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Research Article

Performance of Roselle (*Hibiscus sabdariffa* L.) in different Agro-Ecologies of Ethiopia

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ABSTRACT

Two genotypes of *hibiscus sabdariffa* (Sudan and Jamaica) type was evaluated for the purpose of agronomic adaptability and economic traits. The experiment was done in different agro-ecologies of Ethiopia at Wondogenet and Hawassa and Qoqa by using randomized complete block design with three replications. Data on agronomic and economical traits were collected for two years from 2012 to 2013 and statistically analyzed by analysis of variance using SAS PROC GLM (2002) at P<0.05. Differences between means separated using the least significance difference test at P<0.05. The overall respective mean performance across the test locations varied from 87.13-131.4 cm, 18.8-66.83, 43.93-72.17, 95.93-159.69 g, 19.41-33.59 g, 58.7-98.06 g, 5.87-9.88 g, 2.66-4.44 ton, 5.39-9.33 ton, 16.30-27.50 ton, 1.63-2.75 ton for plant height; number of branches/plant; number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare respectively. The highest value for all this parameter were recorded at Hawassa; and the lowest value were recorded at Qoqa for plant height and number of branch /plant and Wondogenet for the other parameter and *Jamican* type was highly preformed than *Sudan* type. Therefore, these variations are due to fluctuating features of the environmental factors and the two types of hibiscus were adapted well over the testing locations and years. Hence, it is possible to use the existing the two hibiscus cultivars for the production of pod, calyx and seed for local and international consumption for the food and medicinal purpose in Ethiopia

Keywords: Adaptation; Calyx; Ethiopia; Roselle; *Hibiscus subdariffa* L.

INTRODUCTION

The genus Hibiscus is represented by over 300 species of *Hibiscus sabdariffa* with two main varieties: *Hibiscus sabdariffa* var. altissima and *Hibiscus sabdariffa* var. sabdariffa. *Hibiscus sabdariffa* L. var. sabdariffa is a vascular plant belonging to the phylum of seed plants, angiosperms subphylum, class of Dicotyledons, the dialypetalous subclass, the Thalamiflores series on the order of Malvales and the Malvaceae family [1].

It is native to tropical America [2]. However, some authors such as Martin suggest that there are species of West African origin, and tropical Africa. According to Rhoden et al. the roselles are native to the region extending from India to Malaysia. *H. sabdariffa* is currently distributed and cultivated largely in all the tropical and subtropical areas of both hemispheres including Africa, Central America, India and Malaysia [3-6].

Several vernacular names of the species are encountered: roselle (or rozelle), sorrel, red sorrel, Jamaican roselle or sorrel in Asia and flora of Jamaica in Central America, Indian sorrel, Guinea sorrel or bissap in Senegal, Queensland jelly plant, jelly okra, lemon bush, florida cranberry, sour-sour, bissap, foloré, pink tea of Abyssinia, karkadé in North Africa [2,7-16].

The plant is an annual or perennial herb or woody-based sub-shrub, growing up to 2-2.5 m (7-8 ft) tall. The leaves are deeply 3-5 lobed, 8-15 cm long arranged alternatively on the stems [17].

The flowers are 8-10 cm in diameter, white to pale yellow with a dark red spot at the base of each petal and have a stout fleshy calyx at the base 1-2 cm wide, enlarging to 3-3.5 cm, fleshy and

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bright red as the fruit matures. The plant takes about 6-8 months to mature [18]. *H. sabdariffa* is called 'roselle' and all the sabdariffa types are classified in to four main groups according to the extent of pigmentation present on the stem. They are full green, green pigmented, green light red and red.

The warm and humid tropical climate is suitable for Roselle plants as it is exceptionally susceptible to frost and mist [4,19] the temperature range within which Roselle thrives is between 18°C and 35°C, with an optimum of 25°C. Growth of the plant ceases at 14°C [12]. In tropical and subtropical regions, an altitude 3000 ft. (900 m) above sea level is suitable for growing this plant. Annual rainfall between 400 and 500 mm is necessary throughout the Roselle growing season [20]. Roselle is a short day plant that is very sensitive e to the photoperiod. In the first 4-5 months of its growth, Roselle requires a daily light phase of 13 Hours. According to Duke, flowers would not appear if there were more than 13 hours of sunlight in a day, while McClintock et al. reported that flowering of Roselle plants was excellent when daylight was shorter than 12 hours. According to Huxley and Duke Roselle plants prefer well drained humus and rich fertile soils with a pH of 4.5 to 8.0. It tolerates floods and heavy winds [21-23].

Typically, the calyces of the plant are used in the manufacture of beverages, jam and vegetable gelatin [24]. However, *H. sabdariffa* has many other applications. Among the nourishing applications, the leaves are used like vegetables in the preparation of soups and sauces [25]. They are rich in vitamins, natural carbohydrate, protein, tannins, gums and other antioxidants including minerals [26]. The chemistry of the calyx revealed that per 100 g, it contained 49 calories, 84.5% water, 1.99 protein, 0.1 g fat, 12.3 g total carbohydrate, 2.3 g fiber, 1.2 g ash, 1.72 mg calcium, 57 mg phosphorus, 2.9 mg iron, 300 g vitamin A equivalent and 14mg ascorbic acid [17].

Moreover, many medicinal applications of this plant have been developed around the world. It is used to treat hypertension, pyrexia, and liver damage. Today an aqueous extract of dried flowers of *H. sabdariffa* has been used as an effective treatment against and gastric carcinoma, due to its high content of polyphenol [27-29]. Further studies have demonstrated that the calyx extracts of *H. sabdariffa* possess hypoglycaemic [30] hypolipidaemic [31], antioxidant [32]. The calyces of *H. sabdariffa* are also rich sources of vitamin and antioxidants, which are essential as health foods in the building up of body immune system and in preventing diseases [33].

Despite of this fact *H. sabdarifa* being very useful in food, pharmaceutical, soft drink and stimulant Processing industry ; existence of interest from processors for commercial cultivation of the crop. There is no documented information and knowledge regarding agronomic adaptability and productivity of *H. sabdariffa* in Ethiopia. Therefore, the primary objective of this activity was designed to test adaptability and productivity of two variety of *Hibiscus sabdariffa* in Ethiopia.

MATERIALS AND METHODS

Area description

The experiment was conducted in SNNPRS and Oromia regions of Ethiopia at Wondo Genet, Hawassa, and Qoqa for two years between 2011/2012 and 2012/2013. The ecological descriptions of the testing locations are summarized under Table 1.

Table 1: Summarized agro-ecological description of the testing location.

Testing location	Latitude	Longitude	Altitude (masl)	Soil pH	Soil type	Rain fall (mm)	Annual temperature (°C)	
							min	max
Hawassa	7° 05'N	39° 29'E	1652	7.2	Sandy loam	964	12.94	27.34
Qoqa	8° 26'N	39° 1'E	1604	-	clay	830.9	13.68	28.3
Wondogenet	7° 19'N	38° 38'E	1776	6.4	Sand clay loam	1000	12.02	26.72

Material used

The two varieties of *Hibiscus sabdariffa* introduced from Sudan and Jamaica maintained at the botanic garden of Wondo Genet Agricultural Research was evaluated nationally in different agro-ecological area in Ethiopia Table 1. Using randomized complete block design with three replications. Seeds of each variety were sown on the commencement of main rainy season in six rows of six meters long with spacing of 60 cm between rows and plants, No fertilizer and chemical was applied during evaluation activity. All cultural practices and supplementary irrigation were done as required.

Data collected

Representative five sample plants were taken from the central rows of each plot. Data on plant height; number of branches/plant; number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare was collected properly for two consecutive years (2011/12-2012/13).

Statistical analysis

The data was analyze the differences in agronomic and economical characteristics caused by the growing locations and years and it was statistically analyzed by analysis of variance

using SAS PROC GLM (2002) at P<0.05. Differences between means separated using the least significance difference test at P<0.05.

RESULTS AND DISCUSSION

Performance of agronomic and chemical traits

The mean square from combined (ANOVA) of the hibiscus variety tested over location and year are summarized in the (Table 2). Combined analysis of variance has shown the presence of significant difference (p<0.01) due to location effect in all parameters of the hibiscus such as plant height; number of branches/plant; number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare. Interaction effects of location by year exerted a highly significance influence (p<0.01) only on the number of the branch /plant. Testing years and interaction effect of year and treatment exerted a highly significant influence (p<0.01) on all the parameters except number of branch /plant. Interaction effect of location by treatment a significantly influence on all parameters except on plant height and number of branch/plant. On the other hand the interaction effect of location, year and treatment influenced highly and significantly (p<0.01) on plant height and number of branch/plant.

This indicates, these traits were influenced by a change in the growing environment. The significance of location effect was expected and Hawassa, Wondo Genet and Qoqa experimental sites are vary in their soil type, rainfall and temperature (Table 1).

Table 2: Combined analysis of variance for different characters of Hibiscus tested over three locations and years during 2011/12/-2012/13.

Par	Source of variation									CV%
	Rep	L	Y	T	L*T	L*Y	Y*T	L*Y*T	Error	
PH	619	206**	11774**	1516	160	1215	4460**	2782**	421	20.69
NB	217	3891**	102	23237**	1666	2440**	864	3881**	513	24.04
NPPL	2016	4977**	8886**	3173	8118**	1.93	9743**	46	1447	29.23
PYPL	9668	25252**	40997**	11366	40383**	7.55	45126**	221	6761	28.61
DSYPL	402	1232**	1515**	135	1867**	0.14	1688**	9.13	260	16.86
FCYPL	3623	9612**	15212**	3908	15291**	2.66	16761**	83.08	2517	18.45
DCYPL	36	99**	149**	32	156**	0.02	165**	0.83	24.93	18.12
PYPH	746.11	1948**	3163**	877	3115**	0.58	3481**	17.11	521.7	28.61
DSYPH	31.04	95**	116**	10.43	144**	0.01	130**	0.7	20.11	26.86
FCYPH	273	741**	1173**	301	1180**	0.2	1293**	6.4	194	28.45
DCYPH	2.81	7.66**	11**	2.51	12**	0.002	12**	0.064	1.92	28.11

***,** and * Significant at P<0.001, P<0.01 and P<0.05 probability level, PER=Parameters, T=Treatment, REP=Replication, Y=Years, L=Location, PH=Plant Height (Cm); NB=Number Of Branches/Plant; NPPL=Number of Pods Per Plant; PYPL=Pod Yield/Plant (G); DSYPL=Dry Seed Yield/Plant(G); FCYPL=Fresh Calyx Yield/Plant (G); DCYPL=Dry Calyx Yield/Plant (G); PYH=Pod Yield/Hectare (Ton); DSYH=Dry Seed Yield/Hectare (Ton), FCYH=Fresh Calyx Yield/Hectare (Ton), DCYH=Dry Calyx Yield /Hectare (Ton).

Performance on testing year and location

The mean performance of two Hibiscus variety over testing year and location are summarized in Table 3. Over all mean performance of the two hibiscus type over three testing location and year shows that Jamaican type hibiscus produce more plant height (107.15) and number of branch (73.07) compared with the Sudan type hibiscus which produce shorter plant height (91.25) and smaller number of branch /plant (10.83) (Figures 1 and 2).

The overall respective mean value of plant height (cm); number of branches/plant; number of pods per plant; pod yield/plant (g); dry seed yield/plant(g); fresh calyx yield/plant (g); dry calyx yield/plant (g); pod yield/hectare (ton); dry seed yield/hectare (kg), fresh calyx yield/hectare (ton), dry calyx yield /hectare (ton). 99.2 cm, 41.95, 77.29, 169.14 g, 34.45 g, 103.38 g, 10.38 g, 4.698 ton, 0.959 ton, 2.876 ton, 0.2885 ton recorded respectively (Table 3).

Figure 1: Jamaican type *H. subdariffa*.

Figure 2: Sudan type *H. subdariffa*.

Table 3: Mean performance of Hibiscus varieties tested over different locations and years.

Parameters	Treatments		Overall mean	CV%	LSD 0.05
	Jamaican Type	Sudan Type			
PH	107.15a	91.25a	99.2	20.69	17.97
NB	73.07a	10.83b	41.95	24.04	19.85
NPPL	88.79a	65.79a	77.29	29.23	33.31
PYPL	190.9a	147.38a	169.14	28.61	72
DSYPL	36.82a	32.08a	34.45	26.86	14.13
FCYPL	116.32a	90.79a	103.555	28.45	43.93
DCYPL	11.54a	9.21a	10.375	18.12	4.37
PYPH	53.03a	40.94a	46.985	28.61	20
DSYPH	1023a	895a	0.959	26.86	3.92
FCYPH	3.231a	2.522a	2.876	28.45	12.2
DCYPH	0.321a	0.256a	0.2885	18.11	1.21

Means followed by the same letter with in the same column are statistically non-significant at $p<0.05$ according to the least significant difference (LSD) at $p<0.05$ test. PH=Plant Height (cm);

Performance over testing location

Mean squire from combined analysis of variance reviled that the existence of significant variation $p<0.01$. Overall mean performance of the different parameter of hibiscus tested over different location are summarized in (Table 4). The overall respective mean performance across the test locations varied from 87.13-131.4 cm, 18.8-66.83, 43.93-72.17, 95.93-159.69 g, 19.41-33.59 g, 58.7-98.06 g, 5.87-9.88 g, 2.66-4.44 ton, 5.39-9.33 ton, 16.30-27.50 ton, 1.63- 2.75 ton for plant height; number of branches/plant; number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare.

The highest value for all these parameter were recorded at Hawassa; and the lowest value were recorded at Qoqa for plant height and number of branch /plant and Wondogenet for number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare) and JAMICAN type was highly preformed than Sudan type.

Table 4: Performance of Hibiscus for different characters tested over three testing locations.

Parameter	Locations			Mean	CV%	LSD 0.05
	Qoqa	W/Genet	Hawassa			
PH	87.13c	111.30ab	131.40a	109.94	12.35	17.47
NB	18.80b	21.20b	66.83a	35.61	29.31	13.45
NPPL	51.40a	43.93a	72.17a	55.83	40.71	29.24
PYPL	112.30ab	95.93b	159.69a	122.64	40.25	63.49
DSYPL	22.76ab	19.41b	33.59a	25.25	38.96	12.66
FCYPL	68.72ab	58.70b	98.06a	75.16	40.13	38.79
DCYPL	6.88ab	5.87b	9.88a	7.54	39.88	3.87
PYPH	3.119ab	2.665b	4.436a	3.407	4.025	1.764
DSYPH	6.32ab	5.39b	9.33a	0.701	38.95	3.52
FCYPH	19.09ab	16.31b	27.24a	2.088	40.12	10.77
DCYPH	1.91ab	1.63b	2.75a	0.21	39.88	1.07

Means followed by the same letter with in the same Row are statistically non-significant at p<0.05 according to the least significant difference (LSD) at p<0.05 test. PH=plant height (cm); NB=Number Of Branches/Plant; NPPL=Number Of Pods Per Plant; PYPL=Pod Yield/Plant (G); DSYPL=Dry Seed Yield/Plant(G); FCYPL=Fresh Calyx Yield/Plant (G); DCYPL=Dry Calyx Yield/Plant (G); PYH=Pod Yield/Hectare (Ton); DSYH=Dry Seed Yield/Hectare (Ton), FCYH=Fresh Calyx Yield/Hectare (Ton), DCYH=Dry Calyx Yield /Hectare (Ton).

Performance over testing year

The overall mean performance of Sudan and Jamaican hibiscus types over the testing year are summarized in (Table 5). A significance difference was observed on the different parameter considered during the two evaluation years. An overall increased value of 57.49% and 10.38% were recorded in 2012/13 evaluation year compared with 2011/12 on the plant height and number of branches/plant. On the other hand all the characters were found lower at 2012/13 evaluation year compared with 2011/12. Consequently, a respective present decreased values of 39.92, 86.79, 41.94, 61.08, 39.11, 38.77, 39.27, 37.52, 39.12.4 and 0.49 were recorded for number of pods per plant; pod yield/plant; dry seed yield/plant; fresh calyx yield/plant; dry calyx yield/plant; pod yield/hectare; dry seed yield/hectare, fresh calyx yield/hectare, dry calyx yield /hectare in 2012/13 compared with 2011/12 evaluation year.

Table 5: Mean performance of Hibiscus for different characters over the testing years.

Parameters	Year		Overall mean	CV%	LSD 0.05
	2012	2013			
PH	77.05b	121.35a	99.2	20.69	17.97
NB	39.88a	44.02a	41.95	54.04	19.85
NPPL	96.54a	58.05b	77.295	49.23	33.31
PYPL	210.47a	27.81b	119.14	48.61	72
DSYPL	42.39a	16.5b	29.445	46.86	14.13
FCYPL	128.73a	78.38b	103.555	48.45	43.93

DCYPL	12.87a	7.88b	10.375	48.12	4.37
PYPH	58.46a	35.5b	4.698	48.61	20
DSYPH	11.78a	7.36b	0.957	46.86	3.92
FCYPH	35.76a	21.77b	2.8765	48.45	12.2
DCYPH	3.68a	2.19b	0.2935	48.11	1.21

Means followed by the same letter with in the same column are statistically non-significant at $p<0.05$ according to the least significant difference (LSD) at $p<0.05$ test. PH=plant height (cm); NB=number of branches/plant; NPPL=number of pods per plant; PYPL=Pod Yield/Plant (G); DSYPL=Dry Seed Yield/Plant(G); FCYPL=Fresh Calyx Yield/Plant (G); DCYPL=Dry Calyx Yield/Plant (G); PYH=Pod Yield/Hectare (Ton); DSYH=Dry Seed Yield/Hectare (Ton), FCYH=Fresh Calyx Yield/Hectare (Ton), DCYH=Dry Calyx Yield /Hectare (Ton).

DISCUSION

In agreement to the present study, Fehr [34] reported that every factor that is a part of the environment of a plant has the potential to cause differential performance. Likewise, Frankel et al. [35] and IRRI reported that fluctuating features of the location such as rainfall, relative humidity, temperature, etc. are some of the environmental factors that cause performance variation in plants. The influence of location on agronomic and chemical traits of aromatic and medicinal plants was also reported for American and German chamomiles [36].

CONCLUSION

Generally, the two types of Sudan and Jamaican hibiscus type were found adapted well over the testing location and evaluation year. Hence, it is possible to use the existing the two hibiscus cultivars for the production of pod, calyx and seed for local and international consumption for the food and medicinal purpose in Ethiopia.

CONFLICT OF INTEREST

All the authors of this research papers have no conflict of interest.

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