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Studies on correlation and path coefficient analysis for various traits in different strawberry (*Fragaria* × *ananassa* Duch.) cultivars under temperate climatic conditions of Kashmir

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Abstract
The study was conducted at Experimental Farm, Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar (Jammu and Kashmir). Fifteen genotypes were collected to study the correlation and path coefficient analysis among different traits using a randomized complete block design with three replications during the year 2017-18. A brief overview of the data revealed that the fruit yield per plant showed significantly positive correlation with number of flowers per plant, number of berries per plant, per cent berry set, fruit length, fruit diameter, fruit weight, fruit volume and specific gravity at both the levels. While path coefficient analysis revealed that L: D ratio (3.0776) had maximum positive direct effect on yield per plant followed by fruit weight (2.4379), fruit length (2.4078), fruit diameter (1.778) and fruit volume (1.631). While, negative direct effect of per cent berry set (-0.711) and number of days from flowering to harvest (-0.518) was observed on yield per plant. From this, it is clear that there is a true relationship of these characters with yield and direct selection for this trait will be rewarding for the yield improvement in strawberry.

Keywords: Strawberry, correlation, path coefficient analysis, selection

Introduction
Strawberry (*Fragaria* × *ananassa* Duch.) is a herbaceous, perennial plant in which all the parts arise from a compressed stem called the crown. All cultivated varieties of strawberry are octaploid (2n=56), besides, it is non-climacteric fruit, native to France and belongs to the family Rosaceae. *Fragaria* × *ananassa* (Duch.) is a result of natural hybridization between *Fragaria chiloensis* (L.) (That is native to South America) and *Fragaria virginiana* (Duch.) (of North America). Botanically strawberry is an aggregate fruit (Etario of achenes) which is highly perishable in nature and is considered to be the most popular soft fruits. It is a complete fruit with 98 per cent edible portions and is known to give maximum economic returns in the shortest possible time among all the fruit crops (Das *et al*., 2015) [6]. Temperate climatic conditions prevailing in Kashmir valley offer immense potential for quality strawberry production as most of the varieties are sensitive to day length thus do not flowers unless certain photo-periodic requirements are fulfilled. Strawberry requires an average day temperature of 22–23 ° and 7–13 °C night temperature for better growth and development (Shoemaker**,** 1954) [16]. The maximum area and highest production of strawberry is reported from U.S.A. However, Japan ranks second in the world followed by Poland, Italy, Russia, France, Mexico and Spain. In India wild strawberry plants are found in the Kumaon valley, Almora district of Uttar Pradesh and in the Himalayan Mountains of Pindhari Kafni (Mitra, 1991) [11]. Presently, in India, it is mostly cultivated in Himachal Pradesh, Uttrakhand, Maharashtra, West Bengal, Delhi, Punjab, Haryana, Rajasthan, Jammu & Kashmir and Nilgiri hills (Chadha, 2001) [2]. As per Department of Horticulture, 152 hectares of land is under the cultivation of strawberries in J&K which gives a yearly production of 425 metric tons (Anonymous, 2019) [1]. In the state, strawberries are grown mainly in the districts of Baramulla, Srinagar and Ganderbal.
Correlation gives us an idea about the degree of association or interrelationship between different characters. The degree of association among different characters may either be positive (i.e. a direct relationship) or negative (i.e. an inverse relationship) i.e., selection of a

given character with an aim of improving another character depends upon the extent to which they are related and this relationship between the characters is not only influenced by the genotypic correlation but is also dependent on phenotypic correlation and variance. Thus, correlation enables us to formulate an efficient breeding programme by imparting a required balance when two opposite desirable characters affecting the principle character are being selected. Besides, it also helps to improve different characters simultaneously (Falconer, 1981) [7]. The other genetic parameter commonly used is the path analysis as given by Dewey and Lu (1959) [4]. Path analysis simply gives the cause and effect relationship or in other words we can say that path analysis gives us an idea as to how a trait of interest is influenced by other traits by splitting up the correlation coefficient into measures of direct effect and indirect effect or we can say that path analysis unravels whether the association of different characters with the main character say yield is either due to their direct effect on the yield, or arises due to the indirect effect via some other trait. Note that if correlation between yield and some other character is due to direct effect of the character, it is an indication of a true relationship between them and hence selection can be practiced for such a trait in order to improve the yield. Thus, the present study was conducted on 15 genotypes of strawberry to study the extant of genetic variation and correlation present among the traits besides evaluating their performance for various morphological and biochemical characters.

Materials and Methods

The experiment was conducted during the year 2017-2018 at the Experimental Farm, Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar (Jammu and Kashmir). The experimental site was situated at an elevation of 1685 m above MSL with an average annual rainfall of 600 mm. The experiment was laid in randomized complete block design with three replications. The experimental area after proper ploughing, harrowing and levelling was divided into three blocks each of which was further divided into 15 beds (2 × 1m) and the strawberry runners were planted randomly across each block at spacing of 30 × 30cm thus accommodating 20 plants in each bed. The study included fifteen strawberry cultivars namely Everly, Kimberly, Honeoye, Winter Dawn, Oso Grande, Curaltar, Sea Scape, Catskill, Missionary, Jutogh Special, Katrain Sweet, Chandler, Selva, Brighton and Camarosa. Transplants of some of the cultivars were obtained from CITH while the rest were obtained from SKUAST-K nursery. Intercultural operations like weeding, irrigation, mulching was carried out regularly. Harvesting was carried out manually (hand picking) during the early morning hours at commercial maturity i.e. when 80% of the fruit turned bright red.

Number of flowers and number of berries per plant were recorded for five randomly selected plants. The length and diameter of fruit (cm) was measured using vernier caliper while the fruit shape of each cultivar (cm) was categorized into different classes based on visual observation. Fruit weight (gm) was recorded on top pan electronic balance and this value was used to calculate yield per hectare. Fruit volume (cm^3) was calculated by water displacement method and specific gravity was obtained by dividing the weight of the fruit by the volume of water displaced. The values of already obtained estimate of genotypic and phenotypic variances and covariances were substituted in the formula suggested by Panse and Sukatme (1985) in order to calculate correlation coefficient between all possible pairs of characters. The methodology suggested by Wright (1921) and Li (1956) [10, 14] was adopted while using the formula given by Dewey and Lu (1959) [4] to carry out path coefficient analysis.

Results and Discussion

In the present study, fifteen genotypes of strawberry were evaluated with an aim to estimate the correlation and path analysis. Correlation studies pave way to know the association prevailing between highly heritable characters with most economic characters and gives better understanding of the contribution of each trait in building up the genetic makeup of the crop. The phenotypic correlations indicate the extent of the observed relationship between two characters. However, this does not give true genetic picture of the relationship because it indicates both heritability as well as environmental influences. On the other hand, genotypic correlations provide an estimate of inherent association between genes controlling any two characters (Table 1). Hence, it is of greater significance and could be effectively utilized in formulating an effective selection scheme. In the present study, the estimates of genotypic correlation were in general slightly higher than phenotypic correlation (Table 2) showing that masking effects of the environment was little indicating the presence of inherent association between various characters. In all instances, however, more reliance may be placed on the genotypic correlations. The nature of genotypic correlation was more or less similar to phenotypic correlation under study. The present investigation revealed that the per cent berry set showed strong positive correlation with number of flowers per plant and number of berries per plant both at genotypic and phenotypic levels however, strong negative correlation was recorded between number of days from flowering to harvest and per cent berry set. Fruit diameter showed a significantly negative correlation with fruit length. Fruit weight showed significantly positive correlation with number of flowers per plant, number of berries per plant, per cent berry set and fruit diameter in case of both phenotypic and genotypic correlation. L: D ratio showed significantly negative correlation with fruit diameter (Table 1). Besides, it was also noted that fruit yield per plant showed significantly positive correlation with number of flowers per plant, number of berries per plant, per cent berry set, fruit length, fruit diameter, fruit weight, fruit volume and specific gravity at both the levels. Similar results were obtained by Mir *et al.* (2009) [12] who observed positive and significant correlations between yield per plant and height of plant, spread of plant, fruit weight, fruit diameter, fruit volume and number of fruits per plant. Similar correlations of yield with various other horticultural traits had also been reported by Sharma and Sharma (2006), Rao *et al.* (2010) Hortynski (1989), Das *et al.* (2006), Singh *et al.* (2010), Lal and Seth (1981), Chaubey and Singh (1994) and Ojo *et al.* (2006) [3, 5, 8, 9, 13, 15]. Although correlation studies are helpful in determining the components that influence the yield, however, it does not elucidate the nature and extent of contributions made by number of independent traits. Path coefficient analysis provides a clearer picture for allocation of appropriate weightage to various attributes while designing a pragmatic programme for the improvement of yield. The path

coefficient analysis revealed that L: D ratio (3.0776) had maximum positive direct effect on yield per plant followed by fruit weight (2.4379), fruit length (2.4078), fruit diameter (1.778) and fruit volume (1.631). While, negative direct effect of per cent berry set (-0.711) and number of days from flowering to harvest (-0.518) was observed on yield per plant (Table 3). From the above discussion, it is evident that there is a true relationship of these characters i.e., L:D ratio, fruit weight, fruit length, fruit diameter etc with yield and for the sake of improvement of yield in strawberry, direct selection for these trait will be rewarding. Similar such studies were conducted by Sharma and Sharma (2006), Das *et al*. (2006) and Singh *et al.* (2010) [5, 15].

Table 1: Estimates of genotypic correlation coefficients among different traits in different strawberry (*Fragaria* × *ananassa* Duch.) cultivars

S. No.		No. of flowers plant^{-1}	No. of berries plant^{-1}	Per cent berry set	No. of days from flowering to harvest	Fruit length	Fruit diameter	L: D Ratio	Fruit weight	Fruit volume	Specific gravity	Yield plant^{-1}
1.	No. of flowers plant^{-1}	1	0.999**	0.687**	-0.025	-0.292*	0.394**	-0.412**	0.337**	0.432**	0.025	0.891**
2.	No. of berries plant^{-1}		1	0.741**	-0.073	-0.304*	-0.389**	-0.418**	-0.364**	0.417**	0.071	0.901**
3.	Per cent berry set			1	-0.406**	-0.317**	0.231	-0.332**	-0.429**	0.170	0.371**	0.699**
4.	No. of days from flowering to harvest				1	-0.026	-0.168	0.154	-0.072	-0.034	-0.089	-0.012
5.	Fruit length					1	-0.308**	0.810**	-0.221	-0.043	-0.172	0.321**
6.	Fruit diameter						1	-0.800**	0.622**	0.662**	0.182	0.561**
7.	L: D Ratio							1	-0.477**	-0.413**	-0.186	0.513**
8.	Fruit weight								1	0.705**	0.638**	0.730**
9.	Fruit volume									1	-0.080	0.645**
10.	Specific gravity										1	0.336**
11.	Yield plant^{-1}											1

*, ** significant at 5.0 and 1.0 percent level respectively

Table 2: Estimates of phenotypic correlation coefficients among different traits in different strawberry (*Fragaria* × *ananassa* Duch.) cultivars

S. No.		No. of flowers plant^{-1}	No. of berries plant^{-1}	Per cent berry set	No. of days from flowering to harvest	Fruit length	Fruit diameter	L: D Ratio	Fruit weight	Fruit volume	Specific gravity	Yield plant^{-1}
1.	No. of flowers plant^{-1}	1	0.984**	0.585**	-0.022	-0.275*	0.372**	-0.388**	0.329**	0.425**	0.018	0.871**
2.	No. of berries plant^{-1}		1	0.693**	-0.062	-0.295*	-0.351**	-0.384**	-0.355**	0.410**	0.064	0.882**
3.	Per cent berry set			1	-0.345**	-0.287*	0.145	-0.243	-0.380**	0.146	0.330**	0.618**
4.	No. of days from flowering to harvest				1	-0.023	-0.166	0.153	-0.070	-0.033	-0.084	-0.012
5.	Fruit length					1	-0.291*	0.794**	-0.215	-0.041	-0.170	-0.312
6.	Fruit diameter						1	-0.798**	0.594**	0.641**	0.158	0.541**
7.	L: D Ratio							1	-0.451**	-0.399**	-0.165	0.492**
8.	Fruit weight								1	0.700**	0.635**	0.729**
9.	Fruit volume									1	-0.090	0.640**
10.	Specific gravity										1	0.333**
11.	Yield plant^{-1}											1

*, ** significant at 5.0 and 1.0 percent level respectively

Table 3: Path coefficient analysis among different characteristics in various strawberry (*Fragaria* × *ananassa* Duch.) cultivars showing direct (diagonal) and indirect (off diagonal) effect of various traits on yield

	No. of flowers plant^{-1}	No. of berries plant^{-1}	Per cent berry set	No. of days from flowering to harvest	Fruit length	Fruit diameter	L: D Ratio	Fruit weight	Fruit volume	Specific gravity	Yield plant^{-1}
No. of flowers plant^{-1}	-0.4987	1.0528	-0.4124	0.0103	0.6741	0.6579	-1.2002	-0.8045	0.7016	0.0290	0.891
No. of berries plant^{-1}	-0.4888	1.0743	-0.4906	0.0310	0.6982	0.6223	-1.1695	-0.8776	0.6690	0.1015	0.901
Per cent berry set	-0.2892	0.7413	-0.7110	0.1762	0.6741	0.2667	-0.7386	-0.9264	0.2284	0.4785	0.699
No. of days from flowering to harvest	0.0099	-0.0644	0.2417	-0.5182	0.0481	-0.2845	0.4616	0.1706	-0.0489	-0.1160	-0.012
Fruit length	0.1396	-0.3115	0.1990	0.0103	2.4078	-0.5156	2.4313	0.5363	-0.0652	-0.2465	0.321
Fruit diameter	-0.1845	0.3760	-0.1066	0.0829	0.6982	1.7781	-2.4621	-1.4383	1.0443	0.2320	0.561
L: D Ratio	0.1945	-0.4082	0.1706	-0.0777	-1.9021	-1.4225	3.0776	1.0970	-0.6527	-0.2465	0.513
Fruit weight	-0.1645	0.3867	-0.2702	0.0362	0.5297	1.0491	-1.3849	2.4379	1.1422	0.9135	0.730
Fruit volume	-0.2144	0.4404	-0.0995	0.0155	0.0963	1.1380	-1.2310	-1.7065	1.6317	-0.1305	0.645
Specific gravity	-0.0099	0.0752	-0.2346	0.0414	0.4093	0.2845	-0.5232	-1.5358	-0.1468	1.4500	0.336

Conclusion

The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. Genotypic correlations in general, were higher in magnitude than phenotypic ones. Fruit yield per plant showed significantly positive correlation with number of flowers per plant, number of berries per plant, per cent berry set, fruit length, fruit diameter, fruit weight, fruit volume and specific gravity at both the levels. The path coefficient analysis revealed that L: D ratio (3.0776) had maximum positive direct

effect on yield per plant followed by fruit weight (2.4379), fruit length (2.4078), fruit diameter (1.778) and fruit volume (1.631). While, negative direct effect of per cent berry set (-0.711) and number of days from flowering to harvest (-0.518) was observed on yield per plant. From this, it is clear that there is a true relationship of these characters with yield and direct selection for these traits will be rewarding for the yield improvement in strawberry.

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