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Combining ability analysis of strawberry cultivars in complete diallel mating

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Abstract
The study was conducted to find out the breeding value of seven strawberry parental genotypes (Confectura, Gorella, Sweet Charlie, Chandler, Selva, Addie and Ofra) in a full-diallel mating design (Griffing's method I) in terms of general, specific and reciprocal combining ability (GCA, SCA and RECA) effects for several important horticultural traits. Significant differences were found in general combining ability (GCA), specific combining ability (SCA) and reciprocals effects for most of the traits. Parental lines Gorella and Chandler exhibited good general combining ability for number of flowers, number of fruits and yield/plant and suitable for breeding cultivars with more number of fruits, flowers and yield. For early fruit maturity **'**Gorella' and 'Addie' exhibited good general combining ability. For short duration of flowering and early flowering 'Selva', 'Addie', 'Ofra', Confectura were good general combiners, including 'Gorella' for early flowering. Parental lines Chandler, Selva and Sweet Charlie were good general combiners for TSS and 'Addie' for titratable acidity. The F1 hybrids Chandler x Gorella, Chandler x Selva, Chandler x Sweet Charlie, Selva x Sweet Charlie, Selva x Confectura, Gorella x Ofra, Sweet Charlie x Confectura, Selva x Gorella and Selva x Confectura due to their significant SCA effects were considered as good specific combiners for number of flowers, number of fruits and yield. SCA effect for days taken to early flowering were negatively significant for hybrids viz., Chandler x Gorella, Chandler x Confectura, Chandler x Addie, Chandler x Ofra, Selva x Gorella, Selva x Sweet Charlie, Selva x Confectura and Sweet Charlie x Addie. These hybrids could be utilized in breeding programmes for imparting early flowering in genotypes. SCA effect for duration of flowering were negatively significant for hybrids Chandler x Confectura, Chandler x Sweet Charlie, Chandler x Gorella, Chandler x Ofra and Chandler x Addie. F1 hybrids Chandler x Gorella, Selva x Confectura and Selva x Sweet Charlie were good specific combiners for early fruit maturity/harvesting. Chandler x Gorella, Chandler x Selva and Confectura x Addie were good specific combiners for TSS. Among reciprocal crosses, Addie x Chandler, Addie x Selva, Addie x Gorella were good combiners for number of fruit and flowers per and yield/plant. Whereas, for early flowering and early fruit maturity, 'Confectura x Chandler' was good reciprocal combiner. **'**Addie x Confectura', 'Ofra x Selva' and 'Gorella x Selva' were good reciprocal combiners for shortening duration of flowering.

Keywords: Strawberry, complete diallel cross, GCA, SCA, RECA

Introduction
Conventional breeding of strawberry cultivars for a combination of desirable functional traits is time consuming and expensive. The effectiveness of this effort can be increased by carrying out cross-breeding programmes based on a thorough knowledge of the breeding value of the parental genotypes, taking into account their general (GCA) and specific (SCA) combining abilities. The GCA effect is a measure of the additive action of the parent's genes on this trait (Griffing, [4a, 5b]). Thus, a parent to be considered for the quantitative trait, is selected based upon its ability to pass this trait onto progeny (Baker, [1]; Vieira *et al*., [17]). Cross-breeding involving the use of parents characterized by significantly positive GCA effects for a given functional trait that considerably increases the likelihood of obtaining hybrid progenies with the desired values of that trait (Bestfleisch *et al*., [2]; Masny *et al*., [9]; Pluta *et al*., [15]). Specific combining ability (SCA) of a parental genotypes pair for a particular trait is a non-additive genetic interaction (dominance and epistasis) between both parents that is expressed in their progeny (Griffing, [4a, 5b]; Baker, [1]; Masny *et al*., [10]). It represents the difference between the average value of the trait revealed in the progeny (fullsib progeny of two parental forms) and the sum of the GCA effects for these parental forms (Bestfleisch *et al*., [2]).

The GCA and SCA effects of the parents included in a cross design are measures of their breeding value for the traits of interest and determine their usefulness in breeding programmes that aim at improvement of specific traits (Baker, [1]; Bestfleisch *et al*., [2] ; Pluta *et al*., [15]).

The main aim of the research was to identify breeding lines having good ability effects for yield components and fruit characters. Hence, the present study was to estimate the combining ability of seven strawberry inbred lines and identify the important characters to support the breeding program of strawberry.

Materials and Methods

The materials for this study consisted of seven strawberry inbred lines and their F1 hybrids including the reciprocals. The seven inbred lines used as parents were Confectura, Gorella, Sweet Charlie, Chandler, Selva, Addie and Ofra. Seven parents were crossed in complete diallel mating scheme in experimental field at UHF Solan during 2015 and seeds obtained from various crosses were allowed to germinate under laboratory conditions till transplanting stage. The seedlings of 49 genotypes (7 parents, 21 F1 hybrids, 21 F1 reciprocal hybrids) were transplanted during 15th November, 2016 in a randomized complete block design with three replicates of 10 plants each. The plants were planted at 30 x 30 spacing in 1.5 x 1.0 m raised beds. They were overhead irrigated (when necessary) and standard cultivation practices were applied (fertilization and weed control). The following traits were observed: yield components (fruit yield, number of fruits per plant, Days to fruit maturity from planting and) and fruit characters (total soluble solids and Titratable Acidity). Estimates of the general and specific combining ability effects for various traits were obtained using the methodology proposed by Griffing [4] for analysis of diallel with parents, F1 and F1 reciprocal (Method I), considering fixed effect of treatments using OPISTAT.

Results and Discussion

The data on various parameters pertaining to estimates of gca, sca and reca effects have been presented in the Table 1, Table 2 and Table 3, respectively. The parents/crosses which exhibited significant negative or positive gca/sca effects for days taken to start flowering after planting were designated as good or poor combiners, respectively. The remaining parents/crosses, exhibited non-significant gca/sca effects for days taken to start flowering after planting were rated as average combiners for the indicated parameter. Among all parents, Gorella (-7.91), Selva (-3.12), Addie (-2.18) and Ofra (-1.14) were good general combiners for the trait, as these exhibited significant negative gca effects (Table 1). Out of the total twenty one cross combinations, nine crosses *viz.*,Chandler x Ofra (-8.53), Selva x Gorella (-6.18), Chandler x Confectura (-5.99), Selva x Sweet Charlie (-5.27), Selva x Confectura (-4.47), Sweet Charlie x Addie (-4.18), Gorella x Ofra (-2.09), Chandler x Addie (-1.82) and Chandler x Gorella (-0.84) exhibited significant negative sca effects indicated their good specific combining ability for early flowering (Table 2). These crosses involved the parents with poor x good, good x good, poor x poor, good x poor, good x poor, poor x good, good x good, poor x good and poor x good gca effects, respectively. Reciprocal crosses namely Confectura x Chandler (-8.19), Confectura x Gorella (- 7.70), Ofra x Gorella (-3.29), Confectura x Sweet Charlie (-2.02), Gorella x Selva (-2.22) and Sweet Charlie x Chandler (-0.98) revealed significant negative reca effects, hence regarded as good cross combinations for early flowering. Only one cross ('Selva x Chandler', -0.06) had non significant negative reca values, and marked as average combiner for the trait. The remaining reciprocal cross combinations showed significant positive reciprocal combining ability effect and were considered as poor combiners, meaning these combinations were good for late flowering (Table 3).

Parental lines Confectura (-0.83), Addie (-2.62), Ofra (-0.33) and Selva (-0.31) showed significant negative gca effects for duration of flowering, hence designated as good general combiners for shortening the flowering period, whereas, Chandler (2.05), Sweet Charlie (1.46) and Gorella (0.58) had significant positive gca effects depicted their poor general combining ability (Table 1). Amongst all cross combinations, fourteen crosses viz., Confectura x Ofra (-3.96), Gorella x Addie (-3.58), Chandler x Confectura (-3.25), Sweet Charlie x Ofra (-3.14), Gorella x Ofra (-2.85), Chandler x Sweet Charlie (-2.54), Chandler x Gorella (-2.04), Selva x Gorella (-1.82), Chandler x Addie (-1.60), Selva x Ofra (-1.53), Selva x Confectura (-1.32), Sweet Charlie x Addie (-1.09), Chandler x Ofra (-1.02) and Selva x Sweet Charlie (-1.00) revealed significant negative sca effects reflected their good general combining ability. One cross Chandler x Selva (-0.18) registered non significant negative sca value and considered as average combiner for the trait. The remaining cross combinations showed significant positive sca effects hence considered as poor specific combiners (Table 2). Reciprocal effects revealed significant negative values in ten cross combinations viz., Ofra x Selva (-4.25), Addie x Confectura (-4.22), Gorella x Selva (-3.44), Ofra x Gorella (- 2.83), Ofra x Confectura (-2.69), Confectura x Gorella (-2.59), Sweet Charlie x Selva (- 2.58), Ofra x Chandler (-2.30), Sweet Charlie x Chandler (-1.52) and Ofra x Addie (-1.41) indicated that these were good cross combinations for short duration of flowering in present studies (Table 3) and involved the parents with good x good, good x good, poor x good, good x poor, good x good, good x poor, poor x good, good x poor, poor x poor and good x good gca effects, respectively. On the other hand, three crosses, Gorella x Chandler (-0.77), Confectura x Sweet Charlie (-0.81) and Addie x Gorella (-0.18) were designated as average reca combiners due to their nonsignificant negative effects. The remaining reciprocal crosses exhibited significant positive reca effects and considered as poor combiners for the trait.

Among the parents indicated 'Gorella', 'Chandler' and 'Selva' found to be good general combiners for number of flowers per plant (Table 1). Chandler x Gorella, Selva x Gorella Chandler x Selva, Selva x Confictura, Confictura x Ofra, Sweet Charlie x Addie, Sweet Charlie x Ofra and Addie x Ofra were good specific cross combinations (Table 2). Reciprocal cross combinations viz., Confectura x Selva, Addie x Chandler, Addie x Selva, Addie x Gorella and Ofra x Sweet Charlie showed significant positive values, revealed good reciprocal combiners (Table 3). General and specific combining ability effects (gca and sca) differed significantly for the traits in present study, indicated that both additive and non additive genetic effects were important in the expression of these traits (Zurawicz *et al*., [19]) in the studied parents and progenies. A high negative effect of the reciprocal crosses of morphogenetic efficiency was observed for the combination 'Kent x Clone 394'. The other analysed combinations, i.e.'Plena x Kent' and 'Plena x Clone 394', showed positive values of this parameter (Zebrowska and Dyduch, [18]).

In the present study (Table 1), parental lines Gorella (-10.76) and Addie (-2.20) had significant negative gca values for days taken to start fruit maturity and designated as good general combiners for the trait. These lines could be used in breeding programmes to get early fruiting. Parental lines viz., Chandler, Sweet Charlie and Confectura were late in fruit

maturity period due to their significant positive gca effects. Significant and negative sca effects were observed in crosses namely Chandler x Gorella (-17.83), Selva x Sweet Charlie (-10.92), Selva x Confectura (-11.74) and Chandler x Confectura (-5.93) meaning that the genetic interaction of the two parental genotypes determined early fruit ripening time to their progeny. On the other hand, cross combinations viz., Chandler x Selva (12.91), Gorella x Confectura (9.72), Chander x Sweet Charlie (7.07), Sweet Charlie x Ofra (6.87) and Sweet Charlie x Confectura (5.84) showed significant positive sca effects, meaning thereby that the fruit of the hybrids belonging to these families would ripens late (Table 2). Among reciprocals (Table 3), Gorella x Selva (-11.33), Sweet Charlie x Chandler (- 2.34), Confictura x Chandler (-11.72), Confectura x Gorella (-6.11) were best combiners for early fruit harvesting. The earlier harvesting character might be the result of the interaction of the genes of both the parents. Similar reports of significant positive sca effects for early ripening time has been observed in crosses 'Diamante' x 'Figaro', 'Aromas' x 'Salsa' and 'Aromas' x 'Camarosa' (Masny and Zurawicz, 7) and 'Darselect' x 'Salsa' and 'Susy' x 'Albion' (Masny and Zurawicz, 8). Statistically negative sca effect observed in the family 'Selvik' x 'Salsa'. The trait earliness is said to be bilateral with significantly low gca's for early ripening in 'Clery' and 'Daroyal' and significantly high gca's for late ripening in 'Yamaska' and 'Florence'. Crosses with these cultivars are likely to deliver populations with both high yield and an extended ripening period (Bestfleisch *et al*., [2]). Present results are also in line with the outcomes of Masny *et al.* [11] investigation on some aspect, where significant positive sca effects for late fruit ripening was seen in eight families ('Pandora' x 'Filon', 'Pandora' x 'Sophie', 'Vicoda' x 'Pegasus', 'Vicoda' x 'Marmolada', 'Vicoda' x 'Sophie', 'Vikat' x 'Elkat', 'Marmolada' x 'Segal' and 'Filon' x 'Camarosa').

Significant positive gca effects for number of fruits among the parents were exhibited by 'Gorella' (2.41), 'Chandler' (1.91) and 'Selva' (1.08), revealed their good general combining ability (Table 1) Present study revealed that hybrid combinations Chandler x Gorella (3.64), Selva x Gorella (2.73), Chandler x Selva (2.64) and Addie x Chandler (2.68) were best combiners for number of fruits per plant due to their high and positive sca estimates (Table 2). Among reciprocal cross combinations, five cross combinations viz., Confectura x Selva (1.20), Addie x Chandler (2.68), Addie x Selva (1.33), Addie x Gorella (1.74) and Ofra x Sweet Charlie (1.40) showed significant positive values, hence considered as good reciprocal cross combinations (Table 3). Most of the crosses produced by Lata (6) had non significant sca effects and were designated as average specific combiners ('Chandler x Selva' and 'Gorella x Selva'). In contrast, Chuan [3] obtained significantly positive sca in crosses 'Chandler x Fairfax' (4.07), Blackmore x Seascape (3.62) and Blackmore x Tioga (3.33) while highest positive reca effect was in 'Catskill x Seascape' (2.18) for total number of fruits per plant.

Highest breeding value based on gca estimate for yield/plant was estimated in parental lines Gorella (43.75), Chandler (38.97) and Selva (19.82) due to their significant positive gca effect for yield per plant (Table 1). F1 hybrid 'Chandler x Gorella' (66.23) showed highest significant positive sca effect for yield per plant (Table 2) followed by 'Selva x Gorella' (47.85), 'Selva x Confectura' (45.18), 'Chandler x Selva' (38.67), 'Addie x Ofra' (30.78), Gorella x Sweet Charlie (29.64), Confictura x Ofra (22.28), Chandler x Addie (14.48), Sweet Charlie x Addie (13.46), Chandler x Sweet Charlie (9.98) and Sweet Charlie x Confectura (8.34) indicated the usefulness of these hybrids as they possessed highest breeding value for yield. Significant positive reciprocal combining ability effect was also observed for 'Confectura x Chandler' (37.47), all the reciprocal crosses of Addie and 'Ofra x Addie' (Table 3). Positive values, demonstrated the genetic interaction of both parental genotypes in creating a high yield in the progeny, were also obtained for the following hybrid families 'Aromas x Albion', 'Aromas x Figaro', 'Aromas x Salsa', 'Aromas x Camarosa', 'Albion x Granda', 'Albion x Elianny', 'Figaro x Palomar', 'Figaro x Granda', 'Salsa x Elianny' and 'Palomar x Camarosa'. Considering that most of the cultivars that were parental forms of these hybrids had significantly negative values of gca effects for fruit yield (and therefore will pass on to their progeny a low value of this trait), the importance of interactive effects in the inheritance of this trait should be emphasized, and a much higher productivity of these hybrids should be expected compared to the results obtained from the sum of the gca effects for their parental forms. Significant sca effects for yield in various strawberry hybrids were also observed by Mathley *et al.* [14] and Masny *et al.* [11]. Highest breeding value based on gca for fruit yield was also reported by Masny *et al.* [12] in cultivars 'Charlotte' and Camarosa. Similar reports were obtained by Bestfleisch *et al.* [2] for yield where strawberry cultivars 'Polka' and 'Yamaska' registered highest gca which revealed that crosses with these cultivars were likely to deliver populations with high yield. Chuan [3] from open pollinated population also obtained highest, gca effect in line Chandler (21.64), sca effect in cross 'Chandler x Fairfax' (44.40) and reca estimates in cross 'Pajaro x Seascape' (18.33).

The perusal of data (Table 1) for total soluble solids revealed significant positive gca effects among the parents were exhibited by Chandler (0.47), Selva (0.40) and Sweet Charlie (0.38), which made them better donor for high soluble solids due to their good general combining ability. For sca effects, hybrids viz., Confectura x Addie (0.75), Chandler x Gorella (0.67) and Chandler x Selva (0.53) exhibited significant positive sca effects indicated them as good specific combiners. Crosses, Gorella x Sweet Charlie (0.23), Gorella x Ofra (0.24), Selva x Gorella (0.07) and Selva x Sweet Charlie (0.14) showed non-significant positive sca effects hence average specific combiners for the trait (Table 2). Significantly positive reciprocal effect for TSS was maximum in cross 'Gorella x Chandler' (1.20) followed by 'Sweet Charlie x Selva' (0.95), 'Gorella x Selva' (0.93) and 'Addie x Sweet Charlie' (0.57) (Table 3), meant that fruits of hybrids within these families would be richer in soluble solids. The crosses descended from poor x good, good x good, poor x good and poor x good general combiners, respectively. On the other hands, crosses viz., Sweet Charlie x Gorella (0.44), Confectura x Selva (0.36), Ofra x Chandler (0.35), Addie x Chandler (0.32), Ofra x Selva (0.32), Ofra x Addie (0.19), Sweet Charlie x Chandler (0.15), Ofra x Gorella (0.05) and Confectura x Sweet Charlie (0.01) exhibited non-significant positive reciprocal estimates designated as average reciprocal combiners for the trait. Parental lines Chandler, Selva and Sweet Charlie were good general combiners for TSS in present study and reciprocal crosses 'Gorella x Chandler' (1.20) followed by 'Sweet Charlie x Selva' (0.95), 'Gorella x Selva' (0.93) and 'Addie x Sweet Charlie' (0.57) were best. Masny *et al.* [12] also observed highest positive gca values for total soluble solids in 'Palomar' and 'Figaro' strawberries. The best combinations to increase TSS were 'Maehyang' x 'Johong', 'Maehyang' x 'Tochiotome', 'Maehyang' x 'Toyonoka' as observed by Shim *et al.* [16]. Chuan [3] in cross 'Selva x Tioga' showed high positive sca value (0.81) for TSS in open pollinated populations, whereas reciprocal estimates was highest and positive in 'Fairfax x Pajaro' (1.90).

'Chandler' (-0.04) and 'Sweet Charlie' (-0.03) exhibited significantly negative gca estimates designated as poor combiners for titratable acidity (Table 1). Only 'Addie' (0.04) showed significant positive gca effect and considered as good general combiner for this trait. Among different crosses raised only two crosses viz., Sweet Charlie x Confectura and Sweet Charlie x Addie were good specific combiners for titratable acidity due to their significant positive sca effect. Further, sca effects were significantly negative in cross combinations Gorella x Sweet Charlie (-0.06) and Confectura x Addie (-0.07) represented poor specific combiners. Cross combinations, Sweet Charlie x Ofra (-0.04), Selva x Addie (-0.01), Selva x Ofra (-0.01), Selva x Gorella (-0.03), Chandler x Gorella (-0.02), Chandler x Sweet Charlie (-0.01), Chandler x Confectura (-0.03), Chandler x Ofra (-0.04) exhibited non significant negative sca effects (Table 2). Reciprocal cross combinations showed non significant reciprocal effects for the trait (Table 3) and were rated as average combiners. Present study indicated 'Sweet Charlie x Confectura' and 'Sweet Charlie x Addie' as good specific combiners and 'Addie' as good general combiner for titratable acidity due to their significant positive sca effect and gca effect respectively. According to Chuan [3] crosses 'Pajaro x Selva', 'Seascape x Tioga', 'Fairfax x Tioga' in open pollinated population had high positive sca estimates for acidity, whereas Lata [6] found 'Chandler x Selva' as an average combiner for the trait under study.

Thorough knowledge of the breeding value of the parental genotypes is essential for the success of cross fertilization programs. Breeding value can be deduced from the general and specific combining abilities for key desirable traits, as well as from the phenotypic and genotypic value of the parental forms for highly inheritable traits. In the present study parental lines Gorella and Chandler exhibited good general combining ability for most of the traits viz., number of flowers, number of fruits and yield/plant and suitable for breeding cultivars with more number of fruits, flowers and yield. For imparting early flowering and short flowering duration trait 'Selva', 'Addie', 'Ofra', Confectura were good general combiners. Parental lines Chandler, Selva and Sweet Charlie were good general combiners for TSS and 'Addie' for titratable acidity and these parents could be utilized in further breeding programmes.

Table 1: Estimates of general combining ability (GCA) effects of parents for flowering, fruit characters and yield in strawberry.

Parents	Days taken to start flowering after planting	Duration of flowering	Number of flowers/plant	Days taken to fruit maturity from planting	Number of fruit/plant	TSS (ºB)	Titratable acidity (%)	Yield/plant (g)
Chandler	6.39*	2.05*	1.99*	6.32*	1.91*	0.47*	-0.04*	38.97*
Selva	-3.12*	-0.31*	0.86*	-1.28	1.08*	0.40*	-0.02	19.82*
Gorella	-7.91*	0.58*	2.25*	-10.76*	2.41*	-0.26*	0.01	43.75*
Sweet Charlie	5.60*	1.46*	0.07	5.22*	-0.00	0.38*	-0.03*	-4.30*
Confectura	2.36*	-0.83*	-0.95*	2.87*	-1.15*	-0.21*	0.02	-15.24*
Addie	-2.18*	-2.62*	-2.31*	-2.20*	-2.33*	-0.13	0.04*	-36.89*
Ofra	-1.14*	-0.33*	-1.91*	-0.15	-1.91*	-0.65*	0.02	-46.10*
CD(gi)±	0.18	0.29	0.32	1.52	0.39	0.19	0.02	3.18

Positive and negative values with * depicts significant gca effect and designated as good and poor general combiners.
Values without * depicts nonsignificant gca effect and designated as average general combiners.

Table 2: Estimates of specific combining ability (SCA) effects of hybrids for for flowering, fruit characters and yield in strawberry.

Cross Combinations/ traits	Days taken to start flowering after planting	Duration of flowering	Number of flowers/ plant	Days taken to fruit maturity from planting	Number of fruits/ plant	TSS	Titratable acidity	Yield/ plant (g)
Chandler × Selva	12.35*	-0.18	2.28*	12.91*	2.64*	0.53*	-0.00	38.67*
Chandler × Gorella	-0.84*	-2.04*	3.28*	-17.83*	3.64*	0.67*	-0.02	66.23*
Chandler × Sweet Charlie	5.69*	-2.54*	0.38	7.07*	0.10	-0.15	-0.01	9.98*
Chandler × Confectura	-5.99*	-3.25*	-0.44	-5.93*	-0.12	-0.09	-0.03	-0.13
Chandler × Addie	-1.82*	-1.60*	0.26	-0.30	0.28	-0.73*	0.05	14.48*
Chandler × Ofra	-8.53*	-1.02*	-0.05	-2.45	0.17	-0.08	-0.04	-12.32*
Selva × Gorella	-6.18*	-1.82*	2.66*	-4.67	2.73*	0.07	-0.03	47.85*
Selva × Sweet Charlie	-5.27*	-1.00*	0.19	-10.92*	-0.27	0.14	-0.00	3.92
Selva × Confectura	-4.47*	-1.32*	1.15*	-11.74*	1.62*	-0.69*	0.05	45.18*
Selva × Addie	2.12*	2.56*	0.14	-1.87	0.39	-0.48	-0.01	-0.29
Selva × Ofra	4.64*	-1.53*	-1.20*	-2.38	-1.48*	-0.15	-0.01	-15.45*
Gorella × Sweet Charlie	1.59*	0.79*	0.62	1.00	0.70	0.23	-0.06*	29.64*
Gorella × Confectura	6.16*	6.40*	0.46	9.72*	-0.04	-0.15	0.01	-2.80
Gorella × Addie	0.16	-3.58*	-0.23	0.49	-0.25	-0.19	0.02	-5.74
Gorella × Ofra	-2.09*	-2.85*	-0.23	-0.19	-0.43	0.24	0.04	-17.58*
Sweet Charlie × Confectura	2.61*	0.93*	0.00	5.84*	0.43	-0.38	0.10	8.34*
Sweet Charlie × Addie	-4.18*	-1.09*	1.49*	1.23	1.35*	-0.42	0.07*	13.46*
Sweet Charlie × Ofra	6.65*	-3.14*	1.51*	6.87*	1.40*	-0.24	-0.04	14.46*
Confectura × Addie	3.50*	1.24*	0.34	4.88	0.32	0.75*	-0.07*	0.90
Confectura × Ofra	5.34*	-3.96*	1.59*	3.01	1.52*	-0.42	0.03	22.28*
Addie × Ofra	3.15*	2.09*	0.90*	-1.16	1.14*	-0.18	0.01	30.78*
CD (S ij)±	0.45	0.77	0.81	5.26	0.99	0.49	0.06	7.90

Positive and negative values with (*) depicts significant sca effect and designated as good and poor specific combiners.
Values without * depicts nonsignificant sca effect and designated as average specific combiners.

Table 3: Estimates of reciprocal combining ability (reca) effects of hybrids for flowering, fruit characters and yield in strawberry

Cross Combinations/ traits	Days taken to start flowering after planting	Duration of flowering	Number of flowers/plant	Days taken to fruit maturity from planting	Number of fruits/plant	TSS	Titratable acidity	Yield/plant (g)
Selva × Chandler	-0.06	3.38*	-0.69	1.12	-0.59	-0.17	-0.01	-9.92*
Gorella × Chandler	5.73*	-0.77	-1.91*	21.59*	-1.70*	1.20*	-0.05	-24.94*
Gorella × Selva	-2.22*	-3.44*	-1.33*	-11.33*	-1.33*	0.93*	-0.06	-34.33*
Sweet Charlie × Chandler	-0.98*	-1.52*	-0.55	-2.34*	-0.09	0.15	-0.02	-2.74
Sweet Charlie × Selva	12.64*	-2.58*	-1.17*	14.81*	-1.70*	0.95*	-0.08	-30.41*
Sweet Charlie × Gorella	5.38*	1.20*	-0.36	-0.29	-0.69	0.44	-0.00	3.22
Confectura × Chandler	-8.19*	4.74*	-0.92	-11.72*	-0.45	-0.21	0.03	-13.87*
Confectura × Selva	2.96*	0.93*	1.62*	6.97*	1.20*	0.36	-0.05	37.47*
Confectura × Gorella	-7.70*	-2.59*	-1.15*	-6.11*	-0.34	-0.21	0.03	-18.33*
Confectura × Sweet Charlie	-2.02*	-0.81	-0.33	-4.13	-0.49	0.01	-0.05	-0.22
Addie × Chandler	1.18*	1.39*	2.57*	-0.85	2.68*	0.32	0.05	49.31*
Addie × Selva	6.25*	4.06*	0.97*	8.99*	1.33*	-0.19	0.00	9.75*
Addie × Gorella	2.50*	-0.18	1.96*	5.12*	1.74*	-0.15	-0.04	21.20*
Addie × Sweet Charlie	6.48*	5.56*	0.79	4.61*	1.05	0.57*	-0.08	16.57*
Addie × Confectura	8.87*	-4.22*	0.50	9.61*	0.24	-0.51	-0.02	28.59*
Ofra × Chandler	12.00*	-2.30*	0.42	4.29*	0.54	0.35	-0.02	-4.79
Ofra × Selva	6.50*	-4.25*	0.64	5.97*	0.39	0.32	-0.06	-8.64
Ofra × Gorella	-3.29*	-2.83*	-0.39	-8.31	-0.02	0.05	-0.05	-12.48*
Ofra × Sweet Charlie	1.21*	4.40*	0.99*	-2.14	1.40*	-0.29	0.01	-3.45
Ofra × Confectura	5.99*	-2.69*	-0.65	5.18*	-0.77	-0.13	-0.04	-12.97*
Ofra × Addie	5.15*	-1.41*	-0.13	6.02*	-0.21	0.19	0.01	14.67*
CD(rij) ±	0.53	0.87	0.95	4.33	1.15	0.55	0.05	9.10

Positive and negative values with (*) depicts significant reca effect and designated as good and poor reciprocal combiners.
Values without * depicts nonsignificant reca effect and designated as average reciprocal combiners.

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