.2	12.1	25.7	23.3

Means followed by the same letter within a column for the main effects of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. LSD = Least significant difference; CV (%) = Coefficient of variation.

Table 4. Average tuber number and average tuber mass of potato as influenced by the main effects of variety and seed tuber spacing at Haramaya and Hirna (2013 main cropping season).

Parameter	Average tuber number (hill)		Average tuber mass (g)	
Variety	**Haramaya**	**Hirna**	**Haramaya**	**Hirna**
Bubu	11.61[ab]	12.43[ab]	53.56[a]	61.26[a]
Badhasa	13.01[a]	13.59[a]	37.35[b]	40.83[c]
Zemen	10.23[b]	12.16[ab]	42.63[b]	47.86[bc]
Chiro	10.81[b]	11.42[b]	49.70[a]	51.31[b]
LSD (0.05)	1.331	1.511	4.686	5.487
F-test	**	*	**	**
Spacing				
75 cm x 30 cm	9.53[b]	10.65[b]	53.99[a]	60.43[a]
60 cm x 30 cm	11.56[ab]	11.17[b]	51.13[a]	57.64[a]
60 cm x 25 cm	10.95[ab]	12.37[ab]	50.14[a]	56.00[a]
50 cm x 25 cm	12.15[a]	13.62[a]	37.79[b]	39.21[b]
45 cm x 20 cm	12.90[a]	14.20[a]	36.00[b]	38.28[b]
LSD (0.05)	1.488	1.689	5.239	6.135
F-test	**	**	**	**
CV%	15.8	16.5	13.8	14.8

Means followed by the same letter within a column for the main effects of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. * = significant at 5% probability level. LSD = Least significant difference; CV (%) = Coefficient of variation.

The cultivars significantly differed in leaf area index. At Haramaya, the leaf area index of Bubu (2.87) significantly exceeded that of all other cultivars while that of Badhasa, Zemen and Chiro cultivars were in statistical parity with each other. However, at Hirna, the leaf area index of Bubu (3.18) significantly exceeded the leaf area index of only Chiro (2.17), being in statistical parity with the leaf area indices of the other two varieties (Table 3).

Reducing seed tuber spacing (increasing population density) significantly increased the leaf area index of the crop. At Hirna, the narrowest plant seed tuber spacing of 45 cm × 20 cm resulted in the highest leaf area index (4.087) whereas the wider seed tuber spacing of 75 cm × 30 cm and 60 cm x 30 cm resulted in the lowest leaf area index (1.776 and 2.222, respectively). The spacing of 60cm × 25 cm and 50 cm × 25 cm resulted in intermediate leaf area index values (2.487 and 3.065, respectively). However, at Haramaya, plant seed tuber spacing of 45 cm x 20 cm, 50 cm × 25 cm and 60 cm × 25 cm resulted in the highest leaf area index (2.961, 2.476 and 2.344, respectively) whereas the wider seed tuber spacing of 75 cm × 30 cm and 60 cm × 30 cm resulted in the lowest leaf area index (1.303 and 1.668, respectively) (Table 3). The optimum leaf area index for high yield of potato ranges between 3.0 to 6.0 (Marschner, 1991). Accordingly, in terms of varietal response, it was only the Bubu variety that attained a leaf area index value falling in the optimum range. However, a leaf area index value falling in this range was not attained until narrowing the seed tuber spacing to 45 cm x 20 cm at Haramaya, and 50 cm x 25 cm and 45 cm x 20 cm at Hirna (Table 3). This indicates that the narrower spacing resulted in better canopy coverage for more photo-assimilation to take place through light interception, and may result in better tuber yields of the cultivars.

Yield components

Average tuber number per hill

At both locations, the main effects of variety and spacing significantly ($P < 0.01$) affected average tuber numbers per hill. The mean average tuber number per hill of the two locations revealed that the main effects of both spacing and variety significantly ($P < 0.01$) influenced average tuber number per hill. However, the interaction effect of spacing and variety did not affect this parameter at both locations (Table 8).

At both locations Badhasa produced maximum number of tubers per hill closely followed by Bubu while the lowest number of tubers per hill was produced for Chiro. At Haramaya, a non-significant difference was observed between Zemen and Chiro varieties. At Hirna, Bubu, Badhasa and Zemen varieties were in statistical parity.

Average tuber number per hill responded differently to plant spacing at both locations. Narrowing seed tuber spacing led to the production of significantly higher numbers of tubers per hill. At Haramaya, the highest number of tubers per hill was obtained at the narrowest spacing of 50 cm x 25 cm (12 tubers) and 45 cm x 20 cm (13 tubers) whereas the lowest was obtained at the spacing of 75 cm × 30 cm (9.5 tubers). However, significant differences in average tuber number per hill at Haramaya were observed between plants grown at the spacing of 75 cm × 30 cm one hand and those grown at the spacing of 50 cm × 25 cm and 45 cm × 20 cm on the other hand, with production of significantly higher number of tubers produced at the later spacing. Similarly, at Hirna, the highest number of tubers per hill was produced at the spacing of 50 cm × 25 cm (13.6 tubers) and 45 cm × 20 cm (14 tubers) whereas the lowest were produced at the spacing of 75 cm × 30 cm (10.65 tubers) and 60 cm × 30 cm (11.17 tubers). The tuber numbers produced in response to spacing the plant at 60 cm × 25 cm was in the intermediate range (12.4 tubers).

The increase in the tuber number produced per hill in response to narrowing the seed tuber spacing is due to a stiffer competition among tubers for growth factors, which restricts expansion in size and increases tuber number. Beukema and Vander Zaag (1990) suggested that high plant densities should be used to produce relatively large number of seed size tubers. Similarly, Allen and Wurr (1992) also found that the total number of tubers increased with seed size and reduction of spacing.

Average tuber weight

The main effects of variety and plant spacing significantly ($P < 0.01$) affected average tuber mass of potato at both locations (Table 4). However, variety and spacing did not interact to influence this parameter at both locations (Table 8). At Haramaya, Bubu and Chiro had significantly heavier tubers (53.56 g and 49.7 g, respectively) than the other two varieties. However, at Hirna, Bubu had significantly heavier tubers (61.26 g) than all other three varieties (Table 4).

Increasing seed tuber spacing significantly increased average tuber weight at both locations. Thus, the heaviest tubers were produced at the wider spacing of 75 cm × 30 cm, 60 cm × 30 cm and 60 cm × 25 cm whereas the lightest tubers were produced at the narrower spacing of 45 cm × 20 cm and 50 cm × 25 cm (Table 4). The increase in average tuber weight in response to widening plant spacing may be attributed to less stiffer competition among tubers for growth factors. This suggestion is in agreement also with that of Rex et al. (1987) who postulated that a reduction in the average size of tubers because of increased inter-plant competition with closer spacing.

Marketable tuber number

The main effects of variety and plant spacing significantly (P < 0.01) influenced marketable tuber number at both Haramaya and Hirna (Table 5). However, the interaction effect of variety and spacing did not influence this parameter at both locations (Table 8).

Table 5. Marketable, unmarketable and total tuber number per m^2 of potato as influenced by the main effects of variety and seed tuber spacing at Haramaya and Hirna during the 2013 main cropping season.

Parameter	Marketable tuber number (m^2)		Unmarketable tuber number (m^2)		Mean	Total tuber number (m^2)	
Variety	**Haramaya**	**Hirna**	**Haramaya**	**Hirna**		**Haramaya**	**Hirna**
Bubu	51.12[a]	56.98[a]	25.40[d]	27.27[d]	26.34[d]	76.53[a]	84.26[a]
Badhasa	39.27[b]	46.43[b]	38.07[b]	36.79[b]	37.43[b]	77.34[a]	83.22[a]
Zemen	21.45[d]	33.58[c]	42.56[a]	39.31[a]	40.93[a]	64.00[b]	72.89[b]
Chiro	30.99[c]	32.56[c]	31.00[c]	30.46[c]	30.73[c]	61.99[b]	63.02[c]
LSD (0.05)	2.142	2.46	1.347	1.395	0.983	2.782	2.756
Spacing							
75 cm × 30 cm	44.99[b]	48.83[b]	9.15[e]	6.67[e]	7.91[e]	54.14[d]	55.50[d]
60 cm × 30 cm	52.73[a]	52.07[b]	12.25[d]	10.22[d]	11.23[d]	64.99[c]	62.28[c]
60 cm × 25 cm	47.90[b]	57.73[a]	22.50[c]	24.67[c]	23.59[c]	70.4[b]	82.40[b]
50 cm × 25 cm	18.36[c]	31.84[c]	53.74[b]	53.05[b]	53.40[b]	72.10[b]	84.88[b]
45 cm × 20 cm	14.56[d]	21.48[d]	73.63[a]	72.68[a]	73.16[a]	88.19[a]	94.16[a]
LSD (0.05)	1.916	2.751	1.505	1.56	1.099	3.11	3.082
F-test	**	**	**	**	**	**	**
CV%	7.3	7.9	5.3	5.6	3.9	5.4	4.9

Means followed by the same letter within a column for the main effects of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. *= significant at 5% probability level. NS = non-significant. LSD = Least significant difference; CV (%) = Coefficient of variation.

Cultivar Bubu produced a significantly higher numbers of marketable tubers at both Haramaya (51.12) and Hirna (56.98). However, Zemen produced the lowest numbers of marketable tubers (21.45) at Haramaya while Zemen and Chiro produced the lowest number of marketable tubers (33.58 and 32.56, respectively) at Hirna (Table 5). For the main effect of spacing, at Haramaya, significantly highest numbers of marketable tubers was recorded at the spacing of 60 cm × 30 cm (52.73 tubers) whereas at Hirna, significantly highest numbers of marketable tubers (57.73) was recorded at the spacing of 60 cm × 25 cm. The highest numbers of marketable tubers was resulted from the spacing of 60 cm × 30 cm (52.73) at Haramaya, and 60 cm × 20 cm (57.73) at Hirna (Table 5). This might be due to reduced competition among tubers for resources and space at wider seed tuber spacing for better tuber enlargement lead to the production of more number of marketable tubers. Corroborating the findings of this study, Frezgi (2007) reported the higher marketable tuber number at wider seed tuber spacing.

Unmarketable tuber number

The main effects of variety and plant spacing significantly (P < 0.01) influenced the numbers of unmarketable tubers at Haramaya and Hirna (Table 5). However, variety and spacing did not interact to influence this parameter at both locations (Table 8).

At both locations, Zemen had significantly highest numbers of unmarketable tubers than the other varieties while Bubu had the lowest number of unmarketable tubers. At Haramaya, Zemen had 37.3 and 67.6% more unmarketable tuber numbers than Chiro and Bubu, respectively. However, at Hirna, Zemen exceeded Chiro and Bubu for unmarketable tuber number by about 29.1 and 44.2%, respectively. For the other main effect of spacing, 45 cm x 20 cm spacing resulted in a significantly higher number of unmarketable tubers over the other spacing while the spacing of 75 cm × 30 cm led to the production of the lowest number of unmarketable tubers (Table 5). At Haramaya, the narrowest spacing of 45 cm × 20 cm led to the production of 37, 227.24, 501.1 and 705% more numbers of unmarketable tubers over the spacing of 50 cm × 25 cm, 60 cm × 25 cm, 60 cm × 30 cm, and 75 cm × 30 cm, respectively. However, at Hirna, the narrowest spacing of 45 cm × 20 cm exceeded the spacing of 50 cm × 25 cm, 60 cm × 25 cm, 60 cm × 30 cm, and 75 cm × 30 cm spacing by about 37, 194.6, 611.2 and 989.7% more unmarketable tuber numbers, respectively.

Unmarketable tuber numbers increased with decreased plant spacing. This could be attributed to stiffer competitions for growth factors which might have led to the production of under-sized tubers, which are unmarketable. Consistent with the results of this study, Frezgi (2007) also indicated that closer see tuber spacing resulted in a significantly higher yield of small-sized tubers as the consequence of higher competition between plants. Similarly, Tesfa (2012) reported that the narrower spacing of 50 cm x 25 cm and 60 cm x 25 cm resulted in the production of large numbers of under-sized unmarketable tubers compared to the wider spacing of 80 cm x 30 cm and 75 cm x 30 cm.

Total tuber number

At both locations, the main effects of variety and plant spacing had significantly ($P < 0.01$) influenced total tuber numbers (Table 5). However, variety and spacing did not interact to influence this parameter at both locations (Table 8).

At both locations, Bubu and Badhasa produced the highest total tuber numbers. Zemen and Chiro had produced the lowest total tuber numbers (64 and 61.99) at Haramaya whereas Chiro produced the lowest total tuber number (63.02) at Hirna (Table 5). Decreasing spacing significantly increased total tuber number per unit area. Thus, the narrowest spacing of 45 cm × 20 cm resulted in a significantly higher total tuber number than the wider spacing of 75 cm × 30 cm, which produced the lowest total tuber number at both locations. The trend was similar between all the spacing at both locations. Decreasing spacing from 75 cm × 30 cm to 45 cm × 20 cm significantly increased total tuber number per unit area by about 62.89% at Haramaya. Similarly, reducing seed spacing from 75 cm x 30 cm to 45 cm x 20 cm significantly increased total tuber number per unit area by about 69.66% at Hirna.

In general, decreasing the seed tuber spacing led to a significant increase in the number of total tubers produced. This could be attributed to the production of lager numbers of tubers per unit area at the narrower spacing than at wider spacing, owing to stiffer competition among tubers for resources, which would limit their expansion in size. The results of this study are in agreement with the findings of other authors (Beukema and Van der Zaag, 1990), who reported that high planting densities should be used to produce relatively large numbers of seed-sized tubers.

The highest numbers of marketable tubers per unit area of land were obtained from the spacing of 60 cm x 30 cm (52.4 tubers) and 60 cm × 25 cm (52.81 tubers), indicating that the two seed tuber spacing produced the largest number of tubers fit to be used as seed.

Marketable, total, and unmarketable tuber yields

The main effects of variety and plant spacing significantly ($P < 0.01$) affected marketable and total tuber yields at both locations (Table 6). Variety and spacing interacted significantly ($P < 0.01$) to influence unmarketable tuber yield at both locations (Table 7). However, the interaction effect of variety and plant spacing did not affect marketable and total tuber yields at both locations (Table 8).

Table 6. Marketable and total tuber yields of potato as influenced by the main effects of variety and seed tuber spacing at Haramaya and Hirna during the 2013 main cropping season.

Parameter	Marketable tuber yield (ton/ha)		Total tuber yield (ton/ha)	
Variety	**Haramaya**	**Hirna**	**Haramaya**	**Hirna**
Bubu	29.91[a]	30.01[a]	37.84[a]	42.96[a]
Badhasa	23.27[b]	21.86[bc]	32.82[b]	37.71[a]
Zemen	16.20[c]	18.34[c]	24.33[d]	31.61[b]
Chiro	18.14[c]	24.90[ab]	27.83[c]	37.49[ab]
LSD (0.05)	1.796	4.626	2.176	4.583
Spacing				
75 cm x 30 cm	24.03[a]	26.29[a]	25.00[b]	29.95[c]
60 cm x 30 cm	24.70[a]	27.99[a]	28.38[b]	33.50[bc]
60 cm x 25 cm	22.68[ab]	24.52[ab]	32.11[a]	40.20[ab]
50 cm x 25 cm	20.11[bc]	21.56[ab]	33.75[a]	41.48[a]
45 cm x 20 cm	17.88[c]	18.53[b]	34.29[a]	42.07[a]
LSD (0.05)	2.008	5.172	2.433	5.124
F-test	**	**	**	**
CV%	11.1	26.3	9.6	16.6

Means followed by the same letter within a column for the main effects of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. LSD = Least significant difference; CV % = Coefficient of variation.

Table 7. Unmarketable tuber yield (ton/ha) of potato as influenced by interaction effect of variety and seed tuber spacing at Haramaya and Hirna during the 2013 main cropping season.

Parameter		Unmarketable tuber yield (ton/ha)	
Variety	**Spacing**	**Haramaya**	**Hirna**
	75 cm × 30 cm	0.500^{hi}	3.49^{h}
	60 cm × 30 cm	3.143^{ghi}	4.62^{gh}
Bubu	60 cm × 25 cm	9.504^{f}	14.54^{f}
	50 cm × 25 cm	12.086^{def}	18.41^{de}
	45 cm × 20 cm	14.412^{bcd}	23.66^{b}
	75 cm × 30 cm	2.502^{ghi}	4.35^{gh}
	60 cm × 30 cm	4.681^{g}	6.87^{g}
Badhasa	60 cm × 25 cm	9.940^{ef}	18.19^{de}
	50 cm × 25 cm	13.516^{cd}	22.79^{bc}
	45 cm × 20 cm	17.137^{ab}	27.04^{a}
	75 cm × 30 cm	0.031^{i}	3.35^{h}
	60 cm × 30 cm	3.695^{gh}	5.95^{gh}
Zemen	60 cm × 25 cm	9.152^{f}	14.73^{f}
	50 cm × 25 cm	13.130^{cde}	19.80^{cd}
	45 cm × 20 cm	14.674^{bcd}	22.48^{bc}
	75 cm × 30 cm	0.849^{hi}	3.43^{h}
	60 cm × 30 cm	3.217^{ghi}	4.57^{gh}
Chiro	60 cm × 25 cm	9.120^{f}	15.28^{ef}
	50 cm × 25 cm	15.851^{bc}	18.69^{d}
	45 cm × 20 cm	19.397^{a}	21.01^{bcd}
LSD (0.05)		1.844	1.775
F-test		**	*
CV%		12.6	7.9

Means followed by the same letter within a column for the interaction effect of variety and plant spacing are not significantly different at 5% level of significance. ** = significant at 1% probability level. * = significant at 5% probability level. LSD = Least significant difference; CV% = Coefficient of variation.

Table 8. Mean squares from analysis of variance (ANOVA) for potato parameters at Haramaya and Hirna.

Location	Variables	Replication	Variety (V)	Spacing (S)	V x S	Error
	Degrees of freedom	**2**	**3**	**4**	**12**	**38**
Haramaya	Maturity days (50%)	23.117	17**	60.558**	18.792**	3.046
	Plant height	30.34	1153.76**	175.62**	19.26^{ns}	32.05
	Leaf area index	0.1368	3.9045**	5.2544**	0.388^{ns}	0.3053
	Tuber number/hill	33.467	17.384**	8.57**	4.651^{ns}	3.448
	Tuber mass (g/tuber)	278.77	783.98**	823.47**	63.07^{ns}	40.18
	Marketable tuber number	36.661	2380.138**	3818.775**	9.94^{ns}	6.72
	Total tuber number	62.88	983.39**	1836.67**	8.12^{ns}	14.16
	Marketable tuber yield	3.648	563.762**	97.006**	10.866^{ns}	5.904
	Unmarketable tuber yield	1.115	12.763**	507.564**	4.17**	1.245
	Total tuber yield	7.658	521.553**	186.133**	8.426^{ns}	8.664
Hirna	Maturity days (50%)	0.717	37.75**	16.442**	3.486*	1.366
	Plant height	188.52	686.06**	415.03**	26.67^{ns}	54.52
	Leaf area index	1.5887	2.9059**	9.5465**	0.439^{ns}	0.4033
	Tuber number/hill	5.642	12.214*	27.915**	5.613^{ns}	4.179
	Tuber weight (g/tuber)	57.38	1084.04**	1369.32**	52.21^{ns}	55.1
	Marketable tuber number	3.91	2017.24**	2756.6**	11.97^{ns}	11.08
	Total tuber number	22.45	1491.66**	3173.98**	13.15^{ns}	13.9
	Marketable tuber yield	66.22	366.5**	171.43**	34.03^{ns}	39.17
	Unmarketable tuber yield	0.135	32.947**	923.018**	2.975*	1.153
	Total tuber yield	65.21	322.76**	351.31**	35.94ns	38.44

At both locations, Bubu produced the maximum marketable and total tuber yields whereas Zemen produced the minimum. However, Bubu did not differ significantly from Badhasa and Chiro for total tuber yield at Hirna. Higher marketable tuber yields were obtained at Haramaya in response to planting the seed tubers at the spacing of 60 cm x 30 cm (24.7 ton ha^{-1}), 60 cm x 25 cm (22.68 ton ha^{-1}) and 75 cm x 30 cm (24.03 ton ha^{-1}) (Table 6). At Hirna, higher marketable tuber yields were obtained at all spacing except for 45 cm x 20cm (18.53 ton ha^{-1}). However, the spacing of 45 cm x 20 cm, 50 cm x 25 cm and 60 cm x 25 cm produced high total tuber yield at both locations (Table 6). The increased yield at higher densities may be due to ground coverage with green leaves earlier in the season for photosynthesis to take place efficiently. In this case, maximum light is intercepted and used for photo assimilation; fewer lateral branches are formed and tuber growth starts earlier. Consistent with these results, increased plant population increased yield due to more tubers being harvested per unit area of land (Beukema and Vander Zaag, 1990). This result shows that narrower spacing may be required for high yield of potato tuber than the commonly used spacing practiced by the research system of the country now, which is 75 cm x 30 cm. The result of this study agrees with the findings of various authors such as Wurr (1974b) who reported narrow plant spacing led to the production of a higher total tuber yield than wider spacing. Similarly, Nelson (1967) found that a higher plant population density resulted in slightly higher total yields and a greater number of small tubers.

At both locations, the varieties responded differently to spacing treatments for unmarketable tuber yields. Thus, all the varieties produced the highest unmarketable tuber yield at narrow spacing. At Haramaya, the highest unmarketable tuber yield was obtained from Chiro (19.39 ton ha^{-1}) and Badhasa (17.14 ton ha^{-1}) at the narrowest spacing of 45 cm x 20 cm. The next highest yields were obtained from Bubu (14.41 ton ha^{-1}) and Zemen (14.67 ton ha^{-1}) at narrow spacing of 45 cm x 20 cm. The least unmarketable yield was obtained from all varieties at wider spacing of 75 cm x 30 cm (Table 7). Similarly, at Hirna, a significantly highest unmarketable yield (27.04 ton ha^{-1}) was obtained from Badhasa at the narrowest spacing of 45 cm x 20 cm. The least unmarketable yields were obtained for Bubu, Zemen and Chiro at the wider spacing of 75 cm x 30 cm and 60 cm x 30 cm (Table 7). This could be due to stiffer competition at closer spacing for nutrients, moisture and light which promotes the production of more numbers of undersize tubers, which are unmarketable. Frezgi (2007) reported that closest spacing resulted in significantly higher yield of small tubers as the consequence of higher competition between plants. Similarly, Tesfa (2012) also reported that high unmarketable tuber yield was observed at high planting density while a wider spacing of 80 cm x 30 cm and 75 cm x 30 cm resulted in a lower unmarketable tuber yield.

Conclusion

The results of this study have revealed that the spacing of 75 cm x 30 cm, 60 cm x 30 cm, and 60 cm x 25 cm were producing higher marketable tuber yields than the other spacing, and are appropriate for ware potato production. However, the intermediate seed tuber spacing of 60 cm x 30 cm and 60 cm x 25 cm seem appropriate for seed tuber production. Denser spacing of 45 cm x 20 cm, 50 cm x 25 cm and 60 cm x 25 cm produced the highest total tuber yields and consequently higher total starch per hectare. Bubu was superior to other cultivars for all agronomic parameters including tuber yield.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Vol. 10(5), pp. 63-68, May 2018
DOI: 10.5897/JHF2018.0534
Article Number: B103C0757275
ISSN: 2006-9782

http://www.academicjournals.org/JHF

ACADEMIC JOURNALS
expand your knowledge

Journal of Horticulture and Forestry

Full Length Research Paper

On-farm demonstration and evaluation of improved lowland sorghum technologies in Daro Lebu and Boke districts of West Hararghe Zone, Oromia National Regional State, Ethiopia

Mideksa Babu*, Fekede Gemechu and Asfaw Zewdu

Oromia Agricultural Research Institute, Mechara Agricultural Research Center, P. O. Box 19, Mechara, Ethiopia.

Received 11 October, 2017; Accepted 21 December, 2017

This experiment was conducted in Daro Lebu and Boke districts of West Harerghe Zone with the objectives of evaluating lowland sorghum varieties on farmer's field and creating linkage and networking among stakeholders. Three kebeles were selected purposively based on sorghum production potential, two kebeles from Daro Lebu and one kebele from Boke district. Five farmers and one Farmer Training Center participated depending on their interest to the technology, managing the experiment, having appropriate land for the experiment and taking the risk at the time of failures. Two improved varieties namely Ethiopian Sorghum Hybrid-1 and Chare with local checks were demonstrated and evaluated. The experiment was demonstrated on 100 m^2 demonstration plots, and DAP 100 kg/ha-with Urea (50 kg at the time of sowing and at growing stage) were applied to one demonstration plot with a seed rate of 10 kg/ha. Both quantitative and qualitative data were collected through observation, group discussion on field day and data recording sheet. Descriptive statistics, gross margin analysis and independent t-test were used to analyze collected data. Results indicated that Ethiopian Sorghum Hybrid-1 was ranked first in terms of yield, drought tolerant, biomass, early maturity, and seed colour and disease resistance. Independent t-test revealed that mean comparison of Ethiopian Sorghum Hybrid-1 and Chare along with local check were statically significant at 5% significant level on mean yield performance and had more economic advantage than local variety at the study area. Therefore, Ethiopian Sorghum Hybrid-1 and Chare varieties are recommended for further popularization and scaling up in study area and similar agro ecology.

Key words: Sorghum demonstration, evaluation, early maturity, marginal analysis, varieties.

INTRODUCTION

Sorghum is an important cereal crop used by humans as staple food grain in many semi-arid and tropical areas of the world (Belay, 2017). It is the 5th most important cereal crop in the world (FAOSTAT, 2013), the 3rd important cereal (after rice and wheat) in India and the 2nd major crop (after maize) across all agro ecologies in Africa. In West Africa, especially in Burkina Faso, Sorghum is the staple crop and produced in low-input cropping systems. Sorghum is a major food and nutritional security crop to more than 100 million people in Eastern horn of Africa, owing to its resilience to drought and other production constrains (Gudu et al., 2013).

The lives of millions of poor Ethiopians is depend on production of sorghum. It has tremendous uses for the Ethiopian farmer and no part of this plant is ignored. Besides being a major source of staple food, it serves as an important source of feed and fodder for animals. Sorghum exhibits a wide geographic and climatic adaptation. It also requires less water than most cereals; hence it offers great potential for supplementing food and feed resources. Sorghum grows in a wide range of agro-ecologies most importantly in the moisture stressed parts where other crops can least survive and food insecurity is rampant (Tekle and Zemach, 2014).

In Ethiopia, total land of Sorghum production under peasant holdings covers about 456,171.54/ha (CSA, 2017). The main sorghum producing regions are Oromia and Amhara, accounting for nearly 80% of the total production. The leading sorghum producing zones are East and West Hararge in Oromiya and North Gondar and North Shoa in Amhara. Two regions, Southern Nations, Nationalities, and Peoples' Region (SNNPR) and Tigray are relatively less important, contributing 11 and 4% of the national production, respectively. Ethiopia is the second largest producer of sorghum, after the Sudan (Demeke et al., 2013).

In moisture stress area the grain-filling stage was the most important constraint, followed by insect pests, particularly stalk borer. Although drought is largely unpredictable, the farmers dealt with frequent drought events by either growing a diverse set of traditional cultivars from different maturity types, shifting from late-maturing to early-maturing cultivars, or replacing sorghum with tef or chickpea (Beyene et al., 2016).

Sorghum is adapted to a wide range of environments, it is largely produced in the highlands, medium and lowland regions. Even though sorghum is dominantly grown in the zone, most smallholders' farmers use landrace variety of sorghum which results in low yield, susceptible to disease and take long period of time to harvest. Crop production in the study area totally depends on rainfall availability which is highly sensitive to climate change (Fekede et al., 2016). Based on practical problem of shortage of improved variety of sorghum and shortage of rain fall in the zone especially in low land areas, Mechara Agricultural Research Center have been conducting adaptation trail of improved lowland sorghum variety to select well adapted variety to agro-ecology of the area in previous cropping season. Therefore, this activity was initiated with objectives to demonstrate and evaluate improved low land sorghum technologies and create linkage among researcher, farmers, extension agents and other stakeholders.

METHODOLOGY

Description of the study area

Daro Lebu is one of the districts found under West Hararghe Zone. The capital town of the district Mechara is found at about 434 km South East of Addis Ababa. The district is situated between 7°52'10" and 8°42'30" N and 4°023'57" and 41°9'14" E at 08°35'589" North and 40°19'114" East (Abduselam, 2011). The district is characterized mostly by flat and undulating land features with altitude ranging from 1350 to 2450 m.a.s.l. Ambient temperature of the district ranges from 14 to 26°C, with average of 16°C and average annual rainfall of 963 mm/year. The pattern of rain fall is bimodal and its distribution is mostly uneven. Generally, there are two rainy seasons: the short rainy season '*Belg*' lasts from mid-February to April whereas the long rainy season '*kiremt*' is from June to September. The rainfall is erratic; onset is unpredictable, its distribution and amount are also quite irregular (Asfaw et al., 2016). Consequently, most *kebeles* frequently face shortage of rain; hence moisture stress is one of major production constraints in the district (DLWADO, 2015).

Boke is one of districts of West Hararghe zone known for coffee production. It is located at 391 km East of Addis Ababa and about 69 km south of Chiro, capital town of the zone. The district receives an average annual rainfall of 850 mm and average temperature is 20°C. It shares borders with Chiro district in the west and north, Oda Bultum district in the south and Mesala district in the East (Fekede et al., 2016). The district is found within 1300 to 2400 m above sea level (BDAO, 2013) (Figure 1).

Farmers and site selection

The activity was conducted for one year in Daro Lebu and Boke districts of West Harerghe zone (2013). Gadulo and Gudis *kebeles* from Daro Lebu (2015) as well as Dololo *kebele* from Boke district were purposively selected based on their sorghum production potential. Five farmers and one Farmer Training Center (FTC) were selected based on their interest to the technology, model farmers, managing the experiment and have appropriate land for the experiment (Table 1).

Experiment design

Two improved sorghum variety namely ESH-1 and Chare were demonstrated and evaluated with local variety. The experiment was demonstrated on 100 m^2 demonstration plots, and DAP 100 kg/ha and Urea (50 kg/ha at the time of sowing and growing stage) were applied with the seed rate of 10 kg/ha. Drilling sowing methods were applied in the row with fertilizer. The required management like weeding, thinning out and urea application at the growing stage were done by the farmers.

Data collection methods

Both quantitative and qualitative data were collected from farmers

*Corresponding author. E-mail: mideksababu9@gmail.com.

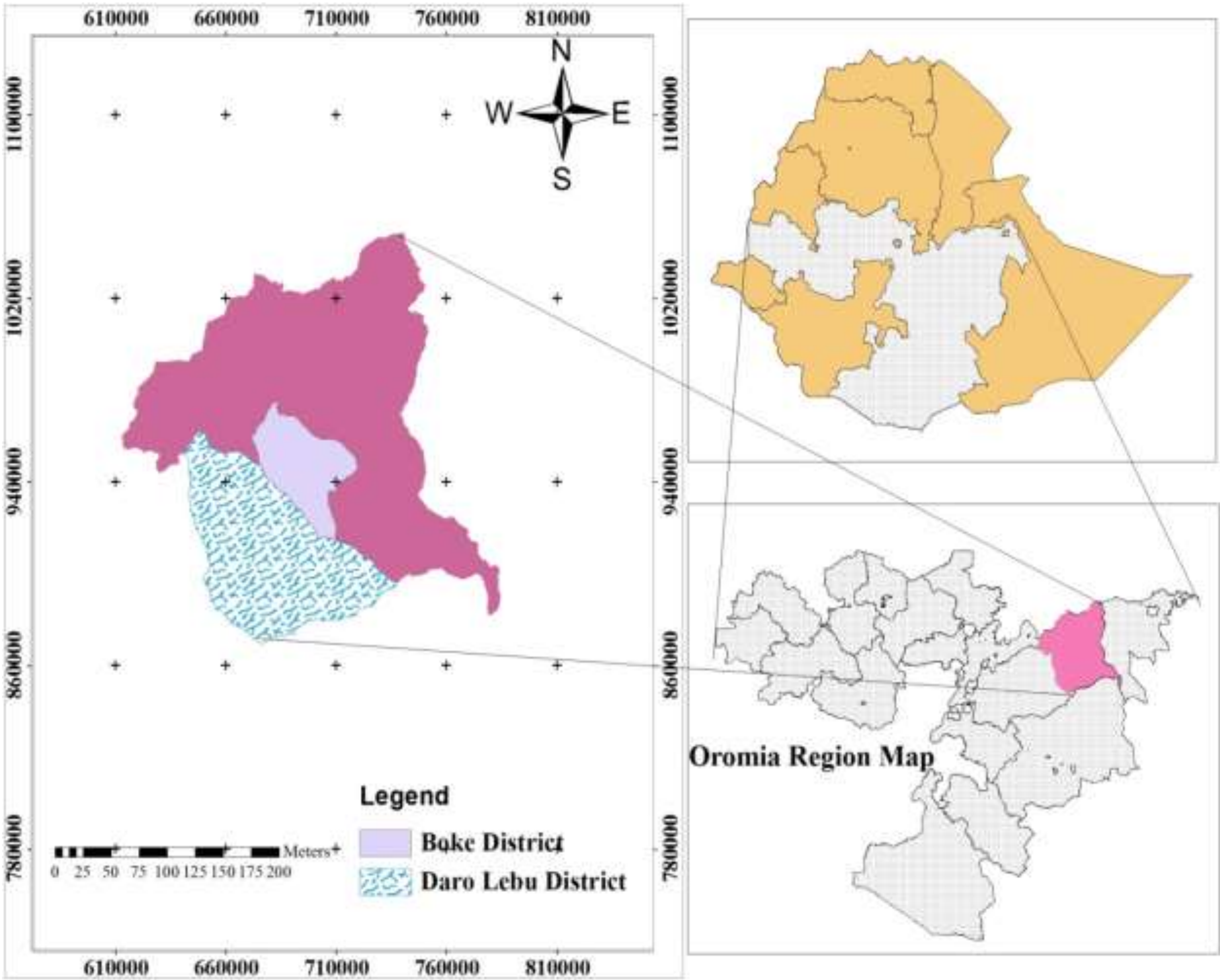

Figure 1. Map of study areas.
Source: Own design (2017).

Table 1. Experiment location, farmers participated and area covered in study area.

Districts Name	*Kebeles*	No. of trail farmers	Area covered (m^2)
Daro Lebu	Gadulo	2	600
	Gudis	3	900
Boke	Dololo	1	300
Total		6	1800

Source: Own results (2017).

(qualitative data were collected on field day by group discussion on the performance of crop and quantitative data like yield of crop were collected on the from the participated farmers land) through observation group discussion on field day and data recording sheet.Data like farmer preference on disease and pest's resistance, early maturity, drought tolerance, grain color, biomass, and yield data were collected through the prepared data collection sheet/record sheet by organizing field day and observation on farmer's field.

Tools of data analysis

Descriptive statistics, gross margin analysis and independent t-test were used to analyze quantitative data. Farmer's preference was collected and analyzed by using simple ranking method in accordance with the given value (De Boef and Thijssen, 2007). The formula of ranking method used was specified as:

$$\text{Rank}=\Sigma^{N}/n \quad (1)$$

Table 2. Yield summary and mean comparison of sorghum varieties on farmer's field.

Varieties	Yield harvested in Qt/ha(N=6)							
	Min	Max	Mean	Std. deviation	t-value	Sig. (2-tailed)	yield difference from local	% yield increase over local check
ESH-1	0.30	43.30	20.9	15.13	7.426**	0.018	11.48	121.9
Chare	0.12	33.20	16.3	14.08	6.704**	0.022	6.88	73
Local	0.00	32.10	9.42	14.04			-	-

** indicates significant at 5% significant level
Source: Own results, 2017.

Where N is value given by group of farmers for each variety based on the selection criteria and n is number of selection criteria used by farmers.

Descriptive statistics

Descriptive statistics (mean of yield) were used to analyse the crop performance to evaluate yield gained from the experiment harvested from demonstration plot.

Gross margin analysis

Gross margin analysis is very useful and in a situation where fixed capital forms a negligible portion of production. It is the difference between gross income and the total variable costs (Mohammed et al., 2015). According to Ayinde et al. (2016), gross margin is expressed as:

$$GM = TR - TVC \quad (2)$$

Where GM = gross margin, TR = total revenue, TVC = total variable cost

Average rate of returns (ARR) was also obtained. This was done by dividing total gross margin (GM) by the total cost of production per hectare.

RESULTS AND DISCUSSION

Crop performance on the farmer's field

The mean yield of ESH-1 and Chare were 20.9 and 16.3 Qt, with standard deviation of 15.13 and 14.08, respectively. Mean yield and standard deviation of the local variety were 9.42 and 14.04 in terms of Qt/ha (Table 2). The mean yield of local variety was less than both improved (ESH-1 and Chare) varieties due to intolerant behavior to drought. The result of independent statistical test indicated that there was statistical difference between the yields of improved ESH-1 and Chare varieties demonstrated on farmer's field at 5% significant level. But from the results of adaptation trial done on ESH-1 and Chare varieties at Mechara Agricultural Research Center, ESH -1 recorded mean yield of 38.67 and Chare recorded mean yield of 29.22 (Kinde et al., 2016). The difference in yield was observed due to presence of extreme drought in the study area in the last year.

The result of the findings depicts that the demonstrated and evaluated improved varieties have high grain yield (ESH-1 43.3 Qt/ha and Chare 33.20 Qt/ha) whereas local has grain yield of 32.10 Qt/ha. Yield increases in percentage of improved variety of ESH-1 and Chare over local check were 121.9 and 73%, respectively. Yield difference pertining to poor tolerance of local variety to drought variety is already debated. It may be concluded here that adaptation of improved variety were more productive than local variety with the same area and management.

Capacity building and experiment evaluation

Training was given for awareness creation at Daro Lebu district (Gadulo and Gudis *kebeles*) before implementing the activity. Thus, eight farmers (seven male and one female) and three development agents (1 female and 2 male) participated in the training session from Daro Lebu district (Gudis and Gadulo *kebeles*). Field day was organized at two *kebeles* of Daro Lebu district to create awareness for participants. Accordingly, thirty-eight (38) male and ten (10) female households participated in mini field day organized at Daro Lebu district (Gudis and Gadulo *kebeles*) (Figure 2). Experts and DA's were also partaken with farmers for evaluation of the experiment. For variety selection on field, researcher divided farmers into three groups with combination of development agents and experts (subject matter specialists). The group of farmers and development agents led by subject matter specialists (SMS) were put in their own criteria to evaluate the technology by observing on field. Each group gave its own value to the experiment on each demonstration plot. As discussed in Table 3, the values given by each group of farmers were summarized and the average value ranked by participants.

From the result revealed as tabulated in Table 3, farmers, development agents and experts selected ESH-1 and Chare variety as 1st and 2nd with all average values given by farmers.

Figure 2. Group discussion on mini field day at Gudis *kebele*.

Table 3. Participants preference of the variety selection on field day.

Varieties	Selection Criteria's (Score out of five)									
	HS	SC	Bms	EM	DsR	DrR	SG	PH	TS	Rank
ESH-1	4.6	4.8	3	3.6	4	4.4	3	3	30.4	1
Chare	3.8	3.6	2.8	4.2	4	4	3.2	3.6	29.2	2
Local	2.25	1.6	4.2	2	3	1.4	4.75	3.6	22.8	3

Note: 5=Excellent, 4=very good, 3=good, 2=Fair, 1=Poor
When HS=Head Size, SC=Sead Color, Bms=Biomass, EM=Early Maturity, DsR=Disease Resistance, DrR=Drought Resistance, SG=Stay Green, PH= Plant height and TS=Total score
Source: Own results (2016).

Table 4. Gross margin of sorghum demonstration per *kebeles*

Variety	Yield (Qt/ha)	market price of output Qt/Birr	Fertilizer cost in ETB	Seed cost in ETB	Labor cost in ETB	TVC	TR(P*Q)	GM (profit)	Return to investment
ESH-1	20.9	1000	5450	900	7500	13850	20,900	7,050	0.51
Chare	16.3	1000	5450	900	7500	13850	16,300	2,450	0.18
Local	9.42	1000	5450	600	7500	13550	9,420	-4,130	-0.3

Source: Own result (2017).

Cost-benefit analysis result

The result shows that highest profit and returns were gained from ESH-1 and Chare varieties. ESH-1 variety gave a profit of 7,050 Birr/ha (seven thousand and fifty birr) and highest returns to investment of 51%. From Chare variety 2,450 birr/ha profit and 18% returns to investment were gained. Negative profit was recorded from local variety (Table 4) due to low yield gained from local variety in condition of drought prevalence in the study area. Thus, the findings summarized that using improved seed were economically profitable than local variety at study area.

CONCLUSION AND RECOMMENDATIONS

Generally, from the demonstrated variety, ESH-1 and

Chare variety were selected as first and with all average values given by farmers. From the result of the study there was yield advantage of ESH-1 over Chare variety and local check. Study unveiled huge yield difference between improved varieties and local check due to difference in drought resistivity between improved and local variety. There was also statistical difference between the yield of improved (ESH-1) and Chare varieties at 5% significance level. From the result of study ESH-1 and Chare have more economic profit than local variety.

Therefore, ESH-1 is recommended for further scaling up in study area and similar agro ecology. It is required to popularize through clustering, and farmer to farmer linkage is required to disseminate this technology widely in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors would like to express profound gratitude to Oromia Agricultural Research Institute (OARI) and Mechara Agricultural Research Center (McARC) for financial support and facilitating this work. We thank the Socio Economic Research team of Mechara Agricultural Research Center namely Birhanu Angasu and Jima Degaga for their good team sprit towards working with us and also development agents for facilitation of the work from beginning to the accomplishment of the research.

REFERENCES

Abduselam M (2011). Diversification of Livelihood Activities as a Strategy to Promote Household Food Security: A Case Study of Daro Lebu Woreda of West Hararghe, Oromia Regional State, Ethiopia. MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia. P 24.

Asfaw Z, Fekede G, Mideksa B, Abdi E, Kemal K (2016). On Farm Demonstration and Evaluation of Improved Dessert Type Banana Varieties in Daro Lebu District of West Hararghe Zone, Oromia National Regional State, Ethiopia. Journal of Biology, Agriculture and Healthcare, 6:90.

Ayinde OE, Abdoulaye T, Takim FO, Oloyede AO, Bankole FA (2016).Economic Analysis of On-Farm Trial of Drought Tolerant Maize in Kwara State Nigeria: A Gender Approach. Trakia Journal of Sciences, 3:290.

Belay G (2017). Determining the Physicochemical Compositions of Recently Improved and Released Sorghum Varieties of Ethiopia. Special Issue: Staple Food Fortification in Developing Countries. Journal of Food and Nutrition Sciences, 5:1-5.

Beyene AA, Hussein AS, Pangirayi T, Fentahun M, Mark DL, Dawit GA (2016). Sorghum production systems and constraints, and coping strategies under drought-prone agro-ecologies of Ethiopia. South African Journal of Plant and Soil, 33:3.

Boke District Agricultural Office (BDAO) (2013).Agriculture Office Annual Report, 2013. Unpublished.

Central Statistical Agency (CSA) (2017).The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey. Report on Land Utilization. Statistical Bulletine Addis Abeba, Ethiopia. P 4.

Daro Lebu District Agricultural Office (DLWADO) (2015). Agriculture Office Annual Report, 2015. Unpublished.

De Boef WS, Thijssen MH (2007). Participatory tools working with crops, varieties and seeds. A guide for professionals applying participatory approaches in agro biodiversity management, crop improvement and seed sector development, Wageningen. Wageningen International, 83p.

Demeke M, Di Marcantonio F (2013). Analysis of incentives and disincentives for sorghum in Ethiopia. Technical notes series, MAFAP, FAO, and Rome. P.3.

FAOSTAT (2013). Database of agricultural production. Rome: Food and Agriculture Organization of the United Nations. P 186.

Fekede G, Kinde L, Tadesse M, Birmaduma G, Shimalis D, Asfaw Z (2016). Effect of Climate Change on Agricultural Production and Community Response in Daro Lebu & Mieso District, West Hararghe Zone, Oromia Region National State, Ethiopia. P 31.

Gudu S, Ouma EO, Onkware AO, Too EJ, Were BA, Ochuodho JO, Othieno CO, Okalebo JR, Agalo J, Maina SM (2013). Preliminary Participatory On-farm Sorghum Variety Selection for Tolerance to drought, Soil Acidity and Striga in Western Kenya. Maina Moi University, Kenya First Bio-Innovate Regional Scientific Conference United Nations Conference Centre (UNCC-ECA) Addis Ababa, Ethiopia. DOI: 10.11648/j.jps.20130101.11.

Kinde L, Gebeyehu C, Abubeker T, Dadi G, Shanene H, Abdela U (2016). Evaluation of Sorghum (*Sorghum bicolor* (L.) Moench) Varietiesand Environments for Yield Performance and Stability. Journal of Biology Agriculture and Healthcare, 6(21):13.

Mohammed AB, Wudil AH, Daneji MI, Jibrin JM, Hussaini MA, Mohammed IB (2015). Economics of On-Farm Sorghum – Legume Strip Cropping System in Kano State, Nigeria. Journal of Agricultural Sustainability, 7(10):103.

Tekle Y, Zemach S (2014). Evaluation of Sorghum (*Sorghum bicolor* (L.) Moench) Varieties, for Yield and Yield Components at Kako, Southern Ethiopia. Journal of Plant Sciences, 2(4):129.

Vol. 10(5), pp. 69-78, May 2018
DOI: 10.5897/JHF2018.0535
Article Number: 23C266C57278
ISSN: 2006-9782

http://www.academicjournals.org/JHF

ACADEMIC JOURNALS
expand your knowledge

Journal of Horticulture and Forestry

Full Length Research Paper

Evaluation of selected botanical aqueous extracts against cabbage aphid (*Brevicoryne brassicae* L. (Hemiptera: Aphididae) on cabbage (*Brassicae oleraceae* L.) under field condition in Kobo District, North Wollo, Ethiopia

Desale Getahun Nahusenay* and Getnet Atenafu Abate

Department of Biology, College of Natural and Computational Sciences, Debre Markos University, Ethiopia.

Received 27 March, 2018; Accepted 30 April, 2018

Cabbage is one of the most important vegetable crops under cultivation throughout the world, especially in Africa including Ethiopia. Cabbage aphid is a sap sucking insect pest that damage cabbage. Growers use synthetic chemicals to control cabbage aphids. The aim of this study was to evaluate the efficacy of *Azadirachta indicae, Otostegia integrifolia* and *Crinum ornatum* aqueous extract against cabbage aphids. The field experiment was carried out at Kobo agricultural research sub-center from December 2016 to April 2017. The experiment was conducted in a Randomized Complete Block Design (RCBD) with 21 treatments along with standard check and untreated control and three replications. Four applications of extracts were applied at the rate of 2.5,5 and 7.5% solely and in combinations. The study revealed that effects of botanicals on aphid mortality, infestation level, area of cabbage leaves, damage of leaves, cabbage head formation, estimation of the yield and economic values. All botanical treatments were toxic against cabbage aphids. Among botanicals, neem and crinum at 7.5% concentration provided maximum cabbage yields that were comparable with dimethoate 40% E.C. Further studies should be conducted on effectiveness of these botanicals in different seasons.

Key words: Cabbage aphid, plants aqueous extract, efficacy.

INTRODUCTION

Cabbage (*Brassicae oleracea* var. capitata Linnaeus) is a versatile vegetable crop that belongs to the Brassicaceae family (Richardson, 2016). It is widely grown vegetables throughout the world. It also remains as a very vital crop for farmers and gardeners that enabling small scale farmer financially viable mainly in Africa and Asia. Therefore, it is also one of the major Ethiopian economically important vegetables, which have recently

*Corresponding author. E-mail: ygetahun42@gmail.com. Tel: +125 910 91 97 46.

emerged as export item (Emana et al., 2015).

Cabbage is one of the most popular food crops and grows well in many parts of the country (Embaby and Lotfy, 2015). It is grown for domestic uses as well as, for the market as one source of business (Munthali and Tshegofatso, 2014). It is also important vegetable that reduces human health problems and used to make cabbage based conventional medicines: Heart disease, stroke, alleviate rheumatism and skin problems (Rokayya et al., 2013).

Leskovar (2014) stated that cabbage production during the fall and winter season mainly depends on supplemental irrigation. In the present study area, small scale farmers continuously use irrigation for cabbage and other crop cultivations. Wubie et al. (2014) reported that one of the constraints for the production and use of cabbage is cabbage aphids which damages cabbage from seedling to final growth (head formation) stage.

Cabbage aphid (*Brevicoryne brassicae* L.) is insect pest, which belongs to the family Aphididae of the order Hemiptera, grouped under serious plant sap sucking pest's worldwide (Wubie et al., 2014). They exist in large numbers underside of the leaves and growing region of infested vegetables (Munthali and Tshegofatso, 2014). They also appear as grayish-white to powdery blue due to waxy covering (honeydew), but naturally, they are grayish green in color (Bodaiah et al., 2016). They can reduce cabbage yields and its quality for the marketable value and nutritional contents (Wubie et al., 2014). They are occupied and cause severe plant infestation that gives the reduction of plant growth, number of side branches and the oil content (Embaby and Lotfy, 2015).

Application of synthetic chemicals for, plant protection plays an important role in addition to other agronomic managements for the maximum crop production (Iqbal et al., 2011). Therefore, small-scale farmers are continuously using chemical insecticides to control aphids and associated with many undesirable and sometimes lethal consequences (Phoofolo et al., 2013). The continued dependence and use of insecticides over the years increased problems, such as: resistance, residues in the harvested product, toxicity to farmers due to improper use and loss of beneficial insects and loss of money (Abdulkadir, 1992). Those problems are associated with pesticide accumulation in animal tissues and plant materials.

Knowing such information's on the effect of synthetic chemicals and pest damage, it can encourage a person who works a research and investigates for safer alternative control methods (botanicals) that can reduce synthetic chemical related problems (Abdulkadir, 1992). With having the above points in view, the current study was done to find out alternative methods for the control of cabbage aphid and other related problems.

Botanical pesticides are an important group of naturally occurring, often slow-acting crop protectants that are usually safer to humans and the environment than synthetic pesticides, and with minimal residual effects (Devi et al., 2016). Most of botanical products either solution or powder form are accepted to be less toxic to non-target organisms, easily degradable, highly effective and do not accumulate in the environment as dissimilar to synthetic chemicals which often end up being pollutants (Mwine et al., 2013).

Farmers have some skill and practice for the preparation and use of botanical pesticides against cabbage aphids. Due to high costs of synthetic pesticides, concern over environmental pollution associated with continuous use the persistence chemicals there is a rehabilitated interest in the use of botanicals for crop protection (Mwine et al., 2013). Botanical are easily prepared and sustainable controlling methods on cabbage aphids from local plants. In addition, this mechanism helps to reduce pest infestation and conventional insecticide related problems. By having all the above points in view, this study was carried out to evaluate the efficacy of *Azadirachta indicae* (A.Juss), *Crinum ornatum* (Ait) and *Otostegia integrifolia* (Benth) plant material aqueous extracts solely and in different mixture and concentration on cabbage aphids' population under field condition.

MATERIALS AND METHODS

This study was carried out in Sirinka Agricultural Research Center (SARC) Kobo sub-center in Kobo District, North Wollo Zone, Amhara region, Ethiopia during winter season from December 2016 to April 2017. Latitude of 11° 54' 04", 12° 20' 56" N and longitude of 39° 25' 56" and 39° 49' 04" E with 1400 to 3100 m above sea level. The average annual rainfall was between 500 and 800 mm and annual temperature was 19.48 to 26.06°C (Magna Magazine, 2015). The experimental field has a clay loam type of soil.

Experimental plants were selected on the bases of their traditional practices and insecticidal properties, abundance and familiarity. However, Neem and Tinjut leaves were collected around Kobo district. Crinum bulb was collected from Abuhoy Mountain in Gidan district (Table 1).

The cabbage nursery bed was prepared on an area of 9 m^2 during the first week of December/2016 and seeds were sown through line spacing at 0.5 inch depth. The seedlings with 6 to 7 true leaves were transplanted during the first week of January 2017. The recommended agronomic practices were followed.

The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and 23 treatments including the control groups and standard check. The experiment contained 3 blocks and 69 plots, each with area of 2 m^2. The space between blocks and plots was 1 and 0.5, m respectively. Each plot had 2 rows and 14 cabbage seedlings. Rows and seedlings were distant by 0.5 and 0.3 m, respectively.

The plant parts (leaves or bulb) were washed with tap water and dried in shade with sufficient air supply for 2 weeks (Sarwar, 2015). The dried materials were cut and grinded into very fine powder by using electrical grinder. Thirty percent stock solution was prepared for each plant material separately (Hailemichael and Raja, 2012). The extraction was made by 3 kg of powder mixed with 7 L of hot water for each sample plant separately. The mixtures were stirred thoroughly with a repeated agitation at 3 h interval for 24 h. After a day, the solution was filtered with the help of fine cotton cloth and thin wire mush and 10 litters of 30% stock solutions were made.

Table 1. Description of tested plants**.**

S/N	Local/common name	Scientific name	Family name	Part used
1	Neem	*Azadirachta indicae* (A.Juss),	Meliaceae	Leaves
2	Tinjut	*Otostegia integrifolia* (Benth)	Lamiaceae	Leaves
3	Crinum	*Crinum ornatum* (Ait)	Amaryllidaceae	Bulbs

The solution was kept in refrigerator until sprayed.

Cabbage aphids were properly appeared two weeks after seedling transplantation on both lower and upper surface of the leaf. Identification of cabbage aphids was done based on the world's aphid identification guide *(*Blackman and Eastog, 2000). The plant aqueous extract stock solutions were diluted and treated at a rate of 1 L per plot using a hand sprayer. Four superiors were done at weekly interval during morning hours.

Data collection was done 2 weeks after transplantation of the seedlings up to harvest from mid January to April, 2017. Five plants were selected randomly in each plot and four leaves per plant were marked. The total numbers of cabbage aphids were counted with the help of a hand lens a day before each treatment application. Mean number of cabbage aphids per plant (efficacy of treatments) were calculated (Shiberu and Mulugeta, 2016).

$$\text{Efficacy (\%)} = \frac{\text{Sci}-\text{Scf}}{\text{Sci}} * 100$$

Where: Sc_i = initial score and Sc_f = final score.

The numbers of infested plants were counted and recorded before each treatment application interval and expressed as percentage (Baidoo and Adam, 2012):

$$\text{\% infestation} = \frac{\text{Number of infested plants in the plot}}{\text{Total number of plants in plot}} * 100$$

Area of the leaf was measured by using a grid square paper (0.25 mm^2) at the mid cabbage growing stages (Mwine et al., 2013) and three leaves (large, medium and small) per plant were selected from 5 marked plants in each plot purposively. Damaged leaves were selected with purposive sampling methods and damaged levels of cabbage leaves were calculated by subtracting the measured or windowed area of the leaves from the whole area of leaf. The process was done a week after the last treatment application. The mean percentages of damaged leaves were calculated as a proportion of the damaged area to total surface area of the leaf covered by the plant per plot using the following formula:

$$\text{\% of damaged leaf} = \frac{total\ damaged\ area}{total\ surface\ area} \times 100$$

Cabbages with and without head in all experimental plots were identified and counted a day before harvesting. The total mean number of cabbages with and without head in each treatment, including control group were calculated. The total yields of both marketable and unmarketable cabbage head were measured by using an electronic sensitive beam balance to get mean weight in kilogram per hectare. The total yield was multiplied with current market price to calculate gross benefit with net benefit was calculated by subtracting total cost.

The data were subjected to one-way analysis of variance (ANOVA) using SAS (version 9.00) statistical software and means separation was calculated by using DMRT (Duncan's multiple range tests) test (P < 0.05). All tables drown using the Excel software 2007.

RESULT S

The roles of selected botanicals on aphid infestation were found significantly different among treatments (P<0.05) (Table 2). After the first treatment application (T_1), infestations were reduced in all treated plots, while increased in untreated plots (52.38±4.76 to 59.52±10.38). In the second treatment application (T_2), the maximum reduction was observed in Crinum 7.5% next to dimethoate (0.03%). Likewise second application, infestation increased in untreated plots by 24%. After the 3th treatment application (T_3), mean percentage of infestation levels were lowered by 45.5% in plots treated with neem 7.5% and after the last treatment application (T_4), infestation was remarkably decreased in all treated plots and the best one was neem + crinum with higher concentration (7.5%). On the contrary, infestation was reached its peak in untreated plots. Infestation was highly reduced in mixture (neem + crinum) at maximum concentration (7.5%) with increasing applications.

Across treatment application period, significant differences (P< 0.05) on the number of cabbage aphids per plot were observed (Table 3). The numbers of cabbage aphids were reduced in all treatments in each application interval, while increased in untreated plots. The highest reduction rate of cabbage aphids were recorded in plots treated with neem and crinum + neem with higher concentration (7.5%). Whereas the least numbers of reduction were recorded in plots treated with tinjut in lower concentration (2.5%). Generally, mean number of cabbage aphids were reduced in all treatments across treatment application interval. Likewise, in untreated plots mean number of cabbage aphids were extremely increased across treatment applications.

The extents of leaf damages caused by cabbage aphids were shown a significant difference (P <0.05) among treatments and control group (0 to 71.84%) (Table 4). Leaf damage was significantly lower in plots treated with botanicals than untreated plots. No damage was observed in plots treated with neem +crinum at 7.5%. But it reached its peak level in untreated plot (>71.84%) (Plate 1).

There was a significant different (P<0.05%) among treatments and control groups in affecting cabbage leaf area (Table 4). Cabbages with larger leaf area were recorded in plots treated with crinum next to neem + crinum at higher concentration (7.5%). However, the smallest leaf area was in untreated plot (control group) of

Table 2. Mean percentage of cabbage head infestations per plot by cabbage aphids.

Treatment	Con.%	BT±SE	T1±SE	T2±SE	T3±SE	T4±SE
	2.5	59.52±12.6^{abc}	42.86±7.14^{cd}	35.71±4.12^{bcde}	28.57±4.12^{bcdef}	21.43±4.12^{bcde}
Neem	5	71.43±7.14^{abc}	52.38± 6.3^{abcd}	38.1±4.76^{bcde}	28.57±4.12^{bcdef}	21.43±4.12^{bcde}
	7.5	69.05±4.76^{abc}	42.86±4.12^{cd}	26.19±6.3^{de}	14.29±4.12^{f}	9.52±2.38^{efg}
	2.5	78.57±4.12^{b}	59.52±2.38^{abc}	54.76±4.76^{b}	35.71±4.12^{bcd}	28.57±4.12^{bc}
Crinum	5	76.19±8.58^{abc}	61.91±2.38^{ab}	40.48±6.3^{bcde}	30.95±6.3^{bcde}	23.81±6.3^{bcd}
	7.5	59.52±11.9^{abc}	40.48±2.38^{d}	23.81±6.3^{e}	19.05±4.76^{ef}	11.91±4.76^{defg}
	2.5	71.43±8.25^{abc}	61.91±2.38^{ab}	45.24±2.38^{bcd}	40.48±2.38^{b}	30.95±4.76^{b}
Tinjut	5	66.67±4.76^{abc}	52.38±6.3^{abcd}	40.48±4.76^{bcde}	30.95±4.76^{bcde}	26.19±6.3^{bc}
	7.5	59.52±6.3^{abc}	42.86±4.12^{cd}	30.95±2.38^{cde}	23.81±2.38^{cdef}	21.43±0.00^{bcde}
	2.5	64.29±10.9^{abc}	50±4.12^{abcd}	38.1±2.38^{bcde}	30.95±4.76^{bcde}	21.43±4.12^{bcde}
Neem + Crinum	5	61.9±11.9^{abc}	45.24±6.3^{bcd}	35.71±4.12^{bcde}	26.19±4.76^{bcdef}	16.67±2.38^{cdef}
	7.5	66.67±4.76^{abc}	42.86±0.00^{cd}	28.57±7.14^{cde}	19.05±6.3^{ef}	2.38±2.38^{g}
	2.5	76.19±6.3^{abc}	64.29±4.12^{a}	47.62±8.58^{bc}	40.48±4.76^{b}	30.95±2.38^{b}
Neem + Tinjut	5	66.67±4.76^{abc}	52.38±8.58^{abcd}	40.48±6.3^{bcde}	30.95±4.76^{bcde}	26.19±2.38^{bc}
	7.5	73.81±10.4^{abc}	54.76±8.58^{abcd}	40.48±2.38^{bcde}	30.95±2.38^{bcde}	19.05±2.38^{bcde}
	2.5	80.93±4.76^{a}	61.91±4.76^{ab}	52.38±2.38^{b}	38.1±2.38^{bc}	30.95±2.38^{b}
Crinum + Tinjut	5	73.81±2.38^{abc}	54.76±4.76^{abcd}	40.48±8.58^{bcde}	26.19±6.3^{bcdef}	16.67±4.76^{cdef}
	7.5	69.05±2.38^{abc}	57.14±7.14^{abcd}	42.86±4.12^{bcde}	30.95±4.76^{bcde}	19.05±2.38^{bcde}
	2.5	50±7.14^{c}	45.24±2.38^{bcd}	38.1±2.38^{bcde}	30.95±2.38^{bcde}	23.81±2.38^{bcd}
Neem + Crinum + Tinjut	5	73.81±9.52^{abc}	54.76±6.3^{abcd}	42.86±7.14^{bcde}	33.33±6.3^{bcde}	23.81±6.3^{bcd}
	7.5	64.29±7.14^{abc}	47.62±2.38^{abcd}	30.95±6.3^{cde}	21.43±4.12^{def}	11.91±2.38^{defg}
Dimethoate	0.03	64.29±4.12^{abc}	45.24±4.76^{bcd}	26.19±6.3^{de}	14.29±0.00^{f}	4.76±2.38^{fg}
Control		52.38±4.76^{bc}	59.52±10.38^{abc}	73.81±14.48^{a}	83.33±2.38^{a}	100.00±0.00^{a}
Grand mean		67.3913±1.6	51.86±1.29	39.75±1.66	30.85±1.77	23.60±2.27653
CV		19.43513	18.2381	26.49348	24.45984	27.26363
P		0.3694	0.0353	0.001	.001	001
F value		1.11	1.88	3.2	9.68	24.6
Df		22	22	22	22	22

BT = Before treatment; T = Treatment; ±SE = Standard error; Means followed by the same letter within a column are not significantly different (DMRT) at P>0.05.

cabbages. Medium sized leaf was measured from all the remaining treatments comparable with dimethoate. Finally, the statistical analysis of leaf area revealed that, application of treatments were completely increased the leaf area of head cabbage as compared to untreated cabbage leaves that ranges from 43.52 to 19.5 cm^2.

The formation of cabbage heads were significantly different (P<0.05) among treatments and control groups (Table 4). The present study revealed that, highest percentage of cabbage heads (97.619%) were observed in plots treated with neem + crinum, neem and neem + crinum + tinjut at higher concentration (7.5%) which was better than dimethoate produced 92.86% per plot. In contrast, minimum percentage of cabbages with head (78.57%) was observed in plots treated with neem + crinum + tinjut at lower concentration (2.5%). Other treatments also provided enough head relative to the control group (33.19%).

The total yield (marketable and unmarketable) of head were shown significant difference (P<0.05) among treatments and control groups across treatment application period (Table 5). All botanical treatments were improved the yields than untreated plot of cabbages. The best yields per plots were recorded in plots treated with neem and crinum at higher concentration (7.5%). In contrast, the lowest yields were gained in botanicals in triple mixture with lower concentration (2.5%). Similarly, marketable yields per plot were significantly different (P<0.05) among treatments and control groups (Table 5). However, the highest marketable yield per plot was obtained from plots treated with crinum and neem in higher concentration (7.5%) than synthetic chemicals. Furthermore, cabbages treated with the remaining treatments gave comparable yields with dimethoate.

Table 3. Cumulative mean reduction rate of cabbage aphids across 4 treatment application period.

Treatment	Con. (%)	BT±SE	T1±SE	T2±SE	T3±SE	T4±SE
Neem	2.5	95.32±8.6[ab]	53.73±12.3[bc]	31.03±3.93[bcdefg]	22.4±3.15[bcde]	14.52±2[bcd]
	5	104.62±8.6[ab]	50.82±3.78[bc]	28.13±4.26[cdefgh]	18.18±2.37[efg]	11.27±0.56[befg]
	7.5	91.4±2.2[ab]	38.02±3.36[c]	16.48±3.28[h]	6.4±0.83[h]	2.5±0.3[h]
Crinum	2.5	99.82±9.7[ab]	59.3±10.41[bc]	38.42±4.46[bcd]	24.52±4.78[bcde]	13.55±1.5[bcde]
	5	112.32±6.72[a]	53.25±8.57[bc]	34.08±2.52[bcde]	23.32±1.41[bcde]	12.12±2.36[cdef]
	7.5	94.25±3.49[ab]	39.65±3.88[c]	18.18±3.69[gh]	7.33±1.45[h]	3.33±0.44[gh]
Tinjut	2.5	104.98±7.3[ab]	79.83±9.94[ab]	39.55±2.5[bcd]	30.42±4.7[bcd]	21.38±2.98[b]
	5	97.83±9.17[ab]	57.92±2.35[bc]	32.02±0.42[bcdefg]	23.78±0.43[bcde]	15.32±0.39[bcd]
	7.5	100.47±4.4[ab]	56.58±12.9[bc]	28.25±2.54[cdefgh]	18.7±2.52[defg]	10.65±1.4[defgh]
Neem + Crinum	2.5	99.77±12.5[ab]	64.73±6.47[bc]	42.98±2.91[b]	29.83±3.35[bcde]	16.98±3.52[bcd]
	5	83.97±6.49[b]	48.12±12.29[c]	27.88±3.91[defgh]	23.68±4.6[bcde]	13.4±2.6[bcde]
	7.5	89.1±1.92[ab]	41.02±7.47[c]	19.9±3.94[fgh]	9.4±1.95[gh]	4.4±0.83[fgh]
Neem + Tinjut	2.5	102.33±6.7[ab]	68.40±8.09[bc]	40.55±5.49[bcd]	31.08±5.93[bc]	20.33±3.92[bc]
	5	89.52±3.55[ab]	46.22±7.82[c]	30.05±2.9[bcdefgh]	19.15±3.3[cdefg]	10.67±0.5[defgh]
	7.5	86.93±8.28[ab]	45.95±4.98[c]	29.13±0.6[bcdefgh]	20.88±0.8[bcdef]	13.8±0.61[bcde]
Crinum + Tinjut	2.5	107.75±4.9[ab]	61.95±2.19[bc]	42.1b±5.2[1c]	32.53±4.05[b]	20.65±4.31[bc]
	5	89.97±12.1[ab]	62.12±14.1[bc]	31.42±3.11[bcdefg]	22.57±2.69[bcde]	13.47±1.5[bcde]
	7.5	89.65±4.63[ab]	55.23±7.44[bc]	30.1±3.74[bcdefgh]	20.15±2.1[cdefg]	12.08±2.2[cdef]
Neem + Crinum + Tinjut	2.5	87.42±10.1[ab]	61.18±12.4[bc]	32.383±4.56[bcdef]	26.28±5.09[bcde]	15.93±2.98[bcd]
	5	94.6±8.07[ab]	56.55±12.6[bc]	32.15±0.72[bcdefg]	22.63±0.65[bcde]	14.1±0.97[bcde]
	7.5	90.1±2.18[ab]	40.63±2.74[c]	20.87±0.92[efgh]	10.87±0.87[fgh]	5.5±0.29[efgh]
Dimethoate	0.03	96.23±8.07[ab]	48.17±12.54[c]	19.77±6.15[fgh]	7±2[h]	3±1[gh]
Control		84.82±12.29[b]	100.88±9.12[a]	114.93±10.34[a]	131.6±8.29[a]	153.87±7.54[a]
Grand Mean		95.35±1.61	56.1±2.27	33.93±2.38	25.34±2.96	18.38±3.59
CV (%)		14.07	27.78	21.1	23.94	24.27
P		0.5031	0.05	0 .001	0.001	0. 001
F value		0.98	2.44	21.56	48.62	135.96
Df		22	22	22	22	22

BT = Before treatment; T = Treatment; ±SE = Standard error; means followed by the same letter within a column are not significantly different (DMRT) at P>0.05.

While, untreated plot (control group) of cabbages produced the lowest yields.

The final economic effectiveness of the yields were shown a significant difference (P<0.05%) among treatments and control groups (Table 6).The highest net benefit was gained from cabbages treated with crinum and neem at higher concentration (7.5%). The other botanical treatments were economically very effective than dimethoate 0.03% and untreated plots. Dimethoate showed maximum costs than the other treatments and supplied lowest net benefit. The untreated (control) plots resulted in the lowest net benefit.

DISCUSSION

Botanical insecticides are considered as plant protection methods, which are naturally safe and harmless to the health of users and consumers. Moreover, botanical insecticides are less expensive and easily prepared. During the present treatments like neem, crinum, neem + crinum and neem + crinum + tinjut with higher concentration (7.5%) were provided greatest efficiency against cabbage aphids. As a result, aphicidal activity of botanicals increased with increasing their concentration and exposure period. The reason might be bioactive compounds found in plant materials.

The present study has shown that, infestation and reduction rate of cabbage aphids showed significant different (P< 0.05) among tested botanical treatments and control groups (Table 2 and 3). Neem was highly effective than dimethoate (0.03%) and the control groups. Similarly, Djomaha et al. (2016) stated that aphid

Table 4. Cumulative percentage of leaf (damage and area) and head formation .

Treatment	Con. %	Leaf damage (%)	leaf area (cm^2)	Cabbage with head (%)
Neem	2.5	$1.07±0.3^{b}$	$30.04±1.08^{fgh}$	$80.95±2.38^{a}$
	5	$0.8±0.21^{b}$	$32.88±0.8^{cde}$	$85.71±4.12^{a}$
	7.5	$0.11±0.11^{b}$	$42.84± 0.67^{a}$	$95.24±2.38^{a}$
Crinum	2.5	$1.53±0.39^{b}$	$29.91±0.4^{fgh}$	$80.95±6.3^{a}$
	5	$1.19±0.22^{b}$	$32.403±0.35^{def}$	$90.48±6.3^{a}$
	7.5	$0.56±0.31^{b}$	$43.131±0.4^{a}$	$92.86±4.12^{a}$
Tinjut	2.5	$1.96±0.3^{b}$	$26.28±0.08^{i}$	$88.1±2.38^{a}$
	5	$1.54±0.59^{b}$	$27.89±0.79^{hi}$	$85.71±10.91^{a}$
	7.5	$0.7±0.2^{b}$	$35.04±0.49^{c}$	$78.57±8.25^{a}$
Neem + Crinum	2.5	$1.20±0.23^{b}$	$30.06±2.02^{fgh}$	$90.48±6.3^{a}$
	5	$0.91±0.27^{b}$	$33.24±1.41^{cd}$	$92.86±7.14^{a}$
	7.5	$0±0.00^{b}$	$43.52±0.38^{a}$	$97.62±2.38^{a}$
Neem + Tinjut	2.5	$1.40±0.28^{b}$	$28.31±1.32^{ghi}$	$85.71±8.25^{a}$
	5	$1.28±0.18^{b}$	$30.48±0.61^{efgh}$	$85.71±4.12^{a}$
	7.5	$0.83±0.54^{b}$	$38.22±0.26^{b}$	$83.33±6.3^{a}$
Crinum + Tinjut	2.5	$2.18±0.15^{b}$	$26.81±0.96^{i}$	$83.33±6.3^{a}$
	5	$0.89±0.25^{b}$	$30.28±0.97^{efgh}$	$83.33±10.38^{a}$
	7.5	$0.42±0.13^{b}$	$38.34±0.38^{b}$	$90.48±6.3^{a}$
Neem + Crinum + Tinjut	2.5	$1.42±0.16^{b}$	$26.28±1.51^{i}$	$78.57±7.14^{a}$
	5	$1.00±0.5^{b}$	$30.79±0.22^{defg}$	$92.86±4.12^{a}$
	7.5	$0.11±0.11^{b}$	$38.73±0.46^{b}$	$97.62±2.38^{a}$
Dimethoate	0.03	$0.64±0.64^{b}$	$41.61±0.48^{a}$	$92.86±0.00^{a}$
Control		$71.84±4.08^{a}$	$19.5±0.04^{j}$	$33.19±1.41^{b}$
Grand mean		4.07±1.76	32.9± 0.77	85.50±1.82
CV		38.59432	4.494822	11.95698
P		0.001	0.001	0.001
F value		265.9	55.01	4.66
Df		22	22	22

Means followed by the same letter within a column are not significantly different (DMRT's) at P >0.05.

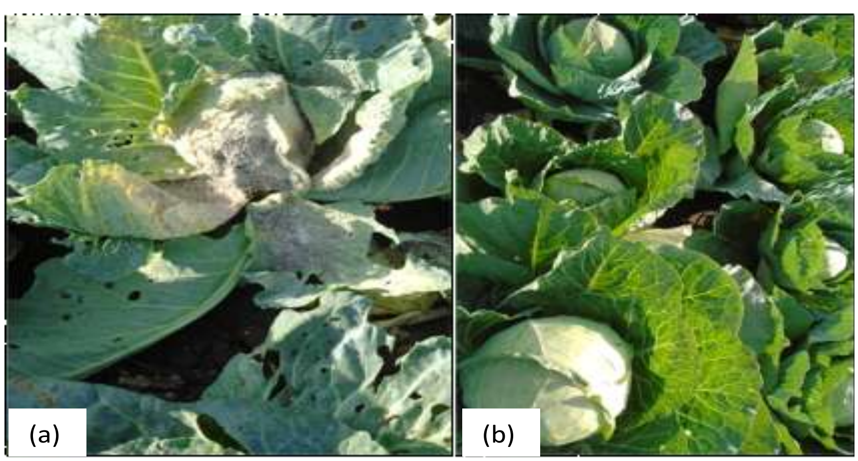

Plate 1. Cabbage heads in treated and untreated plots (Desale Getahun, March/2017). a, Untreated cabbage; b, Treated cabbage.

Table 5. Role of botanicals on cumulative yield of cabbage.

Treatment	Con. %	Total yield (kg/ha)	Marketable (kg/ha)	Unmarketable (kg/ha)
Neem	2.5	35367±6266.9^{fgh}	32617±3949.8^{f}	2750±665.8^{a}
	5	45702±2092.8^{bcdefg}	43968±2228^{bcdef}	1733±1266.7^{a}
	7.5	63078±6110.9^{a}	61212±7133.9^{a}	1867±1179.8^{a}
Crinum	2.5	35897±5405.9^{efg}	32840±5556.4^{f}	3057±372.2^{a}
	5	41755±1741.6^{bcdefg}	38422±2100.3^{def}	3333±2633.3^{a}
	7.5	62392±8690.3^{a}	61292±9232.6^{a}	1100±884.6^{a}
Tinjut	2.5	37937±2896.9^{defg}	35433±3331.3^{ef}	2503±1272.3^{a}
	5	40807±3732^{bcdefg}	36873±2802.3^{def}	3933±993.9^{a}
	7.5	55058±3119.6^{abc}	49642±652.7^{abcde}	5417± 2938.6^{a}
Neem + Crinum	2.5	40555±2796^{bcdefg}	37753±2748.4^{def}	2802±478.8^{a}
	5	49928±2149.2^{abcde}	45283±1435.1^{bcdef}	4645±1328.1^{a}
	7.5	61950±692^{a}	59917±7295.6^{ab}	2033±617.3^{a}
Neem + Tinjut	2.5	38598±2036.3^{cdefg}	35915± 1840.1^{ef}	2683±508.5^{a}
	5	36562±513.7^{efg}	33942±1787.2^{f}	2620±1744.1^{a}
	7.5	48680±4598.5^{abcdef}	46697±3839.6^{abcdef}	1983±1385.1^{a}
Crinum + Tinjut	2.5	35274±6529.4^{efg}	31767±5616.7^{f}	3883±1523.5^{a}
	5	41138±4946.6^{bcdefg}	38647±3814.2^{def}	2492±1347.1^{a}
	7.5	56625±6397.3^{ab}	54942±5537.4^{abc}	1683±1012.6^{a}
Neem + Crinum + Tinjut	2.5	29715± 5280.7^{gh}	30947±2382.9^{f}	1117± 573.3^{a}
	5	41407±5930.8^{bcdefg}	36487±6759.5^{def}	4920±2815.1^{a}
	7.5	57167±5097.8^{ab}	54900±3951.7^{abc}	2267± 1597.5^{a}
Dimethoate	0.03	54373±4150.8^{abcd}	51823±3394.1^{abcd}	2550±1075.1^{a}
Control		17642±6134.9^{h}	12548± 6178.2^{g}	5093±518.5^{a}
Grand Mean		44537±1619.7	41907.18±1614.3	2889.79±286.6
CV		19.16657	19.05648	86.15367
P		0.001	0.001	0.7798
F value		5.59	6.62	0.74
Df		22	22	22

Means followed by the same letter within a column are not significantly different at P> 0.05.

infestations in all treated plots (imidacloprid, neem and control) were significantly different. Pissinati and Ventura (2015) reported that, after the first treatment application, infestation was maximum in cabbage treated with neem [0.5%] than the mixture of neem + Pyroligneous [0.5%]. In contrast, the present study revealed that infestation was lower in cabbage treated with neem [2.5%] than neem + crinum [2.5%]. Therefore, the efficacy of neem was greater than neem + crinum and neem + tinjut at any of the three tested [2.5, 5 and 7.5%] concentrations. In studies made by Begna (2014), cabbage treated with botanicals: such as, garlic, chilli, neem and *Phytolacca dodecandra* L'Herit (endod in Amharic were recorded higher infestation level than conventional (diazinon) pesticides. In contrast, the present study revealed that botanicals, neem and crinum aqueous extracts with higher concentration [7.5%] scored lower percentage of cabbage aphid infestation than dimethoate (Table 2). Therefore, the efficacy of botanicals against cabbage aphid infestations depends upon their concentration. The maximum reduction rate of infestation was observed in neem followed by crinum and lastly tinjut.

The study also revealed that from the first to last treatment application period, tested botanical treatments were shown high percentage efficacy against cabbage aphids. Among them neem and crinum with higher concentration had higher efficacy than conventional insecticides, dimethoate and control groups. It was confirmed with the finding of Ezena et al. (2016), reported that botanicals had considerably reduced number of aphids than conventional insecticides, sunhalothrin and the tap water plots in the minor growing season.

Treatment concentration and application rate had a direct relationship with mortality/reduction rate of cabbage aphids. Phoofolo et al. (2013) reported that an increase in plant extract concentration resulted in an increase in the percentage of aphid mortality. Birhanu et al. (2011), who stated that mortality of cabbage aphids had related to the toxic odor of extracts entered into their spiracle and block the oxygen supply. Similarly, the present study was shown that neem with higher concentration also effectively reduced the number of cabbage aphids than the other botanical pesticides and standard check (Table 3). This might be due to the plants (botanicals) ability to attack aphids, as antifeedant, replant, and toxicant effects. In studies made by Nagappan (2012), reported that aqueous extract of *Milia azadarach* dry fruit was effective in reducing the cabbage aphids, cabbage aphid and important to get maximum benefit. Same way, the present study showed that, aqueous extract solutions of the neem, *A. indica* leaves were more effective than crinum bulb and tinjut leaf aqueous extracts against cabbage aphids. Sarwar (2015) reported that botanicals may not be killed insects for hours or days, but they were acting very quickly to stop its feeding. Similarly, it is evident from the present study that numbers of aphids were drastically reduced from first to last treatment application period. However, numbers of aphids were exceptionally increased in untreated plots. Treatment concentration was the other factor that determines the effectiveness of botanicals compared with conventional insecticides, dimethoate (0.03%). As a result, mortality (reduction) rate of cabbage aphids increased with increasing their concentration.

Mwine et al. (2013) believed that leaf damage levels continuously increased in all treatments and in some cases, cabbage leaf damage were as high as damage from control plots. Unlikely, in the present study in all treatments percentages of cabbage leaf damage were low. It was also observed in plots treated with neem + crinum 7.5% but higher in untreated plots, 71.84% (Table 4). The present results were confirmed with the finding of Begna and Damtew (2015) reported that highest leaf damage was recorded in control plots, whereas the least was in neem treated plots. In studies made by Bhat and Dhoj (2005), concentration of sample plant extract and treatment rate were the most effective which reduced damaged scale of cabbage leaves by controlling aphid population and their infestation level. Sharma and Gupta (2009) reported that the antifeedant effect of different concentration, irrespective of extracts, decreased with lower concentration from 5 to 1%. Likewise, in the present study, the scale of leaf damage was sharply increased from lower to higher botanical [7.5 %< 5 %< 2.5%] concentration. Therefore, percentages of damaged leaves were higher in untreated plots than treated plots.

A good botanical pesticide should protect a crop against target pests to levels below economic threshold (Mwine et al., 2013). In the current study, maximum percentage of cabbage heads per plot were observed in treated plots than untreated plots. In a repeated application of botanicals with higher concentration gave surplus amount of cabbage yields per plot. However, cabbage head development primarily depends upon the treatment efficacy that reduced impact of cabbage aphids. This may be due to toxic, antifeedant or deterrent effect of botanicals that against cabbage aphids. The application of different plant aqueous extracts increased the yield contributing characters; such as, number of leaves per plant, area of leaves, number of heads per plot and finally increasing the quality and quantity of the yield. Ezena et al. (2016) reported that no significant difference among treatments in cabbage yield with the exception of neem seed extract plots which had the highest yield. In contrast, in the current study there was significant difference ($P<0.05$) among treatments and control groups. Cabbages treated with neem and crinum in higher concentration (7.5%) produced highest yields (62,392 kg/ha). However, the lowest cabbage yield was harvested in untreated plots (Table 5).

Bhat and Dhoj (2005) reported that control plots have very low marketable yield compared with treated plots. Likewise, in the present findings highest number of marketable yield per hectare were gained from plots treated with crinum followed by neem in higher concentration (7.5%). This marketable yield variability was formed due to the treatment aphicidal action and concentration differences. The reason might be due to cabbage aphids affecting the yield by producing honeydew on the leaf surface that reduced photosynthesis, transmits viral disease and feeding growing parts that cause leaf damage and head deformation.

In the present study, cabbages treated with botanical aqueous extracts were provided more economic benefit than dimethoate and control groups. Neem and crinum in high concentration was produced peak net benefit per hectare, while no benefit (credit) in untreated plots (Table 6). Rokayya et al. (2013) also reported that the cost of plant protection using pesticides was higher than the use of botanicals. The final income (net benefit) of cabbage was depending upon the total cost and marketability of the yield. Crinum bulb, neem and tinjut leave aqueous extracts were effective in producing more net benefit as compared to dimethoate and untreated plots. The reason might be due to the less cost of botanicals used and produced more crop yield, while conventional dimethoate used more cost than the yield of the crop produced.

The present study revealed that all the treatments showed aphicidal activity against cabbage aphids but the leaf extract of neem followed by bulb extract of crinum plants with higher concentration have been proved the best treatment for the controlling cabbage aphids populations and achieving high yield. Therefore, gardeners especially small scale farmers protect their cabbages from cabbage aphid by using tested botanical

Table 6. The effects of botanicals on mean economic benefit of the yield (ETB/ h).

Treatment	Con. %	Total cost (ETB)	Gross benefit (ETB)	Net benefit (ETB)
	2.5	182823±500^{b}	228317±27648.8^{f}	45494±27598.4^{e}
Neem	5	183823±250^{b}	307778±15595.9^{cdef}	123955±15450.3^{cde}
	7.5	185073±500^{b}	428482±49937.6^{a}	243409±49615.7^{a}
	2.5	182323±500^{b}	229880±38894.7^{f}	47557±38394.8^{e}
Crinum	5	184073±750^{b}	268952±14701.9^{def}	84879±14866.8^{de}
	7.5	185073±250^{b}	429042±64628.4^{a}	243969±64378.5^{a}
	2.5	184073±750^{b}	248033±23319.3^{ef}	63960±23069.3^{de}
Tinjut	5	183073±661.4^{b}	258113± 19615.8^{def}	75040±19259.4^{de}
	7.5	182323±250^{b}	347492±4568.6^{abcde}	165169±4330.4^{abcd}
	2.5	183573±661.4^{b}	264273±19238.6^{def}	80700± 18886.7^{def}
Neem + Crinum	5	183573±661.4^{b}	316983±10045.5^{bcdef}	133410±10706.9^{bcde}
	7.5	184823±433^{b}	419417±51069^{ab}	234594±50736.5^{ab}
	2.5	183323±433^{b}	251405±12880.4^{ef}	68082±12819.9^{de}
Neem + Tinjut	5	183323±866^{b}	237592±12510.5^{f}	54269±11831.7^{de}
	7.5	183573±250^{b}	326877±26877^{abcdef}	143304±27122.8^{abcde}
	2.5	182323±250^{b}	222367±39317.2^{f}	40044±39567.2^{e}
Crinum + Tinjut	5	183323±750^{b}	270527±26699.5^{def}	87204±25949.5^{de}
	7.5	184823±750^{b}	384592±38761.9^{abc}	199769±38301.4^{abc}
	2.5	183073±661.4^{b}	216627±16680.5^{f}	33554±16875.2^{e}
Neem + Crinum + Tinjut	5	183823±500^{b}	255407±47316.6^{def}	71584±46816.8^{de}
	7.5	184823±866^{b}	384301±27661.9^{abc}	199478±28018^{abc}
Dimethoate	0.03	297873±33400^{a}	362763±23759^{abcd}	64890±50615.2^{de}
Control		179323±1639.4^{b}	87838±43247^{g}	91485(-)±41865.8^{f}
Grand mean		188444±3076.5	293350.3±11299.9	104905.5±11192.8
CV		6.429439	19.05648	55.07387
P		0.001	0.001	0.001
F value		8983.54	6.62	8.54
Df		22	22	22

Means followed by the same letter within a column are not significantly different at P> 0.05.

aqueous extracts than conventional insecticides. Furthermore, studies should be conducted on the effectiveness of tested plants against cabbage aphid on different cabbage growing seasons.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENT

The author appreciates the Amhara regional state for funding the field experimental study. Debre Markos University, Department of Biology is acknowledged for logistic support and fulfilled other necessary requirements for the study. The researcher benefited from Sirinka Agricultural Research center and kobo sub-center researchers for their suggestion, material and experimental land support 2016/17. They extend their thanks to Dr. Sudarsan Reddy Malkireddy and Ato Mulat Ayenew who provided many important suggestions and comments.

REFERENCES

Abdulkadir H (1992). Potential of Baculoviruses for control *Diamondback moth and Crocidolomia binotalis* on cabbage. Basic Research Division, MARDI, Serdang, Malaysia. Availableon:http://web.entomology.cornell.edu/shelton/diamondback moth/pdf/1990papers/1990DBM21.

Amoabeng B, Gurr G, Gitau C, Stevenson P (2014). Cost: benefit analysis of botanical insecticide use in cabbage: Implications for smallholder farmers in developing countries. Crop Protection, 57:71-76.

Baidoo P, Adam J (2012). The effects of extracts of Lantana camara (l.) and Azadirachta indica (A. juss) on the population dynamics of Plutella xylostella, Brevicoryne brassicae and hellula undalis on cabbage. Sustainable Agriculture Research, 1(2):229-234.

Begna F (2014). Evaluation of botanical insecticides for managing diamondback moth, *plutella xylostella l. (lepidoptera: plutellidae)* on head cabbage. M.sc.thesis. Haramaya University, Haramaya.

Begna F, Damtew T (2015). Evaluation of four botanical insecticides against Diamondback Moth, *Plutella Xylostella L*. (Lepidoptera: Plutellidae) on head cabbage in the central rift valley of Ethiopia. Sky Journal of Agricultural Research, 4(5):097-105.

Bhat B, Dhoj Y (2005). Effect of Melia Azedarach on Aphid *(Brevicoryne brassicae)* of organic cabbage farming. Team Leader, Ecological Service Centre, Bharatpur-2, Chitwan.

Birhanu M, Awoke Y, Tahgas A, Nagappan R (2011). Efficacy of *Melia azadarach* and *Mentha piperita* plant extracts against cabbage aphids, Brevicoryne brassicae (homoptera: Aphididae). World Applied Sciences Journal, 12(11):2150-2154.

Blackman R, Eastog V (2000). The identification and information guide second edition. In: *Aphids on the Worlds crops*. pp. 167-168. The natural history, Museum, Cross Well Road, Londen. (Wiky, J. and Sons, eds.). England.

Bodaiah B, Kumar A, Varma R, Anuhya G, Sudhakar P (2016). Pesticidal Activity of Plants on Selected insects. International Journal of Recent Scientific Research, 7(3):9298-9304,

Devi E, Devi P, Deepshikha (2016). A Review on Prospects of Entomopathogenic Fungi as Potent Biological Control Agents of Insect Pests. International Journal of Current Research Biosciences and Plant Biology, 3(9):74-82

Djomaha ES, Ghogomu RT, Hanna R, Ngatat ES, Lontchi NF (2016). The effects of extract *Azadirachta indica* (Neem) oil and Imidacloprid (IRON 30SC) on the population dynamics of *Brevicoryne brassicae, Lipaphispseudo brassicae* and *Plutella xylostella* on white cabbage. International Journal of Agronomy and Agricultural Research, 8(4):135-142

Emana B, Afari-Sefa V, Dinssa F, Ayana A, Balemi T, Temesgen M (2015). Characterization and Assessment of Vegetable Production and Marketing Systems in the Humid Tropics of Ethiopia. Quarterly Journal of International Agriculture, 54(2):163-187.

Embaby S, Lotfy D (2015). Ecological studies on Cabbage pests. Journal of Agricultural Technology, 11(5): 1145-1160

Ezena GN, Akotsen HC, Fening KO (2016). Exploiting the insecticidal potential of the invasive siam weed, *chromolaena odoratal* (asteraceae) in the management of the major pests of cabbage and their natural enemies in southern Ghana. Advances in Crop Science and Technology, 4(4):2329-8863

Hailemichael A, Nagappan R (2012). Evaluation of *Melia azedarach* (Linn) *Croton macrostachys* (Hochst) and *Schinus molle* (Linn) Plant Extracts against Cabbage Aphid *Brevicoryne brassicae* Linn and their Natural Enemies. Asian Journal of Agricultural Sciences, 4(6):411-418.

Iqbal M, Kahloon M, Nawaz M, Javaid M (2011). Effectiveness of some botanical extracts on wheat aphids. The Journal of Animal & Plant Sciences, 21(1):114-115

Leskovar D (2014). A growth, physiology and yield response of cabbage is to deficit irrigation. Horticultural Science, 41: 138-146.

Magn Magazin (2015). Kobo district governmental information and communication office. Kobo, Ethiopia. 8:1-40.

Munthali D, Tshegofatso A (2014). Factors Affecting Abundance and Damage Caused by Cabbage Aphid, *Brevicoryne brassicae on*. Four Brassica Leafy Vegetables: *Brassica oleracea, var. Acephala, B. chinense, B. napusand B. carinata*. The Open Entomology Journal, 8:1-9

Mwine J, Ssekyewa C, Kalanzi K, Damme P (2013). Evaluation of selected pesticidal plant extracts against major cabbage insect pests in the field. Journal of Medicinal Plants Research, 7(22): 1580-1586.

Nagappan R (2012). Impact of *Melia azedarach* (Linn). (Meliaceae) dry fruit Extracts, farmyard Manure and nitrogenous fertilizer application against cabbage aphid *Brevicornye brassicae* Linn. (Homoptera: Aphididae) in home garden. Asian Journal of Agricultural Sciences, 4(3):2041-3890

Phoofolo M, Mabaleha S, Mekbib S (2013). Laboratory assessment of insecticidal properties of *Tagetes minuta* aqueous extracts against *Brevicoryne brassicae* on cabbage. Journal of Entomology and Nematology, 5(6): 70-76.

Pissinati A, Ventura M (2015). Control Cabbage Aphid (*Brevicoryne brassicae,* L.) using Kaolin and Neem Oil. Journal of Entomology, 12(1):1812-5670.

Richardson K (2016). Evaluation of the Broccoli (*Brassica oleraceae* L.) Variety imperial. Gladstone Road Agricultural Centre Crop Research Report.

Rokayya S, Li C, Zhao Y, Ying L, Sun C (2013). Cabbage (Brassica oleracea L.var. capitata) Phytochemicals with Antioxidant and Anti-inflammatory Potential. Asian Pac Journal Cancer Prevalence, 14(11):6657-666.

Sarwar M (2015). The Killer Chemicals for Control of Agriculture Insect Pests: The Botanical Insecticides. International Journal of Chemical and Biomolecular Science, 1(3):123-128.

Sharma A, Gupta R (2009). Biological activity of some plant extracts against *Pieris brassicae* (Linn.). Journal of Biopesticides, 2(1):26-31.

Shiberu T, Mulugeta N (2016). Effects of synthetic insecticides and aqueous botanicals extracts on cabbage aphid, Brevicoryne brassicae (L.) on cabbage. Journal of Fertilizers and Pesticides, 7:162.

Wubie M, Negash A, Guadie F, Molla G, Kassaye K, Nagappan R (2014). Repellent and Insecticidal Activity of *Mentha piperita* (L.) Plant Extracts against Cabbage Aphid [*Brevicoryne brassicae* Linn. (Homoptera:Aphididae)]. American-Eurasian Journal of Scientific Research, 9(6):150-156.

Related Journals: