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Interrelationships between Yield and it Components in some Roselle (*Hibiscus Sabdariffa* L.) Genotypes

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Abstract Sixteen genotypes of Roselle (*Hibiscus sabdariffa* L.) were evaluated for two seasons to estimate phenotypic and genotypic correlations, path analysis and selection indices. They study was conducted at Shambat Demonstration Farm in a randomized complete block design with three replications. Data were collected on thirteen plant attributes. Number of capsules/branch, 1000-seed weight, fruit yield /plant, seed yield/plant and calyx yield /unit area exhibited significant positive genotypic correlations with calyx yield/plant in the second season. On the other hand, the plant height, number of fruiting branches/plant, fruit weight, mean calyx weight/capsule, seed yield/plant and calyx yield/unit area showed significant negative genotypic correlations with calyx yield per plant in the first season. At the phenotypic level, calyx yield per plant had positive and significant association with number of capsules/main stem, number of capsules/branch, fruit yield/plant and seed yield/plant in both seasons. The yield components showed different patterns of association with each other. The path analysis indicated that fruit weight had the highest direct effect (0.46) on calyx yield/plant, while fruit yield had the lowest one (-0.19). The selection index based on number of fruiting branches/plant alone produced the highest expected genetic advance (1.66|) and the highest relative efficiency (40.39), followed by number of capsules/main stem and fruit weight. On the other hand, fruit yield/plant produced the lowest expected genetic advance (0.41) and lowest relative efficiency (9.98). Consequently, number of fruiting branches/plant, number of capsules/main stem and fruit weight can be used as selection criteria for the improvement of calyx yield/plant in Roselle.

Keywords: *Hibiscus sabdariffa, correlation, path analysis, selection index, Sudan*

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1. Introduction

Roselle (*Hibiscus sabdariffa* L.), known in Sudan as “Karkade” is an important annual crop which grows successfully inTropic and Sub-tropics. The plant belong to the general order Malvales, family Malvaceae and tribe Hibiscasae. Cotton and Kenaf belong to the same tribe. The specific name, Sabdariffa, is of a Turkish origin [1]. Reference [2] reported that *Hibscus sabdariffa* is a tetraploid (2n = 4x = 72) where the chromosomes are more related to the diploid (2n = 2x = 36) *Hibiscus canabinus*. Murdock [3] and Copley [4] concluded that the crop originated in West Africa and distributed from there to India and other parts of the world. In Sudan, Roselle is grown extensively in Darfor and Kordofan States under rainfed conditions, where large quantities are produced for local consumption and export purposes. Central Bank of Sudan [5] reported that the total exported quantities of dry calyxes of Roselle were 18531 and 15656 tons with total income 17.59 and 14.09 million US dollars in 2011 and 2012, respectively. In the irrigated clays, its production is limited and can only be found scattered in the Northern Region and South Fung area. The production of Karkade in Sudan faces many problems which result in unstable yield. The main yield limiting factor is the low amount and unpredictable distribution of rainfall. Another problem is the high labor requirements for harvesting the crop, the cost of harvesting represents about half the total cost of production. Moreover, most of the cultivars used for production are land races, characterized by low yield potential. Calyx yield in Roselle is a complex character which depends in many components. Therefore improvement of calyx yield requires consideration of all yield components in breeding programs. Knowledge of associations between these plant attributes is very essential to determine the most efficient breeding procedure. Many researchers studied correlations in Roselle [6-13]. This study aimed to:

1/ estimate the interrelationships between different characters and their direct and indirect contributions to calyx yield, using the path coefficient analysis.

2/ compute the expected genetic advance and relative efficiency from selection when different combination characters are used in selection indices.

2. Materials and Methods

The plant materials used in this study consist of sixteen inbred lines of Roselle (*Hibiscus sabdariffa* var. *sabdariffa)*, which were derived by single plant selection by Dr Abdel Wahab Hassan Abdalla (Dept. of Crop Production, Faculty of Agriculture, University of Khartoum). These lines differ mainly in capsule shape, plant height, leaf shape and color of the calyx, stem and petiole, number of branches at the base of the stem and type of foliage. The material was planted in heavy cracking clay soil of the Demonstrating Farm, Faculty of Agriculture, University of Khartoum (latitude 150 40 ` N and 320 32 ` E and 376 meter above sea level) for two seasons, namely, 1998/99 and 1999/00. A randomized Complete Block Design (RCBD) with three replications was used in each season to laying out the field experiment. The gross plot size was 3x3 m2, consisting of four ridges, the spacing was (80 x60) cm. Five or four seeds were sown per hole on the shoulder of the ridge. Sowing was on the 14th of July in the first season and 12th July in the second season. Three weeks after sowing, the plants were thinned to three per hole. The experimental plots were irrigated at an average interval of 12-14 days in both seasons, with a total of eight and nine irrigations for the first and second seasons, respectively. Nitrogen fertilizer at the rate of 40 kg N/feddan was applied, three weeks after sowing. Three weedings were carried out during each season. In both seasons data were collected for: days to 50 % flowering, plant height (cm), number of fruiting branches/plant, number of capsules/branch, number of capsules/main stem, mean calyx weight/capsule (g), calyx yield/plant (g), calyx yield/unit area, number of seeds/capsule, 1000- seed weight (g), fruit weight (g), fruit yield/plant (g), seed yield/plant (g).

The collected data were subjected to analysis of variance according to the method described by Gomez and Gomez [22] and covariance according to Singh and Chaudhary [14].

Estimates of variance and covariance were then used to estimate genotypic and phenotypic correlation coefficients between all possible pairs of characters, at the three seasons, according to the method described by Miller *et al*. [23] as follows:

$$r_{gxy} = \sigma_{gxy}\sqrt{(\sigma 2_{gx}).(\sigma 2_{gy})}$$

$$r_{phxy} = \sigma_{phxy}\sqrt{(\sigma 2_{phx}).(\sigma 2_{phy})}$$

Where:

r_g: is the genotypic correlation coefficient.

r_{ph}: is the phenotypic correlation coefficient.

σ_{gxy} : is the genotypic covariance between two traits, x and y.

σ_{phxy}: is the phenotypic covariance between two traits, x and y.

σ^2_{gx} and σ^2_{gy} are the genotypic variances for traits x and y, respectively.

Path coefficient analysis was calculated, following the procedure suggested by Dewey and Lu [15]. It was used for partitioning the genotypic correlation between seed yield and four of its components into direct and indirect effects. The characters included in the model were: number of capsules/main stem, number fruiting branches/plant, fruit weight (g), fruit yield per plant (g) and calyx yield per plant (g). The residual effect was determined, following Singh and Chaudhary [16].

Five characters were used to formulate different selection indices. These were: number of capsules/main stem, number fruiting branches/plant, fruit weight (g), fruit yield per plant (g) and calyx yield per plant (g).The construction of selection indices and determination of the expected genetic advance under selection were done as described by Robinson *et al*. [17].

3. Results and Discussion

Calyx yield in Roselle is a complex character which depends in many components. Therefore improvement of calyx yield requires consideration of all yield components in breeding programs. This is because improvement of one character may cause improvement or deterioration in associated character/s. so knowledge of associations between these plant attributes is very essential to determine the most efficient breeding procedure.

In this study, the genotypic correlation coefficient exceeded the phenotypic correlation coefficient for most of the characters, in both seasons (Table 1 and Table 2).

The close association between calyx yield and most of its components, at boh phenotypic and genotypic levels over the two seasons may be attributed to genetic effects rather than environmental ones. On the other hand the correlation between calyx yield/plant and number of fruiting branches/plant changed over the two seasons. It was significant in the first season and non significant in the second one indicating that it was not stable. Similar results were reported by Laota [7] and Gasim [8].

The association among yield components showed different patterns at both phenotypic and genotypic levels in this study. The fluctuation which appeared in the estimates of the phenotypic and genotypic correlation coefficients between the two seasons can be attributed to the fact that estimates of the phenotypic correlation are depend on the environmental correlation.

The significant phenotypic and genotypic association among yield components had been attributed to linkage or may be due to developmentally induced relationships between these components, which are indirect consequences of gene action. On the other hand, some of the yield components exhibited negative correlations with each other (number of seeds/capsules and 1000 seed weight). Adams [18] suggested that such associations might caused by competition between these components for assimilates during their development. Therefore, special consideration should be given to those traits which are negatively associated with each other.

3.1. Path Coefficient Analysis

As more variable are included in the correlation study, the association among them will be complex and important. In such situation, path coefficient analysis has been useful to elucidate the direct and indirect relationships among such characters. Calyx yield/plant was positively affected by number of fruiting branches/plant, number of capsules/main stem and fruit weight (Table 3 and Figure 1). Similar conclusion was reported by Gasim [8] The great influence of those traits reflects their importance as yield components. Moreover, number of capsules/main stem had low positive indirect effects on calyx yield/plant via number of fruiting branches/plant and fruit yield/plant, but fruit weight had a high negative indirect effect through fruit yield/plant. Fruit yield/plant had low negative direct effect on calyx yield/plant, but it had the highest positive indirect effect on calyx yield through fruit weight. The number of fruiting branches/plant showed a high negative correlation (-0.45) with calyx yield, but its direct contribution was positive (0.24). This high negative correlation was mainly due to its indirect effect through fruit weight. A similar result was observed for number of capsules/main stem and fruit weight, for which the negative correlation with calyx yield was obtained from its indirect influence through other characters. The high residual effect obtained in this study, however, can be attributed to the exclusion of some traits and sampling errors from the analysis.

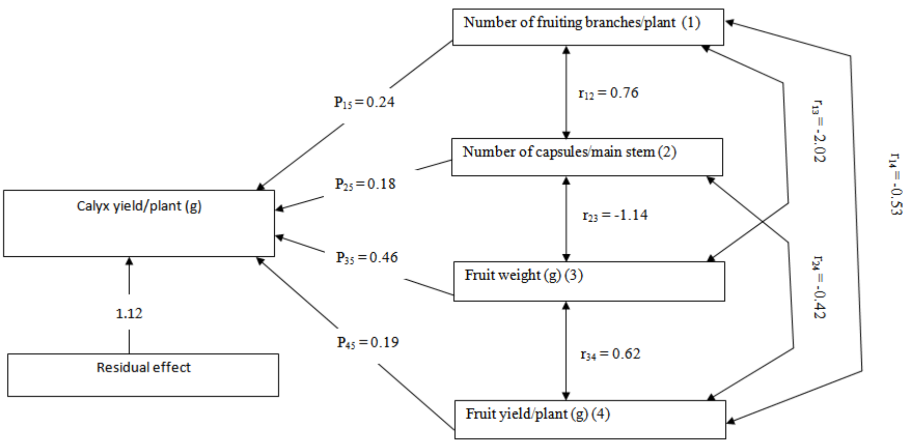
3.2. Selection Indices

Since calyx yield is a complex traits, which depends on many components, its improvement requires simultaneous consideration of all these components in selection programs. Thus, the method of selection index does well in this context.

Table 1. Genotypic and phenotypic correlations between different pairs of characters in roselle in 1998/99 season at shambat

Character	Plant height (cm)	Days to 50% flowering	Number of fruiting branches/ plant	Number of capsules/ main stem	Number of capsules/ branch	Fruit weight (g)	Mean calyx weight/ capsule (g)	Number of seeds/ capsule	1000 seed weight (g)	Fruit yield/ plant (g)	seed yield/ plant (g)	Calyx yield/ plant (g)
Days to 50% flowering	017 0.003											
Number of fruiting branches/ plant	0.18 0.54**	0.52** 0.04										
Number of capsules/main stem	-0.32 -0.06	-34.26** -0.09	0.76** 0.35*									
Number of capsules/branch	-0.93 -0.09	0.01 0.02	0.62** 0.39**	0.14 0.47**								
Fruit weight (g)	0.01 0.18	-0.03 0.05	-2.02** -1.99**	-1.14** 0.17	-0.23 -0.12							
Mean calyx weight/ capsule (g)	-0.83 0.04	-0.46** -0.14	0.83** 0.23	-0.50** 0.12	0.10 0.09	0.14 0.61**						
Number of seeds/ capsule	0.11 0.15	0.89** 0.67**	0.57** 0.22	0.55** 0.27	0.04 0.02	-0.63** -0.21	-0.81** -0.16					
1000 seed weight (g)	-0.27 -0.21	-0.80** -0.64**	-0.47** -0.12	-0.04 -0.27	-0.04 -0.05	0.46** 0.24	0.74** 0.25	-1.02** -0.91**				
Fruit yield/ plant (g)	-0.25 0.49**	1.07** 0.09	-0.53** 0.69**	-0.42** 0.39**	0.25 0.46**	0.62** 0.37**	-0.45** 0.01	0.20 0.09	-0.29* -0.10			
seed yield/ plant (g)	-0.85** 0.03	-0.48** -0.09	-0.48** 0.32*	0.46** 0.45**	0.22 0.29*	-0.51** -0.07	-0.06 0.08	0.03 0.01	0.03 -0.003	-1.64** 0.31		
Calyx yield/ plant (g)	-1.92** 0.19	0.55** 0.08	-0.45** 0.72**	-0.08 0.51**	0.13 0.55**	-0.33* 0.18	-0.93** 0.29*	0.17 0.13	0.21 0.10	-0.11 0.81**	-1.21** 0.42**	
Calyx yield/ unit area (kg/ha)	-0.39** 0.27	0.29* 0.05	-8.47** -0.01	-1.42** 0.02	-0.73 0.23	-0.19 0.26	-1.58** 0.04	0.63** 0.08	-0.81** -0.13	-1.88** 0.31*	-0.58** 0.01	-0.93** 0.09

In each cell the upper and lower figures represent genotypic and phenotypic correlation coefficients, respectively.
* and ** significant at 5% and significant at 1%, respectively



Single - arrowed lines indicate the path coefficients (direct effects).
Doubled – arrowed lines indicate the genotypic correlations between characters

Figure 1. Diagram of the relationships of calyx yield/plant with its components at genotypic level in 1998/99 season at Shambat

Table 2. Genotypic and phenotypic correlations between different pairs of characters in roselle in 1999/00 season at shambat

Character	Plant height (cm)	Days to 50% flowering	Number of fruiting branches / plant	Number of capsules/ main stem	Number of capsules/ branch	Fruit weight (g)	Mean calyx weight/ capsule (g)	Number of seeds/ capsule	1000 seed weight (g)	Fruit yield/ plant (g)	seed yield/ plant (g)	Calyx yield/ plant (g)
Days to 50% flowering	0.15 0.01											
Number of fruiting branches/ plant	0.23 0.29*	0.42** 0.26										
Number of capsules/ main stem	0.29* 0.49**	0.55** -0.35*	1.03** 0.37**									
Number of capsules/ branch	0.04 0.35*	-0.29* -0.18	0.58** 0.51**	1.30** 0.36*								
Fruit weight (g)	-0.03 -0.03	-0.50** -0.43**	-0.51** 0.93**	-1.20** -0.29*	-0.46** -0.25							
Mean calyx weight/ capsule (g)	-0.21 -0.20	-0.52** -0.21	-1.11** -0.76**	-1.29** -0.37**	-0.67** -0.40**	-1.10** 0.88**						
Number of seeds/ capsule	-0.47** -0.08	1.07** 0.62**	0.20 -0.03	-1.03** -0.1	-0.44** -0.32*	-0.41** -0.24	0.09 -0.11					
1000 seed weight (g)	0.08 0.08	-1.004** -0.82**	-0.50** -0.15	0.16 0.19	0.22 0.42**	0.53** 0.42**	0.38** 0.31*	-1.05** -0.83**				
Fruit yield/ plant (g)	0.38** 0.51**	-0.74** -0.21	-0.04 0.45**	0.24 0.59**	0.88** 0.71**	0.20 0.09	0.17 -0.15	-1.00** -0.42**	0.59** 0.43**			
seed yield/ plant (g)	-0.10 0.22	-0.93** -0.68**	-0.01 0.24	0.02 0.39**	0.57** 0.55**	0.13 -0.01	0.01 -0.11	-1.09** -0.49**	0.89** 0.60**	0.61** 0.65**		
Calyx yield/ plant (g)	0.18 0.38**	-0.60** -0.35*	-0.22 0.18	0.05 0.47**	0.73** 0.53**	0.40** 0.28	0.23 0.28	0.73** -0.38**	0.47** 0.43**	1.03** 0.55**	0.48** 0.56**	
Calyx yield/ unit area (kg/ha)	0.28 0.49**	0.94** 0.24	-1.34** -0.06	-0.90** 0.26	0.07 0.39**	1.20** 0.34*	1.40** 0.13	1.16** -0.22	0.95** 0.36*	0.65** 0.59**	0.33* 0.36*	1.03** 0.53**

In each cell the upper and lower figures represent genotypic and phenotypic correlation coefficients, respectively.
* and ** significant at 5% and significant at 1%, respectively.

Table 3. Path coefficient analysis of direct and indirect effects of the different yield components and their genotypic correlation coefficient s with calyx yield/plant at shambat in 1998/99 season

Character	Effect on calyx yield/plant (g) (5)					Genotypic correlation with calyx yield/plant
	Direct effect	Indirect via				
		Number of fruiting branches/plant	Number of capsules/main stem	fruit weight (g)	fruit yield/plant (g)	
Number of fruiting branches/plant	0.24		0.14	-0.93	0.1	-0.45
Number of capsules/main stem	0.18	0.18		-0.52	0.08	-0.08
fruit weight (g)	0.46	-0.48	-0.2		-0.11	-0.33
fruit yield/plant (g)	-0.19	-0.13	-0.08	0.29		-0.11
Residual effect (x)	1.12					

The high relative efficiency (40.39) obtained when selection was based on number of fruiting branches/plant alone. (Table 4). This is an indication of the importance of this trait in contributing to calyx yield. This finding was further confirmed by the fact that whenever number of fruiting branches per plant added to any selection index to form a high order index, or used to replace another trait that was included in the index, the efficiency of such index was tremendously improved. A similar pattern, though not to the same extent as that observed in number of fruiting branches/plant, was observed for number of capsules/main stem. Furthermore, these two traits when combined with calyx yield/plant to form the three-trait selection index, gave the highest relative efficiency (110.71) indicating the importance of these traits in determining genotypic value of any genotype. Thus the two traits could be used as selection criteria.

On the other hand, the relative efficiency of a selection index was reduced when the fruit yield/plant was added or replaced another character in it. This might be due to its negative effects on some yield components. Consequently, the index based on fruit yield/plant and fruit weight showed relatively low efficiency compared to indices of the same order involving number of fruiting branches/plant, number of capsules/main stem and calyx yield per plant.

Indices which were made up of two, three and four characters, at a time were more efficient than those based on individual traits. Similar results have been drawn by many workers in different crops [8,19,20,21].

Table 4. Expected selection genetic advance (GA) from selection in roselle and the relative efficiencies of indices used in 1998/99 season

Trait combination	Genetic Advance	Relative efficiency	Trait combination	Genetic Advance	Relative efficiency
X1	1.03	25.06	X1X2X3	2.2	53.53
X2	1.66	40.39	X1X2X4	1.99	48.42
X3	1.01	24.57	X1X2X5	4.55	110.71
X4	0.41	9.98	X1X3X4	1.50	36.50
X5	4.11	100	X1X3X5	4.36	106.08
X1X2	1.95	47.55	X1X4X5	4.26	103.65
X1X3	1.44	35.09	X3X4X5	4.25	103.41
X1X4	1.11	26.99	X2X3X4	1.98	48.18
X1X5	4.24	103.16	X2X3X5	4.54	110.46
X2X3	1.94	47.2	X2X4X5	4.45	108.27
X2X4	1.71	41.61	X1X2X3X4	2.24	54.5
X2X5	4.43	107.79	X1X2X3X5	4.66	113.38
X3X4	1.09	26.52	X1X3X4X5	4.37	106.33
X3X5	4.23	102.92	X2X3X4X5	4.56	110.95
X4X5	4.13	100.49	X1X2X4X5	4.57	111.19
			X1X2X3X4X5	4.7	114.36

X1 = Number of capsules/main stem, X2 = Number of fruiting branches/plant, X3 = Fruit weight (g),
X4 = Fruit yield/plant (G) and X5 = Calyx yield/plant (G).

4. Conclusions

It could be concluded that since some traits were negatively associated with yield and yield components, special consideration must be made when they are included in a selection program. Moreover, for securing a high efficiency of selection the three traits, number of capsules/main stem, number of fruiting branches/plant and fruit weight could be included.

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