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Evaluation of Some Genotypes of Roselle (*Hibiscus Sabdariffa L.*) for Yield and Quality under Rain-fed in Western Sudan

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Abstract

A mass selection breeding program was conducted on a heterogonous genetic material collected from different parts of the karkadi growing area to genetically improve the crop in Western Sudan. Eight genotypes were identified on the basis of color and shape of the calyx (sepals); in addition to the morphology of the plant and other agronomic, commercial and quality characteristics were evaluated in an experiments conducted at Abu- Omsaaden and Um-Habeela villages during two successive seasons 2015/16 and 2016/ 17. The Eight main genotypes were named as: El Rahad 1 (control), Line 2, Line 3, Line 4, Line 5, Line 6, Line 7 and Line 8. Yield was used to evaluate the productivity, while partial budget analysis was carried out to evaluate the profitability of the different Roselle genotypes. The combined analysis of variance over seasons and locations revealed highly significant differences among the genotypes for all studied parameters with the exception of plant population/ha. The highest yields of dry calyxes were shown by line 2, line 4 and line 3 giving, 328, 302 and 163 kg/ha, respectively. Significant difference in moisture content was detected between the genotypes No. 4, 2, 5 & 6 which recorded the lowest values (7.511 - 7.683). The genotypes had no significant differences in the total TSS. Highly significant differences ($p \leq 0.01$) were recorded between the genotypes in pH. The pH values recorded by the different genotypes ranged from 2.688 to 2.932 (genotype No.3). This range still lies below the level determined by the SSMO specification (2016:2404) which is equal to 3.5. The optical density (O.D) of the different karkadi extracts (diluted 50 times) ranged from 0.004 (genotype No.7) to 0.107 (genotype No.2). The analysis of variance showed marked differences ($p \leq 0.01$) between the genotypes. Genotype No. 2 scored the highest value. Marked differences ($p \leq 0.01$) in total acidity (19.515-24.030) were recorded between the genotypes. The highest net benefit of (3556 SDG/ha) was recorded by genotype line 2 fallowed by line 4 (3179 SDG/ha) and line 3 (1164 SDG/ha). From productivity, quality and profitability point of view it is recommended that the genotypes line 2, line 4 and line 3 to be grown in the targeted areas of Western Sudan.

Keywords: *Roselle, Genotypes, Yield, Quality, Rain-Fed, Partial Budget.*

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.), locally known in Sudan as Karkadi is an important cash and export crop widely cultivated by small scale farmers in Western Sudan [1]. Area cultivated annually by this crop during the last ten years ranged from about 65,000 to 250,000 hectares and foreign exchange earnings from about 10 to 20 million US dollars [2]. The commercial part of the plant is the fleshy calyx (sepals) surrounding the fruit. When fully developed the fleshy calyx is peeled off from the fruit and dried in the shade to give the dry karkadi which is the commercial product of the plant [3]. The color of the calyx plays an important role in determining the quality of karkadi. The crimson red color is the characteristic and the most popular desirable color of karkadi, while other shades and variations of color exist, including the white or greenish white color. Locally in the Sudan, it is used as a beverage where the dried calices are soaked in water to prepare a colorful cold drink taken with sugar, or they may be boiled in water and taken as a hot drink. Karkadi also has some medicinal uses [4]. In

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Europe, it is being used for many purposes including making sauces, jams, jelly as well a using it as coloring material for foods and drinks. The plant is an annual herb with a long leathery taproot and is erect in growth habit. It is about 0.5 to 3 meters high, branching at the base and the leaves are alternate. The flowers have five petals, and are carried singly on stalks. Petals are cream rather than yellow in color and always carry a generally purplish-brown spot near the base, appearing like an eye in the flower [5]. The calyx consists of five large rounded and pointed sepals, which tend to become fleshy and enlarge considerably after flowering. An epicalyx is present; its 9 to 10 narrow bristly segments are about one-third the size of the calyx sepals. The color of both varies according to variety from dark or deep crimson red through to white or greenish white. The flower is self-pollinated. A comprehensive account of karkadi botany, production and commercial utilization, was reported by Mclean [6]. In Kordofan States, most of the karkadi production comes from Um Rowaba and El Rahad localities in North Kordofan State. El Rahad area is the most popular area for karkadi production. Small-scattered areas are planted in other parts of Kordofan and Darfur States. Karkadi is grown by the traditional farmers in small acreages ranging from under 0.25 to 2 ha. Few growers/ merchants can have up to 20 ha [3], [7]. It is usually intercropped or planted in mixtures with other field crops like sorghum, groundnut, cowpea and sesame [8]. A few farmers plant it in pure stand or in borders between farms. The total area planted with karkadi in Kordofan is variable and highly affected by the prices and status of marketing in the previous season. However, the karkadi area planted in North Kordofan state forms over 90% of the total area grown under the crop in the country [9]. Roselle is relatively a hardy crop; a tropical or sub-tropical plant requires a monthly rainfall ranging from 130-250mm in the first three to four months of growth. Most evidence points to West Africa as the home origin of karkadi and from there it had spread to other parts of African countries including Sudan. It is a short day plant, flowering best with 11 to 12 hour days. A temperature range between 20 and 35 C, without prolonged dull weather, available moisture equivalent to 25mm a month through the growing period, together with humid air conditions, are most conclusive to optimum growth. The crop can be grown in a wide range of soil types, the best being heavy retentive, friable loams. Laterite and poor sandy soils and heavy clays are unsatisfactory. It does not withstand flooding. In view of its deep root system it requires adequate depth [10]. With regard to the biodiversity of the crop, the karkadi planted by traditional farmers, is usually a mixture of different plant types or genotypes. Hence, a collection of germ plasm containing different plant types was obtained from different areas of Western Sudan. This collection was subjected to mass selection in order to identify and breed different genotypes on the basis of the calyx shape, calyx color and other plant characteristics [9]. The objective of this study is to evaluate Roselle genotypes developed, together with their agronomic characteristics, yield potential and economic profitability under rain fed in Western Sudan.

MATERIALS AND METHODS

Selection and Breeding

The genetic material collected from North Kordofan State was heterogeneous mixture of different genotypes that varied in plant morphology, plant size, leaf shape, calyx color and shape and other agronomic characteristics. This heterogeneous mixture provided the genetic base for the breeding and selection of distinct commercial genotypes. A mass selection program was thus started for isolating the different genotypes from the heterogeneous mixed population. Selection was mainly based on the characteristics of the calyx, including calyx color, calyx shape, capsule shape and leaf shape. In addition to other specific morphological characters such as easiness of peeling the calyx were included. The mass selection breeding program was followed for three generations, to achieve purification and multiplication of the selected genotypes, using isolation plots. The multiplied seed was then used in the agronomic trials for evaluation of their general, performance and commercial promise. Eight main genotypes were identified including El-Rahad 1 as control, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7 and Line 8. The selection and breeding program resulted in identification of eight main genotypes. The main features and agronomic characteristics of these genotypes are presented in table 1 and figures (1 to 8).

Table 1. The main karkadi genotypes identified and their characteristics.

Genotype	Main Features
El-Rahad.1 (Control)	Also called Shaloft Elnaga or Abu Nagma in some areas. Calyx lobes are fleshy and curving to the outside (like camel lips), seed capsule exposed from top. Calyx color is deep crimson red. The calyx is easy to peel.
Line 2	Long calyx lobes bending inside enclosing the seed capsule in overlapping manner. Calyx color is deep crimson red. The calyx is easy to peel.
Line 3	Calyx lobes are fleshy and curving to the outside, seed capsule is small in size, calyx color is deep white and easy to peel, locally called karkadi abeyad (White).
Line 4	Calyx is deep crimson red. The calyx is bigger and hoof like - shape. It reaches 50% of flowering in 66 days. The plant height ranged from 50 to 65cm, 4- 5 branches/ plant and 15– 20 capsules/plant. Seed yield from 180 to 210 kg/ha and dry calyx yield 302 kg/ha. Late in maturity.

Line 5	Calyx fleshy, bell-shaped with well-developed epicalyx, the plant is late in maturity.
line 6	The calyx is white or greenish white in color. The stem is mostly light greenish in color. The calyx shape could be like that of El-Rahad 1, line 2 or line 8.
line 7	Calyx has a very light or faint red color. The calyx shape could be like that of line 2.
Line 8	Has rounded fruits, spiny, calyx lobes thin and tightly enclosing seed capsule. The calyx is difficult to peel off from the seed capsule which also becomes prickly at the top when dry.

Agronomic Evaluation

Variety trials were conducted at Abu-Omsaaden in Sheikan locality and Um-Habeela village in El-Rahad locality during 2015-2016 and 2016- 2017 under rain fed conditions. Sheikan is located at latitude 12-13º N and longitude 29-30º E. El-Rahad is located at latitude 12 - 13º N and longitude 30 - 31º E. The trials consisted of 8 genotypes of Roselle (El Rahad 1 as control, Line 2, Line 3, Line 4, Line 5, Line 6, Line 7and Line 8) selected from the mixed heterogeneous population that is usually grown by the traditional farmers in Western Sudan. The material was planted on light sandy soil (Goz). A randomized Complete Block Design (RCBD) with four replications was used. Each plot consisted of four rows of 5 meters length, with spacing of 75 cm inter-row spacing and 50 cm intra-row spacing. The total plot size was 15 m^2 the net harvested plot size was 7.5 m^2 (two middle rows). Sowing date was on July in both seasons. Four to five seeds were planted in each hole and seedlings were thinned to tow plants per hole two weeks after planting. Data were recorded on days to 50% flowering, plant height (cm), number of reproductive branches/plant, number of capsules/plant, plant population/ha, dry calyx yield (kg/ha) and seed weight (kg/ha). Most parameters were recorded at maturity stage from the two middle rows of each plot. Individual analyses for each location and combined over locations and over seasons were done. Means calyx yield were recorded from locations and from seasons. All recorded data were analyzed and mean separated using MSTAT- C statistical package.

Quality Evaluation

Karkadi calyx is the most important part of the plant as it contains the valuable components which determine the quality of the product. Eight of the genotypes of Roselle mentioned above were used for evaluation of some quality attributes namely: color (anthocyanin), Flavor (organic acids) and aroma. Accordingly, color intensity, the total soluble solids (TSS), pH and the total acidity in terms of citric acid were evaluated using one factor experiments in randomized complete block design. Moisture content was investigated in completely randomized experiment. Moreover, two panel tests were carried out to determine acceptability.

The criteria for evaluation were as follows:

1. **Physico-chemical analysis:** 10% Karkadi extracts, prepared by soaking Karkadi calyx in tap water for 2 hrs under room temperature using 1:10 Karkadi: water ratio, were subjected to the following tests:

1.1 **Optical density:** The optical density which was used to indicate the color intensity was measured for 10% karkadi solutions diluted 50 times using a spectrophotometer (JENWAY model 6305) adjusted at wave length 535 nm.

1.*2* **PH**: The pH was determined using a glass electrode Microprocessor Bench pH/MV/Cº meter (HANNA instruments pH 211). The pH meter was calibrated with a buffer solution at pH 7.0 and then pH 4.0 [11].

1.3 **Total acidity**: Total acidity was determined by titrating 50 ml of 10% solutions against 0.1 N NaOH to pH 8.1. Total acids were expressed as citric acid according to the eq. shown by Ruck [11]:

$$\text{Total acidity\%} = \frac{\text{eq.wt of citric acid x Normality of NaOHx Titre x d.f}}{\text{Wt. of sample} \times 10}$$

Equivalent wt. of citric acid = 70.0

d.f = Dilution factor

1.4 **The Total soluble solids (TSS):** TSS was evaluated using a hand refract meter.

2. **The organoleptic test**: The Six red karkadi genotypes were assessed according to the color, flavor, after taste and total preference by 15 panelists from the Food Research Centre, Shambat. They ranked each time the 6 genotypes by giving the No. 1 to the best line and the No.6 to the least favorite one (Ranking test as described by Ikehronye and Ngoddy [12]. Moreover, the two white karkadi genotypes were subjected to another panel test (ranking) to find out which one is more preferable.

Economic Analysis

Partial budgeting technique [13] was carried out through the following steps to assess and compare the economic returns and net benefits of the genotypes.

Gross field benefits were calculated by multiplying the price of the unit of the crop (SDG/kg) by the average yields obtained (kg/ha).

Net benefit was obtained by subtracting the total production cost from the gross field benefits.

RESULTS AND DISCUSSION

Agronomic Evaluation

In this study, the significant differences detected among the genotypes, for number of capsules/ plant, calyx yield and seed yield at each location in both seasons and plant height (cm) and number of branches/plant at one location in the first season and two locations in the second one,

indicate the presence of high genetic variability among these genotypes for these characters. Hence it provides a wide scope for improvement through selection. Similar results were reported by Sulaiman [14] for plant height (cm) and seed yield kg/ha. Moreover, similar results had been reported by Sulaiman [9] who found significant differences among genotypes for number of capsules/ plant and calyx yield kg/ha. The non significant differences among the genotypes in number of days to 50% flowering and plant population in most locations, indicate the absence of high genetic variability among the genotypes for these characters. The results for calyx yield, number of branches/ plant and seed yield match the findings of Ibrahim [15]. The results indicate that the genotypes had responded similarly in different environments for the studied characters, meaning that the genotypes ranking would remain almost constant [9]. From the results presented in (Tables 2 to 8), it is clear that the genotypes line 2 and line 4 showed high dry calyx yield and seed yield followed by genotype line 3. Hence, it offers the expansion of its production and the stability of its production in the karkadi growing areas of the Sudan. As reflected in table 8 showing the mean dry calyx yields for the two seasons , 2014/2015 and 2015/2016 , the genotypes line 2, line 4 and line 3 (White) , generally gave the highest dry calyx yield , giving calyx yield of 328, 302 and 163 kg/ ha and highest seed yield, giving 216, 209, and 110 kg/ha respectively. These yields of genotypes line 2 and line 4 are all above the grand mean calyx yield of 193 kg/ha. This can be attributed to add extra income to crop producers. White karkadi is usually consumed locally in the country and it does not play a role in foreign exports. However, locally it fetches higher prices (10 to 20%) compared to the red karkadi.

Quality Evaluation

Significant difference in moisture content (Table 9) was detected between the genotypes No. 4, 2, 5 & 6 which recorded the lowest values (7.511 - 7.683) and the genotypes No. 8,1 & 7 which scored the highest values (8.565 – 8.605) (Table 9). Also marked difference was recorded in moisture content between the genotype No. 3 (8.124) and the rest of the genotypes. However, the range recorded by all the lines (7.511- 8.605) is slightly higher than the upper limit of the specification (2016:2404) released by the Sudanese Standards and Metrology Organization (SSMO) which is equal to 7% max. For the TSS, no significant difference between the genotypes was recorded except that ($p \leq 0.05$) detected between the genotype No.3 which scored the highest value (3.830) and the rest of the lines (3.008 -3.282). Highly significant differences ($p \leq 0.01$) were recorded between the genotypes in pH. But the genotypes No. 7 & 2 which scored the same pH (2.688) were the only exception. The pH values recorded by the different genotypes ranged from 2.688 to 2.932 (genotype No.3). This range still lies below the level determined by the SSMO specification (2016: 2404) which is equal to 3.5.

The optical density (O.D) of the different karkadi extracts (diluted 50 times) ranged from 0.004 (genotype No.7) to 0.107 (genotype No.2). The analysis of variance showed marked differences ($p \leq 0.01$) between the genotypes. Genotype No.2 scored the highest value, followed by the genotypes No.1, 2&6 as the second best, genotype No. 6 as the third, genotype 8 as the fourth and then genotypes 3&7 as the fifth. Marked differences ($p \leq 0.01$) in total acidity (19.515-24.030) were recorded between the genotypes. The highest values 24.030, 23.855 and 23.451 were scored by the genotypes No. 2, 5 & 4 respectively followed by the genotypes No. 8, 7 & 3 as the second best and then genotypes 1 & 6 as the third. The total organoleptic assessment (Table 10) showed no significant difference among the sixth red karkadi genotypes in color, flavor, after taste and the total preference. They shared the votes of the panelists and no genotype was preferred as superior in any of the tested traits. Similarly, the total assessment (Table 11) revealed no marked difference between the white karkadi genotypes No3 &7 in color, flavor, after taste. However, there was a significant difference in the total preference. The genotypes No.3 was preferred as superior to the genotype No.7.

Economic Analysis

Partial budget analyses for the different genotypes are summarized in table 12. All the genotypes gave positive net revenues. The highest net benefit of (3556 SDG/ha) was recorded by genotype line 2 and fallowed by line 4 (3179 SDG/ha) and line 3 (1164 SDG/ha). The farmers ranking confirmed that genotype line 2 was the best among the others followed by line 4 and line 3, respectively.

Table 2. Means performance of 8 genotypes of Roselle from the individual analysis of variance at Abu-Omsaaden (2015/2016).

Genotype	Days to 50% flowering	Plant height (cm)	No. of branches/ plant	No. of capsules/ plant	Plant population/ha	Calyx yield kg/ha	Seed weight kg/ha
El Rahad1	69	68	3	11 b	54333	170 bc	88 bc
Line 2	66	81	5	22 a	69786	291 a	221 a
Line 3	67	72	6	17 ab	51334	242 ab	139 b
Line 4	66	65	4	22 a	61666	301 a	233a
Line 5	65	81	3	16 ab	45334	172 bc	56 c
Line 6	66	66	4	13 b	42667	137 c	48 c

Line 7	66	71	3	13 b	59667	136 c	69 c
Line 8	63	57	4	11 b	63000	159 bc	112 bc
Mean	66	70	4	15	55963	201	121
SE ±	1.20ns	6.42ns	0.71ns	2.08**	8304.45ns	29.61**	22.46**
CV%	3.64	18.36	35.97	26.93	29.67	29.48	37.24

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 3. Means performance of 8 genotypes of Roselle from the individual analysis of variance at Um-Habeela village (2015/2016).

Genotype	Days to 50% flowering	Plant height (cm)	No. of branches /plant	No. Of capsules /plant	Plant Population /ha	Dry calyxes Yield (kg/ha)	Seed weight (kg/ha)
El Rahad1	70	47 c	3 b	7 b	33333	219 c	142 c
Line 2	69	58 b	4 b	17 a	53000	367 ab	237 ab
Line 3	66	45 c	3 b	6 b	4667	217 c	136 c
Line 4	66	54 bc	6 a	16 a	51667	384 a	248 a
Line 5	67	72 a	3 b	7 b	38334	267 bc	134 c
Line 6	65	53 bc	3 b	6 b	35667	254 c	150 bc
Line 7	65	45c	4b	8 b	49500	219 c	158 bc
Line 8	65	47 c	3 b	6 b	46333	225 c	215 abc
Mean	65	53	4	9	43688	269	177
SE ±	1.38ns	2.98**	0.49**	1.23**	8181.71ns	37.58*	28.73*
CV%	4.15	11.34	26.38	27.18	37.46	27.97	32.39

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 4. Mean performance of 8 genotypes of Roselle from the combined analysis of variance evaluated over locations (2015/2016).

Genotype	Days to 50% flowering	Plant Height (cm)	No. Branches (plant)	No. Capsules (plant)	Plant Population (ha)	Calyx yield kg/ha	Seed wt kg/ha
El Rahad1	69 a	58 bc	3 b	9 b	43833	194 b	115 b
Line 2	68 ab	70 ab	6 a	19 a	61393	329 a	235 a
Line 3	67 ab	58 bc	4 b	11 b	46500	229 b	137 b
Line 4	66 ab	59 bc	4 b	19 a	56667	342 a	235 a
Line 5	66 ab	76a	3b	12 b	41834	219 b	95 b
Line 6	66 ab	59 bc	4 b	10 b	39167	195 b	99 b
Line 7	65 ab	58 bc	4 b	10 b	54583	178 b	113 b
Line 8	64 b	52 c	3 b	9 b	54667	192 b	164 ab
Mean	66	61	4	12	49830	235	149
SE±	0.92*	3.54**	0.43**	1.21**	5828.90ns	23.92**	18.23**
CV%	3.90	16.35	31.87	27.89	33.09	28.81	34.61

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 5. Means performance of 8 genotypes of Roselle from the individual analysis of variance at Abu-Omsaaden (2016/2017).

Genotype	Days to 50% flowering	Plant height (cm)	No. of branches /plant	No. of capsules /plant	Plant Population/ha	Dry calyxes Yield (kg/ha)	Seed weight (kg/ha)
El Rahad1	68	49 cd	4	6 d	54000	84 c	55 b
Line 2	66	61 b	5	19 a	53417	218 b	170 a
Line 3	67	41 d	3	9 cd	54667	76 c	58 b

Line 4	66	47 cd	4	15 ab	44333	310 a	150 a
Line 5	65	73 a	4	14 bc	45917	62 c	56 b
Line 6	66	49 cd	4	10 cd	39000	106 c	71 b
Line 7	66	54 bc	4	10 cd	50333	101 c	77 b
Line 8	65	43cd	4	10 cd	45667	101 c	72 b
Mean	66	52	4	11	48417	132	89
SE ±	0.68ns	3.60**	0.60ns	1.56**	6051.39ns	17.30**	13.60**
CV%	2.65	13.84	30.00	27.28	25.00	26.15	30.73

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 6. Mean performance of 8 genotypes of Roselle from the individual analysis of variance at Um-Habeela village (2016/2017).

Genotype	Days to 50% flowering	Plant height (cm)	No. of branches /plant	No. of capsules /plant	Plant Population /ha	Dry calyxes Yield (kg/ha)	Seed weight (kg/ha)
El Rahad1	71 a	50 bc	2 b	6 de	67667	124 b	141b
Line 2	68 b	57 b	3 ab	18 a	49333	305 a	218 a
Line 3	64 cd	46 bc	3 ab	8 cde	59000	116 b	108 bc
Line 4	64 cd	58 b	4a	14 b	42434	342a	224a
Line 5	66 bc	81 a	3 ab	11 bc	55000	108 b	81 c
Line 6	63 d	54 b	3 ab	10 bcd	36667	116 b	114 bc
Line 7	66 bc	54 bc	2 b	5 e	66333	131 b	148 b
Line 8	65 cd	40 c	2 b	6 de	51333	123 b	140 b
Mean	66	55	3	10	53471	171	147
SE ±	0.74**	4.63**	0.47**	1.30**	7785.79ns	22.10**	18.22**
CV%	2.24	16.72	30.89	26.40	29.12	26.01	24.87

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 7. Means of the different characters from the combined analysis of variance evaluated over locations (2016/2017).

Genotype	Days to 50% flowering	Plant hieght (cm)	No. of capsules (plant)	No. of branches (plant)	Plant population (ha)	Calyx yield kg/ha	Seed weight kg/ha
El Rahad1	70a	49 bc	6 d	3b	60833	112 b	98 b
Line 2	67 b	59 b	18 a	5 a	51375	326 a	197 a
Line 3	65 bc	44 c	9 cd	3 b	56833	134 ab	83 b
Line 4	65 bc	52 bc	15 ab	4 ab	43383	205 ab	184 a
Line 5	65 bc	77 a	13 bc	3 b	50458	94 b	68 b
Line 6	64 c	54 bc	10 cd	4 ab	37833	117 b	92 b
Line 7	66 bc	54 bc	7 d	3 b	58333	120 b	112 b
Line 8	65 bc	41 c	8 d	3 b	48500	125 b	106 b
Mean	66	54	11	4	50944	167	118
SE±	0.57**	2.93**	1.02**	0.38**	4930.43ns	37.87**	11.37**
CV%	2.46	15.44	26.98	30.62	27.37	24.33	27.36

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 8. Means performance of eight genotypes of Roselle from the combined analysis of variance evaluated over seasons and locations.

Genotype	Days to 50% flowering	Plant hieght (cm)	Plant population /ha	No. of branches /plant	No. of capsules /plant	Calyx yield kg/ha	Seed weight kg/ha
El Rahad1	70 a	53 bc	52333	3 b	7 b	149 b	106 b
Line 2	68 ab	64 ab	56384	5 a	19 a	328 a	216 a

Line 3	66 b	51 bc	51667	4 ab	10 b	163 b	110 b
Line 4	66 b	56 bc	50025	4 ab	17 a	302 a	209 a
Line 5	65 b	76 a	46146	3 b	12 b	152 b	81 b
Line 6	65 b	56 bc	38500	4 ab	10 b	153 b	95 b
Line 7	66 b	56 bc	56458	3 b	9 b	147 b	113 b
Line 8	65 b	47c	5158	3 b	8 b	152 b	135 b
Mean	66 b	58	50387	4	12	193	133
SE±	0.54**	2.30**	3817.24ns	0.29**	0.79**	13.88**	10.74**
CV%	3.26	15.99	30.30	31.32	27.57	28.74	32.25

According to Duncan Multiple Range Test (DMRT), means with different letters are significantly different at 5% level of significance.

Table 9. The physic – chemical properties of six selected karkadi genotypes (Moisture % & the Total acidity% were transformed to degrees).

Genotype No.	Moisture content	Total soluble solids	Optical density	PH	Total acidity
(1)	30.897 c (8.583%)	3.282 a	0.074 d	2.927 f	73.120 ab (20.281%)
(2)	27.184 a (7.551%)	3.245 a	0.107 e	2.688 a	86.506 f (24.030%)
(3)	30.978 c (8.605%)	3.830 b	0.005a	2.932 g	77.852 bc (21.626%)
(4)	27.038 a (7.511%)	3.244 a	0.070 cd	2.714 b	84.424 def (23.451%)
(5)	27.387 a (7.608%)	3.247 a	0.074 d	2.733d	85.878 ef (23.855%)
(6)	27.657 a (7.683%)	3.250 a	0.063c	2.881e	70.252a (19.515%)
(7)	29.246 b (8.124 %)	3.265 a	0.004 a	2.688 a	78.817 bcd (21.894%)
(8)	30.832 c (8.565%)	3.008 a	0.030 b	2.723 c	79.888 cde (22.191%)

Means with different letter in the same column are significantly different at P ≤ 0.05 according to (DMRT).

Table 10. Rank totals of red Roselle genotypes.

Genotypes no.	Color	Flavor (Taste +Aroma)	After taste	Preference
(1)	53 b	52 b	52 b	46 b
(2)	50 b	51 b	52 b	52 b
(4)	45 b	58 b	50 b	55 b
(5)	51 b	46 b	57 b	46 b
(6)	61 b	55 b	48 b	59 b
(8)	53 b	53 b	55 b	57 b

P ≤ 0.05 according to (DMRT).

Table 11. Rank totals of white Roselle genotypes.

Genotypes No.	Color	Flavor (Taste + aroma)	After taste	Preference
(3)	20 b	20 b	19 b	17 a
(7)	25 b	25 b	26 b	28 c

P ≤ 0.05 according to (DMRT).

Table 12. Mean yield, gross benefit and net benefit (SDG/ha) for eight genotypes of Roselle seasons 2015 to 2017.

Genotypes	Dry calyx yield (kg/ha)	Total gross benefit (SDG/ha)	Net benefit (SDG//ha)	Ranking	Farmers ranking
El Rahad1	149	2161	961	7	7
Line 2	328	4756	3556	1	1
Line 3	163	2364	1164	3	3
Line 4	302	4379	3179	2	2
Line 5	152	2204	1004	6	6

Line 6	153	2218	1018	4	4
Line 7	147	2132	932	8	8
Line 8	152	2204	1004	5	5

CONCLUSION

From the results presented above on aspects of breeding, agronomic trials and quality conducted on the crop, it can be concluded that the genotypes line 2 and line 4 are generally of higher yield potential, better agronomic characteristics, good quality and economic revenues compared to the other tested genotypes. On the other hand, the white karkadi, (line 3) coming next to these two genotypes in calyx yield and profitability, is offering a unique special choice for consumers in the local market.

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