**Morphological and biochemical characterization in strawberry (*Fragaria spp*.)**

**ABSTRACT**

Morphological evaluation as per defined DUS descriptors for seven cultivated varieties of strawberry (*Fragaria* x *ananassa* Duch.) *viz.*, Camarosa, Chandler, Festival, Sweet one 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 following recommended package of practices. Of the thirty qualitative traits studied, variation was observed for nineteen traits. Wide variation was also observed for the fourteen quantitative traits pertaining to fruit size, number of fruits/ inflorescence and total soluble solids (TSS) among others. Pooled ANOVA for the common varieties Festival and Winter Dawn grown in all the four locations studied revealed that G x E component was highly significant for fruit specific traits indicating differential performance from location to location as a result of genotype x environment interaction.

Keywords: *Fragaria ananassa, morphological traits, total soluble solids,*

1. **INTRODUCTION**

Strawberry is a herbaceous member of genus *Fragaria* of Rosaceae family. Cultivated strawberry (*Fragaria x ananassa* Duch.) originated in Europe as a hybrid between the South American *Fragaria chiloensis* Duch and the North American *Fragaria virginiana* Duch (Kichaoui, 2014). There are about twenty recognized species with various ploidy levels. Cultivated strawberry is octoploid (2n=8x=56) (Debnath and Teixeira da Silva, 2007). Wild strawberry has various ploidy levels like diploid, tetraploid, pentaploid, hexaploid, octoploid and nonaploid (Hummer *et al*., 2009).

The numerous cultivars of strawberry available over the world vary remarkably in morphological characters. Selection of a cultivar is of paramount importance for successful cultivation of strawberry as the genotypic and phenotypic interaction of strawberry plant is highly dependent on the cultivar. Moreover it is necessary to evaluate the morphological characters if the crop is grown in new condition. Morphological characters of a plant are of prime importance for nature as well as the yield of a crop (Rahman *et al*.*,* 2013).

Hossan *et al.* (2013) studied the growth and yield of three strawberry germplasm. Significant difference in leaf number was found due to varietals performance. Leaf area, number of flowers per plant, diameter and length of fruit, fruit yield per plant and other reproductive parameters showed significant variation in the germplasm collection studied. Islam *et al.* (2013) studied the growth and yield performance of four strawberry germplasms to find a suitable strawberry cultivar(s). The germplasm with maximum number of flowers and fruits, highest average fruit weight and the highest total fruit yield was identified and considered to be promising cultivar for cultivation. Distinct variations were exhibited for Brix percentage among the four germplasm studied. Sharma *et al.* (2014) studied fifteen strawberry cultivars for yield, fruiting and quality characters and identified the cultivar exhibiting maximum fruit length, breadth, berry weight, yield, total sugars, acidity and sugar/acid ratio. Significant variation was observed among the evaluated strawberry cultivars with respect to total soluble solids, fruit length, breadth, berry weight and yield.

The aim of this study was to study the morphological and biochemical diversity of cultivated strawberry cultivars over the growing season. Given the importance of strawberry cultivation in Meghalaya in generating revenue for farmers, a better understanding of the crop behavior will help to mitigate the problems of the farmers, particularly those related to varietal performance under local conditions of the popular varieties.

**2. MATERIALS AND METHODS**

The current study was conducted during the growing season of strawberry (*Fragaria x ananassa* Duch.) from November 2017 to March 2018 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 where strawberry is commercially grown following recommended package of practices. 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.

**3. RESULTS AND DISCUSSION**

**3.1. Evaluation of qualitative and quantitative characters of plant, leaf, flower and fruit**

Forty five 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 grown by farmers in Meghalaya. Of the thirty one qualitative characters studied, nineteen diagnostic characters (different characters among the seven cultivars studied) identified were position of inflorescence in relation to foliage, anthocyanin colouration of stolon, colour of upper side of leaf, leaf blistering and glossiness, shape of base and margin of terminal leaflet, anthocyanin colouration of stipule, attitude of hair in petiole, arrangement of petals, fruit shape and colour, evenness of colour, glossiness, evenness of surface, position of calyx attachment, attitude of sepals ,colour of flesh (excluding core) and colour of core. Additionally, twelve synthetic characters (same character found on the seven cultivars studied) pertaining to growth habit, density of foliage, plant vigour, shape in cross section of terminal leaflet, petal colour, time of beginning of flowering, width of band without achenes, position of achenes, adherence of calyx, fruit cavity, type of bearing and time of beginning of ripening were observed (Figure 1 and 2) (Table 1, 2,3 and 4). Similar studies carried out by Kasiamdari *et al*., (2017) in nine cultivars of straw­berry for thirty seven vegetative and reproductive characters identified twelve diagnostic and twenty five synthetic characters.

Hofer *et al*., (2012) noted that since strawberry domestication resulted in a reduction of both morphological and genetic diversity with commercial fruit production dominated by only few cultivars, it is not uncommon for different cultivars to share similar traits. Nielsen and Lovell (2010) in a study related to cultivar identification using definitive descriptors for seventeen strawberry cultivars noted that while several cultivars share similar ranks owing to shared pedigree for most strawberry cultivars, several morphological / reproductive traits were highly variable. Chhetri *et al*. (2017) reported that variation between cultivars for traits such as fruit size may be due to the genetic makeup of the cultivars and adaptation to climatic conditions. Similarly, differences in fruit quality, TSS content are particularly correlated to favourable temperature and humidity during the fruit growth period especially during night which effects retention of higher TSS in ripe fruits.

**Table 1. Qualitative data of plant habit and leaf characters as per DUS descriptors of the seven different strawberry varieties studied**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **CHARACTERS** | **CAMAROSA** | **CHANDLER** | **FESTIVAL** | **WINTER DAWN** | **SWEET CHARLIE** | **SABRINA** | **NABILA** |
| Growth habit | Semi upright | Semi upright | Semi upright | Semi upright | Semi upright | Semi upright | Semi upright |
| Density of foliage | Dense | Dense | Dense | Dense | Dense | Dense | Dense |
| Vigour | Strong | Strong | Strong | Strong | Strong | Strong | Strong |
| Position of inflorescence in relation to foliage | Beneath | Above | Beneath | Beneath | Beneath | Beneath | Beneath |
| Stolon: Anthocyanin colouration | Weak | Medium | Weak | Medium | Medium | Medium | Medium |
| Leaf: Colour of upper side | Green | Green | Dark green | Dark green | Dark green | Dark green | Dark green |
| Blistering | Strong | Strong | Medium | Strong | Strong | Strong | Strong |
| Glossiness | Medium | Weak | Weak | Medium | Medium | Medium | Medium |
| Terminal leaflet: Shape of base | Obtuse | Rounded | Obtuse | Obtuse | Acute | Obtuse | Obtuse |
| Terminal leaflet: Margin | Intermediate | Serrate | Crenate | Intermediate | Intermediate | Intermediate | Intermediate |
| Terminal leaflet: Shape in cross section | Convex | Convex | Convex | Convex | Convex | Convex | Convex |
| Stipule: Anthocyanin colouration | Medium | Weak | Medium | Medium | Medium | Medium | Medium |
| Petiole: Attitude of hair | Upwards | Horizontal | Horizontal | Horizontal | Upwards | Upwards | Upwards |

**Table 2.** **Qualitative data of flower characters as per DUS descriptors of the seven different strawberry varieties studied**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **CHARACTERS** | **CAMAROSA** | **CHANDLER** | **FESTIVAL** | **WINTER DAWN** | **SWEET CHARLIE** | **SABRINA** | **NABILA** |
| Arrangement of petals | Free | Free | Free | Overlapping | Overlapping | Free | Free |
| Petal: colour | White | White | White | White | White | White | White |
| Time of beginning of flowering | Early | Early | Early | Early | Early | Early | Early |
| Time of beginning of ripening | Early | Early | Early | Early | Early | Early | Early |

**Table 3.**  **Qualitative data of fruit characters as per DUS descriptors of the seven different strawberry varieties studied**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **CHARACTERS** | **CAMAROSA** | **CHANDLER** | **FESTIVAL** | **WINTER DAWN** | **SWEET CHARLIE** | **SABRINA** | **NABILA** |
| Fruit shape | Conical | Conical | Conical | Wedged | Globose | Conical | Conical |
| Fruit colour | Red | Red | Red | Dark red | Dark red | Red | Red |
| Evenness of colour | Slightly uneven | Even | Even | Even | Even | Even | Even |
| Fruit: glossiness | Medium | Medium | Medium | Strong | Strong | Medium | Medium |
| Evenness of surface | Even | Even | Slightly uneven | Even | Even | Even | Even |
| Width of band without achenes | Medium | Medium | Medium | Medium | Medium | Medium | Medium |
| Position of achenes | Below surface | Below surface | Below surface | Below surface | Below surface | Below surface | Below surface |
| Position of calyx attachment | Level with ground | Level with ground | Level with ground | Exerted | Level with ground | Level with ground | Level with ground |
| Attitude of sepals | Outward | Upwards | Upwards | Upwards | Outward | Outward | Outward |
| Adherence of calyx | Strong | Strong | Strong | Strong | Strong | Strong | Strong |
| Colour of flesh (excluding core) | Orange red | Red | Orange red | Red | Orange red | Orange red | Orange red |
| Colour of core | White | Orange | Orange | Pink | Orange | Orange | Orange |
| Cavity | Large | Large | Large | Large | Large | Large | Large |
| Type of bearing | Non remontant | Non remontant | Non remontant | Non remontant | Non remontant | Non remontant | Non remontant |

|  |  |  |
| --- | --- | --- |
| **C:\Users\User\Desktop\Photos\Camarosa\f cam.jpg** |  | **Camarosa** |
| **D:\Students research\Chumki\Photos\Festival\IMG_0298.jpg** |  | **Festival** |
| **C:\Users\User\Desktop\Photos\Sabrina\f sab.jpg** |  | **Sabrina** |
| **C:\Users\User\Desktop\Photos\Sweet Charlie\f sc.jpg** |  | **Sweet Charlie** |
| **C:\Users\User\Desktop\Photos\chandler\f ch.jpg** |  | **Chandler** |
|  |  | **Nabila** |
|  |  | **Winter Dawn** |
| **Fig.1.** Variation in fruit characters observed in the seven different varieties studied | | |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  | **Camarosa** |
|  |  |  | **Festival** |
|  |  |  | **Sabrina** |
|  |  |  | **Sweet Charlie** |
|  |  |  | **Chandler** |
|  |  |  | **Nabila** |
|  |  |  | **Winter Dawn** |
| **Fig. 2.** Variation in flower and leaf characters observed in the seven different varieties studied | | | |

**Table 4.** **Descriptive statistics of the different quantitative descriptors**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Character** | **Mean** | **Standard Deviation** | **Min** | **Max** | **Co efficient of Variation** |
| Number of stolons | 0.74 | 0.93 | 0 | 1.9 | 125.39 |
| Leaf circumference | 11.21 | 1.23 | 9.3 | 13.02 | 11.01 |
| Terminal leaflet length: width ratio | 1.11 | 0.05 | 1.06 | 1.18 | 4.66 |
| Petiole length | 9.87 | 1.63 | 7.27 | 11.64 | 16.47 |
| Flower diameter | 2.27 | 0.34 | 1.75 | 2.74 | 14.98 |
| Size of calyx : corolla | 0.98 | 0.17 | 0.81 | 1.3 | 16.97 |
| Petal length: width | 1.10 | 0.16 | 0.96 | 1.33 | 14.24 |
| Fruit length: width | 1.27 | 0.14 | 1.1 | 1.52 | 11.23 |
| Fruit size | 14.62 | 4.09 | 8.85 | 20.29 | 28.00 |
| Diameter of calyx in relation to diameter of fruit | 1.36 | 0.29 | 0.83 | 1.64 | 21.20 |
| Number of flowers/inflorescences | 4.60 | 2.98 | 2.65 | 10.9 | 64.66 |
| Number of achenes/fruits | 186.77 | 27.31 | 142.3 | 214.28 | 14.62 |
| Number of fruits/ inflorescences | 4.80 | 2.77 | 2.2 | 10.5 | 57.74 |
| Total soluble solids (TSS) | 6.18 | 1.03 | 4.6 | 7.25 | 16.62 |

ANOVA for individual locations studied (Table 5) 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.

Location wise mean performance for different fruit traits studied in the common varieties Winter Dawn and Festival across four locations (Fig. 3.) revealed that barring length : width ratio, mean performance of all the other traits varied significantly. Since these traits studied showed significant differences, a pooled ANOVA for the quantitative traits studied with respect to these common (Table 6) was performed. It was observed that genotype x environment interaction was highly significant for number of stolon, leaf circumference, petiole length, flower diameter, petal length: width, fruit size, diameter of calyx in relation to diameter of fruit, number of flowers/inflorescence, number of achenes/fruit, number of fruits/inflorescence and total soluble solids. This implied presence of variation within the clonally propagated cultivars for the traits under study.

**Table 5. ANOVA for the fourteen quantitative fruit traits studied over individual locations**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **NS** | **LC** | **TL L:W** | **PL** | **FD** | **C:C** | **P L:W** | **F L:W** | **FS** | **D C:C** | **FL/I** | **A/F** | **FR/I** | **TSS** |
| **Pynursla** | 2.05\*\* | 5.08 | 0.02 | 5.25\*\* | 0.05 | 0.06\*\* | 0.002 | 0.01 | 8.88\* | 0.24\*\* | 0.97 | 1664.69\*\* | 12.98\*\* | 3.15\* |
| **CD** | 0.53 |  |  | 0.68 |  | 0.1 |  |  | 1.34 | 0.11 |  | 9.06 | 0.84 | 0.81 |
| **Sohliya** | 16\* | 2.37 | 0.02 | 9.92 | 0.58 | 0.02\* | 0.38 | 0.002 | 21.34\* | 0.04 | 2.89 | 349.69\*\* | 19.36\* | 1 |
| **CD** | 0.46 |  |  |  |  | 0 |  |  | 0.51 |  |  | 0.23 | 0.46 |  |
| **Umktieh** | 4.73\*\* | 0.92\*\* | 0.01 | 11.35\* | 207.70\*\* | 0.12 | 0.04 | 0 | 48.18\*\* | 0.17\* | 33.31\*\* | 4005.41\*\* | 8.85\* | 6.71\*\* |
| **CD** | 0.23 | 0.12 |  | 0.42 | 0.05 |  |  |  | 0 | 0.11 | 0.92 | 0.92 | 1.61 | 0.35 |
| **Umsning** | 1.90\*\* | 8.16\* | 0.004 | 8.33\* | 0.16 | 0.09\*\* | 0.02 | 0.03 | 8.91 | 0.07 | 0.3 | 779.89 | 0.36 | 0.49\*\* |
| **CD** | 0.41 | 1.29 |  | 1.51 |  | 0.09 |  |  |  |  |  |  |  | 0.16 |

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

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

CD (Critical Difference) values at 0.05% and df = 8

**NS**: Number of stolon, **LC**: Leaf circumference, **TL L:W** Terminal leaflet length: width ratio, **PL**: Petiole length, **FD**: Flower diameter, **C:C** Size of calyx : corolla, **P L:W** Petal length: width, **F L:W** Fruit length: width, **FS**: Fruit size, **D C:C** Diameter of calyx in relation to diameter of fruit, **FL/I**: Number of flowers/inflorescence, **A/F**: Number of achenes/fruit, **FR/I**:Number of fruits/inflorescence, **TSS**: Total soluble solids.

**Table 6. Pooled ANOVA of the quantitative traits studied over the four locations for the common varieties Winter Dawn and Festival**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characters** | **MS value** | | |
| **Genotype(G) at df 1** | **Environment (E) at df 3** | **G x E at df 3** |
| Number of stolon | 0.72\*\* | 2.64\*\* | 5.90\*\* |
| Leaf circumference | 1.76\*\* | 34.16\*\* | 3.45\*\* |
| Terminal leaflet length: width ratio | 0.00 | 0.01 | 3.83 |
| Petiole length | 7.81\*\* | 10.02\*\* | 6.27\*\* |
| Flower diameter | 0.04 | 0.34\* | 0.22\* |
| Size of calyx : corolla | 0.12\*\* | 0.34\*\* | 0.01 |
| Petal length: width | 0.09\*\* | 0.33\*\* | 0.11\*\* |
| Fruit length: width | 0.00\*\* | 0.01\*\* | 0.00 |
| Fruit size | 3.92\*\* | 116.88\*\* | 13.42\*\* |
| Diameter of calyx in relation to diameter of fruit | 0.40\*\* | 0.12\*\* | 0.12\*\* |
| Number of flowers/inflorescence | 5.06\*\* | 7.88\*\* | 1.78\*\* |
| Number of achenes/fruit | 128.82\*\* | 4169.81\*\* | 2660.10\*\* |
| Number of fruits/inflorescence | 16.00\*\* | 14.95\*\* | 3.17\*\* |
| Total soluble solids (TSS) | 1.38\*\* | 1.80\*\* | 1.42\*\* |

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

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



**Fig. 3. Location wise mean performance for different fruit traits studied for the common varieties Winter Dawn and Festival. Error bars= ±S.E.**

ANOVA for the quantitative traits studied in individual locations revealed that significant to highly significant inter cultivar variation was present for number of stolon, petiole length, size of calyx: corolla ratio, fruit size, number of flowers/inflorescence, diameter of calyx in relation to diameter of fruit and number of seeds/fruit. No significant variation was observed for terminal leaflet length: width ratio, flower diameter, petal length: width ratio and fruit length: width ratio. A pooled ANOVA for the same quantitative traits studied for the common varieties Winter Dawn and Festival which were grown in all four locations revealed that G x E component was highly significant for all traits barring length: width ratio of terminal leaflet and fruit length: width ratio indicating differential performance from location to location for majority of the traits as a result of genotype x environment interaction resulting in differential varietal performance in different locations. Identifying the best-performing genotype is often confounded by genotype x environment interactions (Lopez-Medina *et al.*, 2001). Ahsan *et al*. (2014) had observed that cultivars produced different plant height due to cultivation practices during the growing season. However, a significant G x E also implies that varietal performance of these popular varieties can still be improved or better targeted varieties can be introduced or bred, for producing fruits with better market value. In this context, it is necessary to evaluate yield response of these popular commercial cultivars with respect to planting dates, planting densities among other environmental factors in order to better understand the magnitude of interaction effects on yield characters.

**4. CONCLUSION**

The climate of Meghalaya is highly suitable for cultivation of strawberry making it the fourth largest producer of strawberry after Maharashtra, Haryana and Jharkhand. On an average, 500 metric tonnes of strawberry is grown in the state of Meghalaya each year with profits of 25,000-50,000 INR annually making it a highly profitable venture with maximum returns in a short period of time. Several cultivars of strawberry are available for cultivation with variation observed in plant, leaf, flower and fruit characters and with an increase in demand for the fruit and emphasis on fruit quality, it is important for the growers to select cultivars which will produce good returns. In addition to selection of suitable cultivar, quality planting material is also essential for cultivation.

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