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CORRELATION STUDY AND DUS TRAITS OF STRAWBERRY (*FRAGARIA* × *ANANASSA* DUCH.) CULTIVARS UNDER AGROCLIMATIC CONDITIONS OF MEGHALAYA, INDIA

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ABSTRACT

The cultivated strawberry, a member of the Rosaceae family has about 20 recognized strawberry species. Identification of strawberry cultivars is ensured by examination of differences in morphological or physiological characteristics. The current study aimed to study the correlation between fourteen characters of strawberry, and the differences between expected and observed DUS (Distinctness, Uniformity, and Stability) traits in strawberry. Morphological evaluation as per defined DUS descriptors for seven cultivated varieties of strawberry (*Fragaria* x *ananassa* Duch.) *viz.*, Camarosa, Chandler, Festival, Sweet Charlie, Nabila, Sabrina and Winter Dawn were done in the farmer's field across four locations of Sohliya, Umsning, Umktieh and Pynursla in Meghalaya where strawberry is commercially grown. Correlation studies revealed that total soluble solids (TSS) was significantly correlated to fruit size and achenes/fruit while number of fruits/inflorescence was highly significantly correlated to number of flowers/inflorescence. Number of achenes/fruit correlated highly significantly to diameter of calyx in relation to diameter of fruit and number of flowers /inflorescence was significantly correlated to petiole length and petal length: breadth. Petal length: width ratio was highly significantly correlated with flower diameter and significantly to petiole length. Expected and observed DUS character values was same for all the varieties except in Sweet Charlie.

***Key words*:** *Fragaria ananassa*, morphological traits, total soluble solids.

Introduction

The cultivated strawberry, a member of the Rosaceae family is a hybrid developed over 300 years ago in Europe from a cross between *Fragaria virginiana* and *Fragaria chiloensis*. These perennial and stoloniferous herbs reproduce via runners or stolons. There are about 20 recognized strawberry species, classified into five chromosome groups (x=7), comprising diploid, tetraploid, pentaploid, hexaploid, and octaploid forms. The cultivated strawberry is an octaploid (2n = 8x = 56). Nutritionally, strawberries are an excellent source of vitamin C, B1, B2, protein, and minerals like calcium, potassium, and copper. In addition to being low in calories and rich in fiber, strawberries also contain natural antioxidants such as carotenoids, phenolic compounds, and flavonoids. While propagation is typically done using runners, micro-propagation through in-vitro culture of nodal segments has shown great promise, especially in generating disease-free planting material at scale (Jhajhra *et al.*, 2018). Breeding programs for strawberry have been developed to generate new cultivars with improved taste and flavour. Knowledge of genetic diversity and population structure of breeding resources is important for development of new cultivars. Identification of strawberry cultivars is ensured by examination of differences in morphological or physiological characteristics such as leaf, flower and fruit parameters (Lim *et al.*, 2017).

Relationship between different yield contributing characters is essential for better strawberry production. Huge variability exists in various strawberry cultivars with respect to growth habit, flowering, fruiting, yield and other quality contributing characters. Study of interrelationship of different characters through correlation helps the breeder to determine the characters that contribute significantly to desirable traits which can be used for selection in crop improvement. The degree of relationship and association of these components with yield can be measured by correlation coefficient studies. Association of yield contributing characters with yield is of great importance in selecting desirable genotypes. Correlation study in strawberry provides desirable selection criteria for high yield and maximum sweetness through study between yield components and brix percentage. Correlation coefficient analysis measures the relationship between different plant and fruit characters and establishes the component characters which can be used in selection for genetic improvement of a particular character (Mehraj *et al.,* 2014). Hence this study was conducted to study the correlation between fourteen characters of strawberry, and the differences between expected and observed DUS traits in strawberry.

Materials and Methods

The current study was conducted during the growing season of strawberry (*Fragaria x ananassa* Duch.) in seven cultivars *viz.*, Camarosa, Chandler, Festival, Sweet Charlie, Nabila, Sabrina and Winter Dawn in the farmer's field across four locations of Sohliya, Umsning, Umktieh and Pynursla in Meghalaya. Statistical analysis was done with Microsoft Office Excel 2007. Analysis of variance was performed by one-way ANOVA at significance level $P = 0.05$ and 0.01. Correlation coefficients among quantitative descriptors for the seven different strawberry varieties studied were checked at 5% and 1% level of significance. Data on qualitative characters *viz.*, growth habit, density of foliage, vigour, position of inflorescence in relation to foliage, stolon : athocyanin colouration, leaf: colour of upper side, blistering, glossiness, terminal leaflet: shape of base, margin and shape in cross section, stipule: athocyanin colouration, petiole : attitude of hair, arrangement of petals, petal: colour, time of beginning of flowering and ripening, fruit shape, colour, evenness of colour, glossiess, evenness of surface, width of band without achenes, position of achenes, position of calyx attachment, attitude of sepals, adherence of calyx, colour of flesh (excluding core), colour of core, cavity and type of bearing were taken by visual observation while quantitative data *viz.*, leaf circumference, terminal leaflet length: width ratio, petiole length, flower diameter, size of calyx : corolla, petal length: width, fruit length: width, diameter of calyx in relation to diameter of fruit was measured with a ruler. Number of stolon, flowers/ inflorescence, achenes/fruit and number of fruits/ inflorescence were counted, fruit size (weight in grams) and total soluble solids (TSS) was measured with an electronic balance and refractometer respectively.

Results

Correlation between the quantitative traits for the seven different strawberry varieties studied

Pearson's correlation studies for the various quantitative traits revealed that flower diameter correlated significantly with terminal leaflet length: width ratio. Significant correlation was also observed between petal length: width and petiole length while petal length: width and flower diameter correlated highly significantly. Correlation between number of flowers/inflorescence and petiole length, petal length: width was significant as was the correlation observed between number of achenes/ fruit and number of stolon, leaf circumference and fruit size. Correlation for traits number of achenes/fruit and diameter of calyx in relation to diameter of fruit was highly significant. Correlation was also significant between number of fruits/inflorescence and petal length: width while number of fruits/inflorescence and number of flowers/inflorescence correlated highly significantly. Total Soluble Solids showed significant correlation with fruit size and number of achenes/fruit. Total Soluble Solids was positively correlated with number of stolon, leaf circumference, petiole length, size of calyx: corolla, fruit length: width, fruit size, diameter of calyx in relation to diameter of fruit and number of achenes/fruit and negatively correlated to terminal leaflet length: width ratio, flower diameter, petal length: width, number of flowers/ inflorescence and number of fruits/ inflorescence**.** Number of fruits/ inflorescence was negatively correlated to all the traits except petal length: width, number of flowers/inflorescence. Number of achenes/fruit was positively correlated to number of stolon, leaf circumference, flower diameter, size of calyx: corolla, petal length: width, fruit length: width, fruit size and diameter of calyx in relation to diameter of fruit. Number of flowers/inflorescence was positively correlated to petal length: width. Diameter of calyx in relation to diameter of fruit was positively correlated to number of stolon, leaf circumference, flower diameter, size of calyx: corolla, petal length: width, fruit length: width and fruit size. Fruit size was positively correlated to number of stolon, leaf circumference, petiole length, petal length: width and fruit length: width. Fruit length: width was positively correlated

Table 1: Correlation coefficients among quantitative descriptors for the seven different strawberry varieties studied.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14
NS	1													
LC	0.667	1												
TL	-0.643	-0.142	1											
PL	-0.265	0.430	0.604	1										
FD	-0.300	0.249	**0.753***	0.656	1									
SCC	0.409	0.176	0.217	0.007	0.363	1								
PLW	0.305	-0.170	-0.686	**-0.784***	**-0.872****	-0.429	1							
FL	0.068	0.509	0.224	0.354	0.554	0.188	-0.447	1						
FS	0.478	0.591	-0.543	0.015	-0.360	-0.295	0.316	0.482	1					
DCF	0.454	0.608	-0.289	-0.096	0.269	0.048	0.021	0.697	0.494	1				
NF	-0.229	-0.646	-0.261	**-0.753***	-0.651	-0.454	**0.812***	-0.595	-0.188	-0.287	1			
NAF	**0.740***	**0.818***	-0.459	-0.033	0.021	0.137	0.116	0.647	**0.768***	**0.867****	-0.399	1		
NFI	-0.082	-0.405	-0.324	-0.657	-0.564	-0.521	**0.813***	-0.636	-0.181	-0.122	**0.916****	-0.264	1	
TSS	0.458	0.518	-0.499	0.080	-0.049	0.024	-0.086	0.648	**0.798***	0.609	-0.518	**0.767***	-0.538	1

Character: NS: Number of stolon (1); LC: Leaf circumference (2); TL: Terminal leaflet length: width ratio (3); PL: Petiole length (4); FD: Flower diameter (5); SCC: Size of calyx : corolla (6); PLW: Petal length: width (7); FL: Fruit length: width (8); FS: Fruit size (9); DCF: Diameter of calyx in relation to diameter of fruit (10); NF: Number of flowers/inflorescence (11); NAF: Number of achenes/fruit (12); NFI: Number of fruits/ Inflorescence (13); TSS: Total Soluble Solids (14)

* Values in bold are different from 0 with a significance level alpha=0.05; ** Values in bold are different from 0 with a significance level alpha=0.01

to number of stolon, leaf circumference, terminal leaflet length: width ratio, petiole length, flower diameter and size of calyx: corolla. Petal length: width was positively correlated to number of stolon (Table 1). Association studies for fruit traits revealed that percent TSS was negatively correlated with number of fruits/inflorescence but significantly and positively correlated to fruit size and achenes/fruit implying that larger fruits recorded higher TSS values in the current study. Number of fruits/ inflorescence correlated highly significantly to number of lowers/inflorescence while number of flowers/ inflorescence showed significant negative correlation with petiole length. For flower traits, significant positive correlation was also observed for number of flowers/ inflorescence with petal length: width ratio. Flower diameter also showed significant positive correlation with terminal leaflet length: width ratio.

Comparison between expected and observed DUS fruit characters

Study of the expected DUS character values for eight qualitative and quantitative characters of fruit showed that fruit shape for expected and observed DUS character values was same for all the varieties except in Sweet Charlie where the observed fruit shape was globose instead of conical or wedged. Fruit colour observed in Festival was red instead of dark red while fruit colour in Sweet Charlie was dark red instead of orange red. Position of achenes was as expected for all the varieties studied except in Winter Dawn where the achenes were below instead of being level or above the surface. Colour of flesh excluding core in Chandler was red instead of orange red, orange red instead of red in Festival and Sabrina. Type of bearing, fruit length: width ratio and fruit size was non remontant, longer and large respectively for both the observed and the expected DUS character values. Total soluble solids showed variation for all the varieties studied. Differences between observed and expected DUS character values were seen in 25% of the cases (Table 2).

ANOVA for individual locations studied revealed that the number of stolon was highly significant in Pynursla, Umktieh and Umsning while it was significant in Sohliya. Leaf circumference diameter was significant in Umsning and highly significant in Umktieh. Flower diameter and number of flowers/inflorescence was highly significant in Umktieh. Petiole length was highly significant in Pynursla and significant in Umktieh and Umsning while size of calyx: corolla was highly significant in Pynursla and significant in Sohliya and Umsning. Fruit size was highly significant in Pynursla and Umktieh and significant in Sohliya. Diameter of calyx in relation to diameter of fruit was highly significant in Pynursla and Umktieh while number of achenes/fruit was highly significant in all the locations studied except Umsning. Terminal leaflet length: width ratio petal length: width and fruit length: width was not significant in any of the locations studied implying absence of variation for the trait (Table 3).

Discussion

Verma *et al*., 2002 found positive and significant correlation of number of fruits per plant with fruit width,

Table 2: Comparison between observed and expected DUS for qualitative and quantitative fruit traits for the seven different strawberry varieties studied.

Sl. No.	Character	State	Rank	Expected DUS character values							Observed DUS character values						
				CM	CH	FS	WD	SC	SB	NB	CM	CH	FS	WD	SC	SB	NB
1.	Fruit: Shape	Reniform	1														
		Obloid	2														
		Globose	3												3		
		Conical	4	4	4	4	4	4	4	4	4	4	4			4	4
		Rhomboid	5														
		Ovoid	6														
		Cylindrical	7														
		Wedged	8				8	8						8			
		Cordiform	9														
2.	Fruit: Colour	Whitish yellow	1														
		Orange	2														
		Orange red	3					3									
		Red	4	4	4				4	4	4	4	4			4	4
		Dark red	5			5	5							5	5		
		Reddish black	6														
3.	Fruit: Position of achenes	Below surface	1	1	1	1		1	1	1	1	1	1	1	1	1	1
		Level with surface	2	2	2		2										
		Above surface	3				3										
4.	Fruit : Colour of flesh (excl-uding core)	Whitish	1				1										
		Light pink	2														
		Orange red	3	3	3			3		3	3		3		3	3	3
		Red	4			4	4		4	4		4		4			
5.	Type of bearing	Not remontant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Partially remontant	2														
		Fully remontant	3														
		Day neutral	4														
6.	Fruit: Length width ratio	Shorter (<1)	3														
		Equal (=1)	5					3									
		Longer (>1)	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7.	Fruit: Size (weight in g)	Small (<6)	3														
		Medium (6-9)	5														
		Large (>9)	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8.	TSS (°Brix)	Poor (6)		7.4	8.7	7.4	5.7, 6.3	7.5	6.9	7	6.4	4.9	5.6(Pynursla), 7 (Sohliya Umktieh), 7.05 (Umsning)	6 (Sohliya), 7.05(Pynursla), 7.4 (Umsning), 8.5 (Umktieh)	4.6	6.4	7.25
		Average (10)															
		Good(14)															
		Excellent (16)															
CM: Camarosa; CH: Chandler; FS: Festival; WD: Winter Dawn; SC: Sweet Charlie; SB: Sabrina; NB: Nabila																	

Table 3: ANOVA for the fourteen quantitative fruit traits studied over individual locations.

Character	Pynursla	Sohliya	Umktieh	Umsning
Number of stolon	2.05**	16*	0.09	1.90**
Leaf circumference	5.08	2.37	0.02	8.16*
Terminal leaflet length: width ratio	0.02	0.02	0.01	0.004
Petiole length	5.25**	9.92	14.44*	8.33*
Flower diameter	0.05	0.58	0.04	0.16
Size of calyx : corolla	0.06**	0.02*	0.08	0.09**
Petal length: width	0.002	0.38	0.02	0.02
Fruit length: width	0.01	0.002	0.002	0.03
Fruit size	8.88*	21.34*	0.03	8.91
Diameter of calyx in relation to diameter of fruit	0.24**	0.04	0.34	0.07
Number of flowers/inflorescence	0.97	2.89	6.76	0.30
Number of achenes/fruit	1664.69**	349.69**	2061.16**	779.89
Number of fruits/ inflorescence	12.98**	19.36*	5.29	0.36
Total Soluble Solids	3.15*	1.00	2.40	0.49**

* Values are different from 0 with a significance level alpha=0.05; ** Values are different from 0 with a significance level alpha=0.01

length and volume and negative and significant correlation with diameter of flower and fruit weight. Das *et al.*, 2006 observed that number of berries per plant had significant positive correlation with duration of harvest and yield. Berry diameter was significantly correlated with petiole length and berry weight and negatively correlated with number of runners per plant. A highly significant positive association of fruit yield was observed with plant height, number of stolons per plant, number of leaves per plant, number of flowers per plant and number of fruits per plant (Ara *et al.*, 2009). The fruit yield per plant had significant positive correlation with number of leaves per plant, flowers per plant, and fruit weight and negative correlation with fruit set, fruit breadth, fruit volume, fruit weight, days to 50% flowering and total sugars (Singh *et al.*, 2010). The fruit yield was positively correlated to fresh and dry weight of the strawberry plants and root length (Bartczak *et al.*, 2010).

Correlation studies by Hofer *et al.*, (2012) for 108 morphological descriptors showed that number of flowers/inflorescence was positively correlated to the stolon number while flower size was positively correlated to the fruit size. Emdad *et al.*, 2013 observed positive significant association between number of flower buds per plant and number of flowers per plant, length and breadth of fruit and yield per plant. Number of flowers per plant showed positive significant association with the number of fruits per plant, length and breadth of fruit and yield per plant. High correlation was observed between number of flowers per plant and number of fruits per plant. Positive and significant association of crown height of strawberry was observed with the number of flower buds per plant, number of flowers per plant, number of fruits per plant, fruit length, fruit breadth and yield per plant. Positive significant association was observed between number of flowers per plant (Emdad *et al.*, 2013). The number of fruits per plant and average berry weight were positively correlated to yield per plant (Garg *et al.*, 2014). Jan *et al.*, 2022 observed positive correlation between fruit yield per plant and number of flowers per plant, number of berries per plant, per cent berry set, fruit diameter, fruit weight and fruit length. Fruit yield was significantly and positively associated with most of the characteristics except flowering duration, fruiting duration, and volume of fruit (Manivannan *et al.*, 2023). Yield per plant was positively and significantly associated with number of leaves per plant, fruit length, fruit breadth, number of fruits per plant and TSS (Kumar and Kumari *et al.*, 2025). Nielsen and Lovell, 2000 studied differences between observed and expected DUS character values revealed differences between observed and PVR values in over 40% of the cases. Positive correlation between desirable characters helps in improvement of both the characters simultaneously. Correlation analysis favours the plant breeder as it helps to find out the direct or indirect relationship between characters. Characters with positive association with yield should be utilised as selection criteria for improvement. Differences between observed and expected characters are produced due to observer subjectivity, evaluated plants grown in different climatic conditions and also due to variability of strawberries.

Conclusion

Fortyfive qualitative and quantitative characters of plant, leaf, flower and fruit were studied according to the DUS descriptors for seven strawberry varieties *viz.*, Camarosa, Chandler, Festival, Sweet Charlie, Nabila, Sabrina and Winter Dawn which are popularly grown in

Meghalaya. Although strawberry cultivars are clonally propagated, for the fruit traits studied, 25% variation could be detected from the expected DUS traits for the specific cultivar. ANOVA revealed significant variability among cultivars for the different quantitative traits studied, especially those pertaining to fruit traits. The percent TSS was found to be negatively correlated with number of fruits/inflorescence but significantly and positively correlated to fruit size and achenes/fruit implying that larger fruits recorded higher TSS values. Number of fruits/ inflorescence correlated highly significantly to number of flowers/inflorescence.

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Authors' Contributions: Chumki Dutta designed the study, performed the final editing, wrote the objectives, and initial draft of the manuscript. Samir Medhi, Japani Chinir and Star Luikham performed the statistical analyses and data processing of the study. Chumki Dutta, Samir Medhi and Sanjeet Kumar Borah managed the data collection and review of relevant literature, data interpretation and manuscript revision. All authors read and approved the final manuscript.

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