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Genetic variability and correlation studies for growth, yield and quality in Strawberry (*Fragaria ananassa* Duch.)

Manivannan M. I.[1], Premalakshmi V.[1], Theradi Mani M.[1], Allwin L.[2] and Ravindran C[3]

[1]Department of Horticulture, Agricultural College, and Research Institute, Killikulam-628252, Vallanad, Tamil Nadu, India
[2]Department of Rice Research Station, Ambasamudram-627 40, Tamil Nadu, India
[3]Department of Horticultural and Forestry Research Station, Kodaikanal-624 103, Tamil Nadu, India

ABSTRACT

The traits viz., fruit nutritional quality, yield, day neutral nature to be improved in strawberry and hence the present study was undertaken to identify the nature of variability present in the promising advanced strawberry genotypes and to detect the association among yield and yield component traits in strawberry (Fragaria × ananassa Duch.). Fourteen advanced genotypes were evaluated to study genetic variation and the relationship between yield and its components using a randomized complete block design during the year 2021. The results showed significant variance among genotypes of all traits. The phenotypic coefficient of variation (PCV) for all the characters was slightly higher than the genotypic coefficient of variation (GCV), which signified the presence of environmental influence to some degree in the phenotypic expression of characters. The leaf area index had the highest PCV (30.71) and GCV (30.82). The genetic advance was recorded maximum for fruit yield per plant (228.24), whereas genetic advance as a percent of mean was highest for leaf area index (63.05) followed by shelf life of fruits (61.95). The highest heritability (h^2, 95.22) was coupled with higher genetic advance (228.24) estimated for fruit yield per plant, which indicated that the character is controlled by additive genes and therefore further improvement could be brought by selection. Being octoploid, the inheritance of traits is complex in strawberry and the identified heritable traits in the study would be helpful for strawberry improvement breeding programs. Fruit yield was significantly and positively associated with most of the characteristics except flowering duration, fruiting duration, and volume of fruit at both genotypic and phenotypic levels; therefore, these are important prerequisites to formulate a successful strawberry improvement program.

Keywords: *Strawberry, crop improvement, genetic variability, genetic divergence, genotypic coefficient of variation, phenotypic coefficient of variation, genetic advance, genetic advance as a percent of the mean, heritability, genotypic correlation, phenotypic correlation, yield, fruit quality*

1. Introduction

Strawberry (*Fragaria ananassa* Duch.) is one of the most delicious fruits in the world, and as a rich source of vitamins and minerals with a tantalizing aroma (Kher et al., 2010). *Fragaria × ananassa* (Duch.) is a natural hybrid of the South America *Fragaria chiloensis* (L.) and the North America *Fragaria virginiana* (Duch.). This intermingling of genetic characteristics has resulted in a fruit of great variety in taste and color with a cropping ability and season of such versatility that it can be grown from the tropics to the cool temperate regions of the world. Strawberry requires 22–23 °C day temperature and 7–13 °C night temperature for better growth and development (Shoemaker, 1954). Strawberry is the most popular soft fruit and two other species, *F. vesca* L. (2n = 14) and *F. moschata* Duch. (2n = 42), are also grown commercially, but on a much smaller scale (Graham et al., 1996). For any crop improvement program, germplasm collection and assessment of genetic variability is an important step. The breeding approach can be successful if the variability and heritability of yield and related traits are high in the genotypes. The interaction of the genotype with environmental factors and cultivation systems is also important in determining the exploitation of the highest potential of fruit nutritional quality. Strawberries are highly perishable fruits, often sold immediately after harvest at high price, especially when hand-picked. Offering a consistently high quality of berry fruits with superior nutritional status would be an ideal way to increase consumer interest and satisfaction and increased strawberry consumption will contribute positively to a healthy diet. Being a complex character, yield is influenced by a number of yield and yield-attributing characters, by environment, and by polygenes. Thus, the variability in the collections for these characters is the sum total of the heredity effects of concerned genes and the influence of the environment. Hence, it is very

Corresponding Author: **Dr. M. I. Manivannan*
*Email Address: **mimanivannan@rediffmail.com***

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essential to separate the observed variability into heritable and non-heritable components measured as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (h^2), genetic advance (GA), and genetic advance expressed as percent mean (GAM). Surveys of genetic variability with the help of suitable parameters such as GCV, heritability estimates, and GA are absolutely necessary to start an efficient breeding program (Atta et al., 2008). Heritability value alone may not provide clear predictability of the breeding value. Heritability in conjugation with genetic advance over **a** mean (GAM) is more effective and reliable in predicting the resultant effect of selection (Patil et al., 1996; Ramanjinappa et al., 2011). GA is also of considerable importance because it indicates the magnitude of the expected genetic gain from one cycle of selection (Hamdi et al., 2003). Correlation studies help in finding out the degree of interrelationship among various characters and in evolving selection criteria for improvement. The practical utility of selection of a given character as a measure of improving another character depends on the extent to which they are related and this relation depends not only on genotypic correlation but also on phenotypic correlation and variance (Imtiyaz *et al.,* 2012). Achieving a superior cultivar with satisfactory yield along with good fruit quality is an important objective for selection and further improvement. Thus, the present study was conducted in 14 genotypes of strawberries to evaluate genetic variation and correlation among 20 morphological and biochemical characters.

2. Materials and methods

2.1. Experimental site

The field experiment was conducted at the Horticultural Research Station, Kodaikanal (10.20 ′N, 77.50 ′E, 2300 m above mean sea level), Tamil Nadu, India, during the year 2021. The location is in the Pulney hills (eastern parts of western ghats), Dindigul district of South India. The maximum temperature and minimum temperature exist are 28.00°C and -2.5°C. The experimental site receives an average rainfall of 1700 mm with a relative humidity of 40-100%. The soil of the experimental field was peaty and lateritic with a pH of 5.5 to 6.5.

2.2. Experimental design and layout

The experiment was laid out under a randomized block design with three replications. The experimental area was prepared by plowing 30 cm deep, disk harrowing, and proper leveling. The experimental area was then divided into three blocks and each block consisted of 20 beds (2.1 × 0.9 m each) with a 0.5-m drainage channel between two blocks. The strawberry runners were planted at distances of 30 × 20 cm. Each bed consisted of 6 ridges (raised 20 cm above the main field) with 5 plants in each ridge, thus accommodating 30 plants in each bed.

2.3. Treatments

Fourteen promising genotypes, Atra, Selva, Elamanco, Vimarana, Nabila, Ceryerta, Chandler, Fern, Cambibe, Katrain Sweet, Winter Dawn, Camarosa, Festival, and Kodaikanal Local were collected from G.B.Pant University of Agriculture and Technology, Uttarakhand and Regional Research Station, Bowali, India, and were kept for 1 day for proper acclimatization. The strawberry runners were planted during the last week of October 2021.

2.4. Intercultural

operations were done frequently for getting better growth and yield. The mulching sheet was applied around the strawberry plants to conserve soil moisture and to restrict weed populations. Irrigation was applied at weekly intervals in order to maintain proper moisture for better growth and development of plants. Plant protection measures were also applied uniformly for all the plots during the period of the experiment.

2.5. Harvesting

The strawberry fruits were harvested manually (handpicking) at commercial maturity when >80% of the fruit surface turned dark red, at an interval of 3–4 days during early morning hours while the environment was cool. After harvesting, fruits were sorted immediately to get healthy and undamaged fruits. Uniform sizes and colors of fruits were selected for observation and further biochemical analysis.

2.6. Observations recorded

The observations were recorded from the inner plants of each row to avoid border effects. In each bed, 12 plants were selected randomly for observations on different morphological and biochemical attributes. Data were recorded for plant height (cm), plant spread (cm), number of leaves per plant, leaf area index (cm^2), number of flowers per plant, flowering duration, fruiting duration, number of fruits per plant, length of fruit (cm), diameter of fruit (cm), fresh fruit weight (g), dry fruit weight (g), fruit yield per plant (g), volume of fruit (mL), total soluble solids (°brix), titratable acidity (%), reducing sugar(%), total sugars (%) and ascorbic acid (vitamin C, mg/100 g fruit). The height of plant, spread of plant, and length and diameter of fruit were recorded with the help of a digital vernier caliper, whereas number of leaves, flowers, and fruits per plant were counted from each plant under observation. Fruit yield per plant and fresh fruit weight were measured with the help of analytical balance. For estimating dry fruit weight, the fresh fruits were dried in a hot air oven and measured by analytical balance until no further weight loss occurred. Volume of fruit, titratable acidity, reducing sugar, total sugars, and ascorbic acid were computed as per the method suggested by Ranganna (1986). Total soluble solids (TSS) and leaf area index were determined by Erma hand refractometer and portable leaf area meter, respectively.

2.7. Data analysis

Analysis of variance using a randomized block design was done for all the characters by Windows-based computer software SPAR 1.0 (Statistical Package for Agricultural Research Ver. 1.0). Heritability in the broad sense (h^2) was estimated according to Falconer (1989). GCV and PCV to compare the variations among the traits were computed as per the method suggested by Singh and Chaudhury (1985). GA and GAM were calculated as per the procedure recommended by Singh and Chaudhury (1985) and Allard (1960). Phenotypic and genotypic correlations were estimated using the standard procedure suggested by Miller et al. (1958) and Kashiani and Saleh (2010) from the corresponding variance and covariance components.

3. Results and Discussion

The analysis of variance for characters studied during the experiment was found significant ($P < 0.05$) among the 14 strawberry genotypes (Table 1). The mean values of the characters, ranges, genotypic mean sums of squares, f-values, standard error (SE) of means, and coefficients of variation (Table**s** 2 and 3) also showed sufficient amounts of variation for morphological and biochemical components of strawberry genotypes. The significant value of the genotypic mean sum of squares indicating the presence of environmental influence resulted in variation for all the characters among genotypes of strawberries, which can be improved by further breeding techniques. Heritable variation is useful for permanent genetic improvement (Singh, 2000). The most important function of heritability in the genetic study of quantitative characters is its predictive role to indicate the reliability of the phenotypic value as a guide to breeding value (Dabholkar, 1992; Falconer and Mackay, 1996).

The extent of variability (Table 4) among genotypes was determined in terms of PCV and GCV. The PCV for all the characters was slightly higher than the GCV. PCV was recorded as highest for leaf area index (30.82), followed by fruit shelf life (30.35) and length of fruit (21.97). Similarly, GCV was also observed as highest for leaf area index (30.71), followed by fruits shelf life (30.21) and length of fruit (21.87), indicating a higher degree of genetic variability among different genotypes for these characters. The GCV, along with heritability estimates, provides reliable estimates of the amount of GA to be expected through phenotypic selection (Burton, 1952). PCV was found higher than GCV for all the characters studied, which signifies the presence of environmental influence to some degree in the phenotypic expression of characters. High GCV, along with high heritability and high GA, provides better information than single parameters alone (Baye et al., 2005). PCV and GCV with higher value specified that the genotypes show evidence of any variations among themselves with respect to morphological and biochemical characteristics. Lowest values of PCV and GCV indicate that the genotypes do not show much variation among themselves with respect to these morphological and biochemical characteristics. Similar findings were reported by Singh et al. (2008) and Punetha et al. (2011).

Estimates of broad sense heritability (h^2) were recorded as generally lower among all the characters studied. The highest estimate of broad sense heritability was found for leaf area index (99.31%), followed by fruit shelf life (99.09%), length of fruit (99.08%) and plant height (97.37%). GA was found maximum for fruit yield per plant (228.24), followed by leaf area index (15.12) and volume of fruit (13.34), whereas GAM was observed highest for leaf area index (63.05%), followed by fruit shelf life (61.95%) and length of fruit (44.85%). Estimates of broad sense heritability was higher among all the characters studied, suggesting a significant non-additive genetic contribution to total genetic variance. This non-additive component could consist of dominance, epistatic, or maternal variance (Lynch and Walsh, 1998). High heritability estimates for the characters indicate less influence of the environment, and so there is a good scope for the improvement of these traits through direct selection (Kumar et al., 2012).

The highest heritability (h^2) (228.24) coupled with moderate Genetic Advance as **a** percent of the mean (22.33) was recorded for fruit yield per plant and moderate heritability(13.34) coupled with moderate Genetic Advance as a percent of the mean(26.68) was recorded for volume of fruit. Higher heritability (h^2) coupled with high GA was observed for fruit yield per plant, which may be due to the additive gene action, and thus selection would be effective for this character. Similar results were also reported by Sah et al. (2010). Ara et al. (2009) reported that the high heritability (h^2) coupled with high GA for the number of flowers and number of fruits in each year indicated that these characteristics were controlled by additive genes and effective selection could be made for these parameters. The estimate of GA is more useful as a selection tool when considered jointly with heritability estimates (Johnson et al., 1955). High values of GA are indicative of additive gene action, whereas low values are indicative of non-additive gene action (Singh and Narayanan, 1993). Thus, the heritability estimates will be reliable if accompanied by high GA.

Fruit yield was significantly and positively associated with most of the characteristics except flowering duration, fruiting duration and volume of fruit, both at genotypic and phenotypic levels (Table 3). At the genotypic level, strong positive and significant associations of the number of flowers per plant, length of fruit, the diameter of fruit, number of fruits per plant, dry fruit weight, fruit yield per plant, titrable acidity, reducing sugar, total sugar, ascorbic acid and fruits shelf life were recorded with fresh fruit weight. Height of the plant showed the highest positive and significant correlation with the spread of the plant, number of leaves per plant and leaf area index. A number of flowers per plant, length of fruit, diameter of fruit, fresh fruit weight, number of fruits per plant, fruit yield per plant, titrable acidity, reducing sugars, total sugars, ascorbic acid, and fruit shelf life had strong positive and significant correlations with dry fruit weight. Titratable acidity showed the highest positive significant associations with reducing sugar, total sugars and ascorbic acid, respectively. Reducing sugar showed the highest positive significant associations with total sugars and ascorbic acid. Total soluble acids recorded positive significant associations with the length of fruit, the diameter of fruit, the number of fruits per plant, fruit yield per plant, titrable acidity, fresh fruit weight, reducing sugar, total sugar and ascorbic acid. On the contrary, the height of the plant indicated strong negative and non-significant correlations with flowering duration, fruiting duration, volume of fruit and total soluble solids. Spread of the plant showed a negative and non-significant correlation with the volume of fruit wherein the number of leaves per plant and leaf area index showed a negative and non-significant correlation with flowering duration and fruiting duration.

Flowering duration registered the highest positive and significant correlation with fruiting duration however significant and negative correlation with length of fruit, diameter of fruit, fresh fruit weight, number of fruits per plant, dry fruit weight, fruit yield per plant, titrable acidity, reducing sugar, total sugar, ascorbic acid, total soluble solids and shelf life(Table 5). A number of flowers per plant showed a significant and positive association with length of fruit, diameter of fruit, fresh fruit weight, number of fruits per plant, dry fruit weight, fruit yield per plant, titrable acidity, total sugars, reducing sugars, ascorbic acid, total soluble solids and shelf life however significant and negative correlation with flowering duration and fruiting duration. Similar significant and positive associations was also observed between the number of fruits per plant and spread of plant, number of flowers per plant, length of fruit, diameter of fruit, dry fruit weight, fruit yield per plant, titrable acidity, reducing sugar, total sugars, ascorbic acid, total soluble solids, fruit shelf life while significant and negative correlation with flowering duration, fruiting duration and volume of fruit. The genotypic correlation coefficients of fruit yield per plant and yield-contributing characters were higher than phenotypic correlation coefficients in most cases, indicating that the effects of environment suppressed the phenotypic relationship between these characters. In earlier studies, fruit yield was significantly and positively associated with most of the characters (Lacey, 1973; Webb et al., 1974; Guttridge and Anderson, 1981; Nielson and Eaton, 1983; Olsen et al., 1985; Strik and Proctor, 1988; Biswas et al., 2007).

At the phenotypic level, plant height had a significant positive correlation with the spread of plant and the number of leaves per plant. A number of fruits per plant had a significant and positive correlation with the number of flowers per plant, length of fruit, diameter of fruit, fresh fruit weight, dry fruit weight, fruit yield per plant, titrable acidity, total sugars, ascorbic acid, total soluble solids and fruit shelf life while significant and negative correlation with flowering duration, fruiting duration and volume of fruit. Mir et al. (2009) also observed positive and significant correlations between yield per plant and height of the plant, spread of plant, fruit weight, fruit diameter, fruit volume, and number of fruits per plant. Total soluble solids significantly and positively correlated with number of flowers per plant, length of fruit, diameter of fruit, fresh fruit weight, number of fruits per plant, fruit yield per plant, titrable acidity, total sugar, reducing sugar, ascorbic acid and fruit shelf life wherein significantly and negatively correlated with flowering duration and volume of fruit. Similar reports were also suggested by Chaubey and Singh (1994) and Ojo et al. (2006).

Conclusion

The present study narrated the existence of wide ranges of variations for most of the characters among the strawberry genotypes, which provides opportunities for genetic gain through selection or hybridization. Fruit yield per plant, leaf area index, volume of fruit, and length of fruit had high heritability along with high GA, and, therefore, further improvement could be brought about by selection. Fruit yield showed strong positive and significant correlations with most of the characters. Thus, selection may be possible for these characters for improving yield.

Future scope of the study: Since this study contributes to gain information on the genetic variability for different characters in strawberry genotypes, future study can focus into evolving new varieties with improved yield, fruit quality and shelf life through selection and hybridization

Conflict of Interest: There is no conflict of interest between the authors

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Table 1: Analysis of variance for growth, yield and quality attributing characters in strawberry

S.No	Source of Variation	Replication	Treatment	Error
	DF	2	13	26
1.	Plant Height (cm)	0.04	31.99	0.29
2.	Spread of plant (cm)	0.17	14.38	0.22
3.	Number of leaves per plant	0.15	1.63	0.18
4.	Leaf area index (cm^2)	0.51	163.17	0.38
5.	Number of flowers per plant	0.06	0.41	0.06
6.	Flowering duration	1.92	5.07	1.15
7.	Fruiting duration	6.50	6.26	2.49
8.	Length of fruit (cm)	0.02	2.24	0.01
9.	Diameter of fruit (cm)	0.01	0.42	0.01
10.	Fresh fruit weight (g)	0.61	31.21	1.14
11.	Number of fruits per plant	0.23	2.94	0.30
12.	Dry fruit weight (g)	0.11	32.24	1.47
13.	Volume of fruit (mL)	0.04	134.24	2.18
14.	Titrable acidity (%)	0.00	0.00	0.00
15.	Reducing sugar (%)	0.01	0.05	0.01
16.	Total sugars (%)	0.00	0.05	0.02
17.	Ascorbic acid (mg/100 g fruit)	7.00	29.76	2.39
18.	Total soluble solids (°Brix)	0.34	2.35	0.28
19.	Shelf life(days)	0.00	0.74	0.00
20.	Fruit yield per plant (g)	619.98	39321.51	647.07

Table 2 : Mean Performance of strawberry varieties for morphological and yield characters

Traits	Plant Height (cm)	Spread of plant (cm)	Number of leaves per plant	Leaf area index (cm²)	Number of flowers per plant	Flowering duration	Fruiting duration	Length of fruit (cm)	Diameter of fruit (cm)	Fresh fruit weight (g)	Number of fruits per plant	Dry fruit weight (g)	Fruit yield per plant (g)	Volume of fruit (mL)
Atra	23.44	15.75	12.58	14.78	8.52	37.50	68.00	3.00	3.14	42.31	21.25	40.16	899.09	43.81
Selva	21.12	14.01	12.76	15.81	8.45	36.33	69.50	3.04	3.11	43.95	21.14	42.00	929.10	43.01
Elamanco	27.50	19.28	13.24	28.42	8.66	39.25	70.25	3.88	3.49	45.83	22.42	46.45	1027.51	49.97
Vimarana	27.33	20.56	13.92	27.23	8.34	38.65	67.33	3.15	3.04	42.51	21.14	40.99	898.66	42.50
Nabila	28.66	20.40	13.25	31.33	9.29	35.75	65.85	5.20	4.04	51.48	24.65	48.39	1268.98	61.14
Ceryerta	20.32	17.74	13.70	10.94	8.96	37.33	68.75	4.90	3.85	47.71	23.00	47.50	1097.33	55.46
Chandler	26.18	20.26	14.00	25.25	9.04	37.45	67.50	4.94	3.92	44.59	23.10	43.82	1030.03	57.28
Fern	25.00	19.47	13.62	22.22	8.26	37.50	68.85	3.60	3.35	46.33	22.30	47.15	1033.16	49.59
Cambibe	24.89	19.10	14.26	23.97	8.55	38.25	67.33	3.46	3.17	43.18	21.50	41.72	928.37	45.22
Katrain Sweet	21.15	18.11	12.14	23.10	8.82	36.33	66.00	4.53	3.78	50.65	22.94	48.05	1161.91	51.11
Winter Dawn	23.62	19.68	13.33	21.65	8.78	37.25	68.75	4.30	3.61	44.61	22.66	43.79	1010.86	54.72
Camarosa	30.45	22.35	14.14	36.50	9.22	35.50	66.50	5.12	4.01	50.08	23.14	48.12	1158.85	59.67
Festival	29.63	21.42	13.98	34.78	8.20	38.44	69.50	3.18	3.48	43.56	21.88	41.34	953.09	44.29
Local cultivar	22.72	19.99	11.99	19.84	8.18	40.00	70.00	2.91	3.02	41.73	21.80	39.59	909.71	42.33
Mean	**25.14**	**19.15**	**13.35**	**23.99**	**8.66**	**37.54**	**68.15**	**3.94**	**3.50**	**45.61**	**22.35**	**44.22**	**1021.90**	**50.01**
S.E.	**0.31**	**0.27**	**0.25**	**0.35**	**0.15**	**0.62**	**0.91**	**0.05**	**0.05**	**0.62**	**0.31**	**0.70**	**14.69**	**0.85**
SE d	**0.44**	**0.39**	**0.35**	**0.50**	**0.21**	**0.87**	**1.29**	**0.07**	**0.07**	**0.87**	**0.44**	**0.99**	**20.77**	**1.20**
C.D. (5%)	**0.90**	**0.79**	**0.72**	**1.03**	**0.42**	**1.80**	**2.66**	**0.14**	**0.14**	**1.80**	**0.91**	**2.04**	**42.79**	**2.48**
CV (%)	**2.13**	**2.47**	**3.22**	**2.56**	**2.90**	**2.85**	**2.32**	**2.11**	**2.41**	**2.35**	**2.43**	**2.74**	**2.49**	**2.95**

Table 3: Mean Performance of strawberry varieties for quality attributing characters

Traits	Volume of fruit (mL)	Titrable acidity (%)15	Reducing sugar (%)16	Total sugars (%)17	Ascorbic acid (mg/100 g fruit) 18	Total soluble solids (°Brix)	Shelf life(days) 20
Atra	43.81	0.81	3.26	4.19	63.58	18.68	1.00
Selva	43.01	0.75	3.42	4.32	67.48	19.77	2.00
Elamanco	49.97	0.79	3.29	4.20	64.25	18.92	1.00
Vimarana	42.50	0.77	3.32	4.24	66.06	19.44	1.00
Nabila	61.14	0.70	3.63	4.55	73.60	21.10	2.00
Ceryerta	55.46	0.74	3.45	4.40	67.55	19.85	2.00
Chandler	57.28	0.76	3.34	4.25	66.75	19.50	2.00
Fern	49.59	0.79	3.29	4.21	65.93	19.15	1.00
Cambibe	45.22	0.75	3.40	4.28	67.24	19.76	2.00
Katrain Sweet	51.11	0.71	3.55	4.49	71.10	21.00	2.00
Winter Dawn	54.72	0.76	3.36	4.25	66.82	19.56	2.00
Camarosa	59.67	0.71	3.58	4.52	72.00	21.02	2.00
Festival	44.29	0.72	3.51	4.44	69.42	20.49	2.00
Local cultivar	42.33	0.82	3.24	4.19	62.67	18.25	1.00
Mean	**50.01**	**0.76**	**3.40**	**4.32**	**67.46**	**19.75**	**1.64**
S.E.	**0.85**	**0.01**	**0.05**	**0.08**	**0.89**	**0.30**	**0.03**
SE d	**1.20**	**0.02**	**0.08**	**0.11**	**1.26**	**0.43**	**0.04**
C.D. (5%)	**2.48**	**0.03**	**0.16**	**0.23**	**2.60**	**0.89**	**0.08**
CV (%)	**2.95**	**2.70**	**2.74**	**3.18**	**2.29**	**2.67**	**2.90**

Table 4: Estimates of genetic parameters for morphological and biochemical characters in strawberry

S.No	Traits/Genetic Parameters	Genotypic Coefficient of Variations	Phenotypic Coefficient of Variations	Heritability (H^2)	Genetic Advance	Genetic Advance value as percent of mean
1.	Plant Height (cm)	12.93	13.10	97.37	6.61	26.28
2.	Spread of plant (cm)	11.34	11.61	95.49	4.37	22.84
3.	Number of leaves per plant	5.20	6.11	72.34	1.22	9.11
4.	Leaf area index (cm^2)	30.71	30.82	99.31	15.12	63.05
5.	Number of flowers per plant	3.91	4.87	64.39	0.56	6.46
6.	Flowering duration	3.05	4.17	53.26	1.72	4.58
7.	Fruiting duration	1.64	2.84	33.49	1.34	1.96
8.	Length of fruit (cm)	21.87	21.97	99.08	1.77	44.85
9.	Diameter of fruit (cm)	10.53	10.81	95.01	0.74	21.15
10.	Fresh fruit weight (g)	6.94	7.33	89.76	6.18	13.55
11.	Number of fruits per plant	4.20	4.85	74.87	1.67	7.48
12.	Dry fruit weight (g)	7.24	7.74	87.47	6.17	13.96
13.	Volume of fruit (mL)	13.27	13.59	95.29	13.34	26.68
14.	Titrable acidity (%)	4.85	5.56	76.32	0.07	8.74
15.	Reducing sugar (%)	3.29	4.28	59.00	0.18	5.20
16.	Total sugars (%)	2.41	3.99	36.47	0.13	3.00
17.	Ascorbic acid (mg/100 g fruit)	4.48	5.03	79.22	5.54	8.21
18.	Total soluble solids (°Brix)	4.21	4.99	71.25	1.45	7.32
19.	Shelf life(days)	30.21	30.35	99.09	1.02	61.95
20.	Fruit yield per plant (g)	11.11	11.39	95.22	228.24	22.33

Table 5: Genotypic and Phenotypic correlation coefficients of 20 traits in strawberry genotypes

Traits		Plant Height (cm)	Spread of plant (cm)	Number of leaves per plant	Leaf area index (cm2)	Number of flowers per plant	Flowering duration	Fruiting duration	Length of fruit (cm)	Diameter of fruit (cm)	Fresh fruit weight (g)	Number of fruits per plant	Dry fruit weight (g)	Fruit yield per plant (g)	Volume of fruit (mL)	Titrable acidity (%)	Reducing sugar (%)	Total sugars (%)	Ascorbic acid (mg/100 g fruit)	Total soluble solids (°Brix)	Shelf life(days)
Plant Height (cm)	G	0.00	0.768**	0.621**	0.927**	0.200NS	-0.016NS	-0.281NS	0.188NS	0.280NS	0.158NS	0.274NS	0.122NS	0.275NS	-0.282NS	0.317*	0.354*	0.365*	0.347*	-0.013NS	0.212NS
	P	0.00	0.746**	0.519**	0.910**	0.156NS	-0.048NS	-0.152NS	0.185NS	0.278NS	0.152NS	0.228NS	0.123NS	0.260NS	-0.226NS	0.252NS	0.189NS	0.341*	0.288NS	-0.015NS	0.200NS
Spread of plant (cm)	G		0.00	0.530**	0.804**	0.223NS	0.155NS	-0.335*	0.362*	0.400**	0.222NS	0.452**	0.217NS	0.399**	-0.278NS	0.256NS	0.338*	0.329*	0.304*	0.046NS	0.300NS
	P		0.00	0.471**	0.788**	0.138NS	0.094NS	-0.136NS	0.344*	0.376*	0.198NS	0.347*	0.209NS	0.365*	-0.234NS	0.244NS	0.189NS	0.279NS	0.250NS	0.053NS	0.299NS
Number of leaves per plant	G			0.00	0.479**	0.223NS	-0.091NS	-0.237NS	0.289NS	0.298NS	0.022NS	0.105NS	0.154NS	0.329*	-0.334*	0.240NS	0.175NS	0.314*	0.291NS	0.314*	0.040NS
	P			0.00	0.401**	0.186NS	-0.077NS	-0.101NS	0.252NS	0.219NS	0.019NS	0.083NS	0.107NS	0.231NS	-0.296NS	0.127NS	0.096NS	0.176NS	0.246NS	0.262NS	0.058NS
Leaf area index (cm2)	G				0.00	0.230NS	-0.127NS	-0.416**	0.259NS	0.362*	0.316*	0.352*	0.233NS	0.297NS	-0.480**	0.514**	0.556**	0.550**	0.549**	0.155NS	0.338*
	P				0.00	0.181NS	-0.077NS	-0.214NS	0.256NS	0.353*	0.298NS	0.303NS	0.220NS	0.292NS	-0.411**	0.404**	0.335*	0.484**	0.464**	0.156NS	0.329*
Number of flowers per plant	G					0.00	-0.884**	-0.921**	1.011**	0.966**	0.817**	0.922**	0.772**	1.012**	-0.719**	0.741**	0.874**	0.732**	0.703**	0.623**	0.897**
	P					0.00	-0.486**	-0.387*	0.827**	0.753**	0.675**	0.681**	0.586**	0.774**	-0.472**	0.457**	0.344*	0.516**	0.456**	0.490**	0.693**
Flowering duration	G						0.00	1.039**	-0.714**	-0.728**	-0.842**	-0.618**	-0.742**	-0.710**	0.856**	-0.966**	-1.017**	-0.910**	-0.935**	-0.704**	-0.782**
	P						0.00	0.343*	-0.524**	-0.506**	-0.593**	-0.419**	-0.424**	-0.532**	0.515**	-0.459**	-0.432**	-0.616**	-0.524**	-0.522**	-0.556**
Fruiting duration	G							0.00	-0.741**	-0.682**	-0.846**	-0.635**	-0.524**	-0.643**	0.741**	-0.837**	-1.079**	-0.907**	-0.938**	-0.508**	-0.737**
	P							0.00	-0.428**	-0.349*	-0.378*	-0.365*	-0.328*	-0.384*	0.515**	-0.436**	-0.262NS	-0.520**	-0.450**	-0.296NS	-0.471**
Length of fruit (cm)	G								0.00	0.974**	0.841**	0.964**	0.838**	0.983**	-0.686**	0.691**	0.767**	0.696**	0.669**	0.573**	0.896**
	P								0.00	0.942**	0.790**	0.820**	0.784**	0.953**	-0.581**	0.520**	0.484**	0.606**	0.551**	0.565**	0.865**
Diameter of fruit (cm)	G									0.00	0.846**	0.968**	0.832**	0.961**	-0.743**	0.767**	0.877**	0.746**	0.735**	0.618**	0.903**
	P									0.00	0.794**	0.828**	0.746**	0.918**	-0.635**	0.592**	0.537**	0.673**	0.622**	0.594**	0.867**
Fresh fruit weight (g)	G										0.00	0.905**	0.985**	0.815**	-0.786**	0.902**	1.013**	0.843**	0.848**	0.457**	1.005**
	P										0.00	0.732**	0.847**	0.743**	-0.642**	0.612**	0.595**	0.747**	0.655**	0.434**	0.922**
Number of fruits per plant	G											0.00	**0.889****	**0.969****	-0.630**	**0.758****	**0.916****	**0.725****	**0.621****	**0.472****	**0.998****
	P											0.00	0.655**	0.858**	-0.489**	0.436**	0.356*	0.568**	0.526**	0.402**	0.840**
Dry fruit weight (g)	G												0.00	0.830**	-0.628**	0.645**	0.716**	0.652**	0.666**	0.329*	0.942**
	P												0.00	0.754**	-0.473**	0.487**	0.484**	0.578**	0.479**	0.305*	0.858**
Fruit yield per plant (g)	G													0.00	-0.597**	0.642**	0.713**	0.642**	0.585**	0.510**	0.886**
	P													0.00	-0.507**	0.446**	0.405**	0.588**	0.513**	0.497**	0.845**
Volume of fruit (mL)	G														0.00	-1.167**	-1.298**	-1.058**	-1.065**	-0.877**	-0.728**
	P														0.00	-0.705**	-0.588**	-0.802**	-0.860**	-0.755**	-0.653**
Titrable acidity (%)	G															0.00	1.423**	1.142**	1.169**	0.833**	0.832**
	P															0.00	0.599**	0.756**	0.732**	0.654**	0.646**
Reducing sugar (%)	G																0.00	**1.250****	**1.377****	0.882**	0.958**
	P																0.00	0.671**	0.547**	0.524**	0.595**
Total sugars (%)	G																	0.00	1.066**	0.761**	0.827**
	P																	0.00	0.865**	0.673**	0.721**
Ascorbic acid (mg/100 g fruit)	G																		0.00	0.808**	0.780**
	P																		0.00	0.668**	0.655**
TSS (°Brix)	G																			0.00	0.466**
	P																			0.00	0.456**
Shelf life(days)	G																				0.00
	P																				0.00

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