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Growth and Yield Performance of Anchote [*Coccinia abyssinica* (Lam.) Cogn.] in Response to Contrasting Environment

[1]Daba Mengesha, [2]Derbew Belew, [2]Wosene Gebreselassie and [2]Waktole Sori
[1]Oromia Educational Bureau, East Wollega Zone, Ebantu Woreda, P.O. Box 281, Nekemte, Ethiopia
[2]Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 307, Jimma, Ethiopia

Abstract: Among the major root and tuber crops, anchote is a potential crop produced in West Wollega zone of Ethiopia. It serves as a food, cultural, social and economical crop for the farming communities. Due to the lower attention given to the research and development of anchote, there is no variety so far developed and released. Ten promising anchote accessions were tested at Jimma and Ebantu from June 2010 until October 2010 to determine agronomic performance of the accessions. The experimental design was a randomized complete block design with three replications. The results indicated that yield and yield components were significantly ($p<0.05$) higher for the majority of the accessions under Ebantu than Jimma condition. The highest total biomass, 19.13 kg per 4 m^2 plot, was obtained at Ebantu from accession 223098 while the maximum total biomass at Jimma was only 11.69 kg per 4 m^2 plot that was obtained from accession 223087. Almost all accessions took longer average time (128 days) to reach 90% maturity under Ebantu condition than Jimma which took 109 days on average. The maximum storage root yield (76.45 t ha^{-1}) was observed for an accession No. 223098, under Ebantu condition, while, the lowest yield was obtained from accession No. 240407 (51.54 t ha^{-1}) under Jimma condition. The highest mean dry matter (30%) was obtained under Ebantu condition for almost all accessions. On the other hand, the lowest mean dry matter (20%) was obtained under Jimma condition. From this study the six accessions 223109, 223087, 223098, 223096, 90802 and 229702 produced better storage root yield, high dry matter content, high biological yield across the two environments indicating a good performance and adaptation. Therefore, these accessions are suggested to farmers in areas of Jimma, Ebantu and with other areas of similar agro-ecological zones.

Key words: *Coccinia abyssinica*, adaptation, contrasting environment, yield performance

INTRODUCTION

Anchote [*Coccinia abyssinica* (Lam.) Cogn.] is an annual trailing vine belonging to the cucurbitaceous family best known and grown principally for its tuberous root even though its tender leaves are also widely used as food. Among the major root and tuber crops anchote is a potential crop produced on nearly 3000 ha of land in West Wollega zone with a yield about 25,000 tonnes (Anonymous, 2011) and it is used as food, cultural, social and economical crop for the farming communities. The genus *Coccinia* is made up of 30 spp. of which eight are reported to occur in Ethiopia. The species recorded in flora of Ethiopia since 1995 include *C. abyssinica* (Lam.) Cogn., *C. adoensis* (Hochst. Ex. A. Rich.) Cogn.), *C. grandis* (L.) Voigh (Syn. *C. indica* wight and Arn.), C. *megarhiza*, C. Jeffrey and *C. schliebenii* Harms. The remaining three species have not yet been described (Abera *et al*., 1995).

Anchote is cultivated in areas between 1300-2800 m above sea level where the annual rainfall ranged between 762-1016 mm (Amare, 1973). Ethiopia has 18 agro-ecological zones which are endowed with suitable climatic and edaphically conditions for quality and quantity production of various kinds of root and tuber crops (EIAR, 2008). The majority of the Ethiopian population depends mainly on cereal crops as food source. The food potential of root and tuber crops has not yet been fully exploited and utilized despite their significant contributions towards food security, income generation, provision of food energy and resource base conservation (EIAR, 2008). The low agricultural productivity, recurrent drought and socio-political factors have greatly contributed to critical food shortages in Ethiopia coupled with over-dependence on few cereal crops; thus, integration of root and tuber crops into the food system of the people should be given a serious attention. Due to the lower attention given to the research and development

Corresponding Author: Wosene Gebreselassie, Jimma University College of Agriculture and Veterinary Medicine, P.O. Box 307, Jimma, Ethiopia

of anchote, there is no variety so far developed and released. There are traditional selection practices being followed by farmers to have anchote types of desirable qualities, such as larger tuber size (Desta, 2011). According to a report (Abera *et al*., 1995), women usually do the selection and maintenance of good quality anchote root and discard of the undesirable ones. Farmers have their own experience by which they maintain seeds for the next planting. Among the quality attributes the farmers take in to account are cooking quality, durable quality and time taken for tuber formation. Beyond the traditional experience, there is no scientific research done on the selection of more yielder and better adaptive varieties of this crop. Thus, the study was conducted with the objectives of determining the agronomic performance of different anchote accessions and to assess the influence of growing environment on the performance of the accessions.

MATERIALS AND METHODS

Description of the study area: The trial was conducted at two locations namely Jimma (Jimma University College of Agriculture and Veterinary Medicine) and East Wollega Zone (Ebantu district, Adami Kebele). Jimma is located in south-west part of Ethiopia, at 356 km southwest from Addis Ababa. The study area is located at approximate geographic coordinates of latitude 06°36' N and longitude of 37°12' E at an altitude of 1710 m above sea level. It receives an annual average rainfall of 1600 mm and has mean minimum and maximum temperatures of 11.8 and 28°C, respectively. The major soil types that represent the study area are black (koticha) to red soils; chromic nitosol; combiosl bottomland. The soil is clay loam in texture (Kidanu *et al*., 2010). Ebantu district is found in East Wollega Zone. It is located in western central part of Ethiopia at approximately 483 km west of Addis Ababa. It has latitude and longitude of 9°5'N and 36°33'E, respectively. It has an altitude of 2100 m above sea level. Receiving an annual average rainfall of 1244 mm and has mean minimum, maximum and average air temperatures 14.1, 27.9 and 20.6°C, respectively. The major soil types representing the study area are black to red sandy soils and loam sandy soil in texture (Anonymous, 2009).

Materials used in the experiment: Ten promising anchote accessions (all in the genus *Coccina* and species *abyssinica*) namely: Kuwe, 90801, 90802, 223087, 223096, 223098, 223109, 223101, 229702 and 240407 were taken from Debre Zeit Agricultural Research Center (DZARC) which were collected from different anchote growing area of the country (Table 1) and planted at the two locations. Seeds were used as planting material for all accessions.

Experimental design: The experimental design was a randomized complete block design with three replications. The plot size was fixed at two meter long and two meter width and each plot was having five rows with 10 plants each and with row spacing of 40 cm. Between plant spacing was 20 cm and the plots were 0.6 m apart from each other and one meter between replications. The total number of plots was thirty. In the designed plots three seeds per hill were sown. Seeds were planted on well prepared five rows per beds at 5 cm depth in the soil. Sowing was done on 1st June, 2010 for both locations. In the trial, organic fertilizer (FYM) was applied before one month of sowing date in all the plots by broad casting similarly (five t ha^{-1} FYM at Ebantu and six t ha^{-1} FYM at Jimma) as recommended at Bako Agricultural Research Center. Seeds were planted directly on the beds. Weeds were removed manually. Harvesting was done on 3rd October and 19th October 2010 for Jimma and Ebantu, respectively when more than 90% of the plants in a plot showed physiological maturity (at >90% leaves senescence). The necessary agronomic practices such as planting, fertilizer rate, weeding and harvesting were implemented according to recommendations set for anchote (Bako Agricultural Research Center, 2004; Desta, 2011). According to a study, the ideal organic fertilizer rate for better yield of anchote is five t ha^{-1} on sandy loam soil and six t ha^{-1} on red soil (chromic nitosol) and the same recommended amount was used in this experiment before one month of planting and after two months of planting when root development started (Girma and Gudeta, 2007). Quantitative variables were recorded on 15 randomly selected plants from the three middle rows of the five rows per bed of each accession. International Plant Genetic Resources Institute descriptor list for sweet potato (Huaman, 2002) and for cucurbit species (ECPGR, 2008) were adopted with some modifications to suit with the crop performance to record the quantitative variables.

Growth variables

Emergence percentage (EP): The emergence percentage was calculated after 20 days of sowing by counting numbers of seeds that emerged from each plot and dividing by the total sown and then plots average was taken.

Vine numbers (VN): Number of vines per single hill was counted after the maturity of the plant or at four months of sowing, from sampled plants of each of the 15 randomly taken plants on each plot and then average was worked out.

Vine length (VL): Vine length was measured after the maturity of the plant or at four months of sowing in meters from base to tip of the plant by randomly taking 15 plants from each plot and then average was worked out.

Vine internodes length (VIL): Vine internodes' length was measured after the maturity of the plant or at four months of sowing in centimeter by taking the representative part or the middle portion of vines from 15 sampled plants.

Number of leaves (NoL): The total number of leaves was counted three times on two months, three months and four months of sowing from 15 randomly selected sampled plants and then the samples average was calculated.

Leaf area (LA): Leaf area was recorded by measuring the length into width. i.e., Leaf area (cm^2) = Leaf length (cm) x leaf width (cm). Leaf area was measured from the middle parts of the plant by selecting 15 leaves at random from each plot and then average was done at full maturity stage from 15 sampled plants.

Total biomass (TBM): Was obtained by measuring the total above and below ground biological yield in kg from each plot at harvest.

Yield variables: Yield data were obtained by harvesting 15 plants from the three middle rows of each plot. Total root yield was then converted to mean root yield per hectare (t ha^{-1}). The marketable tubers consisted of large clean roots (>55 mm in diameter) and medium roots were 15-55 mm, while the unmarketable portion portion consisted of small roots (<15 mm diameter) like sweet potato (Holland *et al*., 2003).

Number of storage roots (NR): The average numbers of storage roots per single hill was determined by counting from sample plants of each of the 15 randomly taken plants on each plot and then the average was worked out (The clustered number of storage roots per plant was counted).

Storage root diameter (SRD): The diameter of roots was measured at the middle of root in millimeter from 15 randomly selected sample storage roots and then the average was taken from each plot.

Total storage root weight (TRW): The clustered number of storage roots per plant was counted randomly to obtain 15 sample storage roots and the same was measured using a sensitive balance (BP 1600-S) in kilogram (kg) and the average was recorded.

Marketable storage root yield (MRY): MRY was measured in kilogram from the total of yield, which was not affected by disease, not over sized, not under sized and not damaged storage roots from each plot.

Unmarketable storage root yields (UMRY): That measured in kilogram from the total storage root yield that affected, damaged, under or over sized storage root from each plot.

Total storage root yield (TRY): The total root yield measured in tonnes per hectare from the sampled plants to the overall plots.

Data analysis: Raw data were subjected to analysis for RCBD. The statistical analysis was done using SAS statistical package (SAS, 2002) version 9.2. Mean separation was done using Least Significant Difference (LSD) at 5% significance level.

Table 1: Ecological description of ten anchote accessions used for the experiment

Accession no.	Region	Zone	District	Altitude (m.a.s.l.)
90801	Oromia	Horo Guduru Wollega	Abay Chomen	1400
90802	Oromia	Horo Guduru Wollega	Abay Chomen	1400
223087	Oromia	West Wollega		1400
223096	Oromia	East Wollega	Guto Wayu	1909
223098	Oromia	East Wollega	Guto Wayu	1909
223101	Oromia	East Wollega	Jimma Arjo	2470
223109	Oromia	Ilu Ababor	Ale	1940
229702	Amhara	Misirak Gojam	Hulet Iju Enese	2400
240407	SNNPR	Keficho Shekicho	Decha	1820
Kuwe	Oromia	East Wollega	Sibu Sire	1987

SNNPR: Southern Nations, Nationalities and People's region

RESULTS AND DISCUSSION

Growth variables

Emergence percentage and stand count: The emergence percentage of anchote accessions was significantly different ($p<0.05$) due to accessions and environments. The mean emergence percentage ranged from 95 to 42% (Table 2). Maximum mean emergence percentage 95% was obtained from accession No. 229702, followed by accession No. 223109 (87%). However, the latter was not significantly different from accession No.223101 (86%) at Jimma condition. Minimum mean emergence percentage was observed in accession No.223087 (42%) at Ebantu condition. Similarly, the other accessions Kuwe, 90802, 223098, 223109, 223101 were emerged above the overall average (75%) of both locations. However, emergence percentage of accessions No. 90801, 223087 and 223096 was below the overall average of both locations. These results are in conformity with a study which reported existence of variation in emergence percentage of yam genotypes. The author also reported that emergence percentage of genotypes varied depending on the environmental condition (soil temperature) (Zanklan, 2003).

In this study, earlier emergence of anchote seeds was observed under Jimma condition compared to that of Ebantu. Such difference might be due to variation of the two locations in terms of average temperature among other factors. Jimma condition had comparatively higher mean average temperature (18.8°C) as compared to that of Ebantu (16.8°C). After emergence, the number of seedlings was not affected by location; as a result almost all seedlings survived in both locations. As a result the stand count at emergence was statistically similar with the emergence percentage of the same accession among all the accessions (Table 2). This shows that anchote seedling can adapt in different environmental conditions after germination and have the capacity to tolerate different environmental conditions after emergence.

Vine number, vine internodes length and vine length per plant: Significant differences ($p<0.05$) were observed among the accessions, in terms of vine number due to accessions and environments. The highest average vine number (3.06) was observed in accession No. 223109, which was on par with accession No. 223101 (3.03), 223098 (2.94) and 223096 (2.93) under Ebantu condition. The lowest vine number (2.00) was recorded in accession No. 90801 also under Ebantu condition. Accessions 223087, 223096, 223098, 223109, 223101, 229702 and 240407 had above the overall mean vine number (2.46), predominantly under Jimma condition. However, accessions No. 90801, Kuwe and 90802 recorded below the overall average vine number (2.03, 2.06 and 2.15), respectively (Table 3). These results imply that the performance of anchote accessions varies with both accessions and environments.

In terms of vine length, accessions and environments have significant differences ($p<0.05$). The tallest vine (6.23 m) was produced by accession No. 223098, followed by accession No. 90802 (5.56 m). However, the latter was not significantly different from accession No. 223087 (5.33 m) under Ebantu condition. On the other hand, the smallest length (1.76 m) was recorded in accession No. 240407 also under Ebantu condition. The vine length had greater variation among the accessions under Ebantu condition than under Jimma condition this may be due to the interaction of accessions differently with the environment. Hence, the overall average vine length for both locations was (2.78 m); accession No. 90802, 223087, 223096, 223098, 223109, 223101 and 229702 were had vine length above the overall mean under the two locations. However, accession No. 90801, Kuwe and 240407

Table 2: Emergence percentage and stand count of anchote accessions as affected by locations

	Emergence (%)			Stand count (%)		
Accessions	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean
Kuwe	82.0^{d}	72.0^{e}	77.0	81.0^{d}	71.0^{def}	76.0
90801	74.0^{e}	62.0^{g}	68.0	73.0^{e}	62.0^{g}	68.0
90802	84.0^{c}	72.0^{e}	78.0	83.0^{c}	72.0^{de}	78.0
223087	61.0^{g}	42.0^{h}	51.0	60.0^{g}	51.0^{hi}	51.0
223096	68.0^{f}	52.0^{g}	60.0	67.0^{f}	51.0^{h}	59.0
223098	85.0^{c}	72.0^{e}	78.0	83.0^{c}	71.0^{eg}	77.0
223109	87.0^{b}	73.0^{e}	80.0	86.0^{b}	74.0^{e}	80.0
223101	86.0^{b}	74.0^{e}	80.0	86.0^{b}	74.0^{de}	80.0
229702	95.0^{a}	90.0^{b}	92.0	94.0^{a}	89.0^{b}	92.0
240407	85.0^{bc}	81.0^{d}	83.0	85.0^{b}	69.0^{d}	77.0
Mean	81.0	69.0	75.0	80.0	68.0	74.0
LSD (0.05)	0.023	0.03	0.01	0.02	0.03	0.02
CV(%)	0.930	2.66	1.87	0.93	2.66	2.0

Means with the same letter are not significantly different at $p = 0.05$

Table 3: Some growth variables of anchote accessions as affected by locations

	Vine number per plant			Vine length (m)			Vine internode length (cm)		
Accessions	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean
Kuwe	2.06^{f}	2.30^{d}	2.18	2.6^{gh}	2.91^{ef}	2.76	9.70^{b}	9.33^{b}	9.520
90801	2.03^{f}	2.00^{g}	2.01	2.68^{gh}	3.84^{c}	3.26^{d}	8.73^{d}	7.23^{fg}	7.980
90802	2.15^{ef}	2.20^{d}	2.17	3.24^{de}	5.56^{b}	4.40	7.76^{f}	7.50^{f}	7.630
223087	2.28^{de}	2.50^{c}	2.39	3.34^{d}	5.33^{b}	4.34	8.36^{e}	8.30^{e}	8.330
223096	2.45^{c}	2.93^{a}	2.69	3.1^{def}	4.40^{c}	3.76	9.56^{b}	9.27^{b}	9.420
223098	2.43^{cd}	2.94^{a}	2.68	3.27^{de}	6.23^{a}	4.75	9.76^{b}	9.41^{b}	9.590
223109	2.44^{cd}	3.06^{a}	2.75	2.9^{efg}	3.90^{c}	3.405	10.46^{a}	9.97^{b}	10.22
223101	2.37^{cd}	3.03^{a}	2.70	2.79^{ef}	3.0^{de}	2.90	8.63^{d}	8.17^{de}	8.400
229702	2.30^{cde}	2.73^{b}	2.52	3.03^{def}	4.14^{c}	3.59	8.96^{c}	8.60^{d}	8.780
240407	2.28^{de}	2.73^{b}	2.50	2.24^{h}	1.76^{i}	2.01	8.93^{c}	8.26^{de}	8.600
Mean	2.28	2.64	2.46	2.92	2.64	2.78	9.09	8.60	8.850
LSD (0.05)	0.71	0.19	0.12	0.52	0.57	0.52	0.24	0.57	0.280
CV (%)	4.36	4.09	4.16	5.29	8.05	7.92	1.52	3.65	2.680

Means with the same letter are not significantly different at p = 0.05

had the lowest vine length (2.68, 2.6 and 1.76 m), respectively under Jimma condition (Table 3).

Accessions and environments had significant differences (p<0.05) in vine internode length, the trend of which, was similar to that of vine length. The tallest vine internode length (10.46 cm) was produced by accession No. 223109, followed by accession No. 223098 (9.76 cm). However, the latter was not significantly different from accession No. 223096 (9.56 cm) under Jimma condition. On the other hand the smallest length (7.23 cm) was recorded in accession No. 90801 under Ebantu condition. However, it was not significantly different from accession No. 90802 (7.5 cm) (Table 3). The variability in internode length among accessions could be due to the genetic difference and or the environmental effects. According to (Gichimu *et al*., 2009), long and highly branching main vine directly translated to high fruit yields in cucurbits. This also occurred in anchote accessions having long main vines that are directly translated to internodes length. The variation in plant height could be due to genetic make-up of the varieties. Plant height may differ in varieties due to environmental conditions which in turn cause variation in hormonal balance and cell division rate (Chauhan *et al*., 2005).

All accessions developed one vine during emergence and later, after two months of planting, developed more number of vines on one main root. Thus, most of the accessions had about six vines per plant. This result is in accord with the findings (Gichimu *et al*., 2009) who stated water melon accession of Kenya had no main vine as all its vines were found to emerge from one point at the base of the plant, just above the soil surface. The difference in ground coverage could be due to the difference in genetic makeup of the accessions and perhaps due to temperature difference or solar radiation, Ebantu site is found on high altitude and the photosynthesis rate is high; this photosynthesis rate initiate or facilitate the growth rate of the plant. As a result the yield and all yield components of the plant were higher at Ebantu than at Jimma condition. The growth type of all accessions was found to be indeterminate with continually growing vine tips for more than four months. This concurs to the finding (Gichimu *et al*., 2009) who reported that cucurbits are very similar in above ground development but have high genetic diversity for fruit shape and other fruit characteristics. The growth type in runner plant species is due primarily to the genetic makeup of their character (Chauhan *et al*., 2005). The indeterminate growth nature in anchote is indeterminate as its family members, Cucurbitaceae.

Number of leaves and leaf area: The data obtained on number of leaves revealed that accessions and environments had significant differences (p<0.05) within the accessions and across the locations. The largest number of leaves (31.23) was produced by accession No. 223098, followed by accession No. 90802 (30.56). However, it was not statistically different from accessions No. 223087 (30.33) and 223096 (29.4) under Ebantu condition. Minimum leaf number (26.76) was produced by accession No. 240407 and it was statistically on par with accessions No. 90801 (27.68) and Kuwe (27.6) under Ebantu condition. The overall average number of leaves for both locations was (28.51); and accession No. 90802, 223087, 223096, 90801, 223098, 223109 and 229702 scored above the overall average under the two locations. However, accessions No. 240407, Kuwe and 223101 had lower leaf number than the overall average leaf number under both locations (Table 4). Ebantu site produced large number of leaves and more height of the vine, this may be

Table 4: Leaves per plant and leaf area of anchote accessions as affected by locations

	Number of leaves per plant			Leaf area (cm^2)		
Accessions	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean
Kuwe	27.60^{ef}	27.91^{f}	27.76	63.75^{ef}	65.72^{d}	64.74
90801	27.68^{ef}	28.84^{c}	28.26	64.25^{ef}	71.50^{c}	67.87
90802	28.2^{cd}	30.56^{b}	29.40	67.7^{cd}	82.29^{b}	75.02
223087	28.34^{c}	30.33^{b}	29.33	68.30^{c}	80.83^{b}	74.60
223096	28.1^{cd}	29.40^{b}	28.75	66.90^{cde}	75.00^{c}	70.96
223098	28.2^{cd}	31.23^{a}	29.70	67.90^{cd}	86.45^{a}	77.20
223109	27.9^{cd}	28.90^{c}	28.40	65.68^{cde}	71.87^{c}	68.78
223101	27.8^{de}	28.00^{d}	27.89	64.95^{ef}	66.25^{d}	65.60
229702	28.03^{cd}	29.14^{c}	28.58	66.5^{cde}	73.79^{c}	70.14
240407	27.25^{f}	26.76^{f}	27.01	61.54^{f}	58.54^{g}	60.04
Mean	27.92	29.11	28.51	65.77	73.22	69.50
LSD (0.05)	0.520	0.570	0.370	0.540	0.570	0.530
CV (%)	1.070	1.140	1.100	1.070	1.140	1.13

Means with the same letter are not significantly different at $p = 0.05$

due to the sandy loam soil suitability of the site than Jimma clay slit soil, which was a little less suitability in normal growing of the crop. In general, more numbers of accessions produced large number of leaves under Ebantu condition than Jimma condition. This may be due to soil difference and/or temperature. This shows that majority of the accessions responded more positively to Ebantu than Jimma conditions with regarded to growth. This is in agreement with a report mentioning a great variability in the performance of the accessions at different locations, illustrating a strong accession by environment effect (Ortiz *et al*., 2007).

The significant environment and accessions component of interaction indicated that wide differences between the environment and differential genotypic behaviours in the environments. However, the significant deviation from the overall mean revealed the importance of the interaction between accessions with environment. Significantly higher average leaf area was obtained under Ebantu condition (86.45 cm^2) from accession No. 223098. However, the low average leaf area (58.54 cm^2) was obtained under Jimma condition from accession No. 240407 (Table 4). This shows the presence of genetic variability among accessions evaluated and that the accessions interact with the environment resulting in differential genotypic response. This finding agrees with reports in yam (Belford *et al*., 2001) and in potato (Showemimo, 2007), that high yielding varieties tended to be upright with broad leaves than low yielding varieties as in case of this study. The variation in leaf area may also be attributed to variation in genetic make-up and adaptability of these accessions to different environmental conditions and this may be due to physiological process difference among the accessions. Similarly, it was explained (Ahmad *et al*., 2008) that the variation in leaf area and other parameters in different varieties at different locations may also be attributed to varying genetic make-up, soil and environmental adaptability.

According to the result from high yielding accessions, larger leaf area value was recorded; in accession number 223098 (86.45 cm^2 leaf area and 76.45 t ha^{-1} storage root yield), 90802 (82.29 cm^2 leaf area and 72.29 t ha^{-1} storage root yield) and 223087 (80.83 cm^2 leaf area and 70.83 t ha^{-1} storage root yield). Lower leaf area was scored in accession number 240407 (58.54 cm^2). The range of the leaf area among the accessions was between 58.54 cm^2 and 86.45 cm^2. According to a report (Lebot, 2009), an early development of the root system in root and tuber crops, occurs during the period of vine growth and leaf area acquisition and finally tuber development.

Total biomass: Significant differences were observed ($p<0.05$) among the accessions and environments with regard to total biomass. The highest weight (19.13 kg) was produced by accession No. 223098, followed by accession No. 90802 (18.16 kg) under Ebantu condition. On the other hand, the smallest weight (9.53 kg) was recorded in accession No. 240407 under Jimma condition. However, it was not statistically different from accessions No. 90801 (10.36 kg) and Kuwe (10.21 kg). The total biomass of anchote had greater variation among the accessions under Ebantu than under Jimma; this may be due to the growth response of accessions differently with the environments. Hence, the overall average of total biomass for both locations was (12.59 kg); accessions No. 90802, 223087, 223096, 223098, 223109 and 229702 scored total biomass greater than the overall average, the majority of which were under Ebantu condition. However, accessions No. 90801, Kuwe, 223101 and 240407 recorded

Table 5: Some yield variables of anchote accessions as affected by locations

	Total biomass (kg)			Storage roots number per plant			Storage root diameter (mm)		
Accessions	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean
Kuwe	10.21^{ij}	11.50^{g}	10.86	2.07^{f}	2.30^{f}	2.18	29.50^{gh}	32.5^{d}	31.0
90801	10.36^{ij}	13.35^{f}	11.86	2.03^{f}	2.00^{h}	2.01	30.20^{fgh}	40.5^{c}	35.3
90802	11.48^{gh}	18.17^{b}	14.83	2.15^{ef}	2.20^{f}	2.17	35.30^{de}	52.2^{ab}	43.8
223087	11.69^{g}	16.67^{c}	14.18	2.28^{de}	2.50^{c}	2.39	36.50^{d}	50.8^{b}	43.6
223096	11.22^{gh}	14.80^{d}	13.01	2.46^{c}	2.93^{a}	2.69	34.50^{def}	44.7^{c}	39.6
223098	11.55^{gh}	19.13^{a}	15.34	2.43^{cd}	2.94^{a}	2.68	35.70^{de}	55.0^{a}	45.8
223109	10.82^{ghi}	13.80^{ef}	12.31	2.44^{cd}	3.06^{a}	2.75	32.60^{def}	41.0^{c}	36.8
223101	10.59^{hi}	12.00^{g}	11.30	2.38^{cd}	3.03^{a}	2.71	31.50^{efg}	33.5^{d}	32.5
229702	11.08^{ghi}	14.34^{d}	12.72	2.31^{cde}	2.73^{b}	2.52	33.90^{def}	43.3^{c}	38.6
240407	9.59^{k}	9.53^{j}	9.52	2.28^{de}	2.73^{b}	2.50^{b}	25.50^{i}	18.8^{j}	22.1
Mean	10.85	14.33	12.59	2.28	2.80	2.48	32.58	41.3	36.9
LSD(0.05)	1.05	0.76	0.96	0.17	0.19	0.15	0.48	0.42	0.45
CV (%)	5.57	3.07	4.17	4.36	4.09	4.16	8.70	6.01	7.12

Means with the same letter are not significantly different at p = 0.05

below the overall average weight under the two locations (Table 5). It was in conformity with a report (Nagy, 2007) who explained that plant gained weight may differ in varieties due to environmental conditions which in turn cause variation in hormonal balance and cell division rate.

Storage root number per plant, storage root diameter and storage root yield: The data regarding number of roots revealed that accessions and environments had significant differences ($p<0.05$) in storage root number. The highest storage root number (3.06) was observed in accession No. 223109, which was statistically on par with accessions No. 223096(3.03), 223098(2.94) and 223101(2.93) under Ebantu condition. However, the lowest storage root number was recorded (2.00) in accession No. 90801 also under Ebantu condition. Accessions No. 223087(2.39), 229702(2.52) and 240407(2.5) had above the overall average (2.28) the majority of which were under Jimma condition. Accessions No. 90801(2.01), Kuwe (2.18) and 90802 (2.17) had the lowest overall average storage root number under the two locations (Table 5). These results imply that the performance of anchote accessions varies with both accession and environment. The number of storage roots in the accession was found to be directly related to the germination percentage and the number of established plants. Accessions varied significantly ($p<0.05$) with regard to the storage root diameter across the environment. Significantly the highest storage root diameter (55 mm) was obtained under Ebantu condition from accession No. 223098, which was statistically on par with accession No. 90802 (52.2 mm) at the same location. However, low storage root diameter (25.5 mm) was obtained under Jimma condition from accession No. 240407 (Table 5). This shows the presence of genetic variability among accessions evaluated and that the accessions interact with the environments resulting in differential genotypic response. This finding agrees with (Manrique and Hermann, 2000) which showed significant difference among genotypes across locations for root diameter of sweet potato. Significantly the highest total storage root yield (76.45 t ha^{-1}) was obtained under Ebantu condition from accession 223098, followed by accession No. 90802 (72.29 t ha^{-1}). However, the latter was statistically on par with accession No. 223080 (70.83 t ha^{-1}) under Ebantu condition. On the other hand, low storage root yield (48.54 t ha^{-1}) was also obtained under Ebantu condition from accession No. 240407. Hence, accessions No. 90802, 90801, 223087, 223096, 223098 and 223109 produced storage root yield above the overall average (63.23 t ha^{-1}) in both locations (Table 6). However, accessions No. 223101, Kuwe, 90801 below the overall average. This shows the presence of genetic variability among accessions evaluated and that the accessions interact with environments resulting in differential genotypic response. This finding agrees with those in yam (Belford *et al*., 2001) and in potato (Showemimo, 2007); the significant accessions and accession by environment component of interaction indicated wide differences between the environments and differential genotypic behaviour in the environments. The significant accession by environment indicated that response of accessions to change in environment was not the same for all accessions evaluated.

A high storage root yield is among the top criteria for farmers for crop variety selection. Reportedly, an average root yield of anchote was 70.0 t ha^{-1} on vertisol (Desta, 2011). However, in this study with application of organic fertilizers at Jimma site mean of 57.95 t ha^{-1}, most of the accessions produced higher yields, while at Ebantu site mean of 76.45 t ha^{-1}, in this case almost all of the

Table 6: Storage root weight, marketable yield and total storage root yield of anchote accessions as affected by location

	Total storage root weight (kg ha^{-1})			Marketable yield (kg ha^{-1})			Total storage root yield (t ha^{-1})		
Accessions	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean	Jimma	Ebantu	Mean
Kuwe	8.60^{ef}	8.90^{de}	8.75	8.60^{ef}	8.90^{de}	8.75	53.75^{fg}	55.72^{d}	54.74
90801	8.68^{ef}	9.84^{c}	9.26	8.68^{ef}	9.84^{c}	9.26	54.25^{fg}	61.50^{c}	57.87
90802	9.24^{cd}	11.60^{b}	10.40	9.24^{cd}	11.56^{b}	10.40	57.75^{de}	72.29^{b}	65.02
223087	9.34^{c}	11.30^{b}	10.33	9.34^{c}	11.33^{b}	10.33	58.37^{d}	70.83^{b}	64.60
223096	9.11^{cde}	10.40^{c}	9.75	9.11^{cde}	10.40^{c}	9.75	56.90^{def}	65.00^{c}	61.00
223098	9.27^{cd}	12.20^{a}	10.75	9.27^{cd}	12.23^{a}	10.70	57.95^{de}	76.45^{a}	67.21
223109	8.91^{de}	9.90^{c}	9.40	8.91^{de}	9.90^{c}	9.40	55.68^{def}	61.87^{c}	59.78
223101	8.79^{de}	9.00^{d}	8.89	8.79^{de}	9.00^{d}	8.89	54.95^{ef}	56.25^{d}	55.60
229702	9.04^{cde}	10.20^{c}	9.62	9.04^{cde}	10.20^{c}	9.62	56.50^{def}	63.79^{c}	60.14
240407	8.24^{g}	7.76^{h}	8.00	8.24^{g}	7.76^{h}	8.00	51.54^{g}	48.54^{h}	50.04
Mean	10.12	12.50	11.30	10.12	12.50	11.30	55.77	63.23	59.49
LSD (0.05)	0.51	0.57	0.37	0.51	0.57	0.37	3.23	3.57	3.31
CV (%)	3.37	3.57	3.32	3.37	3.57	3.32	3.37	3.29	3.32

Means with the same letter are not significantly different at $p = 0.05$

accessions produced higher yield as shown in Table 6. In general, accessions 223087, 223109, 223098, 223096, 90802 and 229702 gave higher yields at both sites. From this study all the storage root yield produced were highly marketable (Table 6) this was because there was no damaged and affected roots, also there was no over and under sized roots (all had average size ranging from 18 mm to 55 mm) (Table 5) which is in the range of the average size for anchote (Desta, 2011). As a result, all the total yields were marketable even though there were slight variations among accessions and across the locations. Overall, anchote yield and yield components varied among accessions and locations (Table 6). The variation in yield among locations may be attributed to weather or climatic factors and the duration of growing periods. The maturity period of Anchote at Ebantu (2100 m.a.s.l.) took considerably longer time than at Jimma (1710 m.a.s.l.), which may be contributing to vigorous growth and perhaps more dry matter accumulation and make the storage root take longer time to reach physiological maturity. Previous research on sweet potato has shown that greater plant growth and dry matter accumulation could be expected at high altitude locations in the tropics (Behera *et al*., 2010). The variation in yield may also be attributed to accessions response to the environment at specific locations. These results are similar to the findings of yield differences among sweet potato genotypes previously reported in other environments (Manrique and Hermann, 2000). The variation in root yield may be due to climatic or soil factor differences among locations, especially during the root growing period. Water stress during critical periods of root growing have been shown to result in low root yield and quality defects in anchote; in Jimma there was high rain than Ebantu during the growing period. The analysis of variance for root yield across environments resulted in significant differences ($p<0.05$) of accessions in both environments. The significant differences of accessions and environments suggest that root yield and yield component of anchote accessions varied across environments. Previous research has shown similar results of differences in yield of sweet potato cultivars among locations (Singh, 2003). The high root productivity and the genetic potential in anchote were not investigated so far, its storage roots are much more sticky and/or dense than other root and tuber crops. The wider variability in root revealed in anchote accessions is in agreement with the root traits diversity exhibited in dry matter and root yield variability of sweet potato germplasm collection from Tanzania (Elameen *et al*., 2011).

Storage root yield of anchote accessions with compression to other root and tuber crops found in Ethiopia, according to Amsalu *et al*. (2008), released taro varieties from Jimma Agricultural Research Center yielded 9 t ha^{-1} on research site and 45 t ha^{-1} for yam. Sweet potato yields 15-34 t ha^{-1} roots for different varieties (Assefa *et al*., 2008; Girma *et al*., 2008; Million, 2008). A study also revealed that the tuber yield of released potato varieties ranged from 22-47 t ha^{-1} (Gebremedhin *et al*., 2008). However, in this study anchote is the highest yielding storage root crop (42-76 t ha^{-1}) and it has a prospect to develop the better variety from the presently tested accessions by testing their yield (Table 6).

CONCLUSION

The anchote accessions tested showed a differential response to the different environments tested. From this study, we conclude six accessions: 223109, 223087, 223098, 223096, 90802 and 229702 produced better storage root yield, high dry matter content, high biological yield across the two environments indicating a good performance and adaptation. Therefore, these accessions are suggested to be produced by farmers in areas of Jimma, Ebantu and other areas of similar agro-ecological zones.

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