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COMBINING ABILITY AND HETEROSIS FOR CALYX YIELD AND ITS CONTRIBUTING TRAITS IN SIX ROSELLE (HIBISCUS SABDARIFFA L.) CULTIVARS.

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ABSTRACT

This study was undertaken to estimate the combining ability and heterosis in six diverse genotypes of roselle using a half diallel mating design. The 6 parents and the 15 F1s were evaluated in a randomized complete block design with three replications in three different locations, Maiduguri, Yola and Biu, Nigeria. Data were recorded of calyx yield and its contributing traits. Analysis of variance showed there were significant differences among the parents and their hybrids which shows both additive and non-additive gene action were in operation. The estimates of variance components showed GCA variances were lower than the SCA variances with all showing ratios of less than one. This indicates that the non-additive gene action played greater part in the inheritance of all traits than the additive gene action. The parents, Fy, Ft and Nh84 were considered good general combiners for most of the traits studied. While for calyx yield, Fy, Ft and Qr were identified as good combiners and they can be used for calyx yield improvement breeding programme. The best cross combinations which exhibited desirable SCA effects for calyx yield and other important yield components were, Nh84 x Nh75, Fy x Nh75, Qr x Na147 and Fy x Nh84. There were no positive significant heterotic values recorded for all traits. The cross combination Ft x Na147 showed significant negative heterosis for fruit yield, while crosses, Ft x Nh75, Fy x Nh84 and Na147 x Qr also exhibited significant negative heterosis for number of flowers. These crosses can be used for developing early flowering and early fruiting varieties in roselle.

Keywords: Roselle, Diallel crossing, Combining ability, Heterosis

INTRODUCTION

Roselle (Hibiscus sabdariffa L.) is known with so many names as sobo, Yakuwa or Karasu (kanuri) in the Northern part of Nigeria. The plant belongs to the malvaceae family and it is

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thought to have originated in West Africa where it was taken to India and other parts of the world. Roselle has two main types that are cultivated and on the basis of their growth habit or end use are classified broadly under two varieties, H. sabdariffa Var. sabdariffa and H. sabdariffa Var. altisima. The former variety is mainly grown for its fleshy calyces while the latter is grown for its phloem fibre (Sharma, et al., 2016; Mortan, 1987).

Roselle is grown extensively in most parts of Northern Nigeria under rainfed conditions because of its edible calyces, leaves, seeds and medicinal qualities (Babatunde and Mofoke, 2006). Apart from its importance in the preparations of medicines, it is also used in culinaries to make favourable dishes from its edible parts. Its medicinal qualities has many applications in folk medicine in many countries. Many studies have demonstrated that the water and fat extracts of roselle sepals and seeds have high antioxidant qualities which have been useful in lowering blood pressure (Ibrahim and Hussein, 2006) It has also been used for the treatment of hypertention, pyrexia and liver damages in China.

Nowadays demands for its supply has tremendously increased in the country and beyond because of its use in the preparation of a local beverage called "Soborodo" from the red calyces and for export to other countries, particularly to Mexico. Hence in order to meet this demand, there is the need to increase its production. The main limiting factor for its yield increase has been the use of cultivars that are landraces which are inherent with low yield potentials.

Crop improvement through successful selection programme largely depends on the nature and magnitude of genetic variability present in the germplasm, Goyal and Kumar, (1991). Several studies have been conducted on roselle but there is still paucity of information regarding its genetics, breeding and production. The use of hybrid vigor and selection of parents based on their combining ability is the first line in the preparation for breeding towards improvement of crop. Combining ability analysis is one of the important methods in use for identifying the good combiners which may be used in hybridization to exploit heterosis and to select better crosses for direct use or further breeding work. The relevance of heterotic values and combining ability among roselle germplasm is in the increase in effectiveness of hybrid development. Therefore, the breeders have always one objective in mind when selecting hybrids on the basis of expected level of heterosis as well as specific combining ability.

The present study was aimed at estimating the GCA and SCA effects and to evaluate the better parent heterosis for calyx yield and its components for both parents and their hybrids in a half diallel cross in roselle.

MATERIALS AND METHODS

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Six roselle germplasms, Farar Yakuwa (Fy), Farcen Tsuntsun (Ft), NAMH-147 (Na147), NH75-227 (Nh75), Qarara (Qr) and NH84-445 which were selected on the basis of their divergence of characteristics, such as days to maturity, fruit color, stem shape and size, flower shape and size. Some of the cultivars were collected from the Borno State Agricultural Development Programme (BOSADP) Maiduguri, Nigeria and some from Dadin Kowa Horticultural research station Gombe, Nigeria.

During the 2017 cropping season, crosses were made in all possible combinations between the six cultivars excluding the reciprocals. All the fifteen F_1 and the six parents were evaluated in a randomized complete block design with three replications during the 2018 cropping season in three locations, Maiduguri, Yola and Biu. Each plot consist of 12 plants planted in three rows with four plants each. The spacing was 80cm between rows and 60cm within rows. Recommended package of all agronomic practices were employed in raising the crop. Data on the basis of five randomly selected plants were recorded for, plant height, number of leaves per plant, number of branches per plant, number of flowers per plant, branch length, days to 50% flowering, number of calyx per plant, fruit length, fruit yield, number of seeds per plant and calyx yield. The data were subjected to the analysis of variance (ANOVA) for the traits recorded, combining ability and diallel analysis was done following Griffings numerical approach Method 2, Model 1 described by (Singh and Chaudhary, 1979).

RESULTS AND DISCUSSION

The mean squares analysis of variance due to parental lines for eleven traits combined across three locations is presented in table 1. The mean squares due to location were all significant except for plant height per plant and fruit yield per plant which were not significant. The mean squares due to entries were also significant for all the traits except number of calyx per plant. The results also revealed that the mean squares due to parental lines are significant for all the traits except three, number of leaves per plant, number of branches per plant and fruit length. The mean squares due to location x parental lines interaction were also significant except for plant height, branch length, fruit length and fruit yield per plant. This shows that there is enough amount of genetic variability in the parental lines for most of the characters under study.

Table 2 also shows the mean squares due to location, entries and hybrids showing significant differences for all the characters except plant height and fruit yield per plant for location and number of calyx per plant for entries. This also indicates that there are a lot of genetic variability among these materials.

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Table 1: Analysis of variance for mean squares of parental lines in a 6 x 6 diallel cross combined across three locations (Maiduguri, Yola and Biu)

S.O.V	DF	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
LOCATION	2	9.10	903.82*	6.79**	314.03*	777.14*	92.51*	769.99*	5.09*	57.13*	21.78	53.25**
REP. (LOC)	6	67.21*	223.89*	0.45*	20.47*	5.76	3.67*	413.44*	1.64*	26.26*	730.30*	4.62*
PARENT	5	61.06*	166.62	1.56*	1.89	16.41*	4.53*	45.25*	0.84	5.89*	426.14*	3.60*
LOC X PARENT	10	28.08	120.02*	0.62*	3.26*	20.00*	9.23*	8.55	0.64	3.31*	47.34	3.72*
MEAN		31.09	63.12	4.87	18.60	30.13	94.57	29.39	5.92	18.48	286.84	26.30
CV (%)		23.20	26.73	13.37	11.39	11.75	1.70	18.02	20.96	8.44	5.06	7.66
SE±		7.21	16.87	0.65	2.12	3.54	1.61	5.30	1.24	1.56	14.51	2.01

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield

* = Significant at 5% level ** = Significant at 1% level

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Table 2: Analysis of variance for mean squares of hybrids in a diallel cross combined across three locations (Maiduguri, Yola and Biu)

S.O.V	DF	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
LOCATION	2	35.84*	7337.13**	9.32**	888.59*	1970.05*	289.35*	4367.39*	16.71*	285.59*	98.10	86.38**
REP. (LOC)	6	48.54*	1520.61**	3.39*	45.36*	49.67*	2.89	663.54**	2.27*	8.29*	156.71	1.68
HYBRID	14	69.85*	142.93*	1.81*	5.70*	8.41*	5.90*	23.65*	1.11*	2.08*	536.12*	5.08*
LOC X HYBRID	28	26.02	133.97*	0.62*	8.54*	17.94*	4.93*	12.11*	0.89*	3.51*	78.38	4.92*
MEAN		34.07	68.57	4.65	19.89	30.71	94.56	27.60	6.34	19.10	286.90	26.45
CV (%)		17.47	18.80	19.08	12.14	10.99	2.62	13.75	16.40	8.54	5.74	7.47
SE±		5.95	12.89	0.89	2.41	9.34	2.48	3.80	1.04	1.63	16.46	1.98

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield

* = Significant at 5% level ** = Significant at 1% level

The mean squares from the analysis of variance for combining ability combined across the three locations for all the traits are presented in Table 3. The mean squares due to genotypes, variances due to GCA and SCA were all significant for all the traits except for number of calyx and fruit length, and number of seeds per pod for GCA variance. In this study, Griffings Model 1was used in estimating the variance components which was used to estimate the ratio of GCA to SCA variance which were all less than one. The range of ratio varied from zero (0.00) for number of leaves per plant, number of branches per plant, number of calyx per plant, days to 50% flowering, fruit length and number of seeds per pod to the highest ratio of 0.67 for plant height. This indicates the preponderance of non-additive gene action in all the characters. Similar results have been reported by Gasim, (1994) for yield and yield components in roselle and Louis, et al. (2013) in a study on heterosis and combining ability estimates in 6 x 6 half-diallele cross of roselle. They had also suggested the reason for such findings as probably due to the divergence of most of the traits in the selected materials used for the study.

This study has also revealed that both additive and non-additive gene effects have genetic control over all the traits studied. In view of this, a breeding programme that will take care of both the two types of gene action at the same time will be of immense importance as suggested by Ahmad (2002) where the fixable gene action can be mopped up, while at the same time maintaining enough heterozygosity for exploiting the dominance gene action.

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Table 3: Mean squares entries and analysis of variance for combining ability in a 6x6 diallel crosses across three locations (Maiduguri, Yola and Biu)

S.O.V	DF	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
SITE	2	12.66	7708.61*	15.79*	1200.25*	2723.04*	373.74*	4996.08*	21.72*	335.25*	107.46	130.27*
REP.	6	99.88*	1484.32	3.56	61.12*	37.65*	1.99	1044.52*	2.07*	26.66*	292.19*	1.99
GENOTYPES	20	81.24*	199.00*	1.75*	7.65*	10.63	5.26*	34.06*	1.32*	3.68*	481.82	4.50*
GCA	5	148.03*	302.36*	2.32*	4.08*	3.94	8.27*	34.78*	0.75	2.51	728.26*	5.31*
SCA	14	58.98*	164.55*	1.57*	8.84*	12.86	4.26*	33.82*	1.51*	4.07*	399.68*	4.23*
SITE: GENOTYPE	40	26.84	150.40	0.60*	6.91*	18.77*	6.16*	17.68*	0.79	3.66*	67.32	4.83*
SITE: GCA	10	55.65*	175.16*	0.47*	4.13	15.97*	8.23*	13.74*	1.09*	3.50*	56.27*	2.35
SITE: SCA	28	17.24	142.15	0.65*	7.84*	19.70*	5.47*	18.99*	0.69	3.71*	71.01	5.67*
RESIDUALS	120	38.59	200.47	0.67	5.43	11.99	5.16	18.72	1.23	2.87	271.99	3.96
σ^2 GCA/σ^2 SCA Ratios		0.67	0.00	0.23	0.00	0.00	0.00	0.13	0.00	0.00	0.45	0.64

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield\

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The GCA effects are important pointers to the value of parental lines in hybrids combinations. The differences in their effects have been attributed to additive, additive x additive and higher order additive interactions, Falconer, (1960). The GCA effects of parents helps in selecting good parental combiners which when crossed will result in more desirable segregates. The GCA effects pooled over the three locations for calyx yield and attributing characters of six parental lines are presented in table 4.The results revealed that the parent, Farar Yakuwa is considered the highest general combiner, followed by Farcen Tsuntsun and NH84-445 because they showed a relatively high significant positive GCA effects for most of the traits studied. Louis et al., (2013) have reported similar findings where three parental lines out of six consistently exhibited higher GCA effects for most of the traits studied. Cruz and Regazzi, (1994) also reported a high and significant GCA effect of parental line Tainung 6, which is considered as the best general combiner for most of the characteristics estimated for fibre yield in roselle except plant height. They have also reported that parental line with high GCA effects have the potential for generating superior offsprings. Comparatively, Farar Yakuwa can be considered the best general combiner among the parents because it showed significant positive GCA effects for five characters: Viz: plant height, number of leaves, number of branches, number of calyx and number of seeds per pod. For calyx yield, Farcen Tsuntsun (0.31) and Qarara (0.33) were considered to be the best general combiners as both of them showed significant positive GCA effects.

From this study of GCA effects of parents, it can be suggested that, Farar Yakuwa, Farcen Tsuntsun and Qarara can be considered as good combiners for calyx yield. In addition, the parent Farcen Tsuntsun (Ft) has exhibited positively significant GCA effects for number of flowers per plant, fruit length per plant, number of seeds per pod and calyx yield per plant. All these traits are yield components and therefore, the use of these parental lines in breeding programme can be beneficial for calyx yield improvement, Dar et al., (2016).

The parental line NH75-227 (Nh75) recorded significant but negative GCA effects for calyx yield. It has been observed in this study that generally the largest positive GCA effects were obtained from the parents with the highest means and the reverse was the case for those having negative GCA effects. Similar results have been reported by Louis, et al., (2013). It is therefore safe to suggest that the good general combiners can be predicted from the mean performance for each trait without going through the rigors of calculating the GCA effects.

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Table 4: Estimates of General Combining Ability (GCA) effects for eleven characters of roselle in 6x6 diallel cross for three combined locations (Maiduguri, Yola and Biu)

PARENTS	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
Farcen Tsuntsun (FT)	-2.03*	-1.60*	0.08*	-0.28	-0.08	0.22*	-0.17	0.11*	0.22*	-0.62	0.31*
Farar Yakuwa (FY)	1.91*	3.55*	-0.07	0.42*	0.28*	-0.46*	-0.92	-0.13*	0.11*	-1.06*	-0.05
Qarara (QR)	-1.00*	-0.70*	-0.01	-0.15	0.28*	0.34*	0.02	0.12*	-0.01	1.52*	-0.20
NAMH-147 (Na147)	0.53*	-2.19*	-0.19*	0.02	-0.27*	-0.04	0.15	0.02	0.06	-5.09*	0.33*
NH84-445 (Nh84)	-0.43	0.31	0.32*	-0.06	-0.18	0.28*	1.20*	-0.05	-0.33*	0.76*	-0.03
NH75-227 (Nh75)	1.02*	0.63*	-0.12*	0.06	-0.03	-0.34*	-0.27	-0.07	-0.04	4.50*	-0.35*
SE±	0.47	1.08	0.06	0.18	0.26	0.17	0.33	0.08	0.13	1.25	0.15

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield

* = Significant at 5% level ** = Significant at 1% level

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The specific combining ability (SCA) is controlled by non-additive gene action which is an important standard for the evaluation of hybrids, Prague and Tatum, (1942). Table 5 shows the specific combining ability (SCA) effects of the fifteen hybrids for calyx yield and yield components. The results revealed that out of the fifteen cross combinations, five of them exhibited positive SCA effects, while the remaining ten showed negative SCA effects for calyx yield. Out of the five cross combinations, Nh84 x Nh75 exhibited the highest significant positive SCA effects (1.37), followed by Fy x Nh75 (0.80) and Qr x Na147 (0.62) while the other two showed positive but non-significant SCA effects. Louis, et al., (2013) also reported similar findings where out of fifteen cross combinations, five exhibited relatively high positive SCA effects for calyx yield per plant. The cross Bazza-AB2 x Gerio-AB2 showed the highest positive SCA for this trait.

The crosses, Fy x Nh75 and Fy x Na147 showed the highest positive significant SCA effects for number of seeds per pod (0.93) and fruit yield (10.11) respectively, while the cross Fy x Nh84 showed significant positive SCA effects for both number of leaves per plant (4.86) and number of calyx per plant (1.93). It can be observed that significant SCA effects have been recorded for calyx yield and the other traits even in crosses where both or one of the parents are poor combiners. Similar results have been reported by Hariom et al., (2017) in their study on the combining ability and heterosis for fibre yield and quality parameters in roselle. The phenomenon has also been described by Jinks (1956) as due to over dominance and epistasis. For instance in this study, the cross Na147 x Nh75 is one of the best specific cross combiners for most of the traits examined, which has the former parent expressing positively significant GCA effects for calyx yield, while the later parent showed negatively significant GCA effects. Therefore, this type of hybrid can be recommended for recombination breeding.

The study also revealed, the best cross combinations which exhibited positive significant SCA effects for calyx yield and other important yield components which are, Nh84 x Nh75, Fy x Nh75, Qr x Na147 and Fy x Nh84. Therefore, these crosses are of immense practical importance in directly exploiting heterosis for these characters.

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Table 5: Estimates of Specific Combining Ability (SCA) Effects for Eleven Characters of Roselle in a 6x6 diallel cross for three combined locations (Maiduguri, Yola and Biu)

HYBRIDS	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
Ft x Fy	2.63*	0.28	0.12	0.49*	-0.97*	-0.05	0.02	0.76*	0.25	6.28*	0.05
Ft x Qr	-0.47	0.88	0.11	-0.11	-0.65*	0.93*	-1.69*	0.08	-0.24	-3.58*	0.33
Ft x Na 147	0.04	3.10*	0.15*	0.20	0.70*	-0.79*	-2.76*	0.15	0.50*	-13.65*	0.43*
Ft x Nh84	2.26*	6.02*	0.30*	0.26	0.47	0.88*	-0.54	-0.58*	0.49*	-3.88*	0.05
Ft x Nh75	0.76	-0.58	-0.69*	0.58*	-0.63*	-1.04*	0.06	0.09	-0.78*	4.65*	0.12
Fy x Qr	3.98*	6.11*	-0.34*	0.35	0.65*	-0.36	1.71*	0.33*	-0.28	-7.34*	-0.20
Fy x Na147	-0.17	0.16	0.04	-0.01	0.02	0.68*	-1.75*	-0.16	-0.80*	10.11*	-0.05
Fy x Nh84	1.80*	4.86*	-0.61*	-0.01	1.93*	0.28	0.62	0.16	0.52*	-3.96*	-0.11
Fy x Nh75	-0.48	-1.71	-0.16*	1.30*	-1.63*	0.44*	0.80*	0.16	0.93*	0.56	0.80*
Qr x Na147	-1.75*	1.45	-0.06	1.43*	-0.90*	0.50*	-1.33*	0.59*	0.52*	5.75*	0.62*
Qr x Nh84	-2.16*	-3.87*	0.39*	-0.00	0.00	-0.28	-2.99*	0.13	0.34*	9.62*	0.12
Qr x Nh75	3.51*	3.19*	-0.42*	-1.21*	0.98*	0.19	-1.34*	-0.27*	0.30*	-6.50*	-1.31*
Na147 x Nh84	0.36	-1.60	-0.59*	0.85*	1.33*	-0.23	1.45*	-0.10	0.48*	-1.64	-1.17*
Na147 x Nh75	3.18*	5.99*	0.65*	-0.07	-0.13	-1.04*	-1.01	0.01	-0.38*	1.07	-0.36*
Nh84 x Nh75	-0.75	-0.94	0.18*	1.47*	1.31*	-0.13	1.07*	0.43*	0.82*	2.76*	1.37*
SE±	1.84	4.18	0.24	0.69	1.02	0.67	1.28	0.33	0.50	4.87	0.59

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield.

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The heterotic estimates of the cross combinations are presented in table 6. From the results, it is observed that out of the five yield components of fruit length, number of calyx per plant, number of seeds per pod, fruit yield and calyx yield, only one hybrid, Ft x Na147 (-7.99) showed negative but significant heterotic value at the 5% level of significance for fruit yield and all the rest of the hybrids showed non-significant values for these characters. There was no significant heterotic values for calyx yield from all the fifteen hybrids. Louis and Simon, (2013) reported that heterosis for calyx yield per plant was greatest in crosses where the high yielding parents were involved.

For all the characters, only three hybrids recorded significant but negative heterotic values for number of flowers per plant and they are, Ft x Nh75 (-18.45), Fy x Nh84 (-21.17) and Na147 x Qr (-22.98). Heterosis for number of flowers has been reported to be quantitatively photosensitive and it only flowers when total photoperiodic requirement is met, Singh, (1973). For branch length, two hybrids, Ft x Na147 (-1857) and Fy x Na147 (-17.76), had negative but significant heterosis, while only one hybrid for fruit yield, Ft x Na147 (-7.99). All the rest recorded non-significant values of either positive or negative heterotic values. However, the cross combinations with significant negative but desirable heterosis for fruit yield and number of flowers can be considered in a breeding programme for the development of early flowering and early fruiting roselle varieties.

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Table 6: Heterosis of hybrids over better parent for eleven characters of Roselle combined across three locations (Maiduguri, Yola and Biu)

HYBRIDS	PH	NOL	NOF	NOB	NOC	DFPF	BL	FL	NSP	FY	CY
Ft x Fy	`7.75	-0.03	-4.41	4.44	-4.25	-0.81	-10.55	12.39	1.33	0.26	0.67
Ft x Qr	0.17	6.26	0.00	-0.12	-3.15	1.06	-15.17	5.57	-1.85	-2.32	1.17
Ft x Na 147	-5.04	12.49	-2.73	5.96	-0.11	-1.15	-18.57	5.03	2.37	-7.99*	0.53
Ft x Nh84	4.48	9.69	-2.02	6.52	-0.54	0.95	-6.86	-8.08	0.29	-2.61	0.75
Ft x Nh75	2.56	0.26	-18.45*	6.81	-3.63	-1.73	-8.26	2.51	-4.79	0.27	-0.21
Fy x Qr	14.92	9.68	-15.20	4.44	2.11	-0.30	-6.63	8.47	0.84	-3.76	-1.06
Fy x Na147	6.12	-1.06	-11.01	3.40	-1.68	-0.20	-17.76*	-0.92	-3.12	3.16	-2.56
Fy x Nh84	12.61	9.34	-21.17*	3.00	4.75	-0.21	-5.51	1.82	2.13	-1.51	0.55
Fy x Nh75	7.55	0.32	-13.66	10.43	-6.22	-0.49	-0.24	5.10	8.34	-1.27	2.20
Na147 x Qr	-7.31	6.23	-8.26	9.59	-4.58	0.46	-13.36	15.29	3.24	-0.65	-0.65
Na147 x Nh84	-6.25	-4.04	-2.02	1.64	-1.36	0.05	-14.96	5.47	1.79	2.69	0.25
Na147 x Nh75	14.31	7.4	-14.22	-4.09	2.25	0.00	-14.39	-0.55	3.11	-2.79	-6.44
Qr x Nh84	0.72	-2.85	-22.98*	10.71	6.56	-0.29	-0.65	0.00	1.29	-2.10	-6.59
Qr x Nh75	13.48	9.41	7.82	4.90	-1.42	-1.88	-13.29	2.77	-1.71	-2.46	-4.80
Nb84 x Nh75	2.86	2.48	-7.66	12.78	3.60	-0.52	-1.95	7.12	5.32	0.09	4.49

Key: PH=Plant height, NOL=Number of leaves, NOF=Number of flowers, NOB=Number of branches, NOC=Number of calyx, DFPF=Days to 50% flowering, BL=Branch length, FL=Fruit length, NSP=Number of calyx, FY=Fruit yield, CY=Calyx yield

* = Significant at 5% level ** = Significant at 1% level

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CONCLUSION

The present study identified the parent Farar Yakuwa (Fy) as the highest general combiner followed by Farcen Tsuntsun (Ft) and NH84-445 (Nh84) as they showed a relatively high significant positive GCA effects for most of the traits studied. The best cross combinations which exhibited positive SCA effects for calyx yield and other important yield components were Nh84 x Nh75, Fy x Nh75, Qr x Na147 and Fy x Nh84.

From the present findings, it can be concluded that additive and non-additive gene action controlled the expression of calyx yield per plant and its component traits. Therefore, for calyx yield improvement in roselle both additive and non-additive gene action should be exploited using suitable breeding programs. There are cross combinations with significant negative heterosis for fruit yield and number of flowers which are desirable for the development of early flowering and early fruiting roselle varieties. The others with significant negative heterosis can also be used for breeding methods such as biparental mating for creation of more variability and breaking undesirable linkages for improvement of calyx yield and its component traits.

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