Growth, Fruit Yield and Quality of Three Strawberry Cultivars as Affected by Mulch Type and Low Tunnel

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ABSTRACT

Two field experiments were carried out to study the effects of three mulch treatments (black polyethylene, clear polyethylene in addition to a non-mulched control) under low tunnel system (with and without tunnel), on plant growth, flowering traits, fruit yield and quality of three strawberry cultivars (*Fragaria & ananassa* Duch); Festival, Sweet Charlie and Gaviota, grown in sandy soil under a drip irrigation system. The results indicated that the three tested strawberry cultivars which were mulched with clear or black polyethylene and tunneled exhibited significant increases in number of leaves, number of crown, leaf area, dry mass/plant, number of flower trusses / plant and it flowered earlier than the non-mulched and non- tunneled ones. Moreover, most yield potential characters i.e. early yield, total yield, yield/plant, marketable yield, culls yield and average fruit weight; were positively and significantly increased by the application of mulch (clear and black polyethylene mulch) and tunneled compared to non-mulched and non-tunneled ones. Furthermore, these treatments, significantly, enhanced most fruit quality characteristics; total soluble solids, total titratable acidity, ascorbic acid, and reducing, non-reducing and total sugars compared to the control. Both Festival and Sweet Charlie cultivars were exceeded Gaviota one, in this respect.

Key words: Strawberry Cultivars, Polyethylene Plastic Mulch, Low Tunnels

INTRODUCTION

Strawberry (*Fragaria & ananassa* Duch) is one of the most popular vegetable crops. In Egypt, it occupies an important position among the non-traditional vegetable crops due to its multifarious use for local fresh consumption, exportation and food processing. Potentially, it is one of the most profitable horticultural Egyptian exports to Europe (El-Shall *et al* 2003). In recent years, there have been interests to study bioactive compounds of strawberries with an impact on human health such as ascorbic and ellagic acids (Wang *et al* 2002). Strawberries are rich in total antioxidents and are thus important for human health (Halvorsen *et al* 2002). However, the quality and quantity of these compounds are affected by genetic, environmental and agricultural factors (Kallio *et al* 2000; Anttonen and Karjalianen, 2005).

Mulch is any material used to cover the surface of the garden soil. There are many types of mulching materials, but they can be divided into two general categories; natural and synthetic. Synthetic-mulches are plastic and papers. The crops vary in their response to polyethylene mulch covers depending on cultivar, materials used, color and environmental conditions (Salman *et al* 1991; Pan *et al* 1999). Many researchers pointed that mulching had clear effects on microclimate around the plants by modifying the radiation budget of the surface and give significant increased on vegetative growth of many vegetable (Aguyoh and taber, 1999; Osiru and Hahn, 1994). Growing day-neutral strawberry using plastic mulch stimulate growth of young plants, increase soil temperature, weed control, reduces evapotranspiration, maximize water use efficiency and restrains heat loss during cold nights (Lieten, 1991; Gimenez *et al* 2002). Furthermore, it improves the protability by increasing the productivity and/or early fruit production as well as enhancing fruit quality (Orzolek and Murphy, 1993). Positive significant effects of organic and synthetic mulches on vegetative growth, flowering traits and yield and its components of strawberry plants have been reported by several investigators (Kher *et al* 2010; Hasanein *et al* 2011; Medina *et al* 2011; Li-fan *et al* 2012; Abou El-yazied and Mady, 2012; Muhammad Haroon *et al* 2014). Plants mulched with straw or white-on-black polyethylene flowered and yielded more than plants mulched with clear or white polyethylene. Conversely, more crown and root dry weight (DW) were associated with straw or clear-on-black polyethylene, (Fear and Nonnecke, 1989). Black polyethylene provides higher soil temperature in spring than hairy vetch mulch (Teasdale and Abdul-Baki, 1995; Teasdale and Abdul-Baki, 1997). Abou Elyazied and Mady, (2012) found that plastic mulch, significantly, increased NPK content and reduced the number of days to first flower, number flower/cluster and increase the final yield of strawberry plants than control.

Fruit quality of strawberry plants was affected by many factors including cultivar, mulching system, fertilization, irrigation and temperature (Khanizadeh, 1994; Kivijarvi *et al*., 2002; Anttonen *et al*., 2006). Nestby *et al*., (1985) demonstrated that the use of color polyethylene mulch had increased the percentage total soluble solids (Brix), vitamin C content, phenolic, total

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anthocyanin and ellagic acid of strawberry plants compared with the control.

High and low tunnels are very common in the Mediterranean regions and Asia (Faspi *et al.,* 2006) as they prolong the harvesting period and improve fruit quality. A high tunnel fruit growing system provides a competitive edge in the market, compared with a field growing system (Kadir *et al.,* 2006). Significant, effects of high tunnels on vegetative growth, flowering traits, yield and fruit quality of strawberry plants were reported by Qureshi *et al*., (2012).

The objective of the present study was to compare the effects of two types of mulch (black polyethylene, clear polyethylene in addition to a non-mulched control) under low tunnel system (with and without) for three strawberry cultivars; Sweet Charlie, Gaviota, Festival on vegetative growth, flowering traits, fruit yield and quality and chemical composition.

MATERIALS AND METHODS

Strawberry cultivars

Three cultivars of strawberry widely cultivated in Egypt were chosen. These cultivars represent the most sugary with excellent flavor; c.v Sweet Charlie and the universally grown, high yielding and good quality; c.vs, Gaviota and festival. Frigo transplants of the tested strawberry cultivars were obtained from Strawberry and Non-Traditional Crops Research Station Nobaria, El-Buhiera Governorate, Egypt. The transplanting date into the field were on September 1 and 25, in the first and second growing seasons, respectively.

Experimental procedure

Two field experiments were conducted during the growing seasons of 2012/2013 and 2013/2014 at the Experimental Station Farm Horticultural Research Institute (South Tahrir), El-Buhiera Governorate, under drip irrigation system. Some physical and chemical properties of the two experimental sites were determined according to methods described by Black, (1965) and presented in Table (1). The experimental layout was a split-split plot system in a randomized complete blocks design with four replications. Strawberry cultivars were arranged as the main plots and the plastic mulches treatments were considered as the sub – plots; while, the low tunnels systems were placed in the sub-sub-plots. Each sub-sub-plot was two rows of 2.40 m width and 3 m length having an area 7.2 m².A drip irrigation network was designed for this study. The drip irrigation network consisted of lateral's GR of 16 mm in diameter, with emitters at 0.5 m distance, with allocating two laterals for each ridge. The emitters had a discharge rate 4 l h^{-1}.

All Agricultural practices such as fertigation and disease and pest control were carried out whenever it was necessary according to the recommendations of the commercial production of strawberry commercial production as outlined by Ministry of Agriculture**.** During the entire growing season, nitrogen, potassium and phosphor fertilizers were also added through the drip irrigation system four times per week, at the rates of 200kg N /fed, in the form of ammonium nitrate (20.5% N), 120 kg K_2O / fed. as soluble potassium sulphate (48% k_2O) and 80kg P_2O_5 /fed as soluble phosphoric acid.

Data Recorded

1- Vegetative growth traits

At full blooming stage, Five representative plant sample were randomly chosen from each sub-sub plot to measurement the number of crowns/ plant, the number of leaves/ plant, plant leaf area (cm²) and plant dry mass (g) were recorded.

2- Yield potential

Early fruit yield was calculated in ton/ fed. as the fresh weight of harvested fruits from the first four pickings. Total yield was calculated in ton /fed. as the fresh weight of all harvested fruits throughout the growing season. Yield /plant (g) was calculated in a random sample of ten plants per sub-sub plot at each picking.

3-Yield components

Average fruit weight (g), was calculated in a random sample of ten plants per sub-sub plot at each harvest. Non-marketable yield (ton/fed), including splitter, malformed, green shouldered, white tip, damaged and rotted fruits was determined at each picking. Marketable yield (ton/fed) was calculated at each picking.

Table 1. Some physical and chemical analyses of the experimental sites of the 2012/2013 and 2013/2014 growing season

Season	Physical characteristics					Chemical characteristics					
	Sand%	Silt%	Clay%	EC ds/m	PH	Soluble cations mg/l			Soluble anions mg/l		Total N
						Ca	mg	K	HCO_3	So_4	
2012/2013	93	5	2	0.16	8.9	0.72	0.54	0.23	0.59	0.54	0.007
2013/2014	94	4	2	0.21	8.8	0.69	0.55	0.20	0.56	0.55	0.009

4- Fruit quality

Random samples of ten fruits were taken from each sub-sub plot at monthly intervals starting from the first harvest, to determine fruit characteristics. Moisture content (%): was determined on fresh weight basis by calculating the difference between fruit fresh weight and oven dried (70 °c until a constant weight) fruits/fruit fresh weight × 100. Total soluble solids (TSS %): was determined using a carlzeiss hand refractometer.

Reducing and total sugars: were determined according to Nelson's method as illustrated by Mailk and Singh, (1980). Means while the non-reducing sugars were calculated by the difference between total and reducing sugars.

Statistical analysis:

The obtained data were statically analyzed using Statistical Analysis System (SAS), version 6(SAS INSTITUTE INC, Cary, USA).Differences between means were compared by Revised the Least Significant Difference test (LSD) at 0.05 levels.

RESULTS AND DISCUSSION

1- Vegetative growth traits:

Results in Table (2) indicated that Festival cultivar recorded the highest mean values for most vegetative growth parameters i.e. number of leaves and crowns, dry mass and leaf area compared with those of Sweet Charlie and Gavuta, in both seasons. The obtained results seemed to complement with those reported by Shiow *et al* (1998). The results presented in Table (2), generally, clarified the presence of some significant increments on all studied vegetative growth characters of strawberry plant as a result of application of mulches type and tunnels compared with control (non-mulched / non-tunneled), in both seasons. The black polyethylene mulch recorded the highest mean values for all studied growth characters, in both seasons. The lowest mean values of vegetative growth characters were obtained by no soil cover (non-mulched control) treatment. The detected pronounced positive effect of mulches type on the vegetative parameters might be due to the reduced soil erosion; weed emergence; water loss; increased nitrogen; recycling of nutrients and addition of organic matter to the soil. These results, generally, are matched with those reported by Himelrick, (1982); Blatt, (1984); Nestby, (1985) and Fear Nonneck, (1989). Executing the low tunnel resulted in higher vegetative growth than the non-tunneled control. The benefits of plastic tunnels lead to maximum water use efficiency by the plant and reduce weeds which positively reflect on vegetative growth characters (Gimenez *et al* 2002).

The results in Table (3) illustrated the interaction effect between (cultivars × mulch types) on vegetative growth characters of strawberry plants. In both season, significant difference were detected in all vegetative growth traits as a result of the combination between the different mulches and cultivars. The best treatment combination for most vegetative growth characters was obtained when the strawberry plants cv Festival were mulched by black polyethylene, in both seasons.

The interaction effect between tunnel and cultivar on vegetative growth traits are presented in Table(4). Strawberry cv. Festival or Sweet Charlie under low tunnel was responsible for the significant increments for all studied vegetative growth traits, in both seasons. Similar results were reported by Qureshi *et al*., (2012).

The obtained results presented in Table (5) reflected the significant interaction effects between (mulches type × tunnel) on vegetative growth characters of strawberry plants. Application of mulch treatments either black or clear under the low tunnel, significantly, produced more vegetative growth traits, in both seasons. Black mulch exhibited higher mean values for all vegetative growth traits in tunnels, in both seasons. The obtained results seemed to complement with those reported by Medin *et al.,* (2011) and Levent and Sozer, (2001).

2- Flowering traits:

The obtained results tabulated in Table (6) reported that strawberry cvs. Festival and Sweet Charlie were earlier and produced higher number of flower trusses/ plant than Gaviota one. The effect of various mulch types and tunnels on flowering time (earliness) and number of flower trusses / plant were found significant, in both seasons (Table 6). The strawberry plants which were mulched and tunneled flowered earlier and produced more flower trusses than the control (non-mulched and non-tunneled). The observed enhancement effect on flowering parameters due to type of mulches might be attributed to the benefits of organic and synthetic mulches which led to decrease water loss and soil temperature during the hot summer months, reduced soil erosion and action as a slow-release fertilizer (Teasdele and Abdul-backi, 1993). Also, it leads to promote vegetative growth which positively reflects on flowering traits. The low tunnels increased temperature 1-2 °C and enables the plant growing during critical development period, which reflect on flowering traits (Sevgican, 1984). These results seemed to be in general agreements with those reported by Sevgican (1984); Fear and Nonnecke, (1989) and Levent and Sozer, (2001), who reported that plants mulched with black mulches and tunnels flowered and yielded earlier than control one.

Table 2. The Main effects of cultivar, mulch and tunnel on vegetative growth characters of strawberry plant, during the seasons of 2012/2013 and 2013/2014.

Treatment		Number of leaves		Number of crown		Total dry weight (g m)		Leaf area (cm²)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Cultivar	Gafuta	19.98 b	15.13 b	3.38 a	2.84 b	6.76 c	6.43 b	237.51 c	222.95 b
	Festival	25.76 a	21.65 a	3.50 a	3.51 a	18.30 a	15.28 a	640.63a	621.72 a
	Sweet Charlie	22.31 ab	20.20 a	3.98 a	3.33 a	12.44 b	13.97 a	430.91 b	511.65 a
Mulch	Control	19.48 b	17.12 b	2.73 b	2.33 b	9.15 b	8.21 b	343.75c	345.23b
	Clear	23.48 a	19.42 a	3.86 a	3.91 a	12.67 a	12.86 a	426.77 b	518.37 a
	Black	25.09 a	20.43 a	4.27 a	3.44 a	15.63 a	14.63 a	538.50 a	492.72 a
Tunnel	Non	21.77 a	17.24 b	3.54 a	2.55 b	11.62 a	11.39 a	418.99 b	440.66a
	Tunnel	23.59 a	20.75 a	3.70 a	3.91 a	13.34 a	12.40 a	453.69 a	463.55 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level

Table 3. The Interaction effect between cultivar and mulch on vegetative growth characters of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Mulch	Number of leaves		Number of crown		Total dry weight (g m)		Leaf area (cm²)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gafuta	Un- mulched	18.91 c	10.03 c	2.92 d	1.75 d	5.78 d	5.49 d	219.18 c	201.64 b
	clear mulch	22.38 bc	17.94 b	3.52 cd	3.97a	8.19 d	7.81 d	288.78 bc	267.95 b
	Black mulch	18.66 c	17.42 b	3.71 bcd	2.80 bc	6.303 d	6.01 d	204.53 c	199.25 b
Festival	Un -mulched	21.17 c	22.66 a	1.89 e	2.72 bc	14.22 bc	12.52 c	604.49 a	554.34 a
	clear mulch	27.62 ab	20.11ab	3.95 abc	4.27 a	19.51 ab	18.01 b	622.41 a	685.57 a
	Black mulch	28.49a	22.16 a	4.65 a	3.50 ab	21.04 a	15.32 bc	694.98 a	625.24 a
Sweet Charlie	Un -mulched	18.38 c	18.67 b	3.39 cd	2.51 cd	7.46 d	6.55 d	207.58 c	279.71 b
	clear mulch	20.43 c	20.21 ab	4.11 abc	3.45 ab	10.32 cd	12.78 c	369.12 b	601.61 a
	Black mulch	28.14 a	21.72 a	4.44 ab	4.02 a	19.51 ab	22.57 a	715.99 a	653.66 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 4. The Interaction effect between cultivar and tunnel on vegetative growth characters of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Tunnel	Number of leaves		Number of crown		Total dry weight (g m)		Leaf area (cm²)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gafuta	Non	18.52 b	13.80 b	3.63 ab	2.02 c	7.04 d	6.71 b	238.60 d	525.23 c
	Tunnel	21.44 a	16.45 b	3.138 b	3.66 ab	6.48 d	6.17 b	236.39 d	220.66 d
Festival	Non	25.19 a	19.99 b	3.29 b	2.83 bc	19.35 a	14.42 a	575.42 b	595.40 b
	Tunnel	26.33 a	23.61 a	3.71ab	4.16 a	17.17 ab	16.14 a	705.83 a	648.03 a
Sweet Charlie	Non	21.62 a	18.22 b	3.70 ab	2.78 bc	13.65 bc	13.04a	418.84 c	501.35 c
	Tunnel	23.01 a	22.19 a	4.26 a	3.87 a	11.23 cd	14.89 a	442.95 c	521.96c

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05 % level.

Table 5. The Interaction effect between mulch and tunnel on the vegetative growth characters of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Mulch	Tunnel	Number of leaves		Number of crown		Total dry weight (g m)		Leaf area (cm^2)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Un mulch	Non	18.21 b	15.35 c	2.41 c	2.14 b	10.34 bc	8.00 c	332.11 d	308.67 d
	Tunnel	20.77b	18.89 b	3.05 bc	2.52 b	7.96 c	8.37 c	355.39 d	381.79 c
Clear mulch	Non	20.54 b	17.47 b	3.54 b	2.98 b	10.37 bc	11.45 bc	425.07 c	461.57 b
	Tunnel	23.41 a	21.36 a	4.17 ab	4.81 a	14.98 ab	14.28ab	428.47 c	475.17 b
Black mulch	Non	23.58 a	18.88 b	4.04 ab	2.52 b	14.71 ab	11.88 b	499.80 b	451.73 b
	Tunnel	26.61 a	21.98 a	4.51 a	4.36 a	16.54 a	17.37 a	577.20 a	533.70a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 6. Main effect of cultivars, mulch and tunnels on flowering traits of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Treatment		Earliness of flowering (days)		Number of flower Trusses/ plant	
		Season1	Season2	Season1	Season2
Cultivar	Gafuta	127.85 a	128.12 a	20.54 a	18.83 b
	Festival	128.23 a	127.33 a	21.02 a	20.77 b
	Sweet Charlie	123.30 b	170.59 a	19.83 a	21.490 a
Mulch	Control	128.34 a	174.82 a	16.01 b	17.21 c
	Clear	126.47 b	126.57a	23.17 a	20.77b
	Black	124.57 c	124.56 a	22.23a	23.12 a
Tunnel	Non	128.82 a	128.62a	20.22 a	18.84 b
	Tunnel	124.11 b	125.40 a	20.72 a	21.89 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

The interaction effect between type of mulch and cultivar on flowering traits; i.e. earliness of flowering and number of trusses/plant; are presented in Table (7). Strawberry plants cv Sweet Charlie which mulched with black mulches was responsible for causing the earliness of flowering and had positive and significant effect on number of flower trusses/$plant^{-1}$,in both seasons. Similar results were reported by Shiow *et al* (1998).

Results in Table (8) illustrated the significant interaction effect between the tunnel treatments and the three studied cultivars, on flowering traits, in both seasons. The strawberry plants c.vs Festival and Sweet Charlie which tunneled, generally, flowered earlier and produced higher number of flower trusses/plant, in both seasons. However, Festival without tunnel recorded the highest mean values of days from transplanting to floral initiation, indicating that this cultivar requires the tunnel cover to flower earlier. Similar results were recorded by Sevgican (1984) and Levent and Sozer (2001).

The interaction effect between the mulch type and tunnel treatment on earliness and number of flower trusses are shown in Table (9). The results indicated that were significant differences on the studied flowering traits due to mulch type and tunnel treatments, in both seasons. The highest mean value of both characters, were obtained from strawberry plants mulched with black polyethylene mulch and tunneled, in both seasons. The obtained results are in general accordance with those reported by Levent and Sozer (2001) and Medina et al., (2011).

3- Fruit yield and its components:

The results presented in Table (10), exhibited significant difference among the three studied strawberry cultivars in terms of yield parameters, in both seasons. Sweet Charlie and Festival cultivars were superior to Gaviota with respect to all yield potential characters. These results, also, indicated that there were significant increase in all studied yield parameters, i.e. early yield, yield/plant, total yield, marketable yield, culls and average fruit yield due to the application of mulch compared to the non-mulched control, in both seasons. Early yield, yield/plant, total yield, and average fruit yield were positively and significantly increased a result of application the two types of mulch compared to the non-mulched control. The only exception was

noticed with marketable yield, culls; where the differences among the mulch treatments were insignificant, in both seasons.

Black mulch is better than clear one, in respect to yield /plant, marketable yield and total yield. Such positive responses of strawberry yield potential to mulch and tunnel treatments may be due to proper balance of microclimate (moisture and temperature) for strawberry plants, which creates favorable conditions for nutrients uptake, photosynthesis and metabolites translocation. Other possibility was increasing available water and nutrients uptake which ultimately accelerated the rate of vegetative growth and yield. These findings appeared to be in general accordance with those reported by several investigators (Baltt, 1984; Nestby, 1985; Hayness, 1987; Lareau and Lamorre, 1990; Shiow *et al*., 1998; Ali and Radwan, 2008; Medina *et al*., 2011 and Qureshi *et al.,* 2012).

Results in Table (11) illustrated the interaction effect between the various types of mulches and the three studied strawberry cultivars on yield and its components which were found significant, in both seasons.

Table7. Interaction effect between cultivar and mulch on flowering traits of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Mulch	Earliness of flowering(days)		Number of flower Trusses/plant	
		Season1	Season2	Season1	Season2
Gafuta	Un- mulched	130.49 a	130.39 b	17.72 b	17.24 d
	Clear mulch	126.79 c	126.60 f	23.32 ab	20.98 bc
	Black mulch	126.29 d	127.36 e	20.58 ab	18.28 cd
Festival	Un- mulched	129.29 b	128.21 d	16.64 b	18.26 cd
	Clear mulch	129.22 b	128.64 c	22.21 ab	19.99 cd
	Black mulch	126.17 d	125.15 g	24.24 a	24.07 ab
Sweet Charlie	Un- mulched	125.26 e	133.87 a	13.66 b	16.13 d
	Clear mulch	123.39 f	124.46 h	24.00 a	21.348 bc
	Black mulch	121.24 g	121.44 i	21.88 ab	26.99 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 8. Interaction effects between cultivar and tunnel on flowering traits of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Tunnels	Earliness of flowering(days)		Number of flower Trusses/plant	
		Season1	Season2	Season1	Season2
Gafuta	Non	129.89 b	130.02 a	21.11 ab	17.29c
	Tunnel	125.82 c	126.22 a	19.96 ab	20.38 ab
Festival	Non	130.82 a	130.00 a	18.71 b	18.96 bc
	Tunnel	125.64 d	124.67 a	23.34a	22.59 a
Sweet Charlie	Non	125.76 c	125.85 a	18.86 b	19.28 b
	Tunnel	120.83 e	115.33 a	20.83ab	22.71a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 9. Interaction between mulch and tunnel on flowering traits of strawberry plants, during the seasons of 2012/2013 and 2013/2014.

Mulch	Tunnels	Earliness of flowering (days)		Number of flower Trusses/plant	
		Season1	Season2	Season1	Season2
Un mulched	Non	130.33 a	129.35 b	14.13 b	15.69 c
	Tunnel	126.36 d	130.30 a	17.88 b	18.73 b
Clear mulch	Non	128.88 b	129.37 b	20.20 b	20.21 b
	Tunnel	124.06 e	123.77d	25.14 a	22.336 a
Black mulch	Non	127.26 c	127.15 c	20.38 b	20.637 b
	Tunnel	121.88 f	122.15e	23.08 a	25.61 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 10. Main effect of cultivar, mulch and tunnel on strawberry fruit yield and its components, during the seasons of 2012/2013 and 2013/2014.

Treatment		Early yield (Ton/ fed)		Average fruit weight (gm)		Yield / plant (gm)		Marketable yield (Ton / fed)		Culls yield (Ton / fed)		Total yield (Ton / fed)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Cultivar	Gafuta	2.06 b	2.06 b	14.11 b	14.34 b	444.39 c	460.41 c	8.05 b	8.23 b	0.87 a	0.91 a	8.92 c	9.147 c
	Festival	2.88 a	2.42 ab	21.55 a	22.56 a	689.21 a	656.34 a	12.84 a	12.32 a	0.71 b	0.71 b	13.55 a	13.08 a
	Sweet Charlie	2.22 a	2.21 a	21.13 a	29.15 a	642.19 b	624.34 b	12.10 a	12.21 a	0.719b	0.82 b	12.81 a	13.03 a
Mulch	Control	1.93 b	1.90 b	17.65 b	19.08 b	549.88 b	548.36 b	9.89 b	9.55b	0.91 a	0.99 a	10.72 b	10.54 b
	Clear	2.28 a	2.24 a	19.64 a	26.17 a	573.19 b	552.92 b	11.23 a	10.92 a	0.79 b	0.90 b	12.02 a	11.83 a
	Black	2.26 a	2.24 a	20.20 a	20.81 ab	652.72 a	639.82 a	11.95 a	11.65 a	0.79 b	0.80 b	12.74 a	12.45 a
Tunnel	Non	1.96 b	1.95 b	18.31 b	21.37 a	583.11 a	568.84 a	9.26 b	8.73 b	0.95 a	1.41 a	10.21b	10.13 b
	Tunnel	2.29 a	2.31 a	20.01 a	22.67 a	600.75 a	591.89 a	11.41 a	11.35a	0.85 b	0.95 b	12.24 a	12.31 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 11. Interaction effect between cultivar and mulch on strawberry fruit yield and its components, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Mulch	Early yield (Ton/ fed)		Average fruit weight (gm)		Yield / plant (gm)		Marketable yield (Ton / fed)		Culls yield (Ton / fed)		Total yield (Ton / fed)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gavuta	Un mulch	1.80 h	1.81 d	13.20 d	15.01 b	435.33 e	466.60 d	7.99 c	8.52d	0.823 d	0.813 b	8.81 d	9.33 d
	Clear mulch	2.12 e	2.16 bc	12.38 d	13.88 b	454 02 e	448.92 d	8.23 c	7.76 d	0.853 cd	0.847b	9.08 d	8.98 d
	Black mulch	2.27 c	2.22 b	16.74 c	14.137 b	443.82 e	465.73 d	7.94 c	8.42 d	0.937 ab	0.783b	8.89 d	9.31 d
Festival	Un mulch	1.95 g	2.04 c	19.58 bc	19.21 ab	635.50 bc	615.29 bc	12.01 b	10.99 c	0.984 a	1.075 a	13.10 bc	12.42 bc
	Clear mulch	2.23 d	2.19 b	23.25 a	24.52 ab	656.99 b	627.52 b	13.10ab	12.95 ab	0.858 cd	1.012 a	13.14 b	12.55 bc
	Black mulch	2.07 f	2.12 bc	21.81 a	23.96 ab	775.15 a	726.21 a	13.51 ab	12.32 abc	0.878 bc	0.942 b	14.41 a	13.40 ab
Sweet Charlie	Un mulch	1.75 I	1.85 d	20.16 b	23.01 ab	578 82 d	563.19 c	12.42b	12.16 bc	0.921 ab	1.084 a	11.94 c	11.97 c
	Clear mulch	2.49 a	2.36 a	23.28 a	24.33 ab	608.56 cd	582.31 bc	12.46 b	12.07 bc	0.955 ab	1.127 a	13.18 b	13.36 ab
	Black mulch	2.43 b	2.37 a	22.05 a	29.11 a	739.19 a	727.54 a	14.41 a	14.21 a	0.882 c	0.838 b	14.17 a	13.86 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 12. Interaction effects between cultivar and tunnel on strawberry fruit yield and its components, during the seasons of 2012/2013 and 2013/2014.

Cultivar	Tunnel	Early yield (Ton/ fed)		Average fruit weight (gm)		Yield / plant (gm)		Marketable yield (Ton / fed)		Culls yield (Ton / fed)		Total yield (Ton / fed)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gafuta	Non	1.89 f	1.91 c	13.85 d	12.85 d	443.11 c	484.62 b	7.99 c	7.94c	0.923 ab	0.784 c	8.91 b	8.72 d
	Tunnel	2.24 b	2.22 b	14.36 d	15.83cd	445.68 c	436.22 b	8.04 c	8.86c	0.819 b	0.844 c	8.86 b	9.77 c
Festival	Non	1.96 e	1.94 c	20.14 bc	21.13 bcd	626.28 b	651.81 a	11.75 b	11.52 b	0.949 ab	1.004 a	12.72 b	12.53 b
	Tunnel	2.24 b	2.30 a	22.95 a	23.99 bc	701.06 a	660.89 a	12.83 ab	12.74 a	0.864 b	0.919b	13.69a	13.66 a
Sweet Charlie	Non	2.02 d	1.99 c	20.95 b	25.17 ab	658.10 ab	630.17 a	11.89 b	11.40 b	0.971 a	1.028 a	12.85 b	12.43 b
	Tunnel	2.42 a	2.40 a	22.70 ab	33.12 a	677.37a	618.53 a	13.30 a	12.92a	0.866 b	0.944 b	14.17 a	13.87 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 13. Interaction effects between mulch and tunnel on strawberry fruit yield and its components, during the seasons of 2012/2013 and 2013/2014.

Mulch	Tunnel	Early yield (Ton/ fed)		Average fruit weight (gm)		Yield / plant (gm)		Marketable yield (Ton / fed)		Culls yield (Ton / fed)		Total yield (Ton / fed)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Un mulch	Non	1.62 f	1.65 c	16.76 c	18.04 b	540.51 cd	558.44 cd	9.45 b	9.16 b	0.932 a	1.007 a	10.34 b	10.17 b
	Tunnel	2.04 e	2.16 b	18.54 bc	22.24 ab	519.86 d	538.28 d	11.16a	11.95 a	0.886 b	0.876 b	12.05 a	12.53 a
Whit mulch	Non	2.18 c	2.07 b	18.96 b	20.11 b	579.91 bc	505.68 f	9.99 b	10.57 b	0.812 c	1.008 a	10.81 b	11.57 b
	Tunnel	2.37 b	2.41 a	20.32 ab	22.65ab	605.88 b	600.16bc	11.46 a	12.28 a	0.865 b	0.785 b	12.33 a	13.09 a
Black mulch	Non	2.06 d	2.12 b	19.22b	19.37 b	616.47 b	617.08 b	9.17 b	10.68 b	0.992 a	0.940 a	10.02 b	11.62 b
	Tunnel	2.45 a	2.36 a	21.17 a	29.68 a	688.97 a	662.57 a	12.33 a	12.62a	0.846 b	0.872 b	13.18 a	13.49 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 14. Main effect of cultivar, mulch and tunnel on vitamin C, total soluble solids, titratable acidity, reducing and non-reducing and total sugars of strawberry fruits, during the seasons of 2012/2013 and 2013/2014.

Treatments		Non reducing sugars (%)		Reducing sugars (%)		Total sugars (%)		Total titratable Acidity (gm acidic acid/100 gm juice)		Total soluble solid (%)		Vitamin C (mg/100 gm f.w)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Cultivar	Gafuta	3.08 b	3.05 a	11.60 a	11.75 a	14.67 b	14.81 b	0.379 a	0.374 a	10.27 b	9.55 b	25.54 b	25.07 b
	Festival	3.94 a	3.55 a	11.65 a	11.80 a	15.68 a	15.51a	0.361 b	0.361 b	11.35 a	10.84 a	25.16 b	25.26 b
	Sweet Charlie	3.38 b	3.56 a	11.66 a	11.63 a	15.05 b	15.19 b	0.364 ab	0.375 a	11.46 a	10.93 a	27.34 a	27.33 a
Mulch	Control	3.07 b	3.25 a	11.64 a	11.71 a	14.71 b	14.97 a	0.356 c	0.363 a	10.01 b	9.36 b	23.34 b	22.81 b
	Clear	3.85 a	3.43 a	11.63 a	11.82 a	15.48 a	15.25 a	0.369 b	0.374 a	11.98 a	10.64 a	27.21 a	27.48 a
	Black	3.49 a	3.48 a	11.64 a	11.64 a	15.21 a	15.27 a	0.379 a	0.737 a	11.11 ab	11.32 a	27.51 a	27.38 a
Tunnels	Non	3.15 b	2.92 b	11.50 b	11.51 b	14.70 b	14.52 b	0.368 a	0.366 a	10.20 b	9.98 b	23.99 b	24.16 b
	Tunnel	3.79 a	3.86 a	11.73 a	11.94 a	15.57 a	15.80 a	0.368 a	0.374 a	11.85 a	10.90 a	28.04 a	27.62 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 15. Interaction effect between cultivar and mulch on vitamin C, total soluble solids, titratable acidity, reducing and non-reducing and total sugars of strawberry fruits, during the season of 2012/2013 and 2013/2014.

Cultivars	Mulch	Non reducing sugar (%)		Reducing sugars (%)		Total sugars (%)		Total titratable Acidity (gm acidic acid/100 gm juice)		Total soluble solid (%)		Vitamin C (mg/100 gm f.w)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gaviota	Un mulch	3.57 b	3.41 abc	11.46 c	11.69 bcd	15.26 bc	15.09 a	0.361 a	0.366 a	8.32 c	8.85 c	22.58 e	20.78 g
	Clear mulch	2.72 c	3.29 abc	11.25 c	11.40 d	13.97 f	14.69 b	0.358 a	0.392 a	10.45 b	9.72 bc	27.59 b	28.24 b
	Black mulch	3.199 b	3.01 bc	11.54 b	11.60 d	14.74 d	14.61 c	0.383 a	0.364 a	12.05 abc	10.07 bc	26.46 bc	26.21 c
Festival	Un mulch	3.19 b	4.01bc	11.56 b	11.66 c	14.76 cd	15.66 a	0.357 a	0.359 a	10.14 cd	10.04 bc	22.07 e	22.62 f
	Clear mulch	5.07 a	3.24 bc	11.75 ab	12.05 ab	16.82 a	15.31 a	0.361 a	0.360a	11.45 abc	11.07 ab	29.09 ab	29.41 b
	Black mulch	3.32 b	2.85 c	12.01 a	12.24 a	15.31 bc	15.54a	0.364 a	0.365 a	12.47 ab	11.40 ab	24.32 d	23.76 ef
Sweet Charlie	Un mulch	2.71 c	2.91 c	11.16 c	11.24 d	13.87 f	14.15 d	0.349 a	0.365 a	10.27 cd	9.17 c	25.36 cd	25.03 cd
	Clear mulch	3.74 b	3.75 ab	11.99 ab	12.02 abc	15.64 b	15.76 a	0.356 a	0.368a	13.01 a	11.12 ab	24.96 d	24.81 de
	Black mulch	3.69 b	4.04 a	11.93 ab	11.62 d	15.62 bc	15.66 a	0.386 a	0.391a	11.10 abc	12.50 a	31.71 a	32.18 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 16. Interaction effects of cultivars and tunnels on vitamin C, total soluble solids, titratable acidity, reducing and non-reducing and total sugars of strawberry fruits, during the season of 2012/2013 and 2013/2014.

Cultivars	Tunnels	Non reducing sugars (%)		Reducing sugars (%)		Total sugars (%)		Total titratable Acidity (gm acidic acid/100 gm juice)		Total soluble solid (%)		Vitamin C (mg/100gm f. w.)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Gafuta	Non	2.86 c	2.72 c	11.45 b	11.62 bc	14.30 d	14.34 c	0.381 a	0.368a	9.06 c	8.81 b	26.45 b	25.61 b
	Tunnel	3.30 b	3.38 b	11.74 a	11.88 ab	15.05 b	15.25 b	0.376 a	0.381 a	11.48 ab	10.28 a	24.64 c	24.53 b
Festival	Non	3.52 b	2.93 bc	11.51 a	11.47 c	15.17 b	14.69 c	0.365 a	0.365 a	10.55 bc	10.70 a	20.33 d	21.32 c
	Tunnel	4.37 a	4.17 a	11.81 a	12.14 a	16.19 a	16.31 a	0.3563 a	0.357 a	12.16 a	10.97 a	29.99 a	29.21 a
Sweet Charlie	Non	3.07 c	3.11 bc	11.56 a	11.44 c	14.63 c	14.54 c	0.357 a	0.364 a	11.01ab	10.41 a	25.19 bc	25.55 b
	Tunnel	3.69 b	4.03 a	11.77 a	11.81abc	15.46 ab	15.84 a	0.371 a	0.386 a	11.90 ab	11.45 a	29.50 a	29.12 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

Table 17. Interaction effects o between mulch and tunnel on vitamin C, total soluble solids, titratable acidity, reducing and non-reducing and total sugars of strawberry fruits, during the season of 2012/2013 and 2013/2014.

Mulch	Tunnels	Non reducing sugar (%)		Reducing sugars (%)		Total sugars (%)		Total titratable Acidity (gm acidic acid/100 gm juice)		Total soluble solid (%)		Vitamin C (mg/100gm f.w)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Un mulch	Non	2.96 c	2.77 b	11.37 b	11.34 b	14.33 c	14.10 c	0.361 a	0.370 a	10.14 b	9.16 c	24.71 c	24.05 cd
	Tunnel	3.17 c	3.74 a	11.92 a	12.09 a	15.11ab	15.83 a	0.352 a	0.357 a	9.88 b	9.55 b	21.96 d	21.58 e
Clear mulch	Non	3.47 bc	2.99 b	10.72 c	11.82a	14.21 c	14.81 b	0.361 a	0.363 a	10.59 b	10.35 b	25.17 c	25.99 c
	Tunnel	4.22 a	3.86 a	11.54 b	11.83 a	15.76 a	15.69 a	0.374 a	0.363 a	13.36 a	10.92 ab	29.26 b	28.98 b
Black mulch	Non	3.16 c	2.99 b	11.42 b	11.37 b	14.58 bc	14.36b	0.377 a	0.365 a	9.89 b	10.42 b	22.09 d	22.45 d
	Tunnel	3.97ab	3.98 a	11.87 a	11.90 a	15.84 a	15.88 a	0.381 a	0.382 a	12.30 a	12.23 a	32.90 a	32.31 a

Values followed by the same letter(s), within a comparable group of means of any main effect, do not significantly differ, using revised L.S.D test at 0.05% level.

The Sweet Charlie c.v which mulched with black polyethylene and tunneled, generally, produced the highest significant mean values for fruit yield and its components, in both seasons. The obtained results are in general accordance with those reported by (Albregts *et al.,* 1993; Shiow *et al.,* 1998; Ali and Radwan, 2008 and Qureshi *et al.,* 2012).

The difference between tunnel and cultivar were found significant for yield characters and its components (Table 12). The highest mean values for most fruit yield parameters were obtained when strawberry c.vs Festival or Sweet Charlie grown under tunnel than the un-tunneled control one, in both seasons. Similar results were reported by Shiow *et al*., (1998); Levent and Sozer, (2001) and Qureshi *et al.* (2012).

The highest mean values of fruit yield parameters (i.e. early yield, yield/plant, total yield, marketable yield, culls yield and average fruit weight) were resulted from the interaction between the mulched and tunneled found significant for yield fruit parameter, Table (13). The strawberry plants were mulched and tunneled gave, in both seasons. Similar results were reported by (Levent and Sozer, 2001).

Fruit quality traits:

The results in Table (14), generally showed the presence of some significant differences on vitamin C, total soluble solids, titratable acidity, reducing and non-reducing and total sugars, as a result of mulch types and tunnels, in both growing season. Mulch types and tunnels, significantly, improved all fruit quality character, in both seasons. The obtained results, generally, showed significant differences among strawberry plants cv. Festival, Sweet Charlie and Gaviota, in both season. It was observed that, Festival or Sweet Charlie cultivars contained more total soluble solids, V.C and reducing and non-reducing and total sugars than Gaviota one, in both season. However, gaviota fruits had more total titratable acidity than Festival and Sweet Charlie ones. Generally the obtained results compatible with those reported by (Lareau and Lamarre, 1990; Shiow *et al.,* 1998 and Qureshi *et al.,* 2012).

The interaction effects among the cultivar and mulch types on V.C, TSS, Reducing and non-reducing and total sugars are shown in Table (15). The comparisons among the means of the various treatment combinations showed the presence of some significant interaction effects on the V.C, TSS, reducing and non-reducing and total sugars, in both seasons. The highest mean values of these characters were obtained from strawberry plant cv. Festival which mulched with black polyethylene. However, no significant difference in total titratable acidity was detected, in both seasons. The obtained results are in general accordance with those reported by (Shiow *et al* 1998). The results presented in Table (16), illustrated the interaction effects between cultivars and tunnels of strawberry plant on the total soluble solids, vitamin c, reducing and non-reducing and total sugars were found to be significant, in both season. The best results for these characters were obtained from strawberry cv. Sweet Charlie which grown under tunnel, in both season. However, total titratable acidity were not significantly, affected by these interaction. Similar results were recorded by (Levent and Sozer, 2001; Medina *et al.,* 2011 and Qureshi *et al.,* 2012).

The interaction effects between mulch types and tunnels on V.C, TSS, TTA, reducing and non-reducing and total sugars are presented in Table (17), in both seasons, the strawberry plants which were mulched and tunneled gave the highest mean values for total sugars, vitamin C, reducing and non-reducing and total sugars compared than control treatment. However, total titrable acidity were not significantly affected. Similar results were recorded by Levent and Sozer, (2001).

CONCLUSIONS

Based on the results from this study , application of plastic mulch and low tunnel for production strawberry plants caused significant increments in vegetative growth characters ,fruit yield and its components and improved fruit quality. Fistival cultivar exhibited the superiority, in this respect.

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الملخص العربي

نمو ومحصول وجودة الثمار لثلاثة أصناف من الفراولة وتأثرها بنوعية الملش والأنفاق المنخفضة

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اجريت دراسة حقليه خلال الموسم الصيفى لعامى ٢٠١٢- ٢٠١٣ و٢٠١٣- ٢٠١٤ بأرض رمليه بمحطة التجارب الزراعية بجنوب التحرير والتابعة بمعهد بحوث البساتين والكائنة بمحافظة البحيرة. وذلك بهدف دراسة استجابة نباتات الفراولة الطازجة أصناف(فيستيفال– سويت شارلى– جافيوتا) لثلاثة معاملات من الملش الصناعى (البولى ايثيلين الابيض. البولى ايثيلين الاسود. والكنترول) وذلك بالزراعة فى وجود الانفاق المنخفضة وعدم وجود هذه الانفاق والتفاعل بينهما على النمو الخضرى والإزهار والمحصول وجودة ثمار الفراولة.

أوضحت النتائج أن معاملة أصناف الفراولة بأنواع الملش المختلفة(الأبيض- الأسود) والزراعة تحت الانفاق قد أدت الى حدوث زيادة معنوية فى صفات النمو الخضرى والزهرى معبراً عنها بعدد الأوراق وعدد التيجان والمساحة الورقية والوزن الجاف وعدد النورات الزهريه للنبات والتبكير فى الازهار وذلك مقارنة بالكنترول(بدون ملش– عدم وجود اغطية بلاستيكية).

أدت معاملة نباتات الفراولة بواسطة الملش والزراعة تحت الأنفاق إلى حدوث زيادة معنوية فى القدرة المحصولية معبراً عنها بالمحصول المبكر والمحصول الكلى ومحصول النبات الواحد والمحصول الصالح للتسويق والمحصول التالف وكذلك متوسط وزن الثمرة وذلك مقارنة بالكنترول.

كما أشارت النتائج إلى حدوث زيادة معنوية فى صفات الجودة معبرا عنها بمحتوى الثمار من فيتامين سى والحموضة الكلية والمواد الصلبة الذائبة والسكريات الكلية والمختزلة وغير المختزلة وذلك مقارنة بالكنترول.

كانت إستجابة الأصناف للمعاملات بالملش والأنفاق متشابهة تقريبا مع حدوث تفوق للصنف فيستيفال وسويت شارلى على الصنف جافيوتا.