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Full Length Research

Evaluation of Different Amaranth (*Amaranthus spp* L.) Varieties for Yield and Yield Components in Response to Intra-Rows Spacing at Jimma, Southwest Ethiopia

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The present investigation was conducted to identify suitable amaranth varieties/variety and optimum intra-row spacing for high leaf and seed yield. Data was collected from yield components and yield for analysis. The data was analyzed using SAS version (9.3) software and significant treatment means were separated using Tukey test at LSD (p<0.05). The earliest days to 50% flowering (23.67) and days to maturity (58.33) were observed with variety AH-NL- Sel. The maximum plant height (228 cm) was registered by Madiira1 variety planted at 15cm intra-row spacing while the maximum number of leaves per plant (345.7) by Madiira2 variety planted at 35 cm. The maximum number of branches per plant (34.07) recorded by Madiira2 variety planted at35 cm. The maximum grain yield per plant (34.22 g and 32.9 g) were registered by varieties TZMN102-Sel and AH-NL-Sel, respectively planted at 35cm intra- row spacing, where as the highest grain yield per hectare (1802 kg ha^{-1} and 1786 kg ha^{-1}) were recorded by TZSMN102-Sel and AH-NL-Sel, respectively planted at 15 cm intra-row spacing. Therefore amaranth varieties TZSMN102-Sel and AH-NL-Sel planted at 15 cm and Madiira2 planted at 25 cm intra-row spacing were found comparable for grain and leaf yield respectively.

Keywords: Amaranthus spp L; intra-row spacing; leaf yield; seed yield; varieties

1. **INTRODUCTION**

Amaranth (*Amaranthus spp* L.) comprises about 70 species belongs to the genus of Amaranthus and Amaranthaceae family (Ebert and Wang, 2011). Amaranthus are distributed worldwide with a wider geographical adaptability from the primary centers of diversity (Central and South America, India and South East Asia) and secondary center diversity West and East Africa (Oo and Park, 2013). Amaranth is characterized by fast growing, herbaceous, broadleaves, early maturing which harvested within three to four weeks after sowing for leaves whereas it requires 60 to 90 days for grain purpose (Alegbejo, 2013). It tolerates a temperature range 25 ^{0}C to 40 ^{0}C and can thrive under higher light intensity and moisture stress environments (Mlakar *et al*., 2010). And can also grow from sea level to 2400 meter altitude (Oleleji *et al*., 2014)

Amaranth has long been part of indigenous African agriculture and semi-domesticated in Ethiopia and other East African countries, mainly used as vegetable and grain (Emire and Arega, 2012). Evidences indicated that amaranth species such as *Amaranthus cruentus*, *Amaranthus caudatus*, *Amaranthus viridis* and *Amaranthus tricolor* were traditionally distributed in several parts of Ethiopia (Zebdewos *et al*., 2015). Grain parts consumed as cereal while leaf and tender stem parts consumed as vegetable in some parts of the country particularly during the time of food shortage (Hailu *et al*., 2015). It is also used traditionally for preparation of local beverage, porridge and bread mixed with other cereal crops (Molla *et al*., 2011; Amare *et al*., 2015)

Depending on their importance amaranth can be grouped as vegetable, ornamental and weedy types Olaniyi *et al*., 2008). Yet there is no clear sorting out line between grain and vegetable types of amaranth but it depends on intended use of the producers because of the crop used for dual-purposes (Mlakar *et al*., 2010). A weedy type of amaranth comprises all species that have not yet been cultivated and not edible species (Andini *et al*., 2013). Amaranths are grouped under neglected and underutilized species however it has potential to alleviate malnutrition and food insecurity (Achigan-Dako *et al*., 2014). In case of that the crop is contains high nutritional value that contributes for human health (Gerrano *et al*., 2014).The young leaves and grains of amaranths are rich in iron, calcium, zinc, phenolic compounds, vitamin C, vitamin A, lipids, proteins, carbohydrates and dietary fiber (Svirskis, 2003; Kamga *et al*., 2013). In addition the grain contains high levels of lysine and sulphur-containing amino acids which are lacking in many vegetables and cereal grains (Akaneme and Ani, 2013). Unlike other vegetables, an amaranth leaf also contains more calcium, phosphorus and iron (Svirskis, 2003; Ebert and Wang, 2011)

Identification of adaptable varieties and determination of optimum plant spacing are therefore very important for an improved performance of the vegetables in terms of growth and yield (Henderson *et al*., 2000). Plant density is an essential variable for achieving highest yields and uniform maturity of vegetative part of the plant. It can be achieved by establishing suitable distances both between the rows and in the rows of plants (Turbin *et al*., 2014). Currently the major staple food crops production are not yet able to satisfy food demand of Ethiopians because of increasing population growth at alarming rate and current climatic change, among other factors (Alemayehu *et al*., 2015). Production and utilization of amaranth should be promoted in Ethiopia due to its enormous nutritional benefits (Ayalew, 2013). Despite its importance, research focuses on identification of improved varieties and optimum intra-row spacing for leaf and grain yield of amaranth in Ethiopia so far less. So to fill this gap optimum planting density and improved varieties are identified as research and development gaps to promote the leaf and grain yield potential of the crop in Ethiopia in general and Southwest area in particular. In view of this, this study was initiated with the objectives to identify best performing amaranth variety and optimum intra-row spacing for leaf and grain yield.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine Eladale farm from January to May, 2017 under irrigation condition. The study area is located at an altitude of 1710 m above sea level and 7^0 42' N latitude 36^o48' E longitudes (Merkebu and Techale, 2015) in Oromia National Regional State , Jimma zone. It is located 356 km on the Southwest of Addis Ababa and 7km away Northwest of Jimma city on the way to Agaro. During the period of experiment, the study area received an average rainfall of 100.9 mm and exercising an average relative humidity of 62.02%, means maximum and minimum temperatures of 28.64 ^{0}C and 11.72 ^{0}C, respectively (Table 1). The soil of experimental site is well-drained clay to silt clay with pH of 5.5

Table 1: Climate data on the research area during the Experimental period in year 2017

S.N	Meteorological data	Months (Experimental period)						
1	Temperature	January	February	March.	April.	May	total	Average
	Min(^{0}c)	10.4	12.5	12.5	11.3	11.9	58.6	11.72
	Max(^{0}c)	25.61	29	25.61	25.97	27	133.19	26.638
2	Mean Relative humidity (%)	69.4	53	61.4	59.3	67	310.1	62.02
3	Rain fall(mm)	56.2	61.6	97.8	96.5	192.4	504.5	100.9

Source: Jimma Meteorological Station (2017)

2.2. Land preparation and managing

Seedling beds were ploughed, harrowed manually and well prepared by dividing the plot into a size of 1.20m x 5.00m. Ridges were prepared manually using spade and hoe. Seedling beds were partitioned into a distance of 15 cm between row spacing. Seeds were sown at depth of 1.30cm and covered with the soil carefully to facilitate good germination and emergence. The sown seeds were covered with organic mulches to regulate soil moisture and reduce the soil evaporation during the course of seed germination and emergence. Six days later (when about 10% seedlings emergence observed) mulch materials were removed. Irrigation water was applied twice a day in the morning and afternoon by using watering cane to facilitate the germination of seeds.

After hardening off amaranth seedlings for a week, vigorous seedlings which have 3-4 true leaves were transplanted into experiment field. The main field was ploughed and harrowed by tractor. The experimental plots were arranged into three blocks and 54 plots, and the plots were laid out manually using hand hoe. Each plot with a size 3.60 m x 2.10 m=7.56 m^2 prepared, and distance between each plot was 0.50 m, while distance between each block was 1.00 m, making the total experimental area used 592.64m^2. Fertilizers were applied at the rate of 8.16 Kg DAP and 3 kg Urea at planting whereas 3kg Urea applied after two weeks of transplanting based on recommendation of (Dinssa *et al*., 2015). Irrigation was applied manually using watering cane once a day prior to seedling establishment; then after seedlings were watered 5-7 days interval depending on the physical soil condition and gradually watering was stopped at the stage of plant maturity. Weed control was checked by hand weeding.

2.3. Experimental Materials, Design and Treatments

Experimental materials were obtained from Asian Vegetable Research Development (AVRDC), Eastern and Southern Africa regional office Arusha, Tanzania. The identification of the materials, variety codes, name and origin are indicated (Table 2). Randomized complete Bock Design (RCBD) in factorial arrangement with six varieties and three intra-row spacing (15, 25, 35) cm and using inter row spacing of 60cm with three replications.

Table 2: Variety codes, name and origin amaranth experimental materials

No	Codes	Variety name	Origin
1	RVI00057	UG-AM-13	Uganda
2	RVI00085	UG-AM-68	Uganda
3	VI062428	TZSMN102-Sel	Tanzania
4	VI060293	AH-NL-Sel	Tanzania
5	-	Madiira 1	Tanzania
6	-	Madiira 2	Tanzania

Source: Asian Vegetable Research Development (AVRDC), Eastern and Southern Africa regional office Arusha, Tanzania

2.4. Data collected

Days to 50% flowering was recorded as days from transplanting date to when 50% of plants were initiated flowers. Days to maturity determined as days from transplanting date to when inflorescence change to yellow color.

Plant height (cm) was measured from the base of the plant to the top of the inflorescence at harvesting from randomly taken fully grown five plants of the central row (Sogbohossou *et al*., 2014). Number of leaves per plant was counted from randomly sampled fully-grown five plants of the central row and the average was registered.

Number of branches per plant was counted from randomly taken fully grown five plants at seed maturity and the average was recorded (Pourfarid *et al*., 2014)

Leaf length and width (cm) were measured during vegetative growth 6th or 8th leaf from randomly sampled fully grown five plants.

Stem diameter (cm) was measured 12 cm above the ground by using of vernier caliper (Model Number: 141) (Ayalew, 2013)

Leaf area (cm^2) of the sample leaves were determined as described by (Tongos, 2016) multiplied by 0.64.

Leaf area index was calculated as leaf area per unit ground surface area (Pourfarid *et al*., 2014)

Leaf yield (g/plant and t/ha) was determined by considering the fully expanded tender leave starting from four weeks after planting and until final harvesting (Mbwambo *et al*., 2015).

Biological yield dry weight per plant (g)was measured by harvesting randomly sampled fully-grown five plants of the central rows at harvest and from these samples stems and leaves were separately prepared after harvest and chopped then dried using an oven-drying chamber as described by (Olaniyi *et al*., 2008) at 65°C for 48 h.

Grain yield (g/plant and t/ha) was undertaken when inflorescences change to yellow color and inflorescences of each plant were cut, threshed and seeds were cleaned (Mbwambo *et al*., 2015)

Thousand seeds weight (g) were harvested from the sample plants, dried and thousand seeds were counted by seed counter machine called *Cantador*2 manufactured by *Pfeiffer* company with a model of 230 V / 50 Hz (24 V) then thousand seeds weight were measured by digital balance(Mbwambo *et al*., 2015)

2.5. Data Analysis

The collected data on different yield and yield component variables were subjected to analysis of variance (ANOVA) by using SAS (version 9.3) Statistical Analysis Software. All pairs of treatment means were compared using Least Significant Difference (LSD) test at 5% level of significant. Significant treatment means were separated using Tukey test at $P<0.05$. All data normality test and correlation coefficient among these yield and yield components variables were performed.

3. RESULTS AND DISCUSSION

3.1. Phenological Growth and Yield Component Variables

3.1.1. Days of 50% flowering (No.) and days to maturity (No.)

Number of days to 50% flowering and days to maturity were significant ($P<0.05$) affected by varieties. The earliest days to 50% flowering 23.67 days were recorded after transplanting from amaranth variety AH-NL-Sel, while the longest days were recorded 74.4 days from late flowering amaranth variety Madiira2 after transplanting (Table 3) and the earliest variety required (58.33 days) after transplanting to mature, while the late variety required (95.78 days) to mature after transplanting. This result agrees with previous finding of (Mbwambo *et al*., 2015) who revealed that the variations observed in terms of days to 50% flowering and days to maturity can be explained due to the genotypic difference and environmental conditions

Table 1 Days to 50% flowering and days to maturity as influenced by varieties under Jimma.

Variety	Days to 50% flowering	Days to maturity
UG –AM-13	57.78^c	78.22^c
UG-AG-68	61.33^d	83.44^d
TZMN102-Sel	25.11^b	60.67^b
AH-NL-Sel	23.67^a	58.33^a
Madira1	61.89^d	84.33^d
Madira 2	74.78^e	95.78^e
Means	50.76	76.8
LSD (5%)	0.90	0.82
CV (%)	1.9	1.1

Means in columns followed by the same latter (s) are not significantly different using LSD at $P = 0.05$ level of significance

3.1.2. Plant height (cm)

Plant height was significant ($P<0.05$) influenced by the interaction effect of amaranth varieties and intra-row spacing . The highest plant height (228 cm) was recorded with treatment combination of amaranth variety Madiira1along with intra-row spacing of 15 cm and by Madiira1with intra-row spacing 25 cm (225 cm) (Table 4) while the least plant height was recorded by combination of amaranth UG- AM-13 variety and intra-row spacing of 35 cm (63.20 cm).

In this result plant height increased with decreasing of intra-row spacing from 35 cm to 15 cm across all amaranth varieties evaluated. This explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased. To overcome such competition plant provided available resources for height growth rather than developments of other parts such as branches and leaves. Similar result was reported by (Yarnia *et al*., 2010) who found that maximum plant height was registered with a narrow intra-row spacing (high plant density) in search for solar radiation.

3.1.3. Number of leaves per plant (No.)

Number of leaves per plant was significant ($P<0.05$) influenced by interaction effect of varieties and intra-row spacing (Table 4). Maximum number of leaves per plant was recorded with treatment combination of amaranth variety Madiira2 planted at intra-row spacing of 25 cm and 60 cm inter row spacing (345.70) and Madiira2 with intra-row spacing of 35 cm (340.00) (Table 4). Madiira1 variety also registered maximum number of leaves per plant (330.90) at intra-row spacing of 25 cm and by variety UG-AM-13 (317.00) at intra-row spacing of 25 cm, whereas the lowest number of leaves per plant (119.70) were observed with variety AH-NL-Sel at 15 cm intra-row spacing indicating that differential varietal performance in response to different intra-row spacing under Jimma condition (Table 4).

Different intra-row spacing showed significant variation in number of leaves per plant. Except varieties UG-AM-68 (201.80) and AH-NL-Sel (169.20), the highest number of leaves per plant was observed from the majority of varieties at intra-row spacing of 25cm (Table 4). As intra-row spacing increases from 15 cm to 25 cm, the number of leaves per plant increased from 119.70 - 270.90 range to 136.00 – 345.90 ranges. This may be because of planting at intermediate intra-row spacing allow sufficient spacing which in turn facilitates growth of branches that each branch produces more leaves. This might be because plants under narrow intra-row spacing tend to increase in height rather than developing branches and leaves per plant. This result is in confirmation with the work of (Majumder, 2007) who reported that more number of leaves per plant at wider plant spacing than at narrow. Whereas, increasing intra-row spacing from 25 cm to wider intra-row spacing of 35 cm decreased number of leaves per plant for these four varieties (134.10 -340.00) revealing that accommodating intra-row spacing to these varieties will increase number of leaves per plant up to 25 cm. In other study (Ogedegbe *et al*., 2014). It was reported that there is significant genetic variation between amaranth varieties with regard to the number of leaves in response to plant spacing.

3.1.4. Number of branches per plant (No)

Table 4: Interaction effect of intra-row spacing (cm) and variety on plant height (cm), number of leaf per plant (No.), number of branches per plant (No.) under Jimma

Intra-row spacing (cm)	Variety	Plant height (cm)	Number of leaves per plant (No.)	Number of branches per plant (No.)
15	UG-AM-13	91.00^{ef}	179.90^{fg}	11.00^{h}
	UG-AM-68	91.70^{ef}	186.20^{ef}	12.00^{fgh}
	TZMN102-Sel	102.90^{cd}	134.10^{hi}	15.53^{defg}
	AH-NL-Sel	102.40^{cd}	119.70i	15.00^{efgh}
	Madiira1	228.10^{a}	270.90c	27.47^{bc}
	Madiira2	109.30^{c}	225.80d	26.60^{c}
25	UG-AM-13	75.20^{gh}	221.00^{de}	14.27^{fgh}
	UG-AM-68	83.90^{fg}	192.00^{def}	13.47^{fgh}
	TZMN102-Sel	101.00^{cd}	147.70^{ghi}	16.60^{def}
	AH-NL-Sel	91.00^{ef}	136.20^{hi}	19.13^{de}
	Madiira1	225.00^{a}	291.70^{bc}	28.33^{bc}
	Madiira2	99.00^{de}	340.00^{a}	31.13^{ab}
35	UG-AM-13	63.20^{i}	317.00^{ab}	15.33^{defg}
	UG-AM-68	72.20^{h}	201.80^{def}	14.60^{fgh}
	TZMN102-Sel	95.80^{de}	165.80^{fgh}	17.47^{def}
	AH-NL-Sel	96.00^{de}	169.20^{fgh}	19.57^{d}
	Madiira1	199.70^{b}	330.90^{a}	27.60^{bc}
	Madiira2	96.50^{de}	345.70^{a}	34.07^{a}
Means		112.43	220.9	19.95
LSD (5%)		4.72	20.17	2.32
CV (%)		2.5	5.5	7

Means in columns followed by the same latter (s) are not significantly different using LSD at P = 0.05 level of significance

3.1.5. Leaf length (cm) and width (cm)

Leaf length and width were significant ($P<0.05$) influenced by interaction of varieties and intra-row spacing (Table 5). In this study, it was observed that at wider intra-row spacing the longest and widest leaf size was observed while, when narrow intra-row spacing adopted shortest and reduced leaf size per plant was observed. The longest (18.19 cm) and wider (9.749 cm) leaf was recorded by variety Madiira2 with wider intra-row spacing of 35 cm, whereas the shortest (5.67 cm) and narrowest intra-row spacing (4.91 cm) leaf was recorded by variety UG-AM-13 planted at intra-row spacing of 15 cm (Table 5). This study indicated that at wider intra-row spacing might be provided with more free space and encouraged leaves to have increased leaf size (length and width) development. The results from this study corresponded with the work of (Majumder, 2007) who reported that different plant spacing resulted in significant differences on leaf length, emphasizing that the longest leaves were observed from wider spacing (30 cm x 30 cm) compared to narrow spacing (30 cm x 10 cm).

3.1.6. Stem diameter (cm)

Different varieties and intra-row spacing showed significant ($P<0.05$) differences on stem diameter. Thicker stem diameter was observed with an intermediate intra-row spacing (25 cm) for UG-AM-68, Madiira1, Madiira2 and AH-NL-Sel varieties while for UG-AM-13 and TZSMN102-Sel higher values were observed at wider intra-row spacing (35 cm) (Table 5). Increasing intra-row spacing from 15 to 35 cm for UG-AM-13 and TZSMN102-Sel increased stem thickness from 1.86 cm – 1.94 cm and 1.27 cm – 1.91 cm, respectively. In this study, higher value for stem diameter (2.79 cm) was recorded with amaranth variety Madiira2 and Madiira1 at intra-row spacing of 25 cm. The lowest value for stem diameter (1.27 cm) was registered with TZSMN102-Sel at 15 cm intra-row spacing (Table 5). There might be genetic difference among amaranth varieties evaluated in response to intra-row spacing. These findings corroborated with the work of previous results of (Guillen-Portal *et al*., 1999; Pourfarid *et al*., 2014) pointed out the lower plant densities had stronger stems and vice versa.

Table 2: Interaction effect of intra-row spacing (cm) and variety on leaf length per plant (cm), leaf width per plant (cm) and stem diameter per plant (cm) performance under Jimma.

Intra row spacing (cm)	Variety	Leaf width per plant (cm)	Leaf Length per plant (cm)	Stem diameter (cm)
15	UG-AM-13	4.91^{ef}	5.67^{g}	1.85^{ef}
	UG-AM-68	5.34^{de}	6.33^{g}	1.60^{fg}
	TZMN102-Sel	7.70^{c}	12.69^{d}	1.26^{h}
	AH-NL-Sel	$8.20b^{c}$	15.44^{bc}	1.46^{gh}
	Madiira1	4.16^{g}	15.23^{bc}	1.92^{cdef}
	Madiria2	8.27^{bc}	14.00^{cd}	2.01^{cde}
25	UG-AM-13	5.28^{de}	7.22^{fg}	1.88^{def}
	UG-AM-68	5.60^{de}	8.27^{ef}	2.00^{cde}
	TZMN102-Sel	8.49^{b}	15.41^{bc}	1.68^{efg}
	AH-NL-Sel	8.56^{b}	16.63^{ab}	1.88^{def}
	Madiira1	4.34^{fg}	16.27^{b}	2.27^{bc}
	Madiira2	8.70^{b}	16.54^{b}	2.79^{a}
35	UG-AM-13	5.98^{d}	8.47^{ef}	1.94^{cdef}
	UG-AM-68	5.77^{d}	9.00^{e}	1.86^{def}
	TZMN102-Sel	8.64^{b}	15.84^{b}	1.91^{cdef}
	AH-NL-Sel	9.54^{a}	16.39^{b}	1.80^{efg}
	Madiira1	4.24^{fg}	16.65^{ab}	2.23^{bcd}
	Madiira2	9.74^{a}	18.19^{a}	2.43^{ab}
Means		6.86	13.013	1.935
LSD (5%)		0.38	0.84	0.19
CV (%)		3.30	3.90	6.20

Means in columns followed by the same latter (s) are not significantly different using LSD at $P = 0.05$ level of significance

3.1.7. Leaf area (cm^2) and Leaf area index

As it is observed in (Table 6), maximum leaf area (113.42 cm^2) was recorded with amaranth variety Madiira2 at intra-row spacing of 35 cm, whereas the lowest leaf area (17.85 cm^2) was recorded by UG-AM-13 with intra-row spacing of 15 cm which was statistically similar with UG-AM-68 with intra-row spacing of 15 cm (21.70 cm^2). In this study the highest leaf area was recorded from the widest intra-row spacing compared to narrow spacing. Correspondingly, the finding of this study was similar to the result of (Yarnia *et al*., 2010) revealed that increasing plant density decreased leaf area. In addition to influences of intra spacing levels variation in performance was observed among the evaluated amaranth varieties probably because of genetic difference. In a like manner Srivastava (2015) revealed that genetic difference between amaranth varieties also influenced leaf area per plant.

Maximum leaf area index (21.22) was recorded by amaranth variety Madiira2 at intra-row spacing of 25 cm while when UG-AM-68 was planted at 35 cm intra-row spacing minimum leaf area index (3.05) was recorded indicating differential varietal response (Table 6).The three varieties namely UG-AM-13, TZMN102-Sel, AH-NL-Sel, Madiira1 recorded the highest leaf area from the narrower spacing 15 cm (high crop density). This study was in line with that of (Shafi *et al*., 2012) who reported similar effect of planting density on the growth and yield of maize varieties explaining that increasing planting density to optimum level increased the leaf area index.

Table 3: Interaction effect of intra-row spacing (cm) and variety on the performance of leaf area per plant (cm^2) and leaf area index (LAI) under Jimma.

Intra-row spacing (cm)	Variety	leaf area per plant (cm^2)	leaf area index
15	UG-AM-13	17.85^{k}	3.57^{hi}
	UG-AM-68	21.70j^{k}	4.85^{ghi}
	TZMN102-Sel	62.56^{f}	10.28^{cde}
	AH-NL-Sel	81.10^{de}	10.77^{cd}
	Madira1	40.55^{gh}	18.57^{b}
	Madira2	74.18^{e}	18.57^{b}
25	UG-AM-13	24.43^{ijk}	5.16^{ghi}
	UG-AM-68	29.63^{ij}	3.68^{hi}
	TZMN102-Sel	83.76^{cde}	9.24^{de}
	AH-NL-Sel	91.17^{bcd}	8.26^{ef}
	Madira1	45.19^{g}	9.96^{cde}
	Madira2	92.09^{bc}	21.22^{a}
35	UG-AM-13	32.44^{h}	3.41^{hi}
	UG-AM-68	33.28^{hi}	3.04^{i}
	TZMN102-Sel	87.61^{cd}	5.59^{gh}
	AH-NL-Sel	100.28^{b}	8.12^{ef}
	Madiira1	45.23^{g}	6.28^{fg}
	Madiira2	113.42^{a}	18.35^{b}
Means		59.81	9.03
LSD (5%)		5.57	1.29
CV (%)		5.60	8.60

Means in columns followed by the same latter (s) are not significantly different using LSD at $P = 0.05$ level of significance

3. 2. Yield Variables

3.2.1. Leaf yield per plant (g)

Leaf yield per plant was significant (*P<0.05*) influenced by varieties and intra-row spacing (Table 7). Maximum leaf yield per plant (300.00 g) was recorded by Madiira2 variety with intra-row spacing of 35 cm, whereas, minimum leaf yield per plant was recorded by UG-AM-13 (53.10 g) with combination of intra-row spacing of 15 cm (Table 7). From this study, it was observed that variation among the amaranth varieties noted as genetic variability. This study showed leaf yield per plant increased when amaranth varieties arranged from the narrowest intra-row spacing (15 cm) to the widest intra-row spacing (35 cm). In addition to influence of intra-row spacing, genetic variation of amaranth varieties potential to produce leaf yield per plant were observed. For instances, UG-AM-13 variety leaf yield per crop recorded (53.10 g- 66.20 g), UG-AM-68(54.00-58.50 g), AH-NL-Sel (124.80 -184.80 g), Madiira1 (138.10 g- 253.00 g) and Madiira2 (164.70 g-300.00 g) at 15 cm and 35 cm, respectively. This result is in conformity with that of (Mbwambo *et al*., 2015) who revealed that leaf yield per plant was highly affected by genetic variation among the amaranths varieties. Maximum leaf yield was observed when amaranth varieties arranged in order of 35 cm intra- row spacing because, it provides enough spacing that ability to produce more branches per plant and number of leaves per plant.

However when amaranth varieties arrange in order 15 cm intra-row spacing , due to intra competition for nutrients absorbance and solar radiation plant provides available resources for growth of height rather growth of others parts such as branches, leaf and etc. Due to the fact this probably the number of leaves per plant and branch per plant was reduced leaf yield per pant was consequently reduced at narrowest intra-row spacing. This study is also in agreement with previous finding of (Majumder, 2007) who revealed that the maximum fresh leaves yield per plant was recorded from wider spacing than narrow intra-row spacing.

3.2.2. Leaf yield per hectare (t)

Leaf yield per hectare showed significant (*P<0.05*) difference among amaranth varieties in response to intra-row spacing (Table 7). Maximum leaf yield per hectare (18.29 t ha^{-1}) was recorded by amaranth variety Madiira 2 planted at intra-row spacing of 15 cm, whereas the least leaf yield per hectare (2.67 t ha^{-1}) was observed by UG-AM-68 with wider intra-row spacing of 35 cm (Table 7). The results of this study corresponded with the findings of (Miah, 2013) on different intra-row spacing levels that the leaf yield per hectare was decreased at wider spacing in contrast with increased leaf yields per hectare at closet spacing. The possible reason was that closest plant spacing could accommodate more number of plants per hectare.

3.2.3. Biological yield dry weight per plant (g)

Influence of intra-row spacing and variety on biological yield dry weight per plant was significant (*P<0.05*) (Table 7). In this study the maximum biological yield dry weight was obtained from wider intra-row spacing while the least biological yield dry weight was recorded from closest intra-row spacing . In a like manner the highest biological yield dry weight (152.38 g and 127.71 g) were registered by Madiira2 and Madiira1 with wider intra-row spacing (35 cm). Following this optimum figures of 102.78 g, 98.97 g 92.05 g and 91.33 g were registered for Madiira 1 and Madiira 2 with 25 cm, and AH-NL-Sel and TZMN102-Sel with intra-row spacing of 35 cm, respectively (Table 7). Lowest biological yield dry weight in the range of 36.03 g to 48.60 g was recorded by UG-AM-68, TZMN102-Sel, AH-NL-Sel and UG-AM-13 with a narrow intra-row spacing of 15 cm (Table 7). In the present result, biological yield dry weight per plant of amaranth varieties were increased across increased from narrower intra-row spacing (15 cm) to wider intra-row spacing (35). In this result when crop arranged in order of with 35 cm intra-row spacing the crop obtains chance to produce more biological yields such as leaves per plant, robust stem, primary and secondary branches, whereas reduction of branches, leaves and stem were recorded from 15 cm intra-row spacing .

Findings of the present study were agreed with the previous research results of (Pourfarid *et al*., 2014) who indicated that increasing plant density per square meter increased above ground dry weight of plants per square meter but with decreasing dry biomass per plant as a result of stem became thinner. This also is in line with the (Yarnia *et al*., 2010)finding who reported that reduction of dry matter of organs significantly reduced per plant at high crop density because of probable reduction in the biomass components as result of reduction of net assimilate accumulation in plant leaves, plant height and number of lateral branches.

Table 7: Interaction effect of intra-row spacing (cm) and variety on Leaf yield per plant (g), Leaf yield per hectare (t) and Biological yield dry weight per plant (g) under Jimma.

Intra-row spacing (cm)	Variety	leaf yield per plant (g)	Leaf yield per hectare (t)	Biological yield dry weight per plant (g)
15	UG-AM-13	53.10^{i}	5.89^{h}	48.6^{ijk}
	UG-AM-68	54.00^{i}	6.27^{h}	36.03^{k}
	TZMN102-Sel	110.90^{h}	12.32^{de}	45.11j^{k}
	AH-NL-Sel	124.80^{gh}	13.86^{bcd}	45.29^{jk}
	Madiira1	138.10^{fg}	15.34^{b}	85.05^{def}
	Madiira2	164.70^{de}	18.29^{a}	60.62^{ghij}
25	UG-AM-13	63.60^{i}	4.23^{i}	55.7^{hij}
	UG-AM-68	57.90^{i}	3.85^{i}	69.5^{fgh}
	TZMN102-Sel	155.20^{ef}	10.34^{f}	71.44^{fgh}
	AH-NL-Sel	154.20^{de}	9.72^{f}	75.78^{efg}
	Madiira1	199.70^{c}	13.31^{cde}	102.78^{c}
	Madiira2	268.60^{b}	17.90^{a}	98.97^{cd}
35	UG-AM-13	66.20^{i}	3.15^{i}	63.53^{ghi}
	UG-AM-68	58.50^{i}	2.66^{i}	65.5^{gh}
	TZMN102-Sel	151.20^{ef}	7.19^{gh}	91.33^{cde}
	AH-NL-Sel	184.80^{cd}	8.80^{fg}	92.05^{cde}
	Madiira1	253.00^{b}	12.04^{cde}	127.71^{b}
	Madiira2	300.00^{a}	14.28^{bc}	152.38^{a}
Means		142.12	9.974	77.1
LSD (5%)		11.28	0.36	8.89
CV (%)		4.8	5.3	7

Means in columns followed by the same latter (s) are not significantly different using LSD at $P = 0.05$ level of significance

3.2.4. Grain yield per plant (g)

Grain yield per plant was highly significantly ($P<0.05$) influenced by variety and intra-row spacing. In this research, the highest grain yield per plant was obtained with wider intra-row spacing than narrower intra-row spacing . The highest grain yield per plant (34.22 g and 32.9 g) was registered by amaranth varieties TZMN102-Sel and AH-NL-Sel, respectively planted at intra-row spacing of 35 cm, whereas the lowest grain yield per plant (4.4 g) and 4.6 g) recorded by Madiira 2 and Madiira 1 in the same order planted at an intra-row spacing of 15 cm (Table 8). In this finding, it was observed that capacity of the varieties to produce grain increased from narrower intra-row spacing to wider intra-row spacing. The probable reason might be that at a narrow intra-row spacing photosynthetic capability of plants might be reduced due to the low light interception by the plants as a result of shading effects because of plant crowding at closer spacing that negatively affected number of inflorescence per plant. The present study result was in agreement with the finding of (Pourfarid *et al*., 2014) reported increasing plant density per meter square increase yield per meter square but decrease yield per plant.

Similar to our findings (Brienand *et al*., 2008) also reported those at low planting density (wider intra-row spacing) attained larger yields and vice versa Even though there was interaction of varieties and intra-row spacing was observed, but genetic variation potential to produce grain yield per plant was recorded among amaranth varieties. For instance from variety UG-AM-13 (8.60 g -12.58 g), UG-AM-68 (6.80 g-12.67 g), TZMN102-Sel (16.22 g- 34.22 g), AH-NL-Sel (16.22 g -32.9 g), Madiira1 (4.60 -10.50 g) and Madiira-2 (4.60-8.67 g) are obtained. Similar finding was reported by Mbwambo *et al*. (2015) the variation of grain yield of amaranth species were due to genetic makeup and growth environments.

3.2.5. Grain yield per hectare (kg ha^{-1})

There was significant ($p<0.05$) difference in grain yield per hectare among amaranth varieties in response to intra-row spacing. In this experiment the highest grain yield per hectare (1802 kg ha^{-1} and 1786 kg ha^{-1}) was observed by TZSMN102-Sel and AH-NL-Sel, varieties respectively with a narrow intra-row spacing (15cm) possibly because of increased number of plants accommodated under closest intra-row spacing arrangements, whereas, the lowest grain yield per hectare (413 kg ha^{-1}) was recorded from Madiira2 with combination of 35 cm intra-row spacing (Table 8). This finding is in line with previous research result of (Apaza-Gutierrez, 2002)

who asserted that increasing plant density to a certain extent would proportionally increase grain yield. In another study (Oduwaye *et al*., 2016) also reported grain yield increased per hectare linearly within the range of densities increase.

3.2.6. Thousand Seeds weight (g)

Interaction effect of varieties and intra-row spacing on significant ($P<0.05$) influence on thousand seed weight (Table 8). In this experiment the highest value for thousand seeds weight (0.97 g) was observed in amaranth variety TZSMN102-Sel with a intra-row spacing of 35 cm, whereas the lowest value for thousand seeds weight (0.17 g) was recorded inMadiira2 with a narrow intra-row spacing of 15 cm (Table 8). Thousand seeds weight was influenced by intra-row spacing probably when varieties arranged under intra-row spacing 15 cm because in this intra-row spacing there was high competition among plants for resources such as nutrients in the soil and solar radiation above the ground which might be cause result of imbalance between sources and sink relationship. Correspondingly (Pourfarid *et al*., 2014)] ascribed that increasing plant population decreased thousand seeds weight.

Table 8: Interaction effect of intra-row spacing (cm) Grain yield per plant (g), Grain yield per hectare (kg) and 1000 seeds weight (g) under Jimma.

Intra row spacing (cm)	Variety	Grain yield per plant (g)	Grain yield per hectare (kg)	1000 seeds weight (g)
15	UG-AM-13	8.6^{gh}	956^{c}	0.65^{d}
	UG-AM-68	6.8^{hi}	756^{d}	0.78^{c}
	TZMN102-Sel	16.22^{de}	1802^{a}	0.88^{abc}
	AH-NL-Sel	16.07^{e}	1786^{a}	0.86^{abc}
	Madiira 1	4.6^{i}	511^{e}	0.300^{ef}
	Madiira 2	4.4^{i}	489^{e}	0.16^{g}
25	UG-AM-13	18.9^{cd}	839^{cd}	0.77^{c}
	UG-AM-68	19.23^{c}	844^{cd}	0.80^{c}
	TZMN102-Sel	26.35^{b}	1757^{ab}	0.93^{ab}
	AH-NL-Sel	25.93^{b}	1728^{ab}	0.89^{abc}
	Madiira 1	7.05^{hi}	470^{e}	0.38^{e}
	Madiira 2	6.75^{hi}	450^{e}	0.20^{fg}
35	UG-AM-13	12.58^{f}	900^{cd}	0.86^{abc}
	UG-AM-68	12.67^{f}	916^{cd}	0.83^{bc}
	TZMN102-Sel	34.22^{a}	1629^{ab}	0.96^{a}
	AH-NL-Sel	32.9^{a}	1567^{b}	0.93^{ab}
	Madiira 1	10.5^{fg}	500^{e}	0.63^{d}
	Madiira 2	8.67^{gh}	413^{e}	0.28^{efg}
Means		15.14	1017.36	0.67
LSD%5		1.48	105.78	0.06
CV (%)		5.90	6.30	6.00

Means in columns followed by the same latter (s) are not significantly different using LSD at *P* = 0.05 level of significance

3.3. Correlation Analysis

Pearson correlation coefficient analysis results showed in the (Table 9) that leaf yield per hectare had strong positive and significant correlation with number of branches per plant (r = 0.76**), leaf yield per plant (r=0.73**) leaf area (0.55**), leaf area index (r = 0.89**) and biological yield dry weight per plant (0.56**). However, there was negative and significant correlation between thousand seeds weight and leaf yield per hectare (r = -0.69**). There was positive and significant correlation (r=0.71**) leaf yield and leaf area as well as there is positive and significant (r=0.58**) between grain yield and leaf area. This work agreed with Srivastava (2015) who reported that grain and fresh weight were positively correlated with leaf area.

Grain yield per hectare was negatively and significant correlated with number of leaves per plant (r = -0.72**), days to 50 % flowering (r = - 0.89), days to maturity (r = -0.89). This may be because amaranth varieties have had high number of leaves per plant and produce low grain yield. This is probably because of genetic differences among amaranths varieties observed low photo assimilation to grain parts in this crop. This work was in agreement with previous findings of (Mbwambo *et al*., 2015). Oduwaye *et al*. (2016) who showed that grain yield per plant was negatively correlated with the number of leaves per plant. Grain yield per plant was positively and significantly correlated thousand seeds weight (r = 0.60**). This association was in line with the finding (Wnuk *et al*., 2013) who reported that in such association the crop showed that there was high source net exporters of photo assimilate to sink tissues an importer of photo assimilates parts. On other hand, low sink demand can lead to assimilate accumulation in source leaves rather than sink in the grain. Such relation is very important for selection of amaranths crop for grain and leaf purpose (Wnuk *et al*., 2013)

Table 9: Pearson correlation coefficients analysis results of Yield and Yield component variables

Traits	DTF	DTM	PH	NLP	NBP	LL	LW	LA	LAI	SD	LYP	LYha^{-1}	BYDWP	GYP	GYha^{-1}	TSwt
DTF	1	0.98**	0.19	0.76**	0.45**	-0.23	-0.41**	-0.35	0.28	0.64**	0.15	0.14	0.46**	-0.90**	-0.96**	-0.75**
DTM		1	0.21	0.76**	0.52**	-0.12	-0.323	-0.25	0.38*	0.67**	0.24	0.24*	0.52**	-0.86**	-0.92**	-0.80**
PH			1	0.4**	0.55**	0.44**	-0.04**	-0.09	0.2	0.2	0.4**	0.5**	0.56**	-0.22	-0.21	-0.46**
NLP				1	0.69**	0.15**	-0.27	-0.07	0.44**	0.75**	0.50**	0.33	0.71**	-0.65**	-0.72**	-0.65**
NBP					1	0.73**	0.17	0.48**	0.77**	0.72**	0.87**	0.76**	0.91**	-0.23	-0.30*	-0.80**
LL						1	0.52**	0.82**	0.63**	0.33*	0.86**	0.72**	0.67**	0.4**	0.37	-0.31
LW							1	0.51**	0.01	-0.41**	0.42**	0.32	0.06	0.61**	0.06	0.59**
LA								1	0.64**	0.2	0.55**	0.55**	0.39**	0.58**	0.54**	-0.13
LAI									1	0.47**	0.72**	0.89**	0.58**	-0.11	-0.05	-0.74**
SD										1	0.63**	0.32	0.73**	-0.39**	-0.56**	-0.68**
LYP											1	0.73**	0.88**	0.07	-0.01	0.07
LYha^{-1}												1	0.58**	-0.05	0.05	-0.05
BYDWP													1	-0.01	-0.35**	-0.69**
GYP														1	0.91**	0.60**
GYha.$^{-1}$															1	0.62**
TSwt																1

Note Days to %50 flowering (DTF),Days to maturity (DTM);plant height (PH) , Number of leaf per plant (NLP); Number of branch per plant (NBP), Leaf Length (LL), Leaf width (LW) ; Leaf area (LA) ;Leaf area index (LAI) , Stem diameter (SD); Leaf yield per plant (LYP) ; Leaf yield per hectare(LYha^{-1}); Biological yield dry weight per plant (BYDWP) Grain yield per plant (GYP), Grain Yield per ha^{-1} (GYha^{-1}), 1000 seeds weight (TSwt) Those of ** and * is level of significant, those are no any sign the head is Non-significant for both negative and positive correlation

CONFLICT OF INTEREST

The authors are no declared any conflict of interest.

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