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Transplanting Time Influences Plant Growth and Fruit Quality of Strawberries Grown Under Subtropical Climate

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Abstract

Strawberry (*Fragaria* x *ananassa* Duch.) is an aggregate fruit well known for its excellent taste, severe sweetness, and deep colour for its nutrition characteristics. Transplantation time of strawberry runners affects plant growth, yield and fruit quality but strawberry transplantation in Pakistan has not yet be standardized and is practiced from September to December. The present study was conducted to evaluate field performance of strawberry cv. Chandler transplanted at different times from 15th September to 15th December at 15-days interval. Plant growth, harvest and fruit quality-related data were collected. Transplantation time significantly influenced most of the observed parameters. Strawberry runners transplanted on 15th September could not survive, possibly due to heat stress. Fresh plant weight (55.23-111.88 g), leaf dry weight (6.52-11.85 g), number of flowers (19.80-69.33) and fruits per plant (25-75), yield (110.06-1120.41 g), fruit total titratable acidity (0.41-0.62%), total soluble solids (10.68-14.67%) and ascorbic acid contents (130.39-167.13%) were significantly enhanced in plants transplanted in October whereas late transplantations in December exhibited significant reduction in these attributes. Overall, results suggested that transplantation during first two weeks of October favoured plant growth, flowering, yield and fruit quality. It is further suggested to also consider prevailing weather conditions to decide time window for transplantation of strawberry runners.

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a small-size plant from Rosaceae family. Its fruit has an exceptional mouthfeel and rich in vitamins, sugars, phenolics, flavonoids, anthocyanin, antioxidants and ascorbic acid and several important mineral nutrients (Sharma and Sharma, 2004; Hakala *et al*., 2003; Wang *et al*., 1996; Heinonen *et al*., 1998;

Robards *et al*., 1999; Wang and Lin, 2000; Hansawasdi *et al*., 2006). Strawberry fruit consumption improves antioxidants in human body that ultimately helps to counter harmful effects of reactive oxygen species (Wang *et al*., 1996; Sun *et al*., 2002; Wresburger, 2002; Nagai *et al*., 2003). In production of strawberry fruits, China is leading producer in the world followed by USA, Mexico, Turkey and Spain (FAOSTAT, 2015). Cultivars of strawberry are generally categorized by their requirement of day length and called as June bearing, ever-bearing and day-neutral cultivars (Hancock, 2005). Presently cultivated commercial varieties have evolved from diploid to octaploid generations (Anon, 1956). Strawberries are vegetative propagated through runners. Environmental conditions and runner quality plays a critical role in determining fruit quality and yield of strawberries. Temperature, daylight and photoperiod have direct effect on transplanting time which ultimately effects flowering, fruits size and yield (Zheng et al., 2009). In this regard, time of strawberry plantation plays a decisive role in successful strawberry production (Anna et al., 2003). So, a specific variety may require a specific set of environmental and growth conditions to perform at its best potential (Sharma and Sharma, 2004). In Florida, strawberries transplanted in early October give better yield than those transplanted in late October (Duval *et al*., 2005). This practice highly relates to farm-gate income as early-season harvest fetch better price return than peak-season harvest (Freie and Pugh, 1992; Personal observation).

In Pakistan, strawberry is mostly cultivated in Charsaddah, Swat, Mardan, Gujrat, Islamabad, Haripur, Sharqpur/Lahore and Multan areas. Chandler is the single major cultivar being commercially grown throughout the country (Anwar *et al.*, 2017). Transplantation is generally done from early October to Late November. Keeping in view the geological location and climactic conditions, conclusive data on impact of transplanting time on production and fruit quality of strawberry cv. Chandler is lacking and growers' decision to start transplantation highly depends upon previous experience and prevailing weather conditions. There is great need to develop scientific evidence which may help growers to decide an appropriate transplanting time. So, this study was conducted with an objective to determine impact of transplanting time on fruit quality and yield of strawberry under sub-tropical conditions i.e. Faisalabad.

MATERIAL AND METHODS

Healthy and apparently disease-free runners of strawberry cv. Chandler were purchased from a nursery in Mingora, Swat district, Khyber Pakhtunkhwa province, Pakistan. Runner roots were treated with thiophanate-methyl insecticide and immediately transplanted on both sides of mulch-covered ridges. To investigate impact of transplantation time on fruit quality, strawberry runners were transplanted on 15th September (no treatment number assigned, refer to 'results and discussion' section), 1st October (T_1), 15th October (T_2), 1st November (T_3), 15th November (T_4), 1st December (T_5) and 15th December (T_6). Runners were transplanted in three blocks according to randomized complete block design (RCBD). Each block contained five replications whereas each replication had 20 plants. Soil bed preparation, irrigation, weed management, mineral nutrient application and insects and disease management practices were conducted as per commercial practice.

Total number of fully-opened flowers on each plant within a replication were counted. Fruiting time was determined by logging number of days from transplantation to first red-ripe fruit on each plant. Total red-ripe fruits, number of flowers, number of fruits and yield (kg) per plant was also recorded. Percentage of marketable fruits in each treatment was calculated by dividing number of healthy fruits (red ripe fruits without any visible sign of disease or damage) with total number of harvested fruits and multiplying with 100. After fruit harvest, whole plants were gently dug out and cleaned for dirt and other visible signs of contamination. After taking fresh weight, individual plants were kept at 60°C until constant dry weight was achieved. Dry weight percentage was calculated by dividing difference of fresh and dry plant weight to fresh plant weight and multiplying with 100.

After recording fresh fruit weight with digital balance, strawberry fruits were evaluated for incidence of disease and scored from 1 (no decay) to 5 (≥50% surface decay) (Babalar *et al*., 2007). Total soluble solids (TSS) in fruit pulp were determined with digital hand-held refractometer (ATAGO, RS-5000, Atago, Japan) whereas total titratable acidity (TA) was determined by titrimetric method (Jouquand et al., 2008). Results were presented as ratio of TSS and TA. Fruit pulp pH was determined with digital pH-meter (Hanna, HI-98107, Mauritius). Ascorbic acid content in fruit pulp were determined using 2,6-dichlorophenol indophenol dye as earlier described by Khalid *et al*. (2012). Fruit pulp pH was determined with digital pH-meter (Hanna, HI-98107, Mauritius). Sugars (total, reducing and non-reducing) in fruit pulp were determined by the method described by Hortwitz (1960). Briefly, an aliquot of fruit pulp, treated with 25% lead acetate and 20% potassium oxalate, was hydrolysed with HCl and kept overnight to convert non-reducing sugars into the reducing sugars. Then, HCl-hydrolysed aliquot was neutralized with 0.1 N NaOH and titrated against Fehling solutions. For sensory analysis, strawberry fruits were divided into four pieces using sharp knife and placed in unmarked clean plates. Samples were placed in randomized sequence for organoleptic evaluation by a panel of about 15 persons. sample was evaluated for texture, sweetness, tartness/sourness, aroma, appearance and flavour as described earlier (Jouquand et al., 2008; Resende et al., 2008; Schwieterman et al., 2014). Collected data was analysed for analysis of variance (ANOVA) and least significance difference among treatment means at 5% significance level using Statistix 8.1 software.

RESULTS AND DISCUSSION

Weather Profile, Plant Growth and Yield Potential

Mean temperature, relative humidity and day length during the growing season is presented in figure 1 and influence of transplanting time on plant growth and yield potential is presented in figure 2. Transplantation of strawberries on 15th September resulted in complete mortality and no study-related data could be obtained. Highest fresh plant weight (111.88 g) was obtained from plants transplanted on 1st October (T_1) whereas plants transplanted on 1st December exhibited the lowest fresh plant weight (73.80 g) (Figure 1a). Interestingly, dry weight gain was statistically similar but comparatively higher in all transplantation batches than plants transplanted on 1st October (T_1) (Figure 2b). On the other hand, dry leaf weight in different batches (Figure 1c) showed that late transplantation in December (T_5, T_6) also hindered dry weight gain in strawberry leaves (6.52-8.12%) whereas early transplantation in October and November promoted dry weight gain in strawberry leaves (9.28-11.85%).

Influence of transplanting time on number of flowers produced on strawberry plants is presented in figure 1d. Transplantation of strawberry runners on 1st October (T_1) induced production of maximum flowers (69.33 flowers per plant) per plant whereas late transplantation on 15th December (T_6) hindered flower production (19.80 flowers per plant). Flower production is also influenced by the climatic conditions. Less flowering on strawberry plants transplanted in December might be related with reduction in in day length (Figure 1c), low plant growth (Figure 2a-c) and stress from winter chill/frost in January. Similarly, early transplantation of strawberry runners (1st October, T_1) also promoted high fruit production (69 fruits per plant) as compared to other transplantation times whereas late transplantation in December (T_5, T_6) hampered fruit production i.e. 23 fruits per plant (Figure 1e). Maurer and Umeda (1999) also reported similar observations that plantation in late summer (late August-September) results in 4-fold more number of fruits as compared to other plantation times. Strawberry plants transplanted on 1st October (T_1) produced fruits with highest average fruit weight (14.28 g) followed by those transplanted in mid-October (T_2) (Figure 1f). Overall, favourable weather conditions and flowering on early transplantation of strawberry plants in October promoted fruit yield i.e. 1.12 kg per plant (Figure 3). Our results are verified by findings of Stewart and Folta (2010) who suggested that difference in the photoperiod impacts growth, floweri1ng as well as fruit production in strawberry plants. High fresh weight on early season planting might be due to sufficient cell division and availability of sufficient time for their development (Rahman *et al.*, 2014). Singh *et al.* (2007) also reported that the larger size fruits were obtained from the mid-September plantation as compared to plantation in mid-October or mid-November. Singh *et al.* (2005) also reported that larger size fruits were obtained from plantation of mid-September period in strawberry cv. Chandler as compared to plantation of either in mid-October or mid-November. It must be noted that transplantation period suggested in various research papers corresponds to a specific location and varies world-over. In our study, better plant growth attributes, high fruit production and better fruit weight gain suggests that transplantation of strawberries during first two weeks of October would results in better yield compared to late transplantations. Since, climatic conditions influence transplantation date, our suggestion of the time window may fluctuate as per prevailing conditions.

Fruit Physical and Biochemical Quality Attributes

Fruit shape index is referred to length to width ratio (Figure 4a). Fruits from plants transplanted on 1st November (T_1) exhibited lower fruit shape index (1.25) whereas plants transplanted in mid-November (T_3) produced fruits with highest fruit shape index (1.84). Low fruit shape index may correspond to high fruit weight of expanded fruit. These findings were corroborated by Mawkhiew and Pereira (2015) who reported that strawberries transplanted in mid and late season gave highest length and diameter of strawberry fruits.

Biochemical analyses of fruits from different batches of transplantations were also performed. Strawberry fruits from 15th November transplantation (T_4) gave highest pH (3.52) while lowest pH (3.03) was found in fruits from 1st October transplantation (T_1) (Figure 4b). Effect of transplantation time on total titratable acidity (TTA) of strawberry fruits is presented in Figure 4c. Strawberry fruits from 1st October transplantation (T_1) exhibited highest TTA (0.62%) whereas lowest amount of TTA (0.37%) was found in fruits from 1st November transplantation (T_3) followed by 1st December (T_5) and 15th December transplants (T_6) both having same TTA values (0.41%). These findings suggest that early transplantation enhanced total titratable contents in strawberry fruits (Chandler *et al.*, 2003). Singh *et al.* (2005) also reported that titratable acid contents in strawberry cv. Chandler was higher in fruits which were obtained from the transplantation of mid-September. Fruits of 1st October transplanting (T_1) gave highest TSS (14.67%) among all other treatments whereas lowest TSS (10.68%) was calculated in 15th December transplanting (T_6) (Figure 4d). Results of our analysis are also supported by outcomes of Rahman *et al*. (2014) study who reported that highest TSS was found in strawberry fruits of September transplantation and that TSS contents gradually decreased as the plantation time increased. Fruits of earlier transplantation usually contains more TSS contents as compared to TSS contents in fruits from late transplanted plants. This might be because earlier transplanted plants do have more exposure to the favourable environmental conditions and they also might have received sufficient time for accumulation of sugar and acid contents that ultimately might have resulted in higher TSS. Strawberry fruits transplanted on 1st November (T_3) had the highest TSS/TA ratio (36.30) followed by fruits from plants transplanted on 1st October (T_1). Fruits on 15th October transplants (T_2) exhibited minimum TSS/TA ratio (19.99) (Figure 4e). These results were also reinforced by findings of Domínguez *et al.* (2016) who determined higher TSS/TTA ratio in fruits from mid-October transplanted plants.

Transplanting time also significantly affected ascorbic acid (vitamin C) in strawberry fruits (Figure 4f). Strawberry fruits from 1st October transplanting (T_1) exhibited highest ascorbic acid (167.13 mg 100 g^{-1}) whereas lowest ascorbic acid (101.01 mg 100 g^{-1}) was determined in fruit from 1st November transplanting (T_3). In agreement with these findings, Domínguez *et al*. (2016) also stated that early season fruits had highest ascorbic acid level while strawberry fruits from late transplanted plants had the lowest ascorbic acid level. In another study, Del Pozo-Insfran *et al*. (2006) reported that level of ascorbic acid was higher during the earlier season crop as compared to late season crop for six out of nine cultivars in Dover, Florida. Rahman *et al*. (2014) also reported that September-transplanted plants had the highest ascorbic acid compared to fruits from transplantations of September to December. Singh *et al.* (2007) reported that plantation of mid-September usually produced significantly higher ascorbic acid as compared to other transplantations. Thus, it may be assumed that better quality of strawberry fruits from the early transplantation could be associated with prolonged duration of fruiting which ultimately resulted in accumulation of better ascorbic acid in fruit tissues.

Sugars and ion leakage properties of fruits influenced by transplanting time is presented in figure 5. Strawberry fruits from 15th October transplantation (T_2) had highest reducing sugar contents (5.67%) (Figure 5a). Fruits from plants transplanted on 1st October (T_1) had lowest reducing sugars (2.90%). Highest non-reducing sugars (5.30%) was recorded in fruits from 1st October transplantation (T_1) (Figure 5b). This value was 2.5-fold higher than the lowest non-reducing sugars (1.76%) determined in fruits from plants of 15th December transplantation (T_6). It suggests that climatic conditions, especially warmer climate and longer day length (Figure 1) during transplantation and better plant growth (Figure 2a) impact sugar metabolism within fruit tissues (Chandler *et al.*, 2003). Figure 5c shows that strawberry fruits from 1st October transplants (T_1) gave highest total sugars (8.48%) followed by 1st October transplants (T_1) whereas strawberry plants transplanted on 15th December (T_6) produced fruits with least percentage of total sugars (6.0%). Ion leakage indicates integrity of fruit texture as disintegrating fruit tissues have higher electrolyte leakage compared to firmer tissues. Figure 5d shows that strawberry fruits from December transplants (T_5, T_6) were found to have highest ion leakage i.e. 66.97% and 72.02% respectively. In contrast, fruits from November transplants (T_2, T_3) produced fruits with minimum ion leakage (46.0-58.0%).

Organoleptic Evaluation of Strawberry Fruits

Sensory evaluation of fruits from batches of strawberry plants transplanted at different transplanting times is presented in table 1. Strawberry fruits from 1st October transplanting (T_1) gave the highest fruit texture (8.20) whereas the lowest fruit texture (5.53) was found in fruits from 1st November transplants (T_3). Best aroma was found in fruits from 1st October transplants (T_1) while lowest fruit aroma (3.93) was found in fruits from plants transplanted on 15th December (T_5). Strawberry fruits of 1st October transplanting (T_1) gave the highest fruit appearance (8.27) whereas poor fruit appearance (5.00) was observed in fruits from 1st December transplants (T_5). The plants transplanted on 1st October (T_1) had the highest fruit flavour (8.73). Minimum fruit flavour (3.40) was found in fruits from 15th October transplants (T_2). Fruits with highest sweetness (4.45) were found be those harvested from 1st October transplants (T_1). Fruits with minimum fruit sweetness (3.36) were found on plants transplanted on 1st November (T_3) and 15th November (T_4). Strawberry fruits with highest tartness (4.33) were found in 1st October transplants (T_1) whereas fruits with minimum tartness/sourness (2.07) were obtained from 15th December transplants (T_5). Overall, these results suggest that early transplanting of strawberry runners significantly improve fruit sensory attributes.

CONCLUSION

From the studies presented above, it can be cocncluded that high temperature stress during September reduces transplant success whereas transplantation during first two weeks of October favours plant growth, flowering, yield and fruit quality. Prevailing weather condition play a decisive role in transplant success and fluctuations in mean temperature and rainfall/relative humidity and frost incidence may influence final yield and fruit quality. Thus, it would be appropriate to forecast weather pattern before start of transplantation and be prepared for weather uncertainties to ensure better plant growth, yield and fruit quality of strawberries.

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REFERENCES

Anna, F.D., G. Iapichino and G. In calcaterra. 2003. Influence of planting date and runner order on strawberry plug plants grown under plastic tunnels. ActaHort. 614(614):123-129.

Anonymous. 1956. Wealth of India CSIR. New Delhi, India.4:57-60.

Anwar, R., S. Gul, I.A. Rajwana, K. Razzaq. 2017. Strawberry: Scrumptious but still an underutilized fruit in Pakistan. HortiMag. 7(1-2):14-15.

Babalar, M., M. Asghari, A. Talaei, A. Khosroshahi. 2007. Effect of pre- and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of Selva strawberry fruit. Food Chem. 105:449–453.

Chandler, C.K., M. Herrington and A. Slade. 2003. Effect of harvest date on soluble solid and titratable acidity in fruit of strawberry frown in a winter annual hill production system. Acta Hort. 626:353-354.

Del Pozo-Insfran, D., C.E. Duncan, K.C. Yu, S.T. Talcott and C.K. Chandler. 2006. Polyphenolics, ascorbic acid and soluble solids concentrations of strawberry cultivars and selections grown in a winter annual hill production system. J. Amer. Soc. Hort. Sci. 131:89-96.

Domínguez, P., J.J. Medina, L. Miranda, J.M.L. Aranda, M.T. Ariza, C. Soria, B.M. Santos, E.A.T. Quezada and I.H. Ochoa. 2016. Effect of planting and harvesting dates on strawberry fruit quality under high tunnels. Int. J. of Fruit Sci. 16:228-238.

Duval, J.R., C.K. Chandler and E. Golden. 2005. Planting date affects early fruit yield of strawberry in a subtropical environment. J. Amer. Pomol. Soc. 59(1):1-12.

FAO. Food and Agriculture Organization of the United Nations. 2014.

Freie, R.L. and N.L. Pugh. 1992. Florida Agricultural Statistics, Vegetable summary. Fl. Agri. Stat. Serv. 1222 Woodward St., Orlando, FL. 32803.

Hakala, M., A. Lapvetel, R. Huopalahti, H. Kallio and R. Tahvonen. 2003 Modifications of taste-relevant compounds in strawberry fruit under NaCl salinity. J. of Food Composition and Analysis. 16:67-80.

Hancock, J.F. 1999. Strawberries. CAB International, Walling fold, UK.

Hansawasdi, C., S. Rithiudom and P. Chaiprasart. 2006. Quality and antioxidant activity changes during low-temperature storage of strawberry fruits. Acta Hort. 708:301-306.

Heinonen, I.M., A.S. Meyer, E.N. Frankel. 1998. Antioxidant activity of berry phenolics on human low-density lipoprotein and liposome oxidation. J. of Agric. and Food Chem. 46:4107-4112.

Hortwitz, W. 1960. Official and tentative methods of analysis. Association of official agriculture chemists (AOAC), Washington, D. C. 9:320-341.

Jouquand, C., C. Chandler, A. Plotto and K. Goodner. 2008. A sensory and chemical analysis of fresh strawberries over harvest dates and seasons reveals factors that affect eating quality. J. Am. Soc. Hortic. Sci. 133:859-867.

Khalid, S., A.U. Malik, A.S. Khan and A. Jamil. 2012. Influence of exogenous applications of plant growth regulators on fruit quality of young 'Kinnow' mandarin (Citrus *nobilis* × C. *deliciosa*) trees. Int. J. Agric. Biol. 14:229-234.

Maurer, M.A. and K. Umeda. 1999. University of Arizona College of Agriculture 1999 Vegetable Report.

Nagai, T., I. Reiji, I. Hachiro and S. Nobutaka. 2003. Preparation and antioxidant properties of water extract of propolis. Food Chem. 80:29–33.

Rahman, M.M., M.M. Rahman, M.M. Hossain, Q.A. Khaliq and M. Moniruzzaman. 2014. Effect of planting time and genotypes growth, yield and quality of strawberry *(Fragaria* × *ananassa* Duch.). Scientia Horticulturae. 167:56–62.

Resende, J.T.V.D., L.K. Camargo, E.J. Argandoña, A. Marchese and C.K. Camargo. 2008. Sensory analysis and chemical characterization of strawberry fruits. Hortic. Bras. 26:371-374.

Robards, K., P.D. Prenzler, G. Tucke, P. Swatsitang and W. Glover. 1999. Phenolic compounds and their role in oxidative processes in fruits. Food Chem. 66:401–436.

Schwieterman, M.L., T.A. Colquhoun, E.A. Jaworski, L.M. Bartoshuk, J.L. Gilbert, D.M. Tieman, A.Z. Odabasi, H.R. Moskowitz, K.M. Folta, H.J. Klee, C.A. Sims, V.M. Whitaker and D.G. Clark. 2014. Strawberry Flavor: Diverse Chemical Compositions, a Seasonal Influence, and Effects on Sensory Perception. Plos. One. 9:88446.

Sharma, R.R. and V.P. Sharma. 2004. The Strawberry. ICAR, New Delhi, India.

Singh, R. and R. Asrey. 2005. Growth, earliness and fruit yield of micro irrigated strawberry as affected by time of planting and mulching. Ind. J. Hortic. 62(2):148-151.

Singh, R., R.R. Sharma and R.K. Jain. 2005. Planting time and mulching influenced vegetative and reproductive traits in strawberry (*Fragaria* × *ananassa* Duch.) in India. Fruits. 60(2):395-403.

Singh, R., R.R. Sharma, R.K. Goyal. 2007. Interactive effects of planting time and mulching on 'Chandler' strawberry (*Fragaria* × *ananassa* Duch.). Sci. Hortic. 111:344-351.

Stewart, P. J. and K. M. Folta. 2010. A review of photoperiodic flowering research in strawberry (*Fragaria* spp.). Crit. Rev. Plant Sci. 29:1-13.

Sun, J., Y.F. Chu, X. Wu and R.H. Liu. 2002. Antioxidant and antiproliferative activities of common fruits. J. of Agric. and Food Chem. 50:7449-7454.

Wang S.Y. and H.S. Lin. 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry and strawberry varies with cultivar and developmental stage. J. of Agric. and Food Chem. 48:140-146.

Wang, H., G. Cao and R.L. Prior. 1996. Total antioxidant capacity of fruits. J. of Agric. and Food Chem. 44:701-705.

Wresburger, J.H. 2002. Lifestyle, health and disease prevention: The underlying mechanism. Eur. J. Cancer Prev. 2:1-7.

Zheng, J., B. Yang, S. Tuomasjukka, S. Ou and H. Kallio. 2009. Effects of latitude and weather conditions on contents of sugars, fruit acids and ascorbic acid in black currant (*Ribes nigrum* L.) juice. J. Agric. Food Chem. 57 (7):2977- 2987.

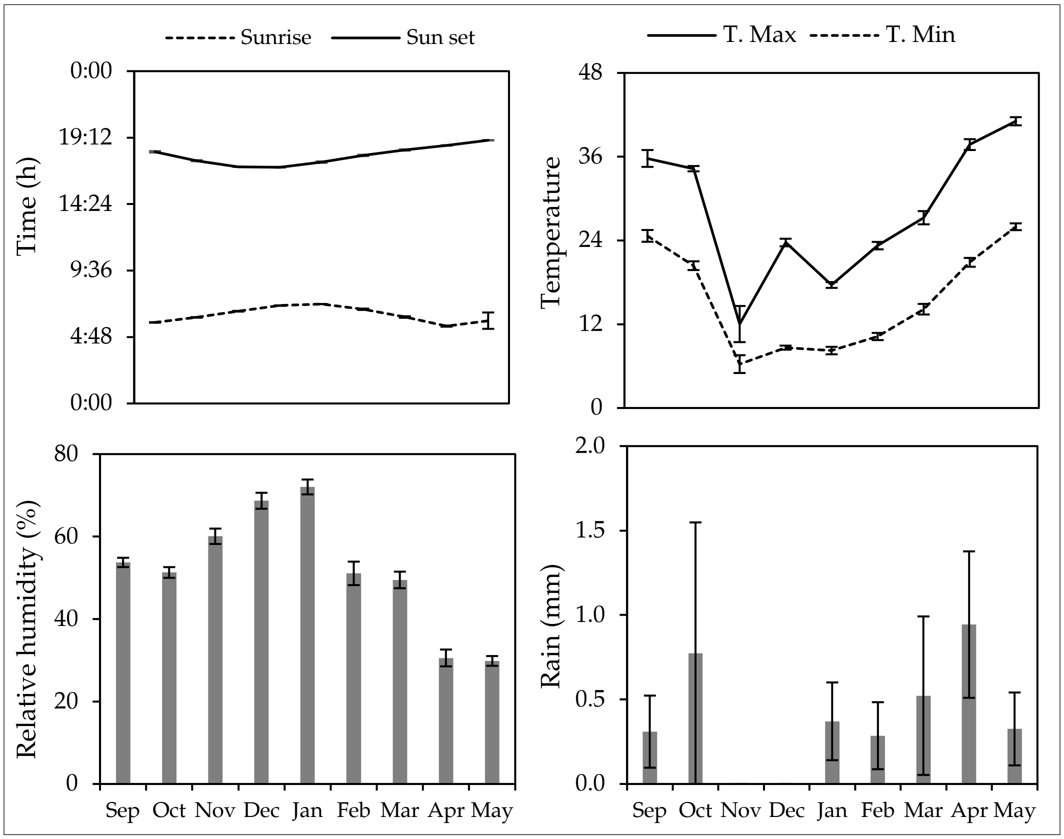

Figure 1: Weather profile during strawberry production period (September 2016 to May 2017).

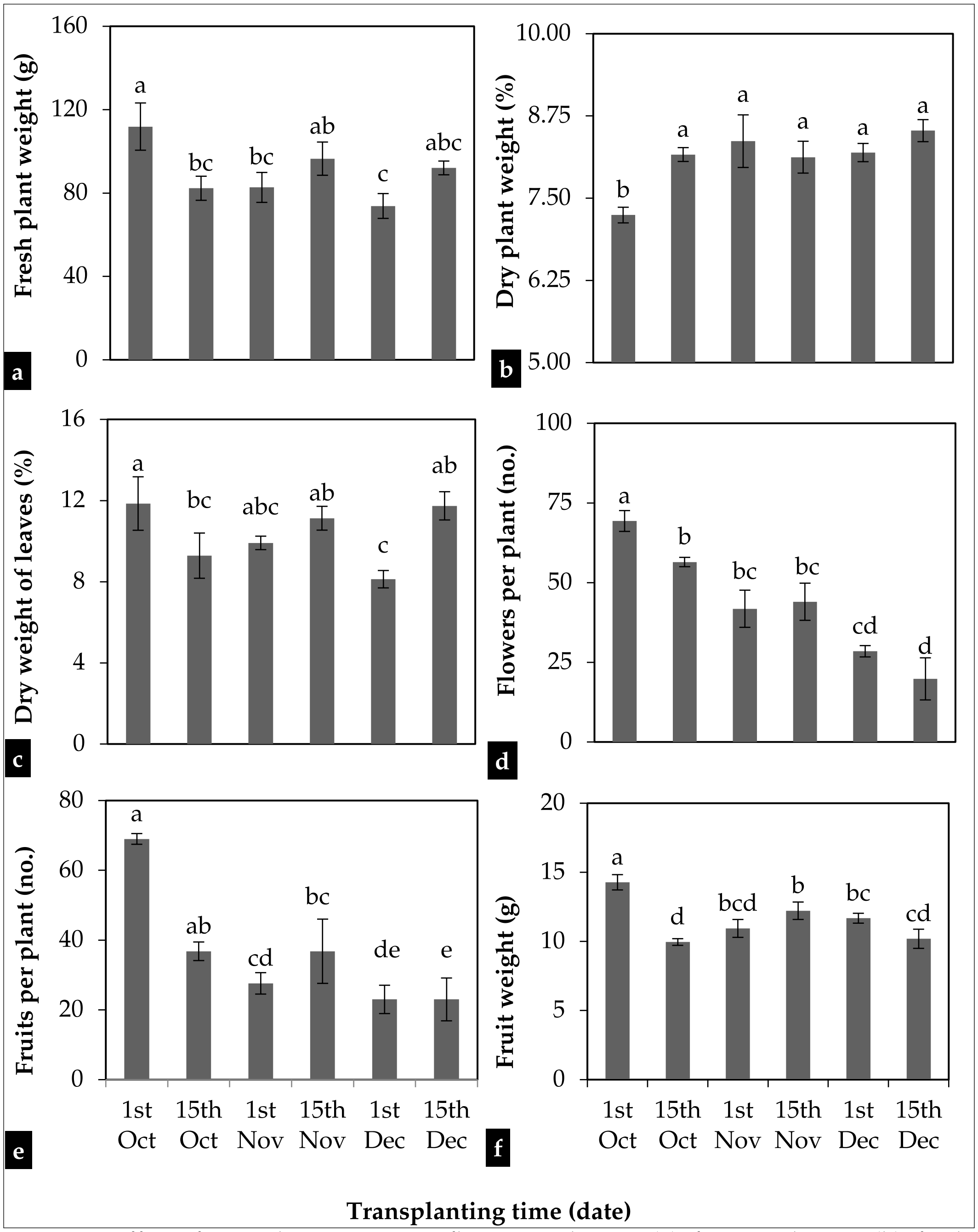

Figure 2: Effect of transplanting time on flower production (a), fruit production (b), fresh plant weight (c), dry plant weight (d), dry leaf weight (e) and fruit weight (f) of strawberries cv. Chandler grown under subtropical climate. Transplantation of strawberries on 15th September resulted in complete mortaility. Strawberry runners transplanted on 1st October (T_1), 15th October (T_2), 1st November (T_3) 15th November (T_4), 1st December (T_5) or 15th December (T_6) are presented. Vertical bars indicate average ± standard error (n=5, 20 plants per replication).

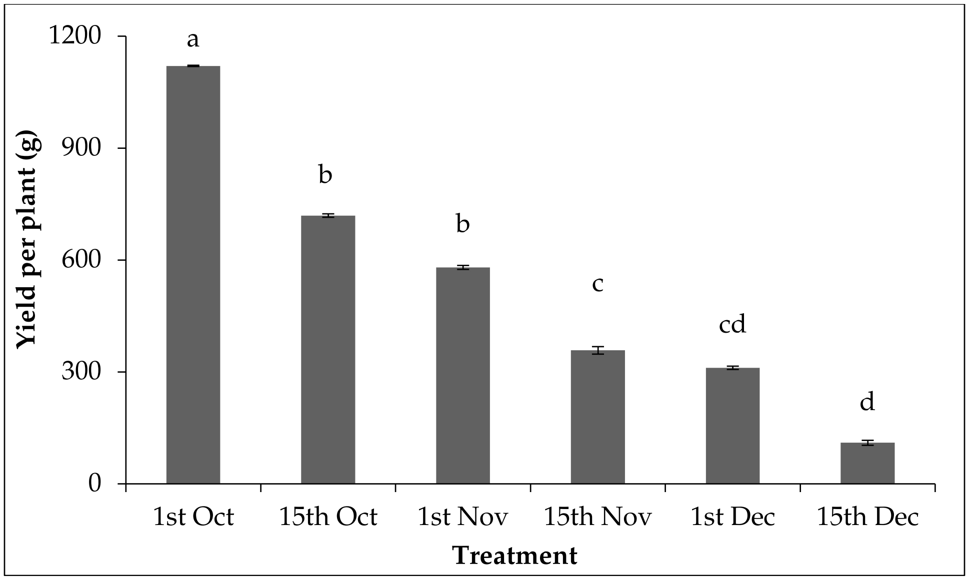

Figure 3: Effect of transplanting time on fruit yield (kg per plant) of strawberries cv. Chandler grown under subtropical climate. Strawberry runners were transplanted on 1st October (T_1), 15th October (T_2), 1st November (T_3) 15th November (T_4), 1st December (T_5) or 15th December (T_6). Vertical bars indicate average ± standard error (n=5, 20 plants per replication).

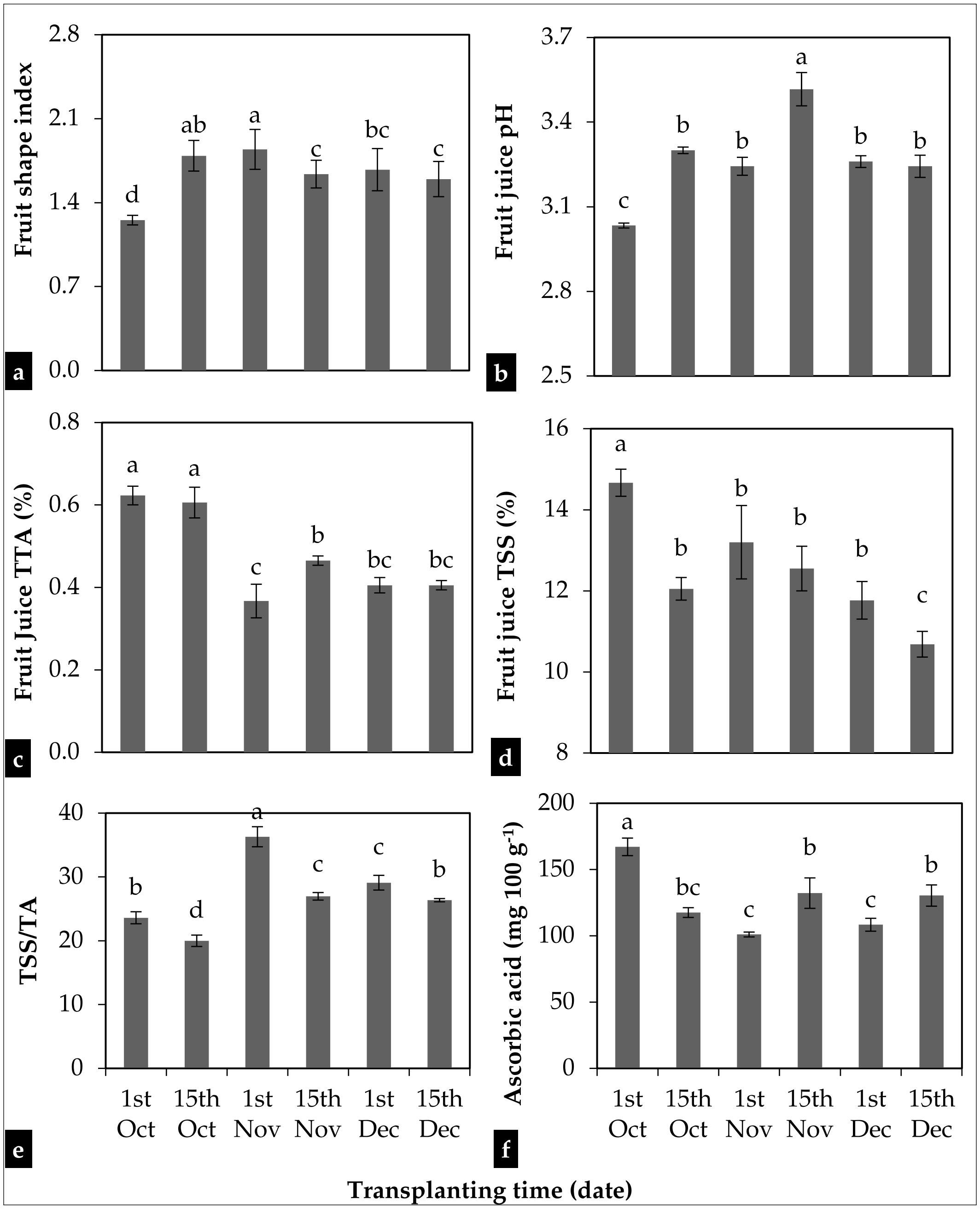

Figure 4: Effect of transplanting time on fruit shape index (a), fruit juice pH (b), total titratable acidity (c), total soluble solids (d) and TSS/TTA ratio (e) and ascorbic acid conetents (f) in fruits from strawberry plants cv. Chandler grown under subtropical climate. Transplantation of strawberries on 15th September resulted in complete mortaility. Strawberry runners transplanted on 1st October (T_1), 15th October (T_2), 1st November (T_3) 15th November (T_4), 1st December (T_5) or 15th December (T_6) are presented. Vertical bars indicate average ± standard error (n=5, 20 plants per replication).

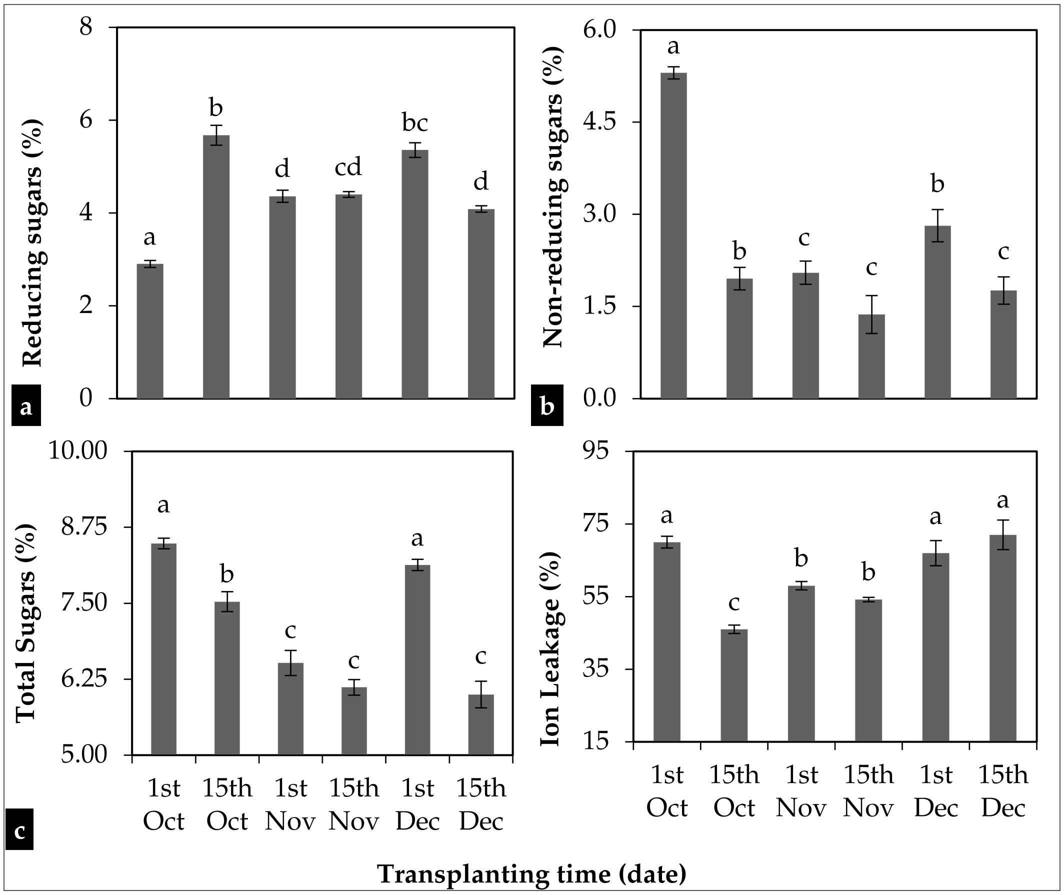

Figure 5: Effect of transplanting time on reducing sugars (a), non-reducing sugars (b), total sugars (c) and ion leakage (d) in fruits fruits from strawberry plants cv. Chandler grown under subtropical climate. Transplantation of strawberries on 15th September resulted in complete mortaility. Strawberry runners transplanted on 1st October (T_1), 15th October (T_2), 1st November (T_3) 15th November (T_4), 1st December (T_5) or 15th December (T_6) are presented. Vertical bars indicate average ± standard error (n=5, 20 plants per replication).

Table 1: Impact of transplanting time on organoleptic attributes of red ripe strawberries cv. Chandler grown under subtropical climate. Values sharing the same letter are non-significantly different ($p \leq 0.05$) within an organoleptic attribute.

Transplanting time	**Texture**	**Appearance**	**Flavour**	**Sweetness**	**Tartness**	**Aroma**
1st October (T_1)	8.2^{a}	8.2^{a}	8.7^{a}	4.5^{a}	4.3^{a}	8.5^{a}
15th October (T_2)	6.1^{bc}	6.3^{b}	3.4^{b}	3.8^{ab}	3.1^{b}	6.1^{bc}
1st November (T_3)	5.5^{c}	6.3^{b}	5.0^{b}	3.1^{b}	3.4^{ab}	6.3^{ab}
15th November (T_4)	7.4^{ab}	7.4^{ab}	5.0^{b}	3.4^{b}	3.1^{b}	6.9^{ab}
1st December (T_5)	7.7^{ab}	4.2^{c}	5.3^{b}	3.4^{b}	3.7^{ab}	7.1^{ab}
15th December (T_6)	7.7^{ab}	6.1^{b}	5.5^{b}	4.2^{a}	2.1^{c}	3.9^{c}

Transplantation of strawberries on 15th September resulted in complete mortaility.