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Research Article

GENETIC VARIABILITY OF ROSELLE (*HIBISCUS SABDARIFFA* L.) GENOTYPES

ULLAH M Z*

Department of Food crops, Bangladesh Institute of Research and Training on Applied Nutrition, Bisnondi, Araihazar, Narayangonj, Bangladesh. Email: zahirsau@gmail.com

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ABSTRACT

Roselle is more than an eye-catching crop and has been used in a number of dishes, beverages, and conventional remedies for diseases for centuries. It is a source of antioxidants and anthocyanin, which acts as a free radical scavenger and inhibits lipid peroxidation. Five Roselle genotypes were evaluated in the Kharif 2 season in 2021 to assess genetic variability, association of traits, and path differentiation of different characters. A field experiment was conducted at the BIRTAN regional station farm in Noakhali, Bangladesh, in a randomized complete block design with three replications. Data were collected on twelve plant attributes. Analysis of variance indicated significant differences among the five genotypes for most of the characters studied except petiole length (cm) and fruit diameter (cm). The phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the studied traits. Phenotypic as well as genotypic coefficients of variability were high for the trait branches per plant (75.92% and 77.81%) and fruits per plant (69.33% and 77.01%), whereas they were medium for calyx per fruit and low for fruit diameter. High heritability estimates (>0.70) were recorded for plant height (cm), leaves per plant, branches per plant, fruit length (cm), calyx per fruit, fruit weight (g), and fruits per plant. On the other hand, the yield components showed medium heritability estimates (<0.70). Medium heritability coupled with a high expected genetic gain was observed for leaves per plant and fruit yield per plant. The highest genetic advance as a percent of men was also observed in branches per plant (152.59%). Fruit yield per plant was found to have a positive and highly significant correlation with branches per plant and fruits per plant, both at genotypic and phenotypic levels, whereas only at the genotypic level for leaf length and fruit diameter. Partitioning the correlation coefficients of various components direct effects on fruit yield into direct and indirect contributions revealed that fruits per plant have the maximum direct effect on fruit yield, followed by fruit weight and branches per plant at the genotypic level. High positive correlation coefficients for branches per plant were due to the indirect effects of fruits per plant. Hence, selection for the traits fruits per plant, branches per plant, and leaf length may be successful for fruit yield improvement in roselle. According to morphological traits and yield attributes the genotype RL 2 is the best among the studied genotypes.

Keywords: Roselle, Variability, Calyces, Correlation, Path analysis.

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INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) belongs to the family Malvaceae, is native to Asia (India to Malaysia) or Africa, and is an annual or biennial plant cultivated in tropical and subtropical regions for its stem, fibers, edible calyces, leaves, and seeds (Babatunde and Mofoke, 2006; Mahadevan *et al.*, 2009). Roselle is a tetraploid species with 2n=4x=72 (Sabiel *et al.*, 2014) and is highly self-pollinated. The chromosomes are more related to the diploid (2n = 2x = 36) *Hibiscus canabinus* (Wilson and Menzel, 1964). It is proven for its importance in the preparation of medicines and in culinaries to make favorable dishes from its edible parts in many countries. There are two botanical types of roselle, viz., *H. sabdariffa* var. altissima and *H. sabdariffa* var. sabdariffa. The second is grown for its fleshy, shiny-red calyxes (Ibrahim *et al.*, 2013). It is an important annual crop that grows successfully in the tropics and sub-tropics (El Naim *et al.*, 2012).

Generally, the success of any crop improvement program largely depends on the magnitude of genetic variability, genetic advance, character association, direct and indirect effects on yield, and its attributes. Correlation and path coefficient analysis of traits will also help component characters in a breeding program whose selection would result in the improvement of complex traits that are positively correlated. Genetic variability and inter-relationship studies have been done in a wide range of fibre crops e.g. kenaf (Mostofa *et al.*, 2002; and Ghodke and Wadikar, 2011), roselle (Ibrahim and Hussein, 2006; Rani *et al.*, 2006; Bhajantri *et al.*, 2007; Ibrahim *et al.*, (2013) and Satyanarayana *et al.*, 2015), jute (Palve and Sinha, 2005 and Bhattacharya *et al.*, 2007) and okra (Murtadha *et al.*, 2004; Adeniji *et al.*, 2007 and Nwangburuka *et al.*, 2012) will provide the information on genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability, genetic advance and genetic advance as percent mean, correlation between different characters with yield along with their direct and indirect effects on yield. In this context, the present investigation was undertaken to assess the genetic variability, heritability, genetic advance, character association, and path coefficient analysis of the fruit yield and its attributing traits of roselle by utilizing five genotypes.

Roselle, in English, is a shrub plant that is grown in tropical countries. It belongs to the family Malvaceae (Osman *et al.*, 2011; Singh *et al.*, 2017) of the Hibiscus genus. It can be planted in a wide range of soil conditions. Relatively infertile soil is sufficient to grow it, even in sandy soil. However, the soil needs to be rich in organic materials and nutrients for commercial cultivation. The plant is an annual or perennial herb or woody-based sub-shrub, growing up to 2–2.5 m tall (Puro *et al.*, 2016). The leaves are deeply 3–5 lobed, 8–15 cm long, arranged alternatively on the stems (Adegunloye *et al.*, 1996). 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 bright red as the fruit matures. The plant is about 3.5 m tall and has a deep penetrating taproot system (Daudu *et al.*, 2015). It takes about 6 months to mature (Brunold *et al.*, 2004). The calyx is the most important part of the plant because it contains the valuable components that determine the quality of the product, namely: colour (anthocyanin), flavor (organic acid), and aroma. The Roselle calyx is also rich in malic acid, anthocyanins, ascorbic acid, and minerals (Javadzadeh and Saljooghianpour, 2017). The dried calyces are commonly used in the preparation of cold and hot beverages and as a food colorant (Maganha *et al.*, 2010). In Nigeria, the common popular drink of roselle is known as "zobo" and the herb is used in folk medicine in the treatment of hypertension (Olaleye and Akindahunsi, 2005). The plant is economically important for proper metabolic processes to be adequately maintained. It was discovered that the dietary constituents contributing to the protective effects of these plant materials are plant secondary metabolites in the form of phytochemicals, vitamins, and minerals (Okereke *et al*., 2015). The aim of this research is to study the genetic variability, correlation, and cause-and-effect analysis of Hibiscus species.

METHODS

Plant material

The experiment was conducted in the research field of the Bangladesh Institute of Research and Training on Applied Nutrition (BIRTAN), regional station, Noakhali, during the summer of 2021. All standard growing measures have been applied. The experiment consisted of five Roselle genotypes (Table 1).

Design and layout

A randomized complete block design with three replications was used in the field experiment. Seed was sown in the main field on July 14, 2021. The plot size is four rows of 2 m in length with an intra-row spacing of 10 cm and an inter-row spacing of 30 cm, accommodating 20 plants in a row. A recommended package of practices was followed to raise a good crop. The experimental trial was laid out in a randomized block design in two replications with a plot size of four rows of 2 m length with intra-row spacing of 10 cm and inter-row spacing of 30 cm, accommodating 20 plants in a row. A recommended package of practices was followed to raise a good crop. Data on the basis of five randomly selected plants were recorded for plant height (cm), base diameter (mm), number of nodes per plant, days to 50% flowering, number of pods per plant, number of seeds per pod, test weight (g), and seed yield per plant (g).

Data record

Data on the basis of five randomly selected plants were recorded for plant height (cm), leaves per plant, leaf length (cm), leaf breadth (cm), petiole length (cm), branches per plant, fruit length (cm), fruit diameter (cm), calyx per fruit, fruit weight (g), fruits per plant, and fruit yield per plant (g).

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, with a total of eight and nine irrigations. Nitrogen fertilizer at a rate of 40 kg N/ha was applied 3 weeks after sowing. Manual weeding was carried out for 3 times during the growing season.

Statistical analysis

The data were subjected to analysis of variance following standard statistical methods (Singh and Choudhary, 1985). Genotypic and phenotypic coefficients of variation (GCV and PCV) were calculated using the formula suggested by Burton and De Vane (1953). Heritability and genetic advance were estimated according to the formulas given by Allard (1960). Genotypic and phenotypic correlations were calculated as suggested by Johnson *et al*., (1955). The phenotypic correlations were used to find out the direct and indirect effects of the component characters on fiber yield per plant, according to Dewey and Lu (1959).

Table 1: Experimental materials

Variety Code/Name	Description
RL 001	Collected from Noakhali local market; fruit and stem red in color, lower leaf red spot
RL 002	Collected from Noakhali local market; fruit and stem red in color, leaf green
RL 003	Collected from Noakhali local area; leaf, spine present in stem and fruit; leaf, stem and fruit green, plant is tall
RL 004	BJRI Mesta 2, leaf red in the upper side and green in the dorsal side, stem red, and fruit deep red
RL 005	Leaf fruit green, plant green in color. Stripe is present in fruit.

RESULTS AND DISCUSSION

Mean performance

The mean performance of five Roselle genotypes for 12 traits revealed significant differences among the genotypes for most of the traits studied except petiole length and fruit diameter (Table 2). Plant height ranged from 147.00 to 250.67 cm. The observed differences among these genotypes can be attributed to genetic as well as environmental factors. Similar results had been reported by many workers. Ibrahim and Hussein (2006) detected significant differences among genotypes for plant height, number of branches, seed weight, and sepal dry weight.

Genetic variability

High values of PCV and GCV were recorded for the traits plant height (25.75% and 23.26%), leaves per plant (43.25% and 36.46%), branches per plant (77.81% and 75.92%), fruits per plant (77.01% and 69.33%), fruit weight (30.89% and 30.86%), and fruit yield per plant (48.78% and 39.03%), suggesting high variability for these traits in the present study, whereas the character calyx per fruit exhibited moderate values of PCV and GCV (17.97% and 17.93%). Leaf length (9.16%) and fruit diameter (6.75%) showed lower values of GCV (Table 3). The trait of fruit diameter exhibited moderate values for PCV and lower values for GCV, which confirms the influence of the environment on these traits. These findings are in agreement with Nwangburuka *et al*., (2012), Ibrahim *et al*., (2013), and Hari Satyanarayana *et al*., (2017). The estimates of PCV were generally higher than their corresponding GCV for all the traits studied, suggesting thereby the important role of environment in the expression of these traits. Hence, phenotypic selection may not be good for genetic improvement in these traits.

Heritability is of greater value to the breeder since it indicates the degree of dependence of genotypic value on phenotypic value. Broad-sense heritability was high (>0.70) for character plant height (81.59%), leaves per plant (71.09%), branches per plant (95.20%), fruit length (91.27%), calyx per fruit (99.56%), fruit weight (99.80%), and fruits per plant (81.05%), indicating that these characters possessed a wide range of genetic variability and that their improvement could be achieved with mass selection alone. These high estimates of heritability could be attributed to the difficulty of separating all genotype and environment interactions from genotypic variance since the study was carried out in one location, and thus the heritability estimates were biased upward. Whereas medium heritability was estimated for fruit yield per plant (64.02%), leaf length (56.58%), leaf breadth (59.09%), petiole length (38.03%), and fruit diameter (35.25%). Similar results were also reported by Nwangburuka *et al.*, (2012), Ibrahim *et al.*, (2013), and Hari Satyanarayana *et al.*, (2017). The estimates of heritability, however, indicate only the effectiveness with which the selection of genotypes can be made based on their phenotypic performance but fail to indicate the amount of progress expected from selection. For an effective selection, knowledge alone based on estimates of heritability is not sufficient, and genetic advancement if studied along with heritability, is more useful. Genetic advance as a percent of the mean was high for the traits plant height (43.28%), leaves per plant (63.33%), branches per plant (152.59%), fruit length (54.95%), calyx per fruit (36.86%), fruit weight (63.51%), fruits per plant (128.57%), and fruit yield per plant (64.33%), whereas it was moderate for leaf length (14.20%), leaf breadth (18.40%), and petiole length (18.74%), and lower for fruit diameter (8.25%). These findings were corroborated by the results of Islam *et al.*, (2002), Nwangburuka *et al.*, (2012), Ibrahim *et al.*, (2013), and Hari Satyanarayana *et al.*, (2017). The greater influence of environment was noticed on the variability parameters of the accessions for different characters can be mainly attributed to the wide range of environments under which the study was undertaken.

The low heritability for petiole length (38.03%) and fruit diameter (35.2%) were due to the fact that they depend on many components, which are greatly influenced by the environment.

Table 2: Mean performance of five Roselle genotypes

G	PH (cm)	LPP	LL (cm)	LB (cm)	PL (cm)	BPP	FL (cm)	FD (cm)	CPF	FW (g)	FPP	FYP (g)
RL 01	147^{b}	264^{b}	13^{ab}	5.83^{ab}	5.53^{b}	2.17^{d}	3.17^{b}	2.3^{ab}	10^{a}	4.71^{d}	117^{b}	551.79^{bc}
RL 02	147.67^{b}	243^{b}	15^{a}	4.5^{c}	5.9^{ab}	7.5^{b}	4.9^{a}	2.43^{a}	10.13^{a}	6.23^{b}	150.67^{b}	999.07^{a}
RL 03	250.67^{a}	479.67^{a}	13.67^{ab}	5.03^{bc}	8.17^{a}	12.33^{a}	2.57^{b}	2^{b}	7^{c}	2.54e	340^{a}	875.87^{ab}
RL 04	183.33^{b}	225.33^{b}	11.67^{b}	6.16^{a}	5.3^{b}	2^{d}	5.17^{a}	2.03^{b}	9^{b}	6.41^{a}	111^{b}	696.5^{ab}
RL 05	163.33^{b}	212^{b}	12^{b}	6^{ab}	6.23^{ab}	4.33^{c}	4.77^{a}	2.1^{ab}	7^{c}	5.34^{c}	49^{b}	261.95^{c}
Min.	147.00	212.00	11.67	4.50	5.30	2.00	2.57	2.00	7.00	2.54	49.00	261.95
Max.	250.67	479.67	15.00	6.16	8.17	12.33	5.17	2.43	10.13	6.41	340.00	999.07
Mean	178.40	284.80	13.07	5.51	6.23	5.67	4.11	2.17	8.63	5.05	153.53	677.03
CV%	11.05	23.25	8.03	9.67	18.83	17.05	8.64	9.14	1.20	1.37	33.53	29.26
F test	**	**	*	*	Ns	**	**	Ns	**	**	**	*

The same letter(s) in a column did not differ significantly at p 0.05 by DMRT, **,*Significant at 1 and 5%, respectively. PH: plant height (cm), LPP: leaves per plant, LL: leaf length (cm), LB: leaf breadth (cm), PL: petiole length (cm), BPP: branches per plant, FL: fruit length (cm), FD: fruit diameter (cm), CPF: calyx per fruit, FW: fruit weight (g), FPP: fruits per plant and FYP: fruit yield per plant (g)

Table 3: Genetic parameters of Roselle genotypes

Parameters	PCV (%)	GCV (%)	ECV (%)	Heritability	Genetic advance (5%)	Genetic advance (% mean)
PH	25.75	23.26	11.05	81.59	77.20	43.28
LPP	43.25	36.46	23.25	71.09	180.38	63.33
LL	12.18	9.16	8.03	56.58	1.86	14.20
LB	15.11	11.62	9.67	59.09	1.01	18.40
PL	23.93	14.75	18.83	38.03	1.17	18.74
BPP	77.81	75.92	17.05	95.20	8.65	152.59
FL	29.22	27.92	8.64	91.27	2.26	54.95
FD	11.36	6.75	9.14	35.25	0.18	8.25
CPF	17.97	17.93	1.20	99.56	3.18	36.86
FW	30.89	30.86	1.37	99.80	3.20	63.51
FPP	77.01	69.33	33.53	81.05	197.39	128.57
FYP	48.78	39.03	29.26	64.02	435.51	64.33

PCV: phenotypic coefficient of variation, GCV: genotypic coefficient of variation, ECV: environmental coefficient of variation, PH: plant height (cm), LPP: leaves per plant, LL: leaf length, LB: leaf breadth, PL: petiole length (cm), BPP: branches per plant, FL: fruit length, FD: fruit diameter, CPF: calyx per fruit, FW: fruit weight (g), FPP: fruits per plant and FYP: fruit yield per plant (g)

Estimates of genetic variances were higher than their respective environmental variances for all the traits except fruit diameter. This result revealed that a large proportion of the phenotypic variance traits were due to genetic effects, so selection for these traits will be effective.

However, the association between genetic advance and heritability does not follow the same pattern as that between genetic advance and genotypic coefficient of variation. An increase in heritability value was not always accompanied by an increase in genetic advance. Similar results were obtained by Gasim and Khidir (1998), but high heritability with high genetic advance were observed in plant height (81.59 and 43.28), leaves pewr plant (71.09 and 63.33), branches per pant (95.20 and 152.59), fruit lengrh (91.27 and 54.95), calyx per fruit (99.56 and 36.86), fruit weight (99.80 and 63.51), fruits per pant (81.05 and 128.57), and fruit yield per plant (64.02 and 64.33), whereas low heritability with low genetic advance was detected in fruit diameter (35.25 and 8.25). The nature of the association between heritability and the genetic advance was explained by Panse (1957), who reported that the association of high heritability with a high genetic advance is an indication of additive gene effects, and, consequently, a high genetic gain from selection could be expected. On the other hand, the association of low heritability with low genetic advance is an indication of non-additive gene effects, and consequently, a low genetic gain would be expected from selection.

However, Johnson *et al.* (1955) stated that heritability does not provide an actual measurement of the amount of genetic variation, as the magnitude of heritability depends on the degree of association between the genotypic and phenotypic variances, regardless of being high or low, while the genetic gain depends on the amount of genetic variability. Similar ideas were expressed by Allard (1960).

Correlation analysis

The correlation coefficients at genotypic and phenotypic levels were estimated for different pairs of characters from their data on five roselle genotypes (Table 4). The intercharacter association with fruit yield was positively significant for branches per plant (0.617** and 0.497*) and fruits per plant (0.637** and 0.682**) at both genotypic and phenotypic levels. Whereas a significant positive correlation was observed for leaves per plant (0.983**) and fruit diameter (0.493*) at the genotypic level. On the other hand, the trait leaf breadth had a highly significant association with fruit yield in a negative direction (−0.878** and −0.698**) at both levels. However, the traits plant height (0.388 and 0.168), leaves per plant (0.448 and 0.446), petiole length (0.407 and 0.126), and calyx per fruit (0.419 and 0.315) were positively and insignificantly correlated with fruit yield per plant at both phenotypic and genotypic levels.

Selections carried out based on the correlation studies are reliable only when there is a significant association both at genotypic and phenotypic levels (Ibrahim and Hussein, 2006) for a particular trait with the dependent variable, yield. Higher genotypic correlation coefficients than the phenotypic correlation coefficients were observed for all characters, suggesting a strong relationship between these characters at the genetic level.

Fruit yield per plant has highly significant positive associations with traits like fruits per plant (0.637** and 0.682**) and branches per plant (0.617** and 0.497*) at genotypic and phenotypic levels, whereas leaves per plant (0.983**) and fruit diameter (0.493*) were positively significant with fruit yield per plant at the genotypic level only. These findings were in agreement with Palve *et al.*, (2003), Nwangburuka *et al.*, (2012), and Ibrahim *et al.*, (2013).

Plant height exhibited a significant positive association with leaves per plant (0.980** and 0.738**), petiol length (0.987** and 0.610**), branches per plant (0.756** and 0.656**), and fruits per plant (0.967** and 0.647**). Fruits per plant exhibited a significant positive correlation with leaves per plant (0.920** and 0.891**), petiole length (0.903** and 0.593*), and branches per plant (0.909** and 0.793**) at both levels.

Table 4: Genotypic and phenotypic correlation of roselle genotypes

Traits	PH	LPP	LL	LB	PL	BPP	FL	FD	CPF	FW	FPP
LPP											
r_g	0.980**										
r_p	0.738**										
LL											
r_g	0.028	0.441									
r_p	−0.087	0.200									
LB											
r_g	−0.173	−0.468	−0.938**								
r_p	−0.108	−0.357	−0.659**								
PL											
r_g	0.987**	0.946**	0.558*	−0.623**							
r_p	0.610**	0.692**	0.073	−0.268							
BPP											
r_g	0.756**	0.913**	0.721**	−0.835**	0.938**						
r_p	0.656**	0.722**	0.474	−0.627**	0.703**						
FL											
r_g	−0.569*	−0.921**	−0.225	0.254	−0.908**	−0.530*					
r_p	−0.524*	−0.668**	−0.271	0.107	−0.427	−0.468					
FD											
r_g	−0.990**	−0.511*	0.798**	−0.642**	−0.599*	−0.205	0.261				
r_p	−0.422	−0.317	0.555*	−0.385	−0.336	−0.115	0.101				
CPF											
r_g	−0.706**	−0.484*	0.400	−0.221	−0.859**	−0.454	0.248	0.986**			
r_p	−0.629**	−0.411	0.330	−0.160	−0.553*	−0.443	0.224	0.623**			
FW											
r_g	−0.788**	−0.980**	−0.191	0.226	−0.990**	−0.699**	0.942**	0.540*	0.562*		
r_p	−0.719**	−0.820**	−0.141	0.186	−0.682**	−0.682**	0.900**	0.307	0.560*		
FPP											
r_g	0.967**	0.920**	0.551*	−0.594*	0.903**	0.909**	−0.784**	−0.279	−0.304	−0.828**	
r_p	0.647**	0.891**	0.369	−0.524*	0.593*	0.793**	−0.600*	−0.320	−0.287	−0.736**	
FYP											
r_g	0.388	0.448	0.983**	−0.878**	0.407	0.617**	−0.208	0.493*	0.419	−0.110	0.637**
r_p	0.168	0.446	0.480	−0.698**	0.126	0.497*	−0.034	0.093	0.315	−0.075	0.682**

*Significant at 5 % probability level, **Significant at 1 % probability level, PH: plant height (cm), LPP: leaves per plant, LL: leaf length, LB: leaf breadth, PL: petiole length (cm), BPP: branches per plant, FL: fruit length, FD: fruit diameter, CPF: calyx per fruit, FW: fruit weight (g), FPP: fruits per plant and FYP: fruit yield per plant (g)

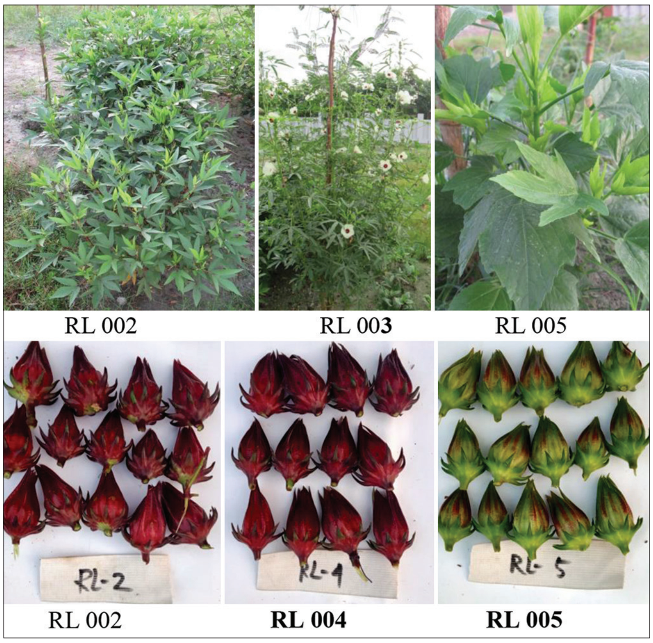

Fig. 1: Plant (above) and fruit photographs of some Roselle genotypes

A negative and significant correlation of fruit weight with fruits per plant (−0.828** and −0.736**) was observed at both levels. A positive and significant correlation of fruit weight was observed with fruit length (0.942** and 0.900**) and calyx per fruit (0.562* and 0.560*).

With this study, it is confirmed that the traits fruits per plant, branches per plant, leaf length, leaves per plant, plant height, fruit diameter, and calyx per fruit are very important for fruit yield per plant as they showed a positive correlation both at genotypic and phenotypic levels. Selections made based on these traits will be successful for higher fruit yield in roselle.

Path analysis studies

Partitioning the correlation coefficients of various component characters with fruit yield into direct and indirect contributions (Table 5) revealed that fruits per plant have the maximum direct effect (1.507) on fruit yield, followed by fruit weight (1.144), branches per plant (0.587), calyx per fruit (0.262), and fruit diameter (0.233). The high correlation coefficient of fruits per plant (0.637**) at the genotypic level with fruit yield was totally due to the direct effects of fruits per plant (1.507). The high correlation coefficient of branches per plant (0.617**) with fruit yield was majorly due to the direct effect (0.587) as well as the indirect effects of fruits per plant (1.370). Likewise, the high correlation coefficient of leaf length (0.983**) with fruit yield was also largely due to the indirect effects of fruits per plant (0.830). Similarly, the high correlation coefficient of fruits per plant (0.637**) at the genotypic level with fruit yield was due to the direct effects of its own (1.507). The significant positive correlation coefficient of fruit diameter (0.493*) with fruit yield was responsible for the indirect effect of fruit weight (0.618). The negative correlation coefficient of leaf breadth (−0.878**) was mainly due to the indirect effect of fruits per plant (−0.895).

The relationship between traits explained through character association studies may not provide a clear picture of the bonding between yield and its contributing traits. Path analysis provides lucid information on the direct and indirect effects of traits and measures the relative

Table 5: Genotypic path coefficient analysis of component traits for fruit yield per plant of roselle

Traits	PH	LPP	LL	LB	PL	BPP	FL	FD	CPF	FW	FPP	r_g
PH	**−0.181**	−0.003	−0.009	0.003	−0.073	0.444	0.092	−0.254	−0.185	−0.901	1.458	0.388
LPP	−0.178	**−0.003**	−0.157	0.008	−0.076	0.536	0.149	−0.119	−0.127	−1.122	1.537	0.448
LL	−0.005	−0.001	**−0.357**	0.021	−0.037	0.423	0.036	0.186	0.104	−0.219	0.830	0.983**
LB	0.031	0.001	0.442	**−0.017**	0.041	−0.491	−0.041	−0.150	−0.057	0.258	−0.895	−0.878**
PL	−0.199	−0.003	−0.199	0.010	**−0.067**	0.669	0.147	−0.139	−0.225	−1.247	1.662	0.407
BPP	−0.137	−0.002	−0.257	0.014	−0.076	**0.587**	0.085	−0.047	−0.118	−0.800	1.370	0.617**
FL	0.103	0.002	0.080	−0.004	0.060	−0.311	**−0.162**	0.061	0.065	1.078	−1.182	−0.208
FD	0.198	0.001	−0.285	0.011	0.040	−0.120	−0.042	**0.233**	0.258	0.618	−0.420	0.493*
CPF	0.128	0.001	−0.142	0.003	0.057	−0.266	−0.040	0.230	**0.262**	0.643	−0.458	0.419
FW	0.143	0.003	0.068	−0.003	0.073	−0.411	−0.152	0.126	0.147	**1.144**	−1.248	−0.110
FPP	−0.175	−0.003	−0.196	0.010	−0.073	0.534	0.127	−0.065	−0.079	−0.947	**1.507**	0.637**

RE: 0.021, *Significant at 5% probability level, **Significant at 1% probability level, r_G-Genotypic correlation with fruit yield per plant, Residual value−0.156, Bold diagonal figures indicate a direct effect. PH: plant height (cm), LPP: leaves per plant, LL: leaf length, LB: leaf breadth, PL: petiole length (cm), BPP: branches per plant, FL: fruit length, FD: fruit diameter, CPF: calyx per fruit, FW: fruit weight (g), FPP: fruits per plant and FYP: fruit yield per plant (g).

importance of each and every trait in shaping the final objective, fruit yield. The direct and indirect effects showed that fruits per plant (1.507) had the maximum direct effect, followed by fruit weight (1.144), branches per plant (0.587), calyx per fruit (0.262), and fruit diameter (0.233), respectively, whereas leaf breadth has a negative direct effect (−0.878**). The positive and highly significant correlation of leaf length and fruit diameter with fruit yield was also mainly due to the indirect effect of fruits per plant and fruit weight, respectively, rather than their direct effects. These results were corroborated by the findings of Islam *et al.*, (2001), and Pervin and Haque (2012).

The value of residual effects was very low, 2.10%, suggesting that about 98% of the total variation for fruit yield in roselle was explained, and the remaining percent has not been studied in the present study. Finally, the path coefficient analysis revealed the importance of fruits per plant, fruit weight, calyx per fruit, and leaves per plant for their contribution either directly or indirectly to fruit yield, and hence, during selection, these traits should be given utmost attention for developing high-fruit yielding roselle varieties.

CONCLUSIONS

H. sabdariffa, or "Roselle" is a medicinal plant with worldwide fame, having various important nutrients. Wide genetic variability was detected in the tested roselle genotypes. This variability is exploited in different breeding programs. There was no definite trend between the genetic coefficient of variation and heritability or between the later and genetic advances. Therefore, the conjunction of heritability estimates with genetic advances in a selection program is essential. In conclusion, selection based on the trait fruits per plant proves very effective, as the trait showed the highest association with fruit yield and had high positive direct and indirect effects through branches per plant and fruit length, coupled with high GCV, PCV, high heritability, and high genetic gain along with fruit yield. The other traits, such as branches per plant, leaves per plant, and leaf length, may also be considered for selection as they have a high positive association with fruit yield both at genotypic and phenotypic levels. Therefore, emphasis should be given to the above traits during selection for evolving high-fruit yielding lines of roselle. According to morphology and yield attributes RL 2 is the best among the studied genotypes.

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