Morphological Markers for Early Selection in Strawberry Breeding Programs

Mohammad E. El-Denary, Ramadan A.M.Ali,[1] Sara E. Gomaa[2]

ABSTRACT

This study was conducted in El Tahrir South Station, Ali Mubarak Farm, Horticulture Research Institute, Agriculture Research Center.,Cairo, Egypt at the winter seasons of 2012, 2013 and 2014. The main aim was to decide upon a morphological character in the juvenile stage of strawberry to be considered as a morphological marker; i.e., Breeding Program Selectable Marker (BPSM) - for expecting the production level in the breeding programs, instead of waiting for the whole growing season; to save time, money, land and labor efforts. Thirty eight characters were evaluated using eleven strawberry cultivars, to assess the important morphological differences among them. Results showed that there were some initial vegetative growth characters at the early stages of development in the nursery during the propagation of seedlings that might be relayed upon to determine the expected yield at an early stage, without delaying to the end of whole growing season. There were some clear and significant differences among all cultivars in most of the studied traits, which might make selection effective for such complicated character of total yield. Correlation results showed significant and desirable positive correlations between total yield and each nine of the morphological traits; i.e., leaf color of the upper side (0.35), terminal leaflet length in relation to width (0.34**), number of stolons (0.04**), flower earliness (0.19*), corolla number (0.18*), flower position in relation to foliage (0.30**), flower diameter (0.24**), calyx size in relation to corolla (0.53**) and petals arrangements (0.29**). On the other hand, some significant negative correlations were detected between total yield and each of other nine traits. Significant differences and correlation among these traits suggests that, they could be taken into account when selecting for productivity improvement in strawberry breeding programs.**

Key words: Strawberry cultivars, Breeding Program Selectable Marker, yield, marketable yield, unmarketable yield and TSS.

INTRODUCTION

Strawberry is broadly developed from different hybrid species of the genus *Fragaria* and is planted mainly for its fruit, which is an aggregate of accessory fruit, widely spread for its trademark fragrance, splendid red shading, delicious juicy composition, and sweetness (Yadav, 2015). It is consumed in substantial amounts; either fresh or prepared (cooked) as jelly, organic juice, pies, desserts, milkshakes and filled chocolates products. Synthetic strawberry fragrance is broadly utilized as a part of numerous manufactured food items (Mak, 2012).

Strawberry cultivars differ broadly in size, flavor, shape, color, degree of fertility, season of ripening and level of resistance to pathogens (Husaini, 2010, and Michele and Warmund, 2010). Some of them differ in foliage or their sexual organs maturity. Mostly, blooms seem hermaphroditic in structure, yet act as either male or female (Fletcher, 1917). Commercially, plants are produced from runners and circulated as either bare root plants or plugs.

Strawberries are usually classified by their flowering habit (Sagers, 1992). Generally, this has comprised of a division between "June-bearing" strawberries, which give rise to their fruit in the early summer and “ever-bearing" strawberries, which frequently bear fruits all through the season. Since strawberry plants more than a year or two old start to decrease in production and quality, this requires replanting new plants every year which in turn enhance yields and allow dense plantings. This needs an extended growing season than normal for the new planting foundation every year, followed by extra expenses for covering the hills and acquiring plants every year, which is not generally viable in all zones (Upson, 1999).

Multiple germplasm is a specific plant type typically studied using qualitative and quantitative phenotypic characteristics, particularly those which are heritable and significant in breeding programs. This germplasm variability is normally known as phenotypic diversity or variation (Mohammadi and Prasanna, 2003; Rotondi *et al*., 2003; Upadhyaya *et al*., 2005).

Phenotypic variation of an attribute in plants is expected in quantitative genetics as a cumulative effect of genetic, environment and the interaction between them (Toker, 2004; Upadhyaya *et al.,* 2005; Xu *et al.*, 2006). Parental genotypes to be used as a start of breeding projects are typically assorted upon trait economical importance. It is important to pick parental genotypes which have characters distant from each other to decrease impacts of inbreeding. An effective breeding program obliges a wide genetic distance and phenotypic assorted qualities among the descendants. This can be accomplished by using unrelated and

[1]Potato, Veg. and Vegetative Reproduction Dept.,
[2]Veg., Medicinal and Aromatic Plants Breeding Dept, Horticulture Research Institute, Agricultural Research Center, Egypt.
Corresponding author: mdenary@yahoo.com
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diverse parents at both phenotypic and genetic levels. In order to achieve breeding efficiency, it is important to plan the breeding program, using the knowledge about the breeding value of the potential parents.

Phenotypic and molecular diversity in *Fragaria* species has been studied by scientists in the United States and Canada (Lacey, 1973; Shaw, 2005; Harrison *et al.*, 2000; Shaw and Larson, 2005). These studies have yielded significant data which can be utilized to set up a center for strawberry accumulation in North America. In Poland, strawberries are generally raised as a small fruit crop (Żurawicz and Masny, 2005). Polish strawberry geneticists and breeders have studied variability in their germplasm of the species and developed many cultivars that are well adapted to agro-ecological conditions of Central Europe and very productive in this growing area (Masny *et al.*, 2005; Żurawicz and Masny, 2005; Żurawicz *et al.*, 2006).

The objectives of this study were to estimate the genetic diversity among some commercial cultivars of strawberry and to determin some morphological selectable markers, as a key role for strawberry early selection in breeding programs, in addition, to select the superior genotypes to be used in commercial hybrid production.

MATERIALS AND METHODS

This study was performed in the successive winter seasons of 2012/2013 and 2013/2014 at El Tahrir South Station, Ali Mubarak Farm, Horticulture Research Institute, Agriculture Research Center.

Eleven strawberry cultivars were used in this study; kindly provided by Pico Co., namely, Sweet Charlie, Chandler, Festival, Yaeel, Earlibrite, Tamar, Gaviota, Suzana, Camaroza, Fentana and Carmen. From each cultivar, 100 plants were arranged in twenty replicates to be used to estimate the morphological differences, according to the international union for the protection of new varieties of plants (UPOV, 2012), and the other quantitative traits, at full bloom stage (≈ 55 days) from transplanting. Vegetative characters included; leaf color of upper side, leaf blistering, leaf glossiness, terminal leaflet length in relation to width, terminal leaflet shape of base, terminal leaflet margin, petiole hair attitude, stipule anthocyanin coloration and cross section of the terminal leaflet. Plant growth characters included; plant growth habit, plant density of foliage, plant vigor, number of stolons, stolon anthocyanin coloration and density of pubescence. Flower characters included; flower earliness (number of days from transplanting to 25% of flowering), leaves number, floral clusters number, corolla number, flower position of inflorescence in relation to foliage, flower diameter, calyx size in relation to corolla, petals arrangements and petal length in relation to width. Fruit characters included; percentage of total soluble solids (TSS), calyx diameter in relation to fruit diameter, fruit adherence of calyx, fruit flesh color, evenness of fruit flesh color, fruit size, fruit length in relation to width (measured by ruler), fruit surface evenness, fruit color, evenness of fruit external color, fruit glossiness, fruit position of achenes, fruit position of calyx attachment and calyx segment status. Yield characters included; total yield (tons/fed), marketable yield (tons/fed), unmarketable yield (tons/fed), fruit yield/plant (g/plant) and average fruit weight at first season (g).

Data were statistically analyzed according to the used Randomized Complete Blocks Design (RCBD), with 5 plants/ each experimental Unit. Comparisons among various means were made using the Least Significant Differences test (LSD). These analyses were calculated using SAS program, version 8.2 (2002).

RESULTS AND DISCUSSIONS

Results showed wide ranges of variability among the genotypes for all studied morphological characters.

Means for nine vegetative characters were estimated at the full bloom stage (≈55 days from transplanting), as shown in Tables (1-A) and (1-B). These results showed that, the leaf color of the upper side was significantly different among strawberry cultivars, as it was light green for Chandler, Gaviota and Suzana; medium green for Earlibrite and Camaroza; dark green for Sweet Charlie, Festival, Yaeel, Fentana and Carmen; and blue green in Tamar; with an average of 1.41, 1.73, 2.00, 2.24; respectively. Leaf blistering was either absent or weak among all the studied cultivars (UPOV, 2012).

In case of the leaf glossiness; the cultivars differed significantly among three levels of glossiness, which ranged from absent to weak (in Sweet Charlie, Chandler, Yaeel, Tamar and Fentana), medium in (Festival, Earlibrite, Gaviota, Camaroza and Carmen) and strong glossiness (only in Suzana) which can be used as a breeding program selectable marker (BPSM). Measurements results of the terminal leaflet length in relation to width, illustrated that leaf length was significantly shorter than width in Sweet Charlie, Gaviota and Camaroza; while, it was equal in Yaeel and Suzana, and moderately longer to width in Chandler, Festival, Earlibrite, Tamar, Fentana and Carmen, with averages of 1.00, 1.41 and 1.73, respectively, for the three ratios. One more important parameter that could be relayed on was the terminal leaflet shape of base, which was significantly rounded only in the Sweet Charlie cultivars (BPSM); while, it ranged between obtuse to acute in the rest of the cultivars.

Table 1-A. Morphological measurements of vegetative growth characters among the eleven strawberry cultivars according to the UPOV index in the full bloom stage

Strawberry variety	Leaf color of upper side	Leaf blistering	Leaf glossiness	Terminal leaflet length in relation to width	Terminal leaflet shape of base	Terminal leaflet margin	Petiole hair attitude	Stipule anthocyanin coloration	Cross section of the terminal leaflet
Sweet Charlie	Dark green	Absent or weak	Absent or weak	Shorter	Rounded	Serrated	Slightly out words	Strong	Straight
Chandler	Light green	Absent or weak	Absent or weak	Moderately longer	Obtuse	Serrated	Slightly out words	Medium	Straight
Festival	Dark green	Absent or weak	Medium	Moderately longer	Acute	Serrated	Absent	Strong	Straight
Yaeel	Dark green	Absent or weak	Absent or weak	Equal	Obtuse	Serrated	Slightly out words	Strong	Concave
Earlibrite	Medium green	Absent or weak	medium	Moderately longer	Acute	Serrated	Slightly out words	Weak	Straight
Tamar	Blue green	Absent or weak	Absent or weak	Moderately longer	Obtuse	Serrated	Upwards	Medium	Concave
Gaviota	Light green	Absent or weak	Medium	Shorter	Obtuse	Serrated	Slightly out words	Strong	Concave
Suzana	Light green	Absent or weak	Strong	Equal	Acute	Serrated	Upwards	Strong	Straight
Camaroza	Medium green	Absent or weak	Medium	Shorter	Acute	Serrated	Absent	Medium	Straight
Fentana	Dark green	Absent or weak	Absent or weak	Moderately longer	Acute	Serrated	Slightly out words	Strong	Concave
Carmen	Dark green	Absent or weak	Medium	Moderately longer	Acute	Crenate	Slightly out words	Weak	Straight

Table 1-B. Comparisons among the means of the vegetative growth characters among the eleven strawberry cultivars in the full bloom stage

Strawberry variety	Leaf color of upper side	Leaf blistering	Leaf glossiness	Terminal leaflet length in relation to width	Terminal leaflet shape of base	Terminal leaflet margin	Petiole hair attitude	Stipule anthocyanin coloration	Cross section of the terminal leaflet
Sweet Charlie	2.00b	1.00	1.00c	1.00c	1.73a	1.00b	1.41a	2.65a	1.41a
Chandler	1.41d	1.00	1.00c	1.73a	1.41b	1.00b	1.41a	2.24b	1.41a
Festival	2.00b	1.00	1.41b	1.73a	1.00c	1.00b	0.00b	2.65a	1.41a
Yaeel	2.00b	1.00	1.00c	1.41b	1.41b	1.00b	1.41a	2.65a	1.00b
Earlibrite	1.73c	1.00	1.41b	1.73a	1.00c	1.00b	1.41a	1.73c	1.41a
Tamar	2.24a	1.00	1.00c	1.73a	1.41b	1.00b	1.00b	2.24b	1.00b
Gaviota	1.41d	1.00	1.41b	1.00c	1.41b	1.00b	1.41a	2.65a	1.00b
Suzana	1.41d	1.00	1.73a	1.41b	1.00c	1.00b	1.00b	2.65a	1.41a
Camaroza	1.73c	1.00	1.41b	1.00c	1.00c	1.00b	0.00b	2.24b	1.41a
Fentana	2.00b	1.00	1.00c	1.73a	1.00c	1.00b	1.41a	2.65a	1.00b
Carmen	2.00b	1.00	1.41b	1.73a	1.00c	1.41a	1.41a	1.73c	1.41a

The terminal leaflet margin was serrated in all cultivars, except in Carmen, as it was crenate which again can be considered as BPSM. Concerning the petiole hair attitude, it was slightly upwards in all cultivars, except in Tamar and Suzana, which was upwards; while, it was totally absent in Festival and Camaroza. Stipule anthocyanin coloration was collectively weak in Earlibrite and Carmen; medium in Chandler, Tamar and Camaroza and obviously strong in the rest of the studied cultivars. Cross section of the terminal leaflet flanked significantly between concave and straight; with an average of 1 and 1.414, respectively in all cultivars as shown in Table (1-B).

Regarding plant growth characters, data in tables (2-A) and (2-B) showed that the eleven cultivars showed significant differences in plant growth habit, that ranged from upright (in Sweet Charlie, Yaeel, Tamar and Suzana); semi-upright (in Chandler, Festival, Earlibrite and Fentana) and spreading in the rest three cultivars with averages of 1.05, 1.45 and 1.73; respectively.

Concerning plant density of foliage; it was medium with no significant difference among all cultivars with an average of 2.28, except for Sweet Charlie and Carmen were dense (2.65) while Yaeel and Camaroza showed spare foliage with an average of 1.79. In plant vigor, Chandler, Suzana, Camaroza, Fentana and Carmen showed strong plant vigor with no significant difference between its mean (2.65) while the rest was medium in their vigor.

Only Carmen cultivar showed dense foliage and a strong plant vigor along the 20 replicates, with an average of 2.65 for both characters. Gaviota and Carmen cultivars had a few number of stolons (1.73); while, Sweet Charlie, Suzana and Fentana possessed many up to 2.65. The rest of the cultivars had a medium number of stolons with an average of 2.24. Regarding stolon anthocyanin coloration, only, cultivar Yaeel showed a weak color when compared with the rest of cultivars, which varied from medium to strong, to very strong in Sweet Charlie, Fentana and Carmen.

Table 2-A. Morphological measurements of plant growth characters among the eleven strawberry cultivars according to the UPOV index in the full bloom stage

Strawberry variety	Plant growth habit	Plant density of foliage	Plant vigor	Number of stolons	Stolon anthocyanin coloration	Density of pubescence
Sweet Charlie	Upright	Dense	Medium	Many	Very strong	Dense
Chandler	Semi-upright	Medium	Strong	Medium	Medium	Medium
Festival	Semi-upright	Medium	Medium	Medium	Medium	Spare
Yaeel	Upright	Spare	Medium	Medium	Weak	Dense
Earlibrite	Semi-upright	Medium	Medium	Medium	Medium	Medium
Tamar	Upright	Medium	Medium	Medium	Medium	Dense
Gaviota	Spreading	Medium	Medium	Few	Strong	Dense
Suzana	Upright	Medium	Strong	Many	Strong	Dense
Camaroza	Spreading	Spare	Strong	Medium	Medium	Spare
Fentana	Semi-upright	Medium	Strong	Many	Very strong	Spare
Carmen	Spreading	Dense	Strong	Few	Very strong	Medium

Table 2-B. Comparisons among the means of the plant growth characters among the eleven strawberry cultivars in the full bloom stage

Strawberry variety	Plant growth habit	Plant density of foliage	Plant vigor	Number of stolons	Stolon anthocyanin coloration	Density of pubescence
Sweet Charlie	1.05 c	2.65 a	2.18 b	2.65 a	3.00 a	1.73 a
Chandler	1.45 b	2.28 b	2.65 a	2.24 b	2.24 bc	1.41 b
Festival	1.45 b	2.28 b	2.18 b	2.24 b	2.24 bc	1.00 c
Yaeel	1.05 c	1.79 c	2.18 b	2.24 b	1.73 c	1.73 a
Earlibrite	1.45 b	2.28 b	2.18 b	2.24 b	2.24 bc	1.41 b
Tamar	1.05 c	2.28 b	2.18 b	2.24 b	2.24 bc	1.73 a
Gaviota	1.73 a	2.28 b	2.18 b	1.73 c	2.65 b	1.73 a
Suzana	1.05 c	2.28 b	2.65 a	2.65 a	2.65 b	1.73 a
Camaroza	1.73 a	1.79 c	2.65 a	2.24 b	2.24 bc	1.00 c
Fentana	1.45 b	2.28 b	2.65 a	2.65 a	3.00 a	1.00 c
Carmen	1.73 a	2.65 a	2.65 a	1.73 c	3.00 a	1.41 b

Density of pubescence was the same inside the cultivars, as it was spare in Festival, Camaroza and Fentana; medium in both Chandler and Carmen; and dense in the rest of cultivars.

With reference to the flower quantitative characters, data were collected in the full bloom stage and the results appear in Table (3). Significant differences in flower earliness were noticed for Earlibrite, Sweet Charlie and Tamar; which were the first cultivars to produce 25% of the flowers within 56, 57 and 67 days after transplanting, respectively; while Camaroza, was the latest with an average of 82 days. Concerning plant leaves number, Sweet Charlie recorded the highest number of leaves, while Camaroza, Suzana and Gaviota were the lowest; with averages of 27 and 10 leaves/plant, respectively. Significant differences were found among some cultivars in the floral cluster number and corolla number; but Sweet Charlie was the highest among all cultivars with average numbers of 14 and 2.83, respectively.

Concerning flower position of inflorescence in relation to foliage, results indicated that, most of the cultivars possessed a high inflorescence above the foliage (1.73). In Sweet Charlie, Suzana and Camaroza, their inflorescences were beneath the foliage level (1.00), while, only, in Festival the inflorescence was at the same level with the foliage (BPSM).

Flower diameters in Tamar, Suzana, Camaroza and Carmen cultivars were relatively small in comparison to Sweet Charlie, Yaeel and Earlibrite which were medium in their diameters; whereas, the rest were large. Calyx size was the same size as corolla in most cultivars, except for Festival, Earlibrite and Camaroza, that gave larger sizes while; those of Gaviota and Carmen were smaller (BPSM). Petals arrangement was touching each other in most cultivars, and was overlapping in Yaeel, Suzana and Fentana, while, it was free in Chandler and Tamar (BPSM). Petal length was moderately shorter compared with width, among most cultivars under study with insignificant differences. On the other hand it was longer in Chandler, Festival and Fentana, while moderately shorter in Tamar cultivar only (BPSM).

Regarding the percentage of total soluble solids (TSS), shown in Fig. (1), there were highly significant differences among the studied cultivars. Sweet Charlie was the highest in its TSS contents, with an average of 11.11%; followed by Sozana (10.24%), then Camaroza (9.45%). High TSS means more ripening and, low humidity, which leads to a longer shelf life (Parker and Maalekuu, 2013; and Khan *et al.,* 2014). The lowest TSS was found in Tamar, with an average of 6.87%.

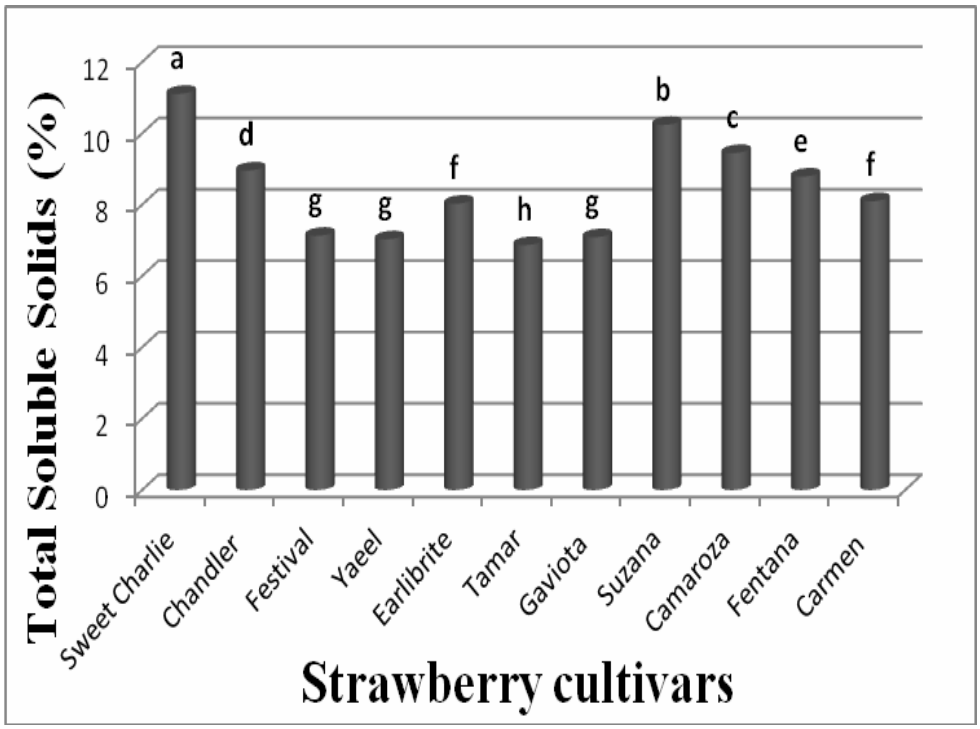

Figure1. Average percentages of total soluble solids of the eleven studied strawberry cultivars during seasons (2012/2013 – 2013/2014)

For morphological characters of fruits; means and significance of the detected differences are illustrated in tables (5-A) and (5-B). Mean values for calyx diameter in relation to fruit diameter showed that the highest values were recorded by Sweet Charlie, Suzana and Carmen ≈2.00, without any significant differences among them. Chandler, Fentana and Gaviota seemed to have similar size (1.73), with insignificant differences among them. Festival, Yaeel and Earlibrite showed smaller fruit diameters and gave (1.41) without any significant differences among their values. On the other hand, Tamar seemed to have the smallest value and recorded (1.00). The comparison among the various cultivars reflected highly significant difference for the calyx diameter in relation to fruit diameter trait. Fruit adherence of calyx, all cultivars appeared very strong (2.24) in their adherence to calyx without any significant differences among them, except the two cultivars; Sweet Charlie (1.81) and Carmen (1.47), which showed significant differences of medium to weak in their adherence respectively. Results showed highly significant differences among all cultivars in the fruit flesh color. Chandler and Sweet Charlie were mostly dark red with the highest mean of 2.45, without a significant difference, while, Festival, Suzana and Carmen appeared to have light red in color (2.00). Also, Earlibrite, Gaviota and Camaroza gave 1.73 with an orange red flesh color. The lightest pink color was recorded for Yaeel, Tamar and Fentana (1.14), with insignificant differences among them.

The mean performance values for the evenness of fruit flesh color are presented in Tables (5-A) and (5-B). Most of the cultivars ranged between aside and in the center evenness, according to UPOV, with mean values of (1.73 to 1.66); while; only Yaeel and Tamar were aside in their evenness (1.00).

There were highly significant differences among all cultivars in fruit size character, suggesting high selection efficiency for this trait. Fruits of most cultivars ranged between medium to large in size with means of (2.36 – 2.54). Chandler, Festival, Yaeel and Carmen were medium in fruit size (2.36), while; Earlibrite and Fentana recorded the largest fruit sizes, with 2.86 mean. Data concerning fruit length in relation to width revealed that Festival, Earlibrite and Tamar fruits seemed longer in their length in relation to width, without a significant difference between their means; 2.24. Fruits of Sweet Charlie, Chandler and Carmen were moderately longer in length with relation to width; whereas, Yaeel, Gaviota and Yaeel had fruits with equal length and width. Camaroza cultivar recorded the lowest value of all, i.e. 1.25, shorter in fruit length/width. Concerning fruit surface evenness, Sweet Charlie, Tamar, Camaroza and Carmen were slightly uneven with means of 1.33; while the rest of strawberry cultivars were even in their surface. Regarding fruit color trait, the highest values were recorded by most cultivars, which tended to be dark red. Also, there were insignificant differences among Yaeel, Earlibrite, Tamar and Carmen fruit color (orange red); whereas, Fentana was medium red in color with a mean of 2.24. There were insignificant differences among most cultivars in the evenness of fruit external color, which were even; while Earlibrite, Suzana and Fentana were slight uneven mostly, and only Sweet Charlie showed uneven fruit surface. Concerning fruit glossiness, it was medium with insignificant differences among Sweet Charlie, Festival, Earlibrite and Fentana; with a mean of (1.41); while the rest of the cultivars were strong in glossiness with an average mean of (1.73). Fruit position of achenes reflected highly significant differences among the studied cultivars. The maximum value was recorded for achenes above surface by Earlibrite, Gaviota, Suzana and Camaroza (1.73), with insignificant differences among them. Fruit position of achenes was at the same level with surface for Chandler (1.41). Lowest values were recorded by the rest of the cultivars without any significant differences among them; whereas, achenes were below the surface. Regarding fruit position of calyx attachment, high significant differences were recorded indicating that selection would be very effective. Festival, Yaeel and Camaroza recorded the highest mean value (1.57); which is raised; while, there were no significant difference between Sweet Charlie and Suzana cultivars as their calyx was in the same level with the fruit. The lowest values were recorded by the rest of the cultivars with inserted calyx, without any significant differences among them. Calyx segment status showed significant differences among the studied cultivars. Sweet Charlie, Chandler, Tamar and Camaroza were single; while, the rest of the cultivars were clasped and none of them was curved. This result suggested that there were highly genetic potentials regarding these cultivars.

Figure (2) illustrated that Fentana, Early bright, Yaeel, Tamar, Festival, Camaroza, Sweet Charlie showed the highest total yield; with significant differences, respectively, followed by Chandler and Suzana without a significant difference. The cultivar Gaviota and Carmen gave the lowest total yield. Also, Fentana and Earlibrite cultivars recorded the highest marketable yield without a significant difference (21.73 and 21.72 tons/fed respectively); while, Carmen recorded the lowest marketable yield (18.54). Tamar, Festival and Camaroza gave intermediate marketable

yields (20.68, 20.45 and 20.00 tons/fed, respectively). Figure (3) showed that Festival had the lowest unmarketable yield (0.60 tons/fed). Carmen and Sweet Charlie gave the highest unmarketable yield of 1.24 and 1.22 (tons/fed), respectively, with no significant difference. According to data in Figure (4), Fentana and Earlibrite showed the highest fruit yield /plant without a significant difference (842.17 and 840.62 g, respectively); while, Carmen cultivar recorded the lowest yield/plant (591.9g). Concerning the average fruit weight (Fig. 5), Fentana had the highest average of fruit weight (30.72 g), while, Carmen gave the lowest average of fruit weight (20.24 g)

The correlation coefficients estimates among 22 traits of vegetative - plant growth and flower - characters revealed that, 66 of them were highly significant correlations (35 positive) and 18 of them (9 positive) were significant correlations; whereas there were 26 insignificant correlations as shown in Table(6). Generating information about the relationships between yield and other agronomic attributes is the key task in genetic improvement of any crop plant. Phenotypic correlation is the association between two characteristics that can be directly observed and determined from measurements of the two characteristics in a number of individuals of the population (Singh, 2009). Results showed significant and desirable positive correlations between total yield and each nine of the morphological traits; i.e., leaf color of the upper side (0.35**), terminal leaflet length in relation to width (0.34**), number of stolons (0.04**), flower earliness (0.19*), corolla number (0.18*), flower position in relation to foliage (0.30**), flower diameter (0.24**), calyx size in relation to corolla (0.53**) and petals arrangements (0.29**).

Table 3. Comparisons among the means of the flower quantitative characters among the eleven strawberry cultivars in the full bloom stage

Strawberry variety	Flower earliness (days)	Leaves number	Floral cluster number	Corolla number
Sweet Charlie	57.37 c	26.83 a	14.17 a	2.83 a
Chandler	70.04 c	16.50 b	4.33 cd	1.92 a
Festival	71..83 b	12.83 c	3.75 d	1.75 bc
Yaeel	70.44 c	11.75 c	5.58 c	1.50 c
Earlibrite	56.02 g	10.42 d	7.25 b	1.58 c
Tamar	67.36 e	17.75 b	4.75 c	1.83 bc
Gaviota	69.08 d	10.33 d	3.00 d	1.42 cd
Suzana	67.92 e	10.67 d	5.00 c	1.58 c
Camaroza	82.21 a	10.33 d	4.92 c	1.50 c
Fentana	71.87 b	16.08 d	4.75 c	2.33 ab
Carmen	70.39 c	12.08 c	2.75 d	1.17 d

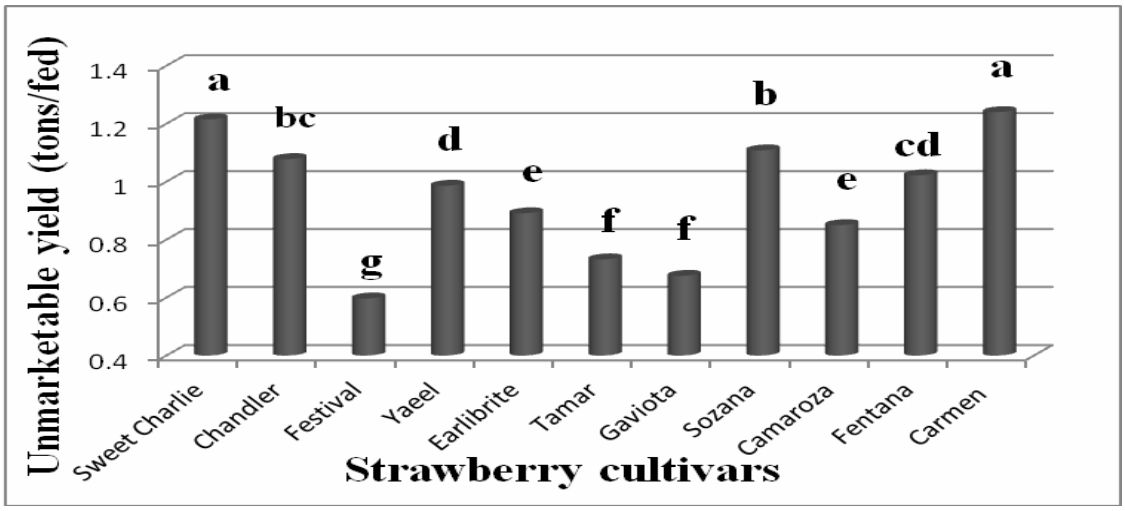

Figure 3. Average of Unmarketable yield (tons/fed) of the eleven strawberry cultivars during the seasons (2012/2013 – 2013/2014)

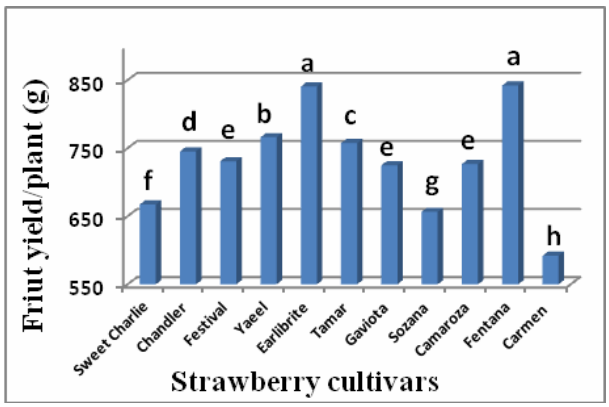

Figure 4. Average fruit yield/plant (g) among eleven strawberry varieties during the seasons (2012/2013– 2013/2014)

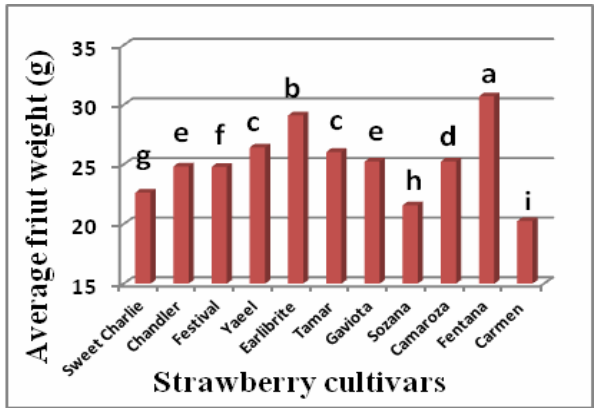

Figure 5. Average fruit weight (g) of the eleven strawberry cultivars during the seasons (2012/2013 – 2013/2014)

Table 4-A. Morphological measurements of flower growth characters among the eleven strawberry cultivars according to the UPOV index in the full bloom stage

Strawberry variety	Flower position of inflorescence in relation to foliage	Flower diameter	Calyx size in relation to corolla	Petals arrangements	Petal length in relation to width
Sweet Charlie	Beneath	Medium	Same size	Touching	Equal
Chandler	Above	Large	Same size	Free	Moderately longer
Festival	Same level	Large	Larger	Touching	Moderately longer
Yaeel	Above	Medium	Same size	Overlapping	Equal
Earlibrite	Above	Medium	Larger	Touching	Equal
Tamar	Above	Small	Same size	Free	Moderately shorter
Gaviota	Above	Large	Smaller	Touching	Equal
Suzana	Beneath	Small	Same size	Over lapping	Equal
Camaroza	Beneath	Small	Larger	Touching	Equal
Fentana	Above	Large	Same size	Over lapping	Moderately longer
Carmen	Above	Small	Smaller	Touching	Equal

Table 4-B. Comparisons among the means of the flower growth characters among the eleven strawberry cultivars in the full bloom stage

Strawberry variety	Flower position of inflorescence in relation to foliage	Flower diameter	Calyx size in relation to corolla	Petals arrangements	Petal length in relation to width
Sweet Charlie	1.00 c	2.24 ab	1.41 b	1.41 b	1.73 b
Chandler	1.73 a	2.65 a	1.41 b	1.00 c	2.00 a
Festival	1.41 b	2.65 a	1.73 a	1.41 b	2.00 a
Yaeel	1.73 a	2.24 ab	1.41 b	1.73 a	1.73 b
Earlibrite	1.73 a	2.24 ab	1.73 a	1.41 b	1.73 b
Tamar	1.73 a	1.73 b	1.41 b	1.00 c	1.41 c
Gaviota	1.73 a	2.65 a	1.00 c	1.41 b	1.73 b
Suzana	1.00 c	1.73 b	1.41 b	1.73 a	1.73 b
Camaroza	1.00 c	1.73 b	1.73 a	1.41 b	1.73 b
Fentana	1.73 a	2.65 a	1.41 b	1.73 a	2.00 a
Carmen	1.73 a	1.73 b	1.00 c	1.41 b	1.73 b

Each mean is the average of 20 healthy plants (replicates)

Table 5-A. Morphological measurements of fruit growth characters among the eleven strawberry cultivars according to the UPOV index in the full bloom stage

Strawberry variety	Calyx diameter in relation to fruit diameter	Fruit adherence of calyx	Fruit flesh color	Evenness of fruit flesh color	Fruit size	Fruit length in relation to width	Fruit surface evenness	Fruit color	Evenness of fruit external color	Fruit glossiness	Fruit position of achenes	Fruit position of calyx attachment	Calyx segment status
Sweet Charlie	Slightly larger	Medium	Dark red	Aside and in the center	Large	Moderately longer	Slightly uneven	Dark red	Uneven	Medium	Below surface	Same level with the fruit	Single
Chandler	Same size	V. strong	Dark red	Aside and in the center	Medium	Moderately longer	Even	Dark red	Even	Strong	Same level with surface	Raised	Single
Festival	Slightly smaller	V. strong	Light red	Aside and in the center	Medium	Much longer	Even	Dark red	Even	Medium	Below surface	Inserted	Clasped
Yaeel	Slightly smaller	V. strong	Light pink	**Aside**	Medium	Equal	Even	Orange red	Even	Strong	Below surface	Raised	Clasped
Earlibrite	Slightly smaller	V. strong	Orange red	Aside and in the center	V. large	Much longer	Even	Orange red	Slightly uneven	Medium	Above surface	Inserted	Clasped
Tamar	Much smaller	V. strong	Light pink	Aside	Large	Much longer	Slightly uneven	Orange red	Even	Strong	Below surface	Inserted	Single
Gaviota	Same size	V. strong	Orange red	Aside	Large	Equal	Even	Dark red	Even	Strong	Above surface	Inserted	Clasped
Suzana	Slightly larger	V. strong	Light red	Aside and in the center	Large	Equal	Even	Dark red	Slightly uneven	Strong	Above surface	Same level with the fruit	Clasped
Camaroza	Much smaller	V. strong	Orange red	Aside	Large	Moderately shorter	Slightly uneven	Dark red	Even	Strong	Above surface	Raised	Single
Fentana	Same size	V. strong	Light pink	Aside and in the center	V. large	Equal	Even	Medium red	Slightly uneven	Medium	Below surface	Inserted	Clasped
Carmen	Slightly larger	Weak	Light red	Aside and in the center	Medium	Moderately longer	Slightly uneven	Orange red	Even	Strong	Below surface	Same level with the fruit	Single

Table 5-B. Comparisons among the means of the fruit growth characters among the eleven strawberry cultivars in the full bloom stage

Strawberry variety	Calyx diameter in relation to fruit diameter	Fruit adherence of calyx	Fruit flesh color	Evenness of fruit flesh color	Fruit size	Fruit length in relation to width	Fruit surface evenness	Fruit color	Evenness of fruit external color	Fruit glossiness	Fruit position of achenes	Fruit position of calyx attachment	Calyx segment status
Sweet Charlie	2.00 a	1.81 b	2.45 a	1.59 b	2.54 b	2.00 b	1.33 a	2.43 a	1.29 b	1.41 b	1.02 c	1.21 b	1.48 a
Chandler	1.73 b	2.24 a	2.45 a	1.73 a	2.36 c	2.05 b	1.00 b	2.43 a	1.00 c	1.73 a	1.41 b	1.57 a	1.48 a
Festival	1.41 c	2.24 a	2.00 b	1.73 a	2.36 c	2.24 a	1.00 b	2.43 a	1.00 c	1.41 b	1.00 c	1.00 c	1.00 b
Yaeel	1.41 c	2.24 a	1.41 d	1.00 d	2.36 c	1.73 c	1.00 b	2.00 c	1.00 c	1.73 a	1.00 c	1.57 a	1.00 b
Earlibrite	1.41 c	2.24 a	1.73 c	1.66 ab	2.86 a	2.24 a	1.00 b	2.00 c	1.41 a	1.41b	1.73 a	1.00 c	1.00 b
Tamar	1.00 d	2.24 a	1.41 d	1.00 d	2.54 b	2.24 a	1.33 a	2.00 c	1.00 c	1.73 a	1.00 c	1.00 c	1.48 a
Gaviota	1.73 b	2.24 a	1.73 c	1.15 c	2.54 b	1.73 c	1.00 b	2.43 a	1.00 c	1.73 a	1.73 a	1.00 c	1.00 b
Suzana	2.00 a	2.24 a	2.00 b	1.73 a	2.54 b	1.73 c	1.00 b	2.43 a	1.41a	1.73 a	1.73 a	1.21 b	1.00 b
Camaroza	1.00 d	2.24 a	1.73 c	1.08 cd	2.54 b	1.25 d	1.33 a	2.43 a	1.00 c	1.73 a	1.73 a	1.57 a	1.48 a
Fentana	1.73 b	2.24 a	1.41 d	1.73 a	2.86 a	1.73 c	1.00 b	2.24 ab	1.41a	1.41 b	1.00 c	1.00 c	1.00 b
Carmen	2.02 a	1.47 c	2.00 b	1.70 a	2.36 c	2.24 a	1.33 a	2.00 b	1.00 c	1.73 a	1.00 c	1.21 b	1.48 a

Table 6. Phenotypic correlation coefficient between each of the vegetative growth characters, plant growth characters, flower growth characters and yield characteristics of the eleven strawberry cultivars

	Total Yield (tons/fed)	Marketable yield (tons/fed)	Unmarketable yield (tons/fed)	Fruit yield/plant (g)	Average fruit weight (g)
Leaf color of upper side	0.35**	0.35**	-0.16*	0.29**	0.30**
Leaf glossiness	-0.37**	-0.33**	-0.12 N.S	-0.37**	-0.39**
Terminal leaflet length in relation to width	0.34**	0.31**	0.01 N.S	0.28**	0.24**
Terminal leaflet shape of base	-0.19**	-0.19*	0.11 N.S	-0.10 N.S	-0.13*
Terminal leaflet margin	-0.41**	-0.48**	0.43**	-0.62**	-0.53**
Petiole hair attitude	0.12N.S	0.05 N.S	0.45**	0.15*	0.16*
Stipule anthocyanin coloration	0.02 N.S	0.05 N.S	-0.18*	0.05 N.S	0.40 N.S
Cross section of the terminal leaflet	-0.38**	-0.43**	0.32**	-0.43**	-0.49**
Plant growth habit	-0.39**	-0.38**	0.04 N.S	-0.21*	-0.16*
Plant density of foliage	-0.26**	-0.31**	0.36**	-0.38**	-0.34**
Plant vigor	-0.19*	-0.25**	0.39**	-0.16*	0.10 N.S
Number of stolons	0.40**	0.33**	0.27**	0.26**	0.22**
Stolon anthocyanin coloration	-0.29**	-0.36**	0.45**	-0.39**	-0.27**
Density of Pubescence	-0.29**	-0.30**	0.20*	-0.30**	-0.35**
Flower earliness	0.19*	0.14*	-0.22**	0.10N.S	0.04 N.S
Leaves number	0.03N.S	-0.02 N.S	0.22**	-0.06N.S	-0.06N.S
Floral cluster number	0.11N.S	0.06 N.S	0.27**	-0.02N.S	-0.04N.S
Corolla number	0.18*	0.14*	0.14*	0.11N.S	0.12N.S
Flower position in relation to foliage	0.30**	0.33**	-0.18*	0.42**	0.43**
Flower diameter	0.24**	0.27**	-0.26**	0.47**	0.46**
Calyx size in relation to corolla	0.53**	0.55**	-0.29**	0.49**	0.40**
Petals arrangements	0.29**	0.23**	0.21*	0.03 N.S	0.10 N.S

On the other hand, some significant negative correlations were detected between total yield and each of other nine traits. Significant differences and correlation among these traits suggests that, they could be taken into account when selecting for productivity improvement in strawberry breeding programs.

These results came in a general agree with Xinmei *et al.* (1995), who stated that associated morphological characteristics can be taken as markers at juvenile stage in strawberry breeding programs when investigated some phenotypic characters and tried to correlate them to the economic characters of strawberry to develop good strawberry cultivars, with thermophilic resistance and long shelf life. Also, Kamangar *et al.* (2014) proved that plant yield was significantly and positively correlated with inflorescences number/plant, flowers number/inflorescence and fruits number/plant. Ukalska *et al.*, (2006) similarly reported a strong and positive correlation between strawberry yield and flowers number/inflorescence.

The significance of correlation between yield and traits related to reproductive organs number including the number of inflorescences, flowers and fruits and vice versa the non-significance of correlation between yield and fruit weight and size, indicated that the influence of fruit number on plant yield was more pronounced as compared with the influence of fruit size (Kamangar *et al.*, 2014). Similarly Acuna-Maldonado and Pritts (2008) declared that strawberry yield was a function of fruits number rather than size. Furthermore fruit weight was negatively correlated with inflorescences number/plant and fruits number/plant suggesting a reverse relationship between the number and the size of fruits referred to the competition among fruits for assimilate during fruit filling period. Furthermore, results agreed with Gawronski and Hortynski (2011), who found a negative correlation between the number of flowers per inflorescence and fruit weight.

They concluded that search for genotypes with high numbers of inflorescences and fruits per plant may be more effective because of high correlation of these traits with fruit yield. According to these results the selection of genotypes based on producing high numbers of flowers and fruits per plant is recommended to achieve a high plant yield of strawberries. Also, correlation made it accessible to choose superior hybrid seedlings at early times in strawberry breeding programs. Investigating the relation between phenotypic and economic properties adds to strawberry reproducing proficiently.

In conclusion; presence of many numbers of stolons with a very strong anthocyanin coloration and a spare density of pubescent only when combined together can give the maximum yield among the cultivars under study (Table 2-A). When the leaf upper side color is dark green, the leaf glossiness is absent to weak with a moderately longer terminal leaflet of length in relation to width and concave terminal leaflet shape in cross section, this can be an early indicator to a high yield (+ve BPSM). Results in Table (1-A) indicated that, dark green leaf upper side with crenated terminal leaflet margin and weak stipule anthocyanin coloration all together gives the lowest yield as represented in Carmen. Also, rounded terminal leaflet base shape is considered a negative indicator (-ve BPSM). When leaf glossiness is strong and terminal leaflet length in relation to width is equal, those two characters together can give a weak yield as shown by Suzana cultivar (-ve BPSM). However, absence of petiole hair can give a moderate yield (Table 1-A). When considering plant nature of growth, few number of stolons is a negative indicator for a good yield as represented by Carmen and Gaviota cultivars. On the other hand, weak stolon anthocyanin coloration is considered an indicator for a moderate yield (Table 2-A).

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الملخص العربي

المعلمات المورفولوجية للانتخاب المبكر في برامج تربية الفراولة

محمد العراقى الديناري، رمضان عبد العاطى محمد على، سارة عماد الدين جمعه

تمت هذه الدراسة في محطة جنوب التحرير– بمزرعة علي مبارك، معهد بحوث البساتين- مركز البحوث الزراعية" جمهورية مصر العربية، وذلك خلال مواسم نمو فصول الشتاء المتعاقبة لأعوام ٢٠١٢/٢٠١٣– ٢٠١٣/٢٠١٤. ويهدف هذا البحث إلى تحديد صفة أوصفات مورفولوجيه مبكرة ومميزة في برامج انتخاب الفراولة(BPSM) حتى يمكن الاستدلال المبكر بها على الإنتاجية دون المضيُ قدماً إلى نهاية الموسم الزراعي، بغيَة توفير الوقت والتكاليف والمساحة المنزرعة والجهد المبذول.

ولقد تم تقدير ودراسة تسعه وثلاثوي صفة في أحد عشر صنفاً للفراولة لتقييم الفروق المورفولوجيه فيما بينها،. وأظهرت استدلالات النتائج أن هناك صفات أولية خاصة بالنمو الخضري في المراحل الأولية من برنامج التربية أثناء نمو الشتلة، والتي يمكن الاعتماد عليها في توقع الإنتاجية للصنف دون الانتظار حتى نهاية الموسم لتقييم المحصول. وأوضحت النتائج أن هناك مدى واسع من الاختلافات الوراثية بين الأصناف في مختلف صفات الدراسة. كما أظهرت تقديرات معامل الارتباط المظهري بين الصفات والمحصول أن هناك علاقات معنوية إيجابية بين الإنتاجية(المحصول الكلى) وتسعه صفات مورفولوجيه، وهم كالتالي: لون الجانب العلوي للورقة (٠,٣٥**)، وعلاقة طول الورقة الطرفية بعرضها(٠,٣٤**) وعدد الفروع(٠,٠٤**) والتزهير المبكر(٠,١٩*)، وعدد التيجان(٠,١٨*)، ووضع الزهرة بالنسبة للنمو الخضري (٠,٣٠**)، وقطر الزهرة(٠,٢٤**)، وحجم الكأس بالنسبة للتويج (٠,٥٣**)، وترتيب البتلات (٠,٢٩**)، بينما كانت هناك علاقات معنوية سلبية بين الإنتاجية وسبع صفات أخرى. وبذلك أوضحت الدراسة أن تلك الصفات يمكن أن تؤخذ في الاعتبار عند الانتخاب لتحسين الإنتاجية في برامج تربيه الفراولة.