Registration of *"Haramaya I"* Carrot (*Daucus carota* L.) Variety

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Abstract: *Haramaya I* is the common name for the carrot (*Daucus carota* L.) variety with the original collection name AUA-108. The variety was developed through selection in the eastern highlands of Ethiopia. It was selected from 64 carrot genotypes collected from Haramaya woreda (district). The genotypes were maintained by farmers for a long period of time through an open-pollinated seed production system. The released carrot variety was found to be superior in marketable and total root yields and other desirable traits to the commercial Nantes variety, which was used as the standard check, and a famers' open pollinated cultivar, which was used as a local check. Furthermore, this variety was superior to the Nantes variety and the farmers' open-pollinated cultivar in terms of producing lower proportions of small-sized, cracked, forked, and hairy roots. The variety had also a margin of seed production potential amounting to 11.81% over the Nantes variety. Moreover, its root yield was found to be stable over seasons and locations. Therefore, it could be cultivated sustainably by smallholder farmers in the highlands of eastern Ethiopia and in other places with similar agroecology.

Keywords: Core-size; Farmers' cultivar; Nantes variety; Root yield; Seed yield; Yield stability

1. Introduction

Carrot (*Daucus carota* L.) is a widely grown root vegetable of the Apiaceae family. The first certain recorded use of carrot roots as a vegetable was in the 10th century in what is today known as Afghanistan. Orange carrots first appeared as a genetic variant in Europe in the 16th century and these more refined orange carrots quickly spread around the world, and by the early 20th century they became the predominate carrots in most growing regions of the world (www.seedalliance.org). Carrot is an important source of alpha- and beta-carotene, the precursors of vitamin A in human nutrition in many countries worldwide. The carotenoids contained in the edible portion of carrots can range from 6000 to more than 54,000 μg per 100g (60–540 ppm) (Simon and Wolff, 1987).

Although the exact time of introduction of carrots to Ethiopia is not known, the crop has been known since the early 1960s in the research system. Research on carrots in Ethiopia was started at Alemaya College of Agriculture (now Haramaya University) using imported seeds of eight varieties from Kenya in the early 1960s. Among the eight varieties tested, Nantes and Chantenay were identified as high yielders (Kifle-Iyesus, 1994; Kidanemariam, 1969). Carrot production has been expanding since then and the total production reached 12345.8 tonnes on 2215 hectares of land (CSA, 2010/11). On the other hand, vitamin A deficiency is widespread in the country (Haile-Meskel, 2011). The prevalence is 2 to 15-fold higher than the World Health Organization (WHO) cut-off point (0.5%) for public significance.

The Nantes carrot has become popular in Hararghe Zone of Ethiopia because it produces quality roots as a result of which it obtained niche market in neighbouring Djibouti and Somalia. Farmers also produce seeds of this carrot variety albeit the poor quality of the seed. The crop is cross-pollinated. Although there is a possibility to produce inbred lines for F_1 hybrid production to attain plant uniformity, inbreeding results in severe depression. Therefore, mass selection using root-to-seed production method is preferred to improve the crop. Haramaya University initiated research on carrots two decades ago with the attempt to improve the locally produced Nantes variety for root uniformity, high yield, good root texture, small core diameter, resistance to cracking, and adaptation to different agroecolgical conditions. Eventually, the university has come up with the variety named *Haramaya 1* from the locally collected 64 genotypes through successive selections.

2. Varietal Origin and Evaluation

Sixty-four carrot genotypes were collected from Haramaya woreda, which were originally introduced into the region by overseas seed companies in 1960s. Farmers maintained and used the genotypes for a long period through an open pollinated seed production system. The genotypes were selected for root uniformity, high yield, good root texture, small core diameter, resistance to cracking, and adaptation to different environments. The mass selection using root-to-seed production method was used to improve the crop. The genotypes were initially evaluated for root yield potential under Haramaya condition using single rows. Seventeen of the genotypes were promoted to replicated yield trials. Trials were conducted for evaluation of total and marketable root yields for

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several years. Finally, two candidate varieties were promoted to a regional trial and evaluated for two years at three locations along with a farmers' cultivar and the commercial Nantes variety.

Table 1. Agronomic and morphological characteristics of *Haramaya I* carrot variety and the commercial *Nantes* carrot variety.

Characteristics	*Haramaya I* (AUA-108)	*Nantes*
Adaptation area	Medium to high altitudes of eastern Ethiopia (1600-2400 metres above sea level)	Medium to high altitudes (1600-2400 metres above sea level)
Rainfall (mm)	760-1010 mm	760-1010 mm
Planting season	Year-round both under rain-fed and irrigated conditions	All year round both under rain-fed and irrigation
Planting date	At the start of the main rainy season (June) and at any time with irrigation considering the frost period	At the start of the main rainy season (June) and at any time with irrigation considering the frost period
Seeding rate (kg ha^{-1})	3.5 to 5	3.5 to 5
Row spacing (cm)	25	25
Spacing between plant (cm)	5	5
Fertilizer rate (kg ha^{-1})	46 kg P_2O_5 or100 kg DAP and 64 kg N or100 kg Urea(18% N from100 kg DAP)	46 kg P_2O_5 or100 kg DAP and 64 kg N or100 kg Urea (18% N from100 kg DAP)
Fertilizer application time	All DAP at planting but half of the N at planting and the remaining half at active growth stage	All DAP at planting but half N rate at planting and half at active vegetative growth stage
Fertilizer application method	Drilling in row	Drilling in row
Leaf length (cm)	55.71	58.65
Leaf width (cm)	39.8	40.83
Root colour	Deep orange	Orange
Root core diameter (cm)	2.83	2.88
Root length (cm)	18.89	17.12
Root weight (gm)	108	107.2
Proportion of small size roots (%)	32.67	67.22
Proportion of cracked roots (%)	0.22	1.89
Proportion of forked roots (%)	2.56	6
Proportion of hairy roots (%)	8.33	12.67
Proportion of twisted roots (%)	17.56	25.22
Root yield (t ha^{-1})		
Research field	52.65	47.26
Farmers' field		
Marketable root yield (t ha^{-1})	42.52	36.99
Total root yield (t ha^{-1})	48.17	45.52
Seed yield (g/plant)	5.87g per plant	5.25g per plant
Release year	2014	
Breeder/Maintainer	Haramaya University	

3. Agronomic and Morphological Characteristics

The released variety (*Haramaya I*) can be grown medium to high altitudes in eastern Ethiopia (1600-2400 metres above sea level) and similar areas of the country either under rain-fed or irrigation. It has a deep orange root color. The released variety has attractive root size and shape, long roots with small cores. The variety was released mainly for its total root yield advantage of 11.41 and 16.23% over the commercial Nantes variety and the farmers' open pollinated cultivar, respectively. It has also 5.82 and 6.48% marketable root yield advantage over the commercial Nantes variety and farmers' open pollinated cultivar, respectively. The seed yield of *Haramaya I* was 5.87 g/plant, which exceeded the seed yield of the commercial Nantes variety by 11.81%. The yield and some agronomic and morphological characteristics of the released variety areshown in Table 1.

4. Yield Performance

At the early breeding stage, the released variety (*Haramaya I*) was evaluated on the research field of the main campus of the university for several years along

with other collections and the commercial Nantes variety. In 2008/9 and 2009/10, it was evaluated at one location along with the commercial variety and other eight selections. Finally, this variety, together with another promising selection (AUA-22) and checks (the commercial Nantes variety and the farmers' cultivar), were evaluated for two seasons (2010/11 and 2011/12) at three locations (Haramaya, Hirna, and Chelenko) in east and west Hararghe zones in the eastern highlands of the country. In the multi-location yield trials, *Haramaya I* produced total and marketable mean root yields of 48.17 and 42.52 tha^{-1}, respectively. The variety also produced 5.87 gram seed per plant.

5. Yield Stability Test

The yield stability of the released variety along with the two checks (the commercial Nantes variety and the farmers' open pollinated cultivar) and one other candidate variety (AU-22) was tested using the two stability models. The AMMI model was used since it combines the analysis of variance with the principal component analysis (Zobel *et al*., 1988) and joint linear regression model as proposed by Eberhart and Russell (1966). In addition, AMMI stability value (ASV) was calculated as proposed by Purchase (1997). The two stability parameters of Eberhart and Russell viz. regression coefficient (b_i) and deviations from the linear regression (S^2di) were considered to test the wide adaptability of the released variety efficiently. The released variety (*Haramaya I*) had the first lowest ASV values for both total and marketable root yields, and it produced the highest total and marketable root yields. On the basis of Eberhart and Russel's Model, *Haramaya I* had the lowest value of deviation from the regression which is near zero (0.16) and regression coefficient value (0.98) which is near unity for total root yield. Although the deviations from regression stability parameter values for marketable root yield were negative and higher for all genotypes, *Haramaya I* had relatively lower values of deviation from regression and regression coefficients (Table 2). This indicates that the newly released variety is stable and high yielding, and could be recommended for cultivation in a wider range of environment.

6. Reaction to Major Diseases

Among the expected diseases for carrot, Alternaria leaf blight *(Alternaria dauci),* Black rot (*Alternaria radicina*) and Carrot bacterial blight (*Xanthomonas carotae* pv. *Carotae)* are the major ones. The released variety (*Haramaya I*) and other selections were evaluated for these and other diseases and insect pest. No pesticide was applied during the evaluation of the variety starting from the initial screening to verification. However, it has not been observed the symptom of any one of the major diseases.

7. Quality Attributes

There is a good opportunity to select genotypes for desirable root traits with the root-to-seed method of seed production. The released variety is the result of a long period of selection using this method. *Haramaya I* has deep orange root colour, long roots and small core diameter. It has also low proportions of forked, hairy and twisted roots. The shape of the root and the listed desirable traits of the released variety are preferred by consumers and producers.

8. Conclusion

The results of this study have demonstrated that the released variety *Haramaya I* is superior to the commercial *Nantes* variety as well as the farmers' cultivar in terms of root and seed production potential. The results have also revealed that this variety is stable over locations and seasons, and has desirable root quality attributes. The high seed production potential of the variety implies that it would save smallholder farmers from purchasing imported carrot seeds of unknown quality from the market at hefty prices. In conclusion, the newly released variety *Haramaya I* could be cultivated profitably and sustainably in the highlands of Hararghe zones and other places with similar agroecolgy, and could lead to enhanced income of smallholder farmers.

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Table 2. Stability parameters for total and marketable root yield from AMMI analysis (environment and genotypes IPCA 1 & 2 scores, ASV, and ASV based rank) and from Eberhart and Russel's Model (regression coefficient (b_i) and deviation from regression (S^2di) of four carrot genotypes tested at three locations and two cropping seasons.

Trait	Genotype	2011 cropping season			2012 cropping season			Pooled Mean & Rank	AMMI model stability parameters				ER's Model stability	
		Haramaya	Hirna	Chelenko	Haramaya	Hirna	Chelenko		IPCA 1	IPCA 2	ASV	ASV rank	b_i	S^2di
Total root Yield	Commercial *Nantes*	46.61	37.74	26.93	76.39	34.22	51.22	45.52 (3)	-1.06	-2.02	2.21	2	0.98	1.76
	Haramaya I	45.99	34.42	29.64	77.17	38.89	62.89	48.17 (1)	0.66	2.18	2.16	1	0.98	0.16
	AU-22	42.4	40.61	22.97	86.56	35.78	57.67	47.66 (2)	-2.58	0.56	5.51	3	1.19	0.47
	Local check	53.39	32.63	29.01	68.06	33.39	54.94	45.24 (4)	2.97	-0.72	5.99	4	0.82	13.38
	Mean	47.10	36.35	27.14	77.05	35.57	56.68	46.65						
Environment	IPCA1	2.22	-1.53	1.49	-2.72	0.23	0.31							
Marketable root yield	Commercial *Nantes*	35.42	27.8	20	67.5	28.67	42.56	36.99 (3)	-0.59	1.59	1.55	2	0.97	-6.28
	Haramaya I	39.34	27.18	20.21	73.78	33.89	52.11	42.52 (1)	1.25	-1.64	1.22	1	0.95	-2.51
	AU-22	34.11	33.94	15.68	69.55	29.83	48.78	40.32 (2)	-2.75	-0.59	5.97	4	1.21	-2.55
	Local check	36.98	24.66	16.77	60.39	28.56	44.94	35.38 (4)	2.09	0.64	3.83	3	0.86	-3.26
	Mean	36.46	28.40	18.17	67.81	30.24	47.10	38.05						
Environment	IPCA1	1.31	-1.24	1.16	-2.82	0.99	0.59							

Numbers in parenthesis are mean yield rank of genotypes. IPCA1 and IPCA2 = the first and the second interaction principal component scores, respectively, ASV = AMMI stability value, ER's= Eberhart and Russel's, b_i = regression coefficient and S^2di = deviation from linear regression.

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