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Effects of different propagation methods on the strawberry cv. 'Florida Fortuna' yield gown under low tunnel

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Abstract

This study was conducted to test the effects of three different propagation methods on the yield and fruit quality performance of strawberry cv. 'Florida Fortuna'. Experimental studies were conducted during the 2018-2019 growing period in Yedidalga village, located in Lefke region in Northern Cyprus. Tested methods of present study are: 1) bare root cold stored (frigo), 2) fresh/green bare root, and 3) strawberry plug propagation methods. Studies were conducted in a low-tunnel (4 m wide and 2 m height) with three replications according to the completely randomized block design. Each replication consisted of 20 plants. Regular measurements were carried to measure yield (g plant^{-1}), number of fruits (# plant^{-1}), total soluble solids (TSS) concentration, fruit firmness (kg cm^{-2}) and titratable acidity (g/100 g citric acid). Results showed that the propagation methods have high influence on the weekly and total yield of the strawberry plants. According to the obtained data, plug propagation method was found to provide earliness on fruit yielding and continuous yielding (except winter period). Moreover, frigo propagation method was found to be the latest for fruit bearing, but to have highest yield in the end of the growing period.

Keywords: Bare root cold stored (frigo), Fresh/green bare root, Strawberry plug, Total yield, Earliness

Introduction

Strawberry (*Fragaria x ananassa* Duch.) has a high adaptation ability to different ecological conditions (Hennion et al., 1997) and is highly favoured by consumers due to its unique flavour and health benefits, such as: antioxidant, anti-cancer and anti-inflammatory characteristics (Seeram et al., 2006). Due to the unique flavour and scientifically accepted health benefits, the production and consumption of the strawberry fruits has been increasing during the past decades. The non-climacteric fruits of strawberry do not ripen after harvest (Cordenunsi et al., 2005) and are very sensitive to storage conditions (Kahramanoğlu, 2019). Strawberry plants generates stolons (runners) as they grow and those stolons produce adventitious roots generally from the second node and leads the development of new plants. This is called as asexual propagation where "mother" plants clone itself and is called "daughter" plant. Therefore, propagation of the strawberry plants are generally and commercially carried out by asexually. However, during the commercial production, the stolons are being removed and do not let to produce daughter plants (Narváez-Ortiz et al., 2018).

The most important commercial way of strawberry propagation is the use of bare root cold stored (frigo) plants which are generally planted in summer and bear fruit in early spring (Lieten, 2002). Propagation from frigo plants requires long time, sensitive to diseases, and grows slowly (Pritts, 2001). On the other hand, strawberry production from plugs is known to be quick way of production where planting takes place in mid-autumn and harvesting starts in spring. The disadvantage of plugs is that, it is more expensive than frigo plants (Dolgun, 2006). The strawberry plugs had been used as an alternative to frigo propagation for a long time and reported to develop quickly and overcome some problems of bare root plants (Hennion et al., 1997; Dolgun, 2006). The use of strawberry plugs was also noted to extend the production period (Kadir et al.,

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2006; Durner et al., 2002). Manipulating plugs with photoperiod also reported to enhance fruit bearing (Fernandez and Ballington, 2003; Takeda and Newell 2006). However, the field performance of these propagation methods would vary according to the varieties and climatic conditions (Pritts, 2001; Dolgun, 2006). Moreover, this is time consuming which requires intensive capital and labour and the results might be positive (Fernandez and Ballington, 2003) or even negative (Takeda and Hokanson, 2002) for improving fruiting. Previous studies also reported that the propagation method of the strawberry plants plays an important role on the nursery performance and yield of the plants (Paszko et al., 2014; Capocasa et al., 2019). In line with this information, present study aimed to study the yield performance of bare root cold stored (frigo), fresh/green bare root, and strawberry plug propagation methods on the strawberry cv. 'Florida Fortuna'.

Materials and Methods

Materials

Present study was conducted in the years of 2018-2019 growing period in Yedidalga village, located in Lefke region in Northern Cyprus. The area is specialized with the Mediterranean climate with hot and dry summers and mild and light rainy winters. Experimental studies were carried with 'Florida Fortuna' cultivar. The 'Florida Fortuna' cultivar is an early season cultivar with medium to large berry size, fair flavour and firm fruits. The smooth appearance fruits of 'Florida Fortuna' are bright to dark red in colour (Anonymous, 2019). The yield of cv. 'Florida Fortuna' was tested when plants are propagated with 1) bare root cold stored (frigo), 2) fresh/green bare root (bare root), and 3) strawberry plug propagation methods. The frigo and fresh/green bare root plant materials of present study were purchased from Lassen Canyon Nursery (USA) and transferred to Northern Cyprus with Air Cargo in one day. The frigo materials were kept at -2 C and the bare root plants at 22 C.

The strawberry plug materials of present study are propagated from actively growing terminal runner tips of stolons locally. First of all, high evolution mother plants of strawberries were imported from Lassen Canyon Nursery in mid of April 2018. These plants were planted onto the Trodos mountains (elevation 1.100 m). Climatic data for this site is given in Table 1. One month later, the un-rooted stolons (runners) of those mother plants with 2 to 4 leaves were planed into plug tray (45 units of round-conic cells). The cells were in 5 cm wide and 6 cm deep. Peat moss was used as a growing media for the plugs. The mother plants continued to receive normal irrigation and fertilization while the daughter plants in plugs were regularly misted 3 times in a day until September.

Table 1. Climatic data for the strawberry plug production area (Trodos mountain)

Parameter	Months					
	Apr	May	Jun	Jul	Aug	Sep
Mean Monthly Max. Temp.	24.8 °C	27.9 °C	30.8 °C	32.4 °C	32.4 °C	30.5 °C
Mean Monthly Min. Temp.	0.4 °C	4.4 °C	9.0 °C	13.2 °C	13.8 °C	10.0 °C
Mean Daily Sunshine Duration	7.5 h	8.8 h	10.4 h	10.5 h	10.0 h	8.4 h
Mean RH at 08:00 hrs LST	52 %	46 %	40 %	33 %	35 %	42 %
Mean RH at 13:00 hrs LST	53 %	48 %	42 %	36 %	41 %	43 %

Experimental Studies

Experimental studies were conducted with three different propagation methods of two different cultivars, as described above. Studies were conducted in a low-tunnel (4 m wide and 2 m height) with three replications according to the completely randomized block design. Each replication consisted of 20 plants. The frigo materials of cv. 'Florida Fortuna' of present study were transplanted on 15th of August, 2018 and the fresh/green bare root and strawberry plugs were transplanted on 15th of September, 2018. The frigo and bare root plants (after purchasing); and the strawberry plug plants (after producing at Trodos mountain) were directly planted into low-tunnels without any adaptation periods. Plants were set at 33 cm spacing in rows and 33 cm between rows with two rows per bed by using cross planting. Production beds were in 50 cm wide and 100 cm distance were given between the two production beds. Black polyethylene mulch was used for covering the beds and mulching was performed 3 days before planting. Weed management was done regularly by hand. Irrigation and fertilization were carried according to the below given program (Table 2.).

Data Collection and Analysis

Besides to the plant yield, the percentage of rooting was also measured in the present study. In the beginning, 20 plants were planted for each replication. Thus, regular observations were done to determine the number of alive plants. The number of alive (rooted) plants were used to determine the rooting percentages of each cultivar with different propagation method. Hereafter, 10 plants were selected from each replication to continue yield and quality measurements. Total yield and number of harvested fruits were regularly measured and noted throughout the growing period. Harvesting was performed regularly by hand at commercial maturity. Number of fruits harvested from each plant and their total weight was measured and noted. Apart from the yield, one fruit was selected from each replication at every harvest; and total soluble solids (TSS) concentration, fruit firmness (kg cm^{-2}) and titratable acidity (g/100 g citric acid) were measured.

Fruit weight was measured with a digital scale sensate to ±0.01 g. The fruit firmness (kg cm^{-2}) was determined by a hand penetrometer (cylindrical probe: 2 mm in diameter) by measuring the firmness from three distinct locations (around the equatorial region) of a selected fruit from each replication. Hand refractometer was used to determine the total soluble solids (TSS) concentration of the fruits as % Brix. Titratable acidity (TA) of fruits was determined according to the procedure and formula reported by AOAC (1990) by titrating the juice samples with 0.1 N NaOH to an endpoint of pH 8.1.

Table 2. Irrigation and fertilization program of the present study

Months	Irrigation Interval	Irrigation Amount (L day^{-1} $plant^{-1}$)	Fertilization (Amount $plant^{-1}$)	Pesticide Application
August	2	0.50	15th of Aug: 0.9 g MAP (12-61-0)	N/A
			29th of Aug: 0.9 g MAP (12-61-0) + 0.9 g 20-20-20+ME	N/A
September	3	0.75	15th of Sep: 0.9 g MAP (12-61-0)	100 ml 100 L^{-1} Kresoxim-Methyl
			29th of Sep: 0.9 g MAP (12-61-0) + 0.9 L Humic acid	200 ml 100 L^{-1} Boscalid
October	3	0.75	15th of Oct: 0.9 g 19-19-19	100 ml 100 L^{-1} Deltamethrin
			29th of Oct: 0.9 g 19-19-19 + 0.9 L Humic acid	250 ml 100 L^{-1} Bupirimate
November	5	0.75	15th of Nov: 0.9 g 19-19-19	N/A
			29th of Nov: 0.9 g 19-19-19 + 0.9 L Humic acid	125 ml 100 L^{-1} Folpet 80%
December	5	0.75	11th of Dec: 0.9 g 19-19-19 + 0.9 L Humic acid	N/A
			18th of Dec: 0.9 g 19-19-19	400 ml 100 L^{-1} Copper oxychloride 50% WP
			25th of Dec: 0.9 g 19-19-19 + 0.20 g Fe	N/A
January	5	0.75	5th of Jan: 1.8 g 14-7-21 + 0.4 L MgO	250 ml 100 L^{-1} Spinosad 480
			12th of Jan: 1.8 g 14-7-21 + 0.4 L MgO + 0.2 Fe	N/A
			19th of Jan: 0.9 g 14-7-21 + 0.4 L MgO + 0.9 g KNO_3	250 ml 100 L^{-1} Azoxystrobin
			26th of Jan: 0.9 g 14-7-21 + 0.4 L MgO + 0.2 Fe	500 ml 100 L^{-1} Fenhexamid
February	3	0.75	2nd of Feb: 0.9 g K_2O	250 ml 100 L-1 Spinosad 480
			9th of Feb: 0.9 g 14-7-21 + 0.4 L MgO	N/A
			16th of Feb: 0.9 g $Ca(NO_3)_2$	500 h ha^{-1} Tebufenpyrad
			25th of Feb: 0.9 g 14-7-21	N/A
March	2	1.00	10th of Mar: 0.9 g 14-7-21 + 0.9 g KNO_3	250 ml 100 L^{-1} Spinosad 480
			16th of Mar: 0.9 g $Ca(NO_3)_2$	N/A
			23th of Mar: 0.9 g K_2O + 0.9 g 14-7-21	N/A
			30th of Mar: 0.9 g KNO_3	35 ml 100 L^{-1} Etoxazole 110
April	1	1.00	6th of Apr: 0.9 g 14-7-21	250 ml 100 L^{-1} Spinosad 480
			13th of Apr: 0.9 g $Ca(NO_3)_2$	N/A
			25th of Apr: 0.9 g K_2O + 0.9 g 14-7-21	100 ml 100 L^{-1} Milbemectin 9.3 g L^{-1}
			30th of Apr: 0.9 g 14-7-21	N/A
May	1	1.00	7th of May: 0.9 g 20-20-20	250 ml 100 L^{-1} Spinosad 480
			11th of May: 0.9 g 14-7-21 + 0.9 g Fe	N/A
			18th of May: 0.9 g $Ca(NO_3)_2$	35 ml 100 L^{-1} Etoxazole 110
			23th of May: 0.9 g 14-7-21 + 0.9 g Fe	N/A
			30th of May: 0.9 g $Ca(NO_3)_2$	N/A
June	1	1.20	8th of Jun: 0.9 g $Ca(NO_3)_2$	60 ml 100 L^{-1} Bifenazate 240 g L^{-1}

Results and Discussions

The first important result of study is the survival rates of the plants after transplanting (Table 3.).

According to the results obtained, the highest survival rate is obtained from strawberry plug propagation method with 86.67% and the lowest survival rage was measured from the frigo plants with 63.33%.

According to the results of present study, propagation of the strawberry plants with plug method provides earliness on the yielding. First yield was obtained in mid-November for this propagation method (Figure 1.). The second fruit bearing treatment of present study is the fresh/green bare root propagated strawberries. Plant of this method gave yield 7 days after the plug propagated strawberries. However, the yield was too low and the interval between the other yields was high. The continuous yield for fresh/green bare root propagated plants was obtained at the end of December (about 1.5 months after plug method). Hereafter, plants went into a dormancy period during the winter time and provided less yield. The final treatment, frigo propagated plants gave first yields in the beginning of March. However, the yielding interval was close and total yield of this propagation method was very high, when compared with the other methods. Thus, the cumulative yield of frigo propagated plants reached the cumulative yield of bare roots in 30 days; and reached the cumulative yield of plug propagated plants in 60 days. At the end of the growing period, the highest total yield was obtained from the frigo plants with a mean of 960.0 g plant^{-1} yield, and is followed by the plug propagated plants with 864.2 g plant^{-1}. The plants which were propagated with fresh/green bare root method found to have a total of 550.0 g plant^{-1} yield.

Table 3. Survival rates of the strawberry plants propagated with different methods

Propagation methods	Survival rate
Strawberry plug	86.67 %
Fresh/Green bare root	76.67 %
Bare root cold stored (Frigo)	63.33 %

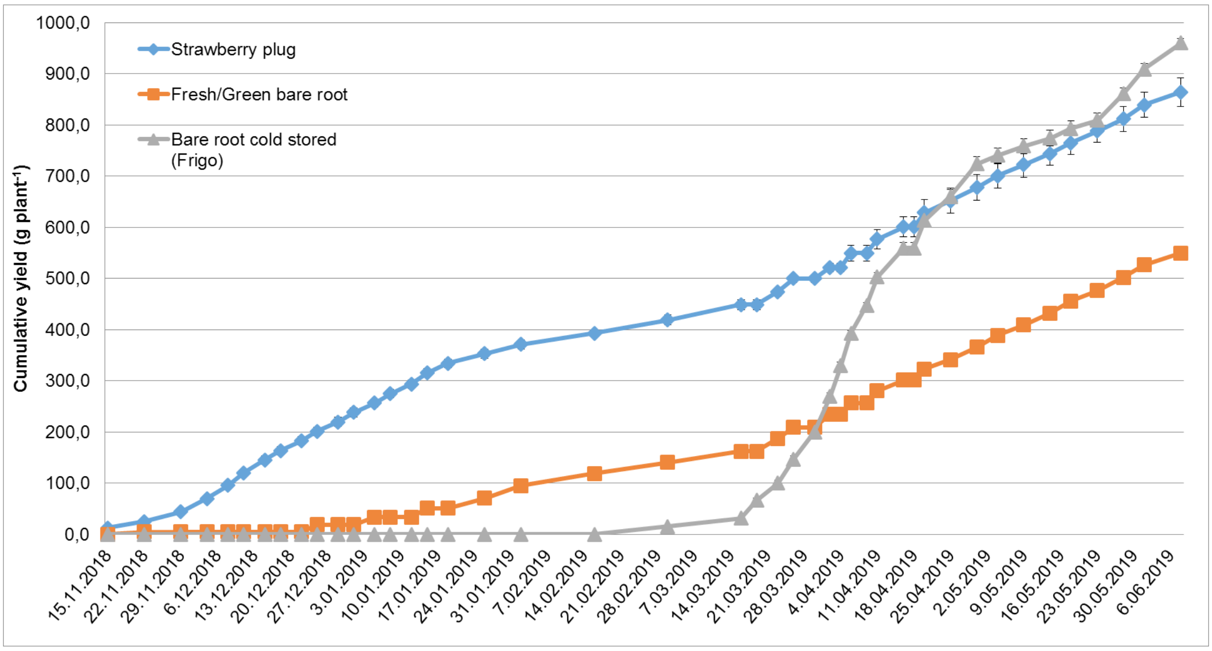

Figure 1. Cumulative fruit yield (g plant^{-1}) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

Present results are in accordance with the findings of some other previous studies conducted in different environments and suggested that plug plants have similar yield with frigo plants (Bish et al., 1997; Hamann et al., 1997; Durner, 1999). Similar to present study, Takeda and Hokanson (2003) previously conducted a study about the strawberry production from plugs in greenhouse and reported that the plug production provides earliness on the yielding. In another study Durner (2016) reported that the plug propagation enhanced spring and total fruit production (weight and number) but have no significant effect on winter production. These results are also in accordance with the findings of present study. The main reason behind the earliness and continuous productivity of strawberries were reported to the chilling period received during transplant preparation and the photoperiod. It is known that if the plants receive the chilling injury in a short period of time, the flushing period (fruit bearing) happens in a short period and *vice versa* (Takeda, 1999). On the contrary, Takeda and Hokanson (2002) noted that the exposure of July propagated plugs of cv. 'Chandler' to chilling (10 °C) did not affect fall or winter greenhouse productivity. This would be due to that the chilling was applied to the plugs long after the development. In support to this idea, some previous studies (Takeda and Newell, 2007; Deyton et al., 2009;) suggest that earlier plug propagation provides higher yield at the strawberry fruits.

The results for the cumulative number of fruits plant^{-1} are in accordance with the results of cumulative yield of the plants (Figure 2.). The raw data behind the cumulative results showed that the highest number of fruits plant^{-1} at a harvest was obtained from the frigo propagated plants and is 3. The average number of harvested fruits plant^{-1} during the whole growing period was found to be 1.18 for fresh/green bare root method, 1.19 for plug method and 2.07 for frigo propagation method. This result together with the yield data suggests that plug method is better when farmers aim to have earliness and continuous yield during the growing season; and the frigo propagation method could be recommended when earliness in not targeted while high yield is important.

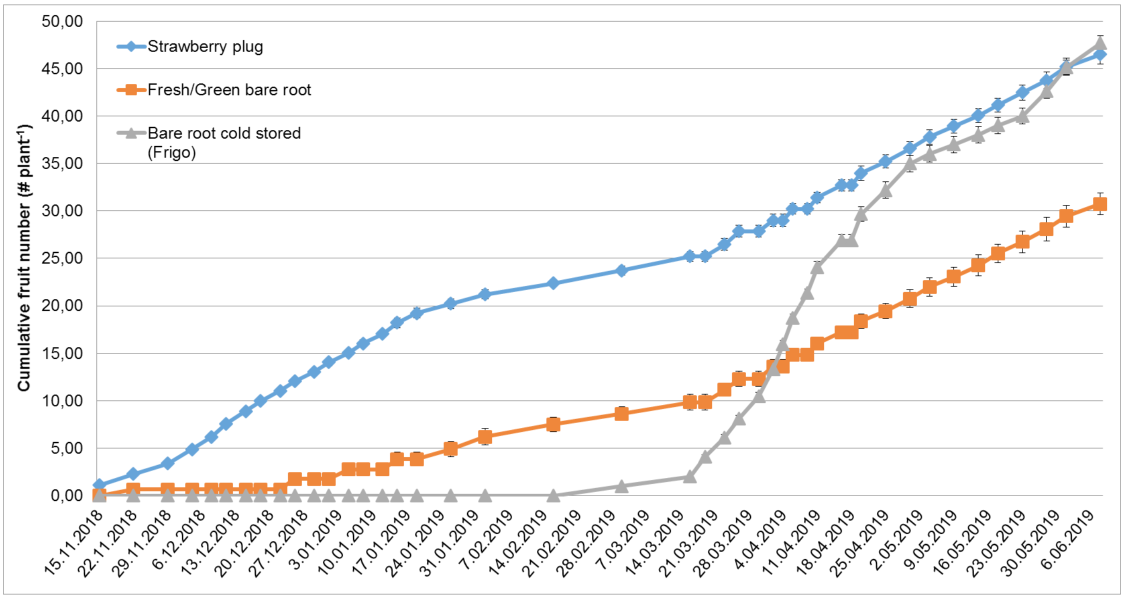

Figure 2. Cumulative fruit number (# plant^{-1}) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

Another important result of present study is about the average fruit weight of the strawberries propagated with different methods. According to the results obtained, the frigo propagated plants have higher fluctuations than the other two methods in terms of the change in the average fruit weight (Figure 3.).

While there is an important difference among the average fruit weight of the different propagation methods, no significant difference was obtained for the average fruit weight of all growing period. At the end of the growing period, the average fruit weight of plants propagated with plug, bare root and frigo methods was found to be 18.53 g, 17.66 g and 19.45 g, respectively. Total soluble solids (%) of the strawberry fruits found to vary during the growing period. At the beginning of the harvesting period, the fruit TSS of the plants propagated with plugs and fresh/green bare root method were 9.83% and 9.65%, respectively (Figure 4.). Until the end of the February, the fruit TSS was similar for all plants. Hereafter, with the increase and decrease in yield, the fruit TSS started to vary.

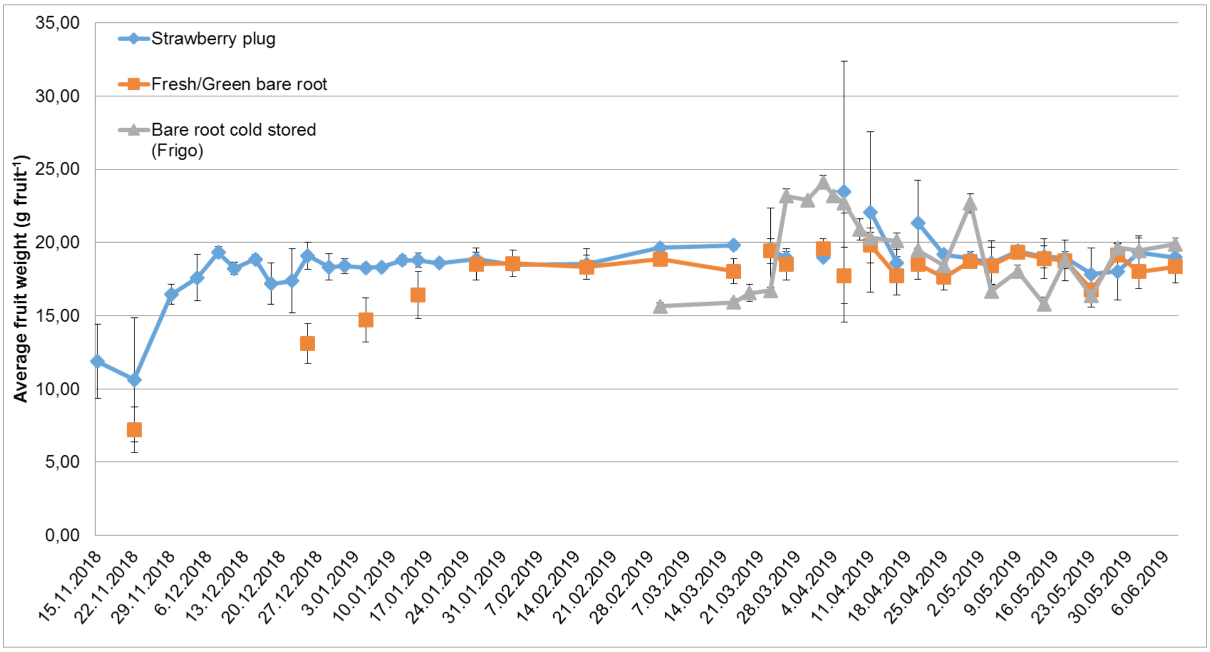

Figure 3. Average fruit weight (g plant^{-1}) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

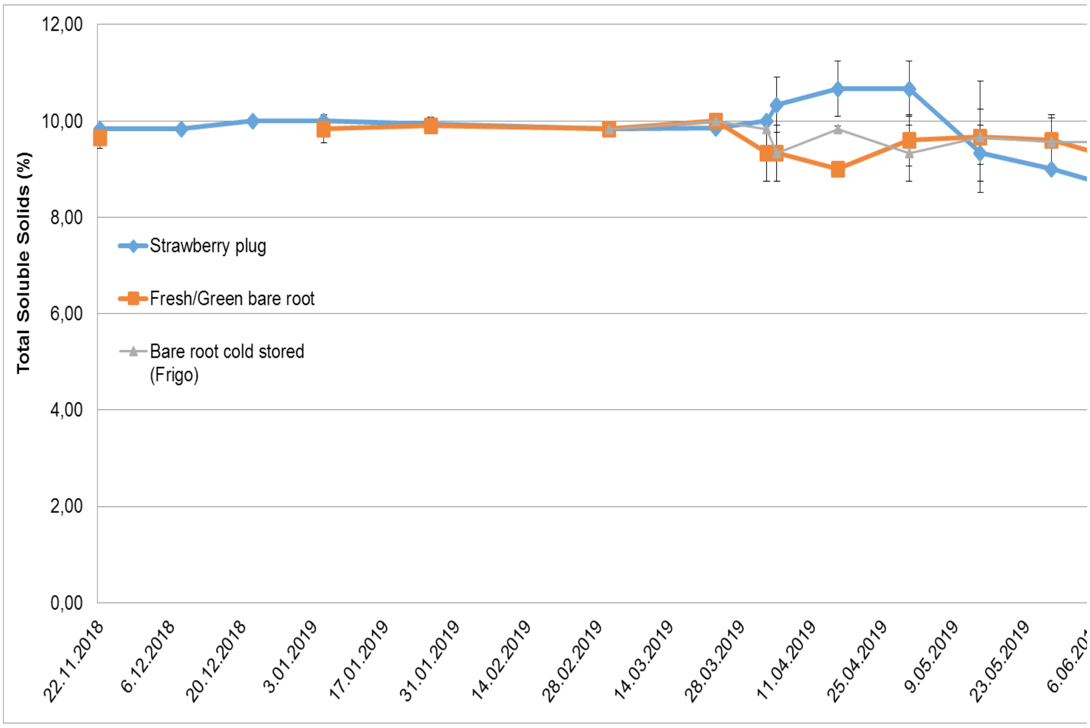

Figure 4. Total soluble solids (%) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

According to the results of present study, the titratable acidity (TA) of the fruits did not vary during the growing period and also did not vary among the different propagation methods (Figure 5.). The results for TA varied from 0.60 to 0.61 during the studies.

Similar with the TA results, the fruit firmness of fruits in present study did not show any significant differences either among the propagation methods or during the growing period (Figure 6.). The results for fruit firmness varied from 0.74 to 0.77 during the studies.

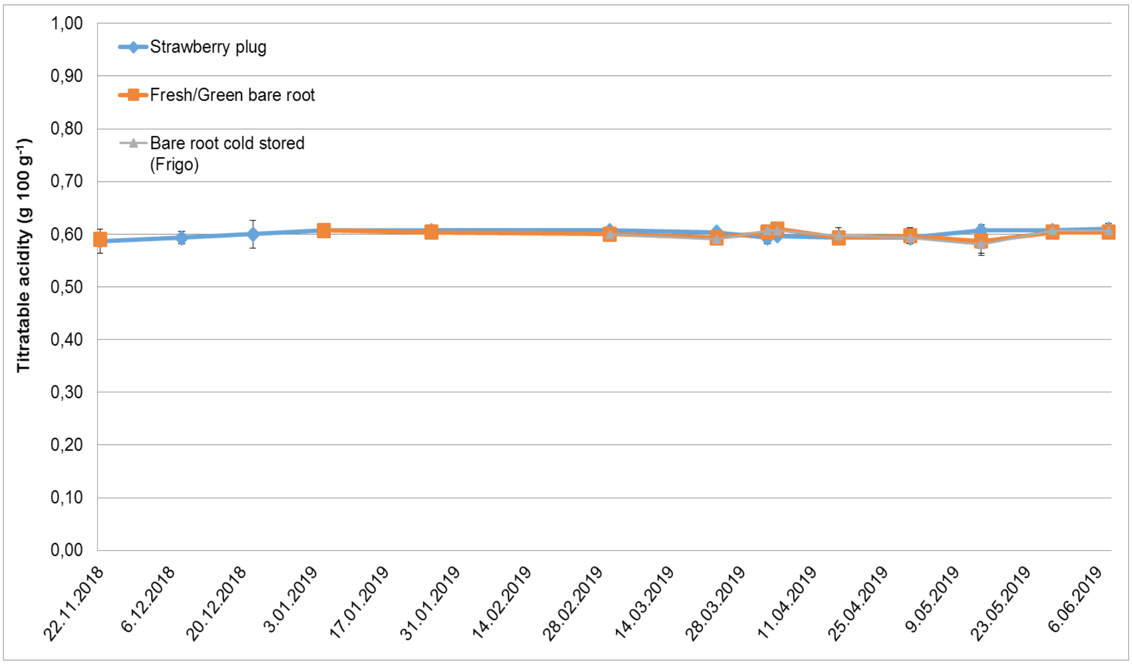

Figure 5. Titratable acidity (g 100 g^{-1}) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

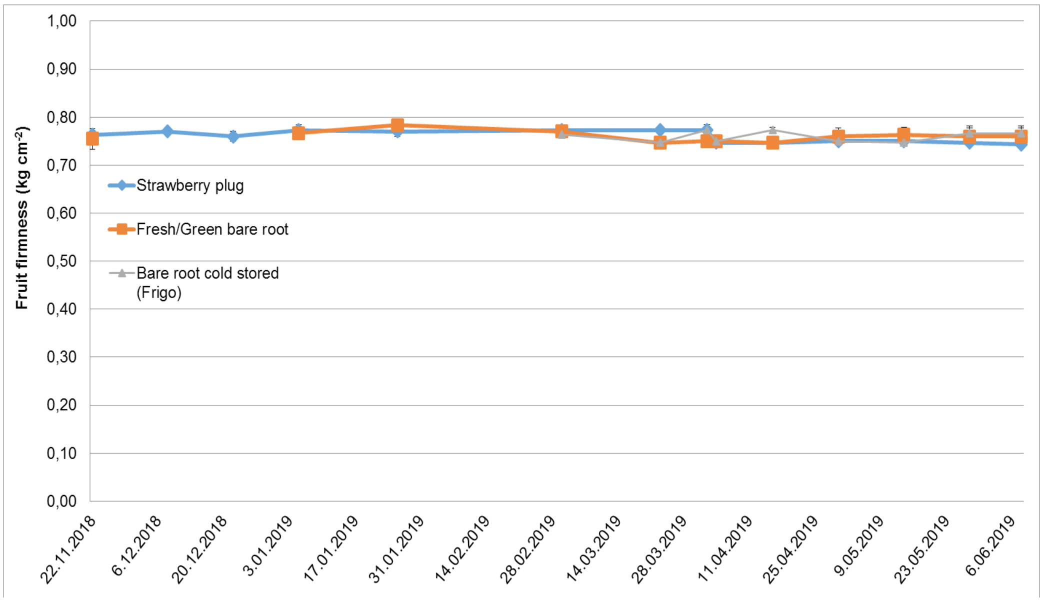

Figure 6. Fruit firmness (kg cm^{-2}) of strawberry plants cv. 'Florida Fortuna' propagated with different methods

Conclusion

According to the results obtained, strawberry plug propagation method provides better survival rate in the field conditions as compared with bare root and frigo methods. Another important result is that, plug propagation provides earliness on fruit yielding and continuous yielding (except winter period). The frigo propagation method was found to be the latest for fruit bearing, but to have highest yield. To sum up the results, plug method provides earliness and continuous yielding throughout the growing season, while the frigo propagation method delays fruit bearing but provides higher yield with less interval. Results also showed that there is slight difference in the average fruit weight of the plants throughout the growing period and the frigo plants have higher fluctuations in the weekly average fruit weights. Another important result of present study is that the increase in the weekly yield cause a decrease in TSS and *vice versa*.

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