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Full Length Research Paper

Yield character variability in Roselle (*Hibiscus sabdariffa* L.)

Sanoussi Atta[1]*, Hadiara Hassane Seyni[1], Yacoubou Bakasso[2], Benoît Sarr[1], Issaka Lona[1] and Mahamane Saadou[2]

[1]Centre Régional AGRHYMET, BP 11011 Niamey, Niger.
[2]Faculté des Sciences, Université Abdou Moumouni, BP 10662 Niamey, Niger.

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Roselle (*Hibiscus sabdariffa* L.) has considerable economic importance in the western Sahel because of its nutritional and medical properties. In order to obtain information on variability, a study of yield and some related characters (number of branches/plant, number of capsules/plant, number of seeds/fruit, hundred seed weight) using nine ecotypes of Roselle was undertaken during the rainy season (from July to September) in 2004 at the experimental station of the Agrhymet Regional Centre in Niamey (Niger). Results indicated considerable variability among ecotypes for most of the measured parameters. Seed yield ranged from 292±8.80 kg/ha (ecotypes E8) to 497±8.91 kg/ha (E4). Calyx yield varied significantly ($P < 0.01$), from 123±8.26 kg/ha (E1) to 766±36.81 kg/ha (E9). The ecotypes which produced the highest seed yield also had high leaf yield but low calyx yield. There was also a significant ($P < 0.05$) difference among ecotypes in yield components such as hundred seed weight, number of branches/plant, number of capsules/plant and number of seeds/fruit. Ecotypes with higher calyx yield had lower hundred seed weight and shorter plants. Results indicated the possibility to increase calyx yield and consequently farmer's income through selection programs.

Key words: *Hibiscus sabdariffa*, variability, leaf, seed, calyx yield, components, Niger.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an annual erect, bushy, herbaceous shrub of the Malvaceae family (Berhaut, 1979). Probably native from India to Malyasia, Roselle was introduced to the other parts of the world such as West Indies, Central America and Africa (Purseglove, 1968; Morton, 1987) where it best grown in tropical and sub-tropical regions (Fasoyiro, 2005). Apart from nutritional and health importance, Roselle plays an important role in income generation and subsistence among rural farmers in developing countries (Cissé et al., 2009). For example, in Senegal, the average annual income generated by leaves of Roselle varied from 41 to 500 $US (Diouf et al., 2007). The crop is cultivated for its leaves, seeds and calyces used as vegetables, refreshing drinks, source of oils, and food preserves (Wong, 2000) and for medicinal and health purposes (D'Heureux and Badrie, 2004). The leaves of Roselle are consumed as a green vegetable and prepared like spinach (Delgado-Vargas and Parcedes-Lopez, 2003).

In Niger, they are also used as an ingredient in sauces and therefore serve as a nutrient complement in cereals such as sorghum or millet. Nutritionally young leaves of *H. sabdariffa* contain nutrients such as phosphorus, calcium, magnesium, and potassium (Atta et al., 2010). The calyces of Roselle are utilized in producing drinks, jellies, sauces, chutneys, wines, preserves (Delgado-Vargas and Parcedes-Lopez, 2003). The calyces drink, which has received industrial attention internationally (Egharevba and Law-Ogbomo, 2007), is a readily available and inexpensive source of vitamin C (Babajide et al., 2004). The seeds of Roselle are subjected to a solid-state fermentation process to produce a meat

*Corresponding author. E-mail: S.Atta@agrhymet.ne. Tel: (+227) 20315316. Fax: (+227) 20315435.

Table 1. Location where ecotypes of Roselle were collected and main plant part used.

Ecotype	Location of collect		Main plant part used
	Location name	Annual rainfall (mm)	
E1	Tillaberi	378	Leaves or seeds
E2	Maradi	458	Leaves or seeds
E3	Dosso	551	Calyces
E4	Maradi	458	Leaves or seeds
E5	Maradi	458	Leaves or seeds
E6	Zinder	385	Calyces
E7	Maradi	458	Calyces
E8	Dosso	551	Calyces
E9	Dosso	551	Leaves or seeds

¶: mean of 30 years (1971 to 2000).

substitute condiment known as dawadawa-botso in Niger, bi-kalga in Central Burkina and datou in Mali (Bengaly et al., 2001). This condiment is mostly used in sauces of rural populations accompanying cereals pastas. Nutritionally, the seed of Roselle is a valuable food resource on account of its protein, calorie and also substantial amount of fiber and valuable micro-nutrients (Akandi et al., 2009). Roselle is also considered to be one of the most famous folk medicinal plants due to its colored calyces which are used for pharmaceutical and cosmetic industries (Ibrahim and Hussein, 2006). However its seeds, calyx and leaves yields are very low in farmer's conditions in Niger due to the poor potential of cultivated varieties. In order to improve the yield of Roselle, plant breeders should have a better understanding of the genetic variability of yield and it components.

The present investigation aims to study the variability of (a) leaves, seeds and calyx yields and (b) yield components among nine ecotypes of Roselle collected at different locations in Niger. Such information is necessary to make a breeding program for the specie.

MATERIALS AND METHODS

Plant materials and growing conditions

The experiment was conducted under natural rainfall conditions from July to September 2004 at the experimental station of the Agrhymet Regional Centre in Niamey, Niger (latitude 13° 29' N and longitude 2° 10' E, and altitude 222 m). The daily mean minimum and maximum temperature during the growth season were respectively 24 and 35°C, and the incoming radiation was 2023 $MJ.m^{-2}.j^{-1}$. The relative humidity was 90% for the maximum and 64% for the minimum. The cumulated rainfall was about 370 mm. The pH of soil at the experimental site was near neutral (7.4), with approximately 0.20% of C, 0.162% of total N and 0.0479% of P (Ndiaye, 2002). 9 ecotypes of Roselle (Table 1) from different locations of Niger (Figure 1) where field tested in farmer conditions (without fertilizer, none pesticide nor irrigation). The experimental design was a completely randomized block design with four replicates. The treatment plot consisted of 18 rows (2 rows per ecotype), each 13.5 m long and 2 m apart between both types of rows. The distance between two consecutive blocks was about 3 m. 10 Roselle seeds were drilled on July 8, 2004 with an intra-row spacing of 1.5 m. Thereafter holes were thinned at two plants at 27 days after sowing (DAS).

Measurements

After plant emergence, leaf area index (LAI) of all ecotypes of each plot where measured using LAI 2000 (Plant Canopy Analyser, Licor, Nebraska, USA). Measurements where carried out twice a week until maturity as follows:

One and four measures of radiations respectively above and under the canopy (Breda, 2003).

These measurements were repeated three times in the middle of rows of each ecotype. The final LAI value was the mean of the three repetitions. After harvest, following measurements were performed on five individual plants coming from middle of rows of each plot:

Total number of branches per plant, number of capsules/plant, number of seeds/fruit, plant collar diameter, total plant height, leaves, seeds and calyx yields, and hundred seed weight.

Statistical analysis was performed using the GenStat *s*oftware version 7.0. Tests for significant difference between means were made using the procedure of analysis of variance (ANOVA) and the Student Newman Keuls test at 0.05 and 0.01 probability levels.

RESULTS

The results indicated a significant difference ($P < 0.01$) among ecotypes in terms of plant height and collar diameter (Table 2). Ecotypes E1 and E2 gave the tallest plants, with a height of about 170 cm while E4 and E9 had the shortest ones (113 cm). The other ecotypes were intermediates. The plant collar diameter ranged from 2.23 cm (E3) to 3.14 cm (E4). The time course of leaf area index (LAI) during plant cycle is presented in Figure 2. The LAI reached a peak at different period according to the ecotypes, from 78 DAS (for about 50% of the

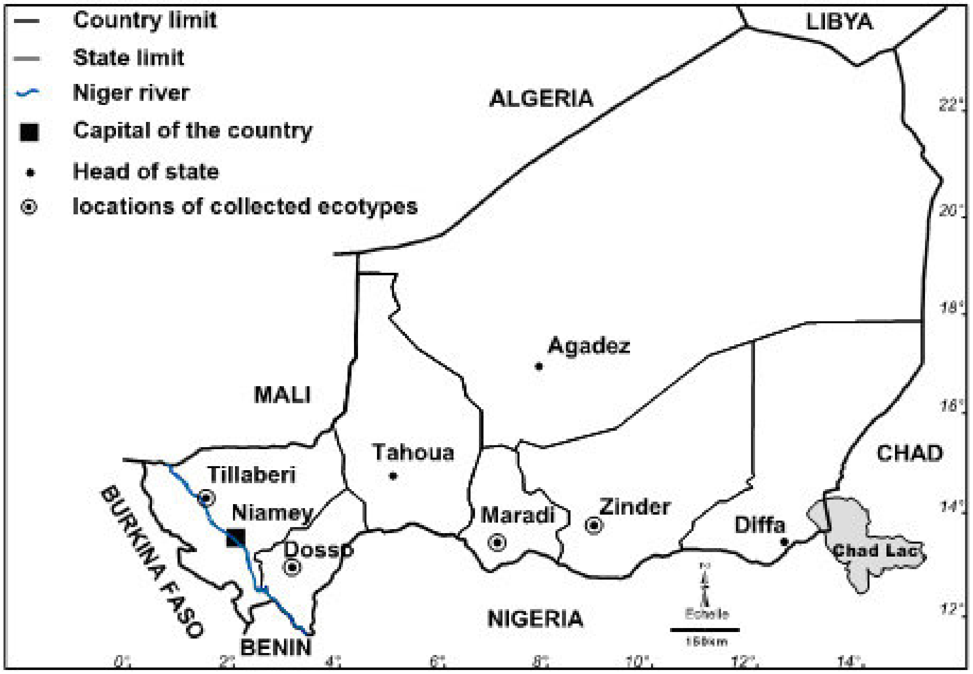

Figure 1. Map of the Republic of Niger and locations where ecotypes of Roselle were collected.

Table 2. Means (±SE) of maximum leaf area index (LAI), plant height and collar diameter of nine Roselle ecotypes.

Ecotype	Plant height (cm)	Plant collar diameter (cm)	LAI max ($cm^2.cm^{-2}$)
E1	169a ± 11.90†	2.96ab ± 0.77	2.37b ± 0.11
E2	175a ± 8.24	2.93ab ± 0.26	3.00ab ± 0.54
E3	129c ± 13.62	2.23d ± 0.49	3.06ab ± 0.79
E4	110d ± 9.21	3.14a ± 0.28	3.13a ± 0.62
E5	142b ± 7.16	2.62bcd ± 0.53	2.67ab ± 0.31
E6	133bc ± 18.41	2.64bcd ± 0.58	2.90ab ± 0.30
E7	131bc ± 13.73	2.70abc ± 0.11	3.07a ± 0.25
E8	131bc ± 8.05	2.45cd ± 0.12	2.81ab ± 0.23
E9	116d ± 12.60	2.75abc ± 0.16	3.11a ± 0.33
Significance	**	**	*

†: Values in the same column with the same letter (s) are not significantly different. ¶: Maximum value of Leaf area index. * and ** : Indicate significant differences among ecotypes at respectively 0.05 and 0.01 probability level.

ecotypes) to 85 DAS. Thereafter, the LAI decreased steadily down to reach its lowest value at around 110 DAS, corresponding to the end of the plant growth. The maximum LAI value differed significantly ($P < 0.05$) among ecotypes (Table 2). Ecotypes E4, E7 and E9 had the highest LAI values while E1 recorded the lowest one. Table 3 presents leaf, seed and calyx yields and the different yield components for the nine ecotypes. There was no significant difference among ecotypes in terms of leaf yield. Average leaf yield for the nine ecotypes was around 340 kg/ha. But ecotypes differed significantly ($P < 0.05$) in term of seed and calyx yields.

The highest seed yields were registered for E2 and E4 and the lowest ones for E7 and E8. The range of difference among ecotypes was higher for calyx yield which varied from 123 kg/ha (E1) to 766 kg/ha (E9). Ecotypes E2, E3, E4 and E5 had similar calyx yield, around 220 kg/ha (Table 3). There was also a significant ($P < 0.05$) difference among ecotypes in the yield components such as hundred seed weight, total number of branches per plant, number of capsules per plant and number of seeds per fruit (Table 3). Ecotype E4 produced the highest total number of branches per plant (36.73) and E8 the lowest one (18.47). The number of capsules/

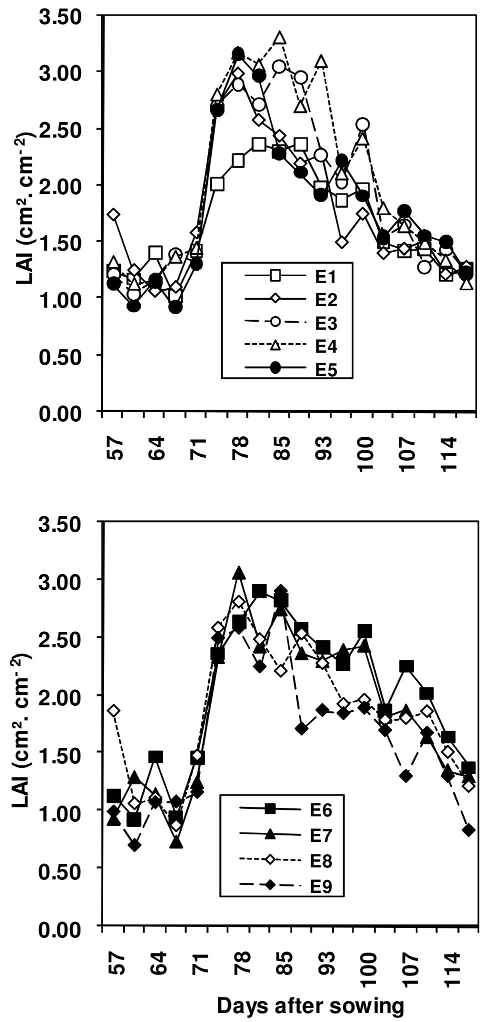

Figure 2. Time course of leaf area index (LAI) of nine Roselle ecotypes according to plant growth stage.

plant varied from 67 (E3 and E7) to 156 for E4. The range of variation among ecotypes was higher for the number of seeds per fruit: from 11.78 for E8 to 27 for E2 and E9. Table 4 presents the matrix of correlation between measured parameters. The seed yield was significantly ($P < 0.01$) and positively correlated with the plant collar diameter, the total number of branches/plant, the number of seeds/fruit and leaf yield. But was not significantly correlated either with the calyx yield nor the hundred seed weight.

The leaf yield was significantly ($P < 0.01$) and positively correlated with plant height ($r = 0.87$), but negatively with calyx yield ($r = - 0.57$). There was a significant ($P < 0.05$) and negative correlation between calyx yield and hundred seed weight. Plant collar diameter was significantly ($P < 0.05$) and positively correlated with the total number of branches/plant and the number of capsules/plant. There was also a significant ($P < 0.01$) and positive correlation between the total number of branches and the number of capsules per plant. Indeed, the correlation between the number of seeds/capsule and hundred seed weight was not significant.

DISCUSSION

The results indicated variability among ecotypes for the maximum LAI values and confirm those previously reported by Mahapatra et al. (2009) in *H. cannabinus*. The peak of LAI was reached between 78 and 85 days after sowing, according to ecotypes. However Giginyu and Fagbayide (2009) found in northern Guinea savanna, that the LAI of two cultivars of Roselle still increased until 20 weeks after sowing. This difference could be attributed to the conditions of plants growth. Among the ecotypes, significant differences were observed for all measured characters under study except leaf yield. This variation reflects the diverse geographic origin and distribution of

Table 3. Yield and yield components of nine Roselle ecotypes at harvest time.

Ecotype	Yield			100 seed weight (g)	Number of		
	Leaves (kg/ha)	Seeds (kg/ha)	Calyx (kg/ha)		Branches/plant	Capsules/ plant	Seeds/ capsule
E1	396±25.74	465ab±28.85†	123d±8.26	3.88b±0.09	22.33bc±8.33	98.33bc±37.75	18.95b±1.61
E2	402±11.53	497a±8.91	197cd±3.75	3.64cd±0.05	22.93bc±3.00	87.13bc±14.10	27.75a±1.17
E3	331±5.04	339abc±19.34	217cd±10.77	3.84bc±0.11	20.00bc±7.12	67.60c±18.75	19.70b±1.55
E4	333±6.92	491a±30.79	272bcd±17.21	3.52d±0.13	36.73a±11.00	156.07a±44.28	19.10b±2.71
E5	343±11.77	304bc±8.63	227cd±10.73	4.16a±0.07	20.40bc±1.51	75.00bc±8.61	18.60b±1.62
E6	336±6.93	384abc±21.75	391bc±20.42	3.91b±0.05	26.87b±9.13	97.53bc±33.04	14.78c±2.34
E7	295±13.10	292c±8.80	275bcd±9.17	3.85bc±0.19	20.20bc±5.57	67.27c±14.85	17.55b±2.93
E8	333±13.06	238c±17.73	458b±18.33	3.44d±0.09	18.47c±2.66	103.20bc±29.75	11.78d±2.60
E9	308±1.41	398abc±25.08	766a±36.81	3.15e±0.25	25.33bc±3.92	107.00b±33.12	26.65a±5.44
Significance	ns	*	**	**	**	**	**

†: Values in the same column with the same letter (s) are not significantly different. ns : non significant. * and ** : Indicate significant differences among ecotypes at 0.05 and 0.01 probability level respectively.

Table 4. Measured parameter correlation matrix.

	Plant collar diameter	Plant height	No. of branch/pl	No. of caps/pl	No. of seeds/capsule	HSW	Calyx yield	Leaf yield	Seed yield
Plant collar diameter	1								
Plant height	0. 185	1							
Tot no branch/pl	0. 682*	- 0. 423	1						
No caps/pl	0. 645*	- 0. 396	0. 860**	1					
No seeds/ capsule	0. 357	0. 177	0. 176	0. 003	1				
HSW	- 0. 187	0. 397	- 0. 294	- 0. 535	- 0. 349	1			
Calyx yield	- 0. 145	- 0. 579*	0. 094	0. 236	0. 179	- 0. 745*	1		
Leaf yield	0. 378	0. 866**	- 0. 040	0. 031	0. 211	0. 228	- 0. 571*	1	
Seed yield	0. 778**	0. 305	0. 660*	0. 508	0. 596*	- 0. 167	- 0. 227	0. 592*	1

* and ** : Indicate significance at 0.05 and 0.01 probability level respectively. No of branch/pl = number of branches/plant. No caps/pl = number of capsules/plant. No of seeds/ caps = number of seeds/capsule. HSW = hundred seed weight.

the ecotypes. The seed yield differed significantly ($P < 0.01$) among ecotypes, from 238 to 497 kg/ha. Similar pattern of variability in germplasm evaluation have been also reported by Ibrahim and Hussein (2006) and support the selection programs for better seed yield.

A great variability among ecotypes was also recorded in calyx yield indicating also the possibility to increase calyx production through selection. Farmer's income would therefore be increase by exportation of calyx to country such as Europe and United States where prices are between 1,000 and 2,500 $US t^{-1} (Cissé et al., 2009). In country such as Senegal, the contribution of leafy vegetables in the income of the households can reach 100% (Diouf et al., 2007). Watson and Eyzaguire (2002) indicated that when the capacity of leafy vegetables to produce high yields and their relatively short growing periods, as compared to cereals, are taken in account, their potential to play a key role in fighting hunger becomes evident. On the other hand, with the Niger population increasing at a rate of 3.3 per year (RGPH, 2001) and poverty on the rise in rural and peri-urban areas, malnutrition is becoming endemic. Women and children are the most vulnerable groups. The increase of the production of leafy vegetables such as Roselle which is mainly cultivated by women with low inputs could greatly help to solve malnutrition problems.

Chadha et al. (2000) have previously shown that the traditional leafy vegetables are richer in vitamins, mineral elements and crude fiber than European vegetables. Westphal et al. (1987) reported an average consumption of leafy vegetables in Sub-Saharan countries of 24 g/person/day. This value has been recently confirmed by Diouf et al. (2007) in Senegal. The seed yield is significantly and positively correlated with leaf yield, plant collar diameter, total number of branches per plant, and number of seeds per fruit (Table 4). Seed yield is determined by the number of seeds per fruit rather than hundred seeds weight. Leaf yield was significantly and positively correlated with plant height and seed yield, but negatively with calyx yield. This indicated that ecotype with higher leaf yield tended to be tall, produced high seed yield but low calyx yield. Therefore the selection for both seed and calyx yields seemed difficult in Roselle. Within the measured yield components, the calyx yield was negatively correlated only with the hundred seed weight.

This result confirm those of Ahmed et al. (2009) who reported also significant and negative correlation between calyx yield and hundred seed weight. However Ibrahim and Hussein (2006) found that the calyx yield was positively correlated with the number of capsules/plant and the seed yield. Within yield components, Gasim and Khidir (1998) found that for Roselle, the number of branches/plant has the highest direct influence on calyx yield. The results also indicated that there was a significant correlation between the total number of branches/plant and the number of capsules per plant and confirmed those previously recorded by Gasim and Khidir (1998). Results showed genetic variability of seed and calyx yields and yield components in Roselle. Thus selection program can be undertaken in order to improve yield and therefore increase farmer's income.

This research indicates the potential contribution of Roselle to poverty alleviation in the Sahel and also for sustainable development.

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