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Plastic Covering Accelerates Phenological Stages and Causes Abiotic Stress in Table Grapes in Egypt

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ABSTRACT

Egypt, like other global countries, faces climate changes that threaten its economy and food security. Grape farmers and exporters protect grape vines from an unfavorable microclimate by using plastic covering (PC). This study assessed the impact of early plastic covering, from mid-January to the end of April, on the phenological stages, yield, and fruit quality of two seedless table grapes (Flame and Superior). Also, to find out if covering could cause additional stress on grape vines by assessing its effect on vegetative growth, chlorophyll content, and photosynthesis efficiency, as well as carbohydrates, proline, total phenols, lipid peroxidation, catalase, and ascorbate peroxidase content in leaves. Our research findings indicate that PC accelerates all phenological stages; additionally, it causes abiotic stress, leading to an increase in soluble sugar, total phenols, and proline content in vine leaves. Plastic covering did not affect most fruit quality parameters at harvest, such as cluster weight, small berries (%), TSS%, and titratable acidity (%). Nevertheless, PC reduced the anthocyanin content in Flame berries by 31.1% and 33.6% in the first and second seasons, respectively, compared to the uncovered group.In conclusion, PC could be recommended as a good strategy for combating climate change and hastening the harvesting of grapes. However, further research is needed to improve the pigmentation of grapes cultivated under plastic to provide an appealing appearance for consumers.

Keywords: *Vitis vinifera;* Ripening; Microclimate; Antioxidant enzymes; Proline; Carbohydrates

INTRODUCTION

Table grapes (*Vitis vinifera* L.) are one of the most essential fruit crops farmed globally in terms of total planted area and commercial value (FAOSTAT, 2020). According to the Egyptian Ministry of Agriculture and Land Reclamation (2019), table grapes are Egypt's second most significant fruit crop, following citrus, in terms of planted area and production. Its harvested area reached 174715 acres with a total production of 1594782 tons annually. Superior and Flame are two of the most common early-season grape varieties in Egypt and worldwide. Superior berries are creamy greenish-yellow, whereas Flame berries are light red. They are harvested in late May and exported to Europe, where fresh grapes are scarce at this period of year. Early maturation and harvesting of table grapes might improve their economic value by increasing their export competitiveness to foreign markets. Çoban (2007) mentioned that early harvesting time (only 15 to 30 days earlier than usual) increases total income by 40%.

To produce early or late-season crops, growers have used covered cultivation as a widespread strategy. Even though covered production of perennial trees is less common, glasshouses have been used to protect some fruit crops from winter frosts since the 17th Century (Britz, 1974). Recently, plastic covering has been performed as a promising strategy for grapevines to hasten maturity and harvest time (Çoban, 2007; Alonso *et al.*, 2021). Since covering offers the proper temperatures and accelerates the dates of phenological phases such as grape bud-burst, blooming, veraison, and ripening (Çoban, 2007; Salem *et al.*, 2021). Also, covering is performed to alleviate the adverse effects of climate change that have occurred recently throughout the world, including winter frost, especially after dry and hot summers (Nenko *et al.*, 2019). Covering could shorten the time till ripening than the period in the open field by 10 to 40 days. Depending on the variety, covering date, and environmental circumstances (Di Lorenzo *et al.* 1999). Plastic covering changes the microclimate and gives physical protection to vines and clusters from the negative effects caused by rains, winds, and frost temperature (Chavarria *et al.*, 2010), induces plant productivity, and improves fruit quality (Deus *et al.*, 2016).

On the other hand, changes in temperature, humidity, and light brought on by plastic covering lead to abiotic stress (Rana *et al.*, 2004). Under a plastic covering, the air temperature can reach or surpass 30-35˚C (Uarrota *et al.*, 2020). These high temperatures can cause harmful effects on vegetative development, flowering, pollination, fertilization, fruit set, cell division processes, and photosynthetic rate and may cause an increase in sunburn and berry shrivel incidence and delay ripening, as well as reduce vine yield and fruit quality (Palliotti and Poni, 2016; Uarrota *et al.*, 2020). The genotype could also influence the strength of these impacts (Palliotti and Poniz, 2016). In addition, extreme temperatures, like other abnormal environmental conditions such as drought and salinity, promote the generation of reactive oxygen

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species (ROS), such as hydroxyl radicals (OH^-), superoxide (O_2^-), and hydrogen peroxide (H_2O_2) (Apel and Hirt, 2004). Plant cells have non-enzymatic and enzymatic antioxidant mechanisms to balance generating and scavenging ROS (Apel and Hirt, 2004). Non-enzymatic antioxidant scavengers include ascorbate, glutathione, flavonoids, alkaloids, and carotenoids. Since ascorbate is oxidized by ROS, forming monodehydroascorbate (MDA) and dehydroascorbate, MDA concentration is used as an indicator of lipid peroxidation. Ozden *et al.* (2009) found that MDA levels increased in grapevine leaves with excessive oxidative stress compared to control. On the other hand, enzymatic ROS scavengers in plants include superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione peroxidase (GPX), and catalase (CAT). SODs act as the initial defense line against ROS. Subsequently, APX, GPX, and CAT detoxify H_2O_2. Proline also acts as a singlet oxygen quencher and ROS scavenger (Hayat *et al.,* 2012). The accumulation of proline may serve as a cellular osmotic regulator to protect plants against different abiotic stresses (Ozden *et al.*, 2009).

Therefore, the study evaluated the effects of early plastic covering on the quality of two significant exportable table grape varieties in Egypt. Additionally, Examine the impact of early plastic covering on vegetative growth, photosynthetic activity, and antioxidant levels in grape leaves to assess if the covering causes additional stress on the plants.

MATERIALS AND METHODS

Field conditions and plant material

The experiment was conducted under plastic covering and open field conditions for two early-season grapevine varieties (Flame and Superior). Grapevines were grown at a private orchard at Cairo-Alexandria Desert Rood, Wadi El-Natron, Beheira Governorate, Egypt (30° 19.11 N and 30° 32.01 E). The vines of the two varieties were trellised using the Spanish Barron system. All selected vines for each variety were at the same age (5 years for Flame and 7 years for Superior), had homogenous vegetative growth, were healthy, and were free from visible disorders. Grapevines were planted in sandy soil with a spacing of 2.0 meters between them and 3 meters between rows under drip irrigation. They received standard and recommended agricultural practices for vineyards in this region, including soil fertilization, pruning, Dormex application, and pest control. Vines were pruned in the first week of January. After seven days of pruning, a 5% hydrogen cyanamide (Dormex 0.5% V/V) was applied to promote bud break. Both varieties were grown under either plastic covered (covered), as shown in Photo (1), or the open field without cover (control). Plastic covering was performed using 100 μm thickness and 90% light transmission semitransparent polyethylene film (produced by AL-Kuds for plastic products company, Egypt) after the Dormex application, from mid-January to the end of April. Covering was performed at 330 cm height from the soil surface. The plastic cover was kept closed until the air temperature reached 35°C. At that point, the lateral sheets are wrapped to provide passive ventilation and avoid overheating. Meteorological data in the open field were taken from Sadat City Meteorology Station. A data logger (Tenmars, TM-305U, Taiwan) captured the temperature and humidity under a plastic covering.

Studied parameters were determined on 30 vines of each variety, 15 under a plastic covering and 15 in the open field, during the 2021 and 2022 seasons. Vines were selected in the middle lines to ignore the impact of border lines.

Photo 1. Grapevines under plastic covering conditions

Phenological stages

Phonological stages, including bud-burst, flowering, veraison, and ripening time, were recorded at a 50% progress midpoint for each stage in both seasons.

Vegetative growth

In March, before spring shoot pruning, the shoot length and shoot diameter (measured in the middle of the third internode from the base of the branch) of five random shoots/vine were measured. Ten mature leaves (the 7th leaf from the top of the shoot) from each chosen vine were taken to measure the leaf area using a portable laser leaf area meter (CI-202, CID, Inc., USA).

Chlorophyll content

The relative chlorophyll content (SPAD value) was measured in the fully expanded and mature 30 leaves per treatment using a portable chlorophyll meter SPAD-502 (Konica-Minolta, Osaka, Japan).

Chlorophyll a, b, and total chlorophyll were measured chemically in fresh leaves using 80% acetone as an extraction solvent. Absorptions for the extracts were read by using a UV spectrophotometer (Thermo Spectronic Helios Gamma 9423 UVG 1202E UV-VIS Spectrophotometer, England) at wavelengths of 662, 644, and 440 nm according to Asimovic *et al.* (2016).

Photosynthetic efficiency

A portable chlorophyll fluorimeter (OS-30p, OPTI-SCIENCES) was used to quantify a chlorophyll fluorescence parameter (Fv/Fm) in each treatment on 30 mature, fully expanded leaves at random. For dark-adapted leaves, maximum variable fluorescence (Fv = Fm - F0) and the photochemical efficiency of PSII (Fv/Fm) were determined (Dewir *et al.*, 2015). The portable chlorophyll fluorimeter (OS-30p, OPTI-SCIENCES) was modified to read out the Fv/Fm directly.

Estimation of carbohydrates

A fresh tissue was homogenized with 80% ethanol, heated in a water bath, and filtered. The extract was then dissolved in 20% of water for soluble sugar determination. The anthrone sulphuric acid method was used to determine soluble sugars (Prud'homme *et al.*, 1992). The blue-green color was measured using a UV spectrophotometer at a wavelength of 620 nm in comparison to a blank made up merely of water and anthrone reagent. Polysaccharides were identified using the remaining dry residue after soluble sugar extraction. The hydrolysate was created up to a known volume for polysaccharide analysis. Data were computed from a calibration curve constructed with pure glucose (Whistler *et al.,* 1962). Soluble sugars and polysaccharides were calculated as mg glucose/100g fresh weight.

Estimation of total phenol

According to Lowe (1993), the Folin-Ciocalteau reagent is used to estimate total phenol concentration. The sample is ground in 80% ethanol, centrifuged, and the supernatant collected. The residue is extracted, dissolved in distilled water, and added to test tubes. A volume of 0.5 ml of Folin-Ciocalteau reagent was added. After 3 minutes, 2 ml of 20% $NaCO_3$ solution was mixed well in each tube, and then immersed in boiling water for one minute before being cooled and examined at 650 nm against a reagent blank. The standard curve is created to calculate phenol concentration. The concentration is expressed as mg phenols/100 g fresh weight.

Estimation of proline

The study used a method to measure free proline, which was prepared by heating 1.25g ninhydrin in 30 ml glacial acetic acid and 20 ml of 6 M phosphoric acid (Bates *et al.*, 1973). 1 g Fresh tissue was homogenized, mixed with the ninhydrin solution, heated, and extracted using toluene. The absorbance was measured at 520 nm using toluene as a blank, and proline concentration was calculated as mg proline 100 g^{-1} fresh weight using a standard curve.

Estimation of antioxidant system

250 mg leaf sample was frozen, ground in liquid nitrogen, mixed with phosphate buffer, centrifuged at 15000 rpm and filtered. The supernatant was collected and stored at 4°C for analysis of catalase (CAT) and ascorbate peroxidase (APX) activities.

The CAT activity (EC 1.11.1.6) was measured in a reaction mixture (3 ml) that contained phosphate buffer (50 mM, pH 7.0), 30 % (w/v) H_2O_2, and 0.5 ml of enzyme extract (Aebi, 1984). The catalase enzyme activity was estimated by the decrease of absorbance at 240 nm using a UV spectrophotometer. As a consequence of H_2O_2 consumption, it was expressed according to Havir and McHale (1987) as μM H_2O_2 oxidized g^{-1} fresh weight min^{-1}.

Ascorbate peroxidase activity (EC 1. 11. 1. 11) was assayed according to Asada (1992) using a UV spectrophotometer at a wavelength of 290 nm for 1 min of ascorbic as ascorbic acid oxidized.

Determination of lipid peroxidation

The level of lipid peroxidation was measured in terms of malondialdehyde (MDA) content following Hodges *et al.* (1999) method. 0.2 g leaf sample was homogenized in 5% trichloracetic acid, centrifuged, and then diluted with 0.5% thiobarbituric acid in 20% TCA. The absorbance was recorded at 532 nm, and the MDA content was determined as n mole (MDA) g^{-1} fresh weight.

Yield and fruit quality

Cluster numbers per vine were recorded in March for all selected vines just before adjusting the crop load to 28 and 30 clusters/vine in Superior and Flame, respectively. At commercial maturity of each group (TSS $\geq$ 15 %), clusters were harvested manually, packed in plastic boxes, and transported immediately to the Pomology Laboratory at the Environmental Studies and Research Institute. The cluster weight (g) and small berries (%) were measured for 10 randomly chosen clusters from each vine. Three clusters were randomly selected from each vine to evaluate other physical and chemical characteristics. The weight of 10 berries (g), berry length (mm), and berry width (mm) were determined in a sample of 30 berries collected randomly from each cluster. TSS (%), total acidity content (%), and anthocyanin (mg/100g) were determined in a squeezed sample of 20 berries collected randomly from each cluster. Total soluble solids (%) were obtained with a handheld refractometer (Atago, Japan). Total acidity content was assessed using 0.1 NaOH according to AOAC (2003) and expressed as a gram of tartaric acid in 100 ml juice. Total anthocyanins were extracted from 0.5 g of berry skin by a mixture of 95% ethanol and 1.5 M HCl acid (85:15 v/v) as described by (Iland *et al.*, 2013). Weight loss (%) was measured after 7 days of shelf life at room temperature (23±3°C) for six marked clusters in each treatment.

Statistical analysis

Recorded data was statistically analyzed by independent samples t-test with two growth conditions: early plastic covering (PC) compared to uncovered vines (field condition) for at least ten replicates in each parameter. Separate analyses were done on the data of each variety (Flame and Superior) and season (2021-2022). Statistical analysis was made using the software SPSS version 16 (SPSS, Inc., Chicago, IL, USA) at a 0.05 probability.

RESULTS AND DISCUSSION

The effect of early plastic covering, in comparison to uncovered vines (control), on phenological stages, biochemical parameters, vegetative growth, chlorophyll content, yield, and fruit quality of Flame and Superior table grapes were determined during 2021 and 2022 seasons. Recorded data for air temperature under plastic covering and in the open field from January to April are presented in Table (1).

Table 1. Minimum and maximum temperature (˚C) under plastic covering and in the open field of Flame and Superior grapevines during 2021 and 2022 seasons.

	2021				2022			
	Plastic covering		Open field		Plastic covering		Open field	
	Flame							
Month	min	max	min	Max	Min	max	min	Max
January	9	42	9	27	6	39	3	24
February	8	43	7	27	4	42	3	28
March	9	38	9	36	5	38	3	33
April	10	42	10	44	9	42	9	43
	Superior							
	min	max	min	Max	Min	max	min	Max
January	10	41	9	27	5	40	3	24
February	9	41	7	27	3	39	3	28
March	10	38	9	36	5	45	3	33
April	11	42	10	44	10	40	9	43

Data revealed that the first season (2021) was much warmer than the same period of the second one (2022). Plastic covering caused evident changes in the microclimate in both seasons. Thus, temperature and relative humidity (RH) were higher under PC. The maximum temperature was observed in the afternoon, while the minimum temperature occurred in early morning and night. The relative humidity exhibited a range from 33 to 75 % in the open field, while under PC, it was higher from 92 to 100% (data are not shown). These variations in the ambient microclimate were expected since similar variations in air temperature, RH, wind, rains, sunlight, air CO_2 concentration, and evaporative potential had been recorded in previous works (Tarricone *et al.,* 2020).

Effect of plastic covering on phenological stages

Bud-burst, flowering, veraison, and ripening dates of Flame and Superior grapevines were accelerated by plastic covering (Table 2). Compared to vines in the open field, plastic covers faster bud bursts, about 12 to 14 days in Flame and 12 days for Superior. In addition, covering the vines advanced flowering about 11 and 5 days for Flame and Superior, respectively, in both seasons, which causes early veraison and ripening. Covering hastened the harvest time by 12 days in Flame and 14-15 days in Superior compared to uncovered vines in both seasons. In both varieties, bud-burst, and other phenological stages occurred earlier in 2021 than in 2022 in covered and uncovered vines. This observation could be attributed to higher air temperatures in 2021 compared with 2022 season.

There were no differences in the period length between the bud break and ripening stages of covered and uncovered Flame grapevines since it took 105 & 110 days in PC and 105 & 109 days in the open field in the 2021 and 2022 seasons. Meanwhile, Superior grapevines showed a slight difference; they took 105 and 108 days under PC and 108 and 110 days in the open field during the 2021 and 2022 seasons, respectively. This behavior could be explained as a heritable related trait for each variety more than ecologically affected ones. The positive effect of covering all phenological stages in grapes was emphasized by many previous researchers. Salem *et al.* (2021) reported that covering Flame grapevines hastened all phenological stages and sped up harvesting time by 17–22 days compared to uncovered ones. According to Alonso *et al.* (2021), flame vines require an average of 1633 growth degree days (GDD) from bud break to ripening in the open field, with a base temperature range of 5°C to 30°C. However, within a greenhouse, flame vines only need 1542 GDD.

Table 2. Effect of plastic covering on the dates of the phenological stages (dd/mm) of Flame and Superior grapevines during 2021 and 2022.

phenological stages	2021			2022		
	covered	uncovered	Difference (days)	covered	uncovered	Difference (days)
				Flame		
Budburst	03/2	15/2	12	08/2	22/2	14
Flowering	22/3	02/4	11	30/3	10/4	11
Veraison	12/4	22/4	10	19/4	30/4	11
Fruit ripening	19/5	31/5	12	30/5	11/6	12
Bud break to ripening (days)	105	105		111	111	
				Superior		
Budburst	14/2	26/2	12	18/2	02/3	12
Flowering	28/3	02/4	5	05/4	10/4	5
Veraison	10/5	15/5	5	16/5	22/5	6
Fruit ripening	30/5	14/6	15	6/6	20/6	14
Budbreak to ripening (days)	105	108		108	110	

Effect of plastic covering on vegetative parameters

Data presented in Table (3) revealed that plastic covering caused a significant effect on all studied vegetative growth parameters. The plastic covering has led to a considerable increase in shoot length compared to the uncovered vines. Shoot diameter was markedly greater in the uncovered vines of the Flame and Superior. The leaf area of the uncovered Flame vines was considerably larger in both seasons of the study, but no significant differences were observed between the covered and uncovered Superior vines. Novello and De Palma (2008) attributed shoot growth and stem elongation under covering to the higher thermal-hygrometric regime and lower irradiance available to the foliage, especially in the UV wavelength.

Table 3. Effect of plastic covering on the vegetative parameters of Flame and Superior grapevines during 2021 and 2022.

	2021		P value	2022		P value
	covered	Uncovered		covered	uncovered	
			Flame			
Shoot length (cm)	280.2	165.25	0.005**	243.25	137.50	0.001**
Shoot diameter (cm)	0.91	1.2	0.044**	0.80	1.07	0.01**
Leaf area (cm^2)	129.16	139.13	0.002**	127.21	137.56	0.005**
			Superior			
Shoot length (cm)	197.2	122.3	0.001**	171.75	104.58	0.002**
Shoot diameter (cm)	0.87	0.90	0.801	0.75	0.93	0.248
Leaf area (cm^2)	137.37	139.37	0.234	136.01	137.18	0.583

**** Statistically significant at P ≤ 0.01**

The rapid vegetative growth of covered vines enhanced plant strength and prevented insect infection. The efficacy of prevention was specifically observed for Grape Thrips (*Retithrips syriacus* Mayet), notably during the 2022 season in comparison to vines cultivated in the open field (data are not recorded). The protective mechanism can also be attributed to several other factors, including the mechanical preservation that limits insect infestation and the inappropriate environment created by the plastic covering, which inhibits thrips survival.

Effect of plastic covering on Photosynthetic parameters

The relative chlorophyll content (SPAD value) was measured on the fully expanded and mature leaves. Chlorophyll a, b, and total chlorophyll were also examined using chemical extraction (Table 4). The presented data showed no significant differences between all chlorophyll parameters in the vines grown in the open field or under PC.

Photosynthesis efficiency can be referred to as (Fv/Fm value), which refers to the maximum efficiency of PSII. The decrease in this value signifies a decrease or fall in the efficiency of plant photosynthesis (Dewir *et al.* 2015). Table (4) shows a significant increase in photosynthesis efficiency under plastic covering compared to uncovered in both seasons. The values of Fv/Fm were still in the range of 0.75 and 0.85, which demonstrates that there was no harmful effect of covering on the maximum quantum efficiency of open photosystem II centers of the plants (Bolhàr-Nordenkampf and Öquist, 1993). These results highlight that covered plants overcame the reduction of solar radiation from shading and kept their photosynthetic capacity as uncovered vines. Chavarria *et al.* (2009, 2012) interpret this as covered plants recognizing shading conditions and adapting accordingly by changing their leaf anatomy (as an increase in palisade parenchyma) or increasing their pigment content and, consequently, their photosynthetic potential. Also, there is an advantage in the biochemical pathway due to facilitating stomatal opening and increasing dry mass compared with uncovered plants.

Table 4. Effect of plastic covering on the photosynthetic parameters of Flame and superior grapevines during 2021 and 2022.

	2021		P value	2022		P value
	covered	**Uncovered**		**covered**	**Uncovered**	
Flame						
SPAD value	30.68	30.20	0.711	28.65	29.70	0.814
Chl a (mg/cm^2)	16.85	19.69	0.354	15.54	17.34	0.128
Chl b (mg/cm^2)	3.36	4.63	0.320	4.24	4.90	0.222
Chl t (mg/cm^2)	20.21	24.22	0.086	19.78	22.24	0.153
Fv/Fm	0.781	0.766	0.027**	0.779	0.764	0.045**
Superior						
SPAD value	34.11	30.80	0.029**	33.22	30.82	0.172
Chl a (mg/cm^2)	17.62	16.20	0.211	16.60	15.18	0.121
Chl b (mg/cm^2)	4.78	4.05	0.221	4.29	3.76	0.129
Chl t (mg/cm^2)	22.40	20.25	0.213	20.90	18.94	0.121
Fv/Fm	0.807	0.776	0.081*	0.798	0.769	0.010**

*** Statistically significant at P ≤ 0.05** **** Statistically significant at P ≤ 0.01**

Effect of plastic covering on soluble sugars, polysaccharides, and total carbohydrates

The impact of plastic covering on the levels of soluble sugars, polysaccharides, and total carbohydrates in Flame and Superior fresh leaves is illustrated in Figure 1(a-c). A substantial rise in soluble sugars was noted with plastic covering. The concentration of soluble sugars in Flame and Superior leaves rose by 28.2% and 81.9%, respectively, compared to vines in the open field. By contrast, the concentrations of polysaccharides and total carbohydrates declined in covered vines. The levels of polysaccharides declined by 35.4% and 43.1%. Compared to uncovered ones, Flame and Superior leaves exhibited a reduction of total carbohydrates by 22.5% and 7.1%, respectively. These variations may be due to the easier opening of stomata under plastic cover, attributed to the reduction of the transpiration process with low sunlight and wind under PC (Holcman et al., 2018; de Almeida et al., 2020). In addition, higher levels of soluble sugars in PC may be attributed to cellular respiration and the transformation of disaccharides into monosaccharides (Orak, 2009).

Effect of plastic covering on total phenols and proline

The effects of plastic covering on the endogenous proline content and total phenols in Flame and Superior leaves are presented (Fig 1d&e). Obtained data revealed that total phenols and proline contents were higher in grape vines grown under plastic covering compared to other vines grown in the open field. These findings are in harmony with Kok and Bal (2022), who state that PC increased phenolic content due to the breakdown of cell structure. According to our data, plastic covering could cause additional stress on grown vines, as proline accumulation has been hypothesized to protect plants from stress by its function as a cellular osmotic regulator (Ozden *et al.,* 2009). Also, Proline acts as a singlet oxygen quencher and ROS scavenger (Hayat *et al.,* 2012). The highest values of phenols and proline were recorded in Superior leaves under a plastic covering.

Effect of plastic covering on lipid peroxidation and antioxidant enzymes

Levels of lipid peroxidation in leaf samples, measured as MDA concentration, are shown in Fig.1f. The differences between MDA content in the leaves of covered and uncovered vines were insignificant in both varieties. Higher MDA in covered vines suggests a pronounced disruption of lipid peroxidation in the vines' biomembranes. Flame leaves exhibit higher MDA content in both plastic covering and open field conditions than in superior leaves. This observation may indicate that flame vines are more susceptible to unfavorable effects than superior vines.

The responses of CAT and APX enzymes to plastic covering are given in Fig.1 (g and h). The highest values of CAT and PAX were observed in covered vines compared to uncovered ones in both varieties. The increase in antioxidant enzymes is in parallel with Xia *et al.* (2009) finding that plants protect themselves in stressful conditions by balancing ROS metabolism in cells using antioxidant enzymes.

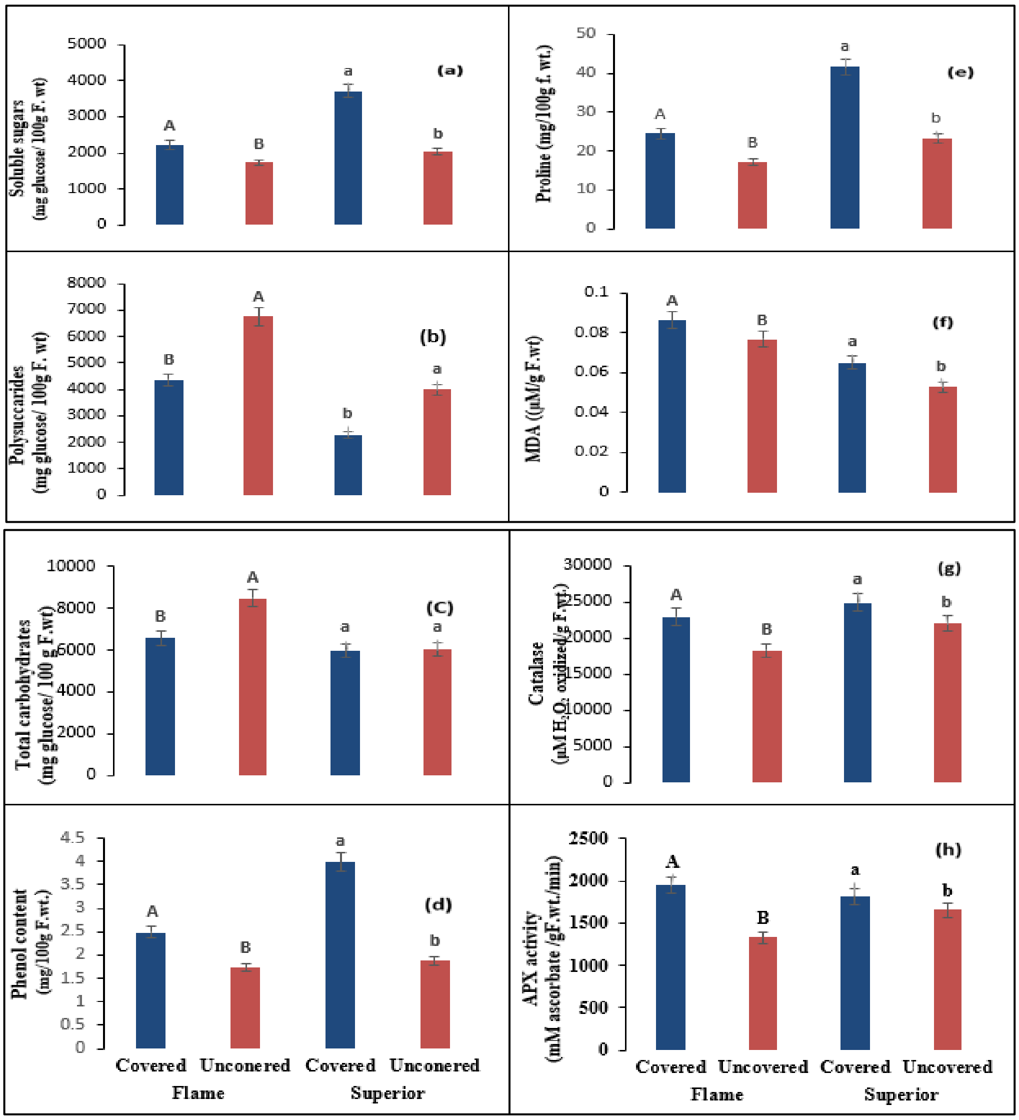

Fig. 1. Changes in soluble sugars (a), polysaccharides (b) and total carbohydrates (c), phenol content (d) and proline (e) and the activity of MDA (f), antioxidant enzymes; CAT (g) and APX (h) in fresh leaves of Flame and Superior grapevines grown under a plastic covering (covered) and in the open field (uncovered) conditions. Data represented are means of three replicates ±S.E.

Effect of plastic covering on physico-chemical parameters of clusters

Regarding the impact of plastic covering on the physical and chemical parameters of the clusters, the data presented in Table 5 indicated that, before adjusting the crop load, there was a significant decrease in cluster number for covered vines compared to uncovered vines. This observation may be attributed to the negative impact of covering on reduced carbohydrate accumulation, which subsequently leads to flower abscission (Li *et al.*, 2022).

In general, there were no significant differences detected between PC and the control on most of the physical and chemical parameters such as cluster weight, weight of 10 berries, forming of small berries (%), berries length and diameter, TSS %, and titratable acidity (%) of both varieties in both years. These results align with the findings of Çoban (2007) on three covered grape varieties in Turkey.

On the other hand, plastic covering harms anthocyanin formation and coloration of Flame clusters. The anthocyanin content in PC was 31.1% and 33.6% lower compared to the uncovered conditions in the 2021 and 2022 seasons, respectively. This reduction suggests that conditions associated with the open field, such as light exposure and temperature, may enhance the production of anthocyanin in grapes. The results for anthocyanin content are in harmony with those obtained by Zheng *et al.* (2013), who reported that sunlight exposure substantially influenced anthocyanin accumulation. Moreover, Feng *et al.* (2015) and Zou *et al.* (2019) found that berry anthocyanin biosynthesis is completely suppressed under dark conditions. Reducing sunshine from veraison to harvest resulted in a reduction in the formation of anthocyanins in Nebbiolo grapes (Chorti *et al.*, 2010)

As shown in Table 5, the presence of plastic covering had a significant impact on berry firmness. The use of plastic covering led to a noteworthy enhancement in fruit firmness and improved its crisp bite compared to the uncovered group in both varieties.

Concerning the weight loss of clusters after seven days of shelf life at room temperature at 22 ± 3ºC, the highest weight loss was recorded in clusters of the uncovered Flame, while there were no significant differences in Superior in both seasons. In general, fruit weight loss is caused by a lack of moisture caused by transpiration, respiration, and a deficit in vapor pressure between the ambient air and the fruits. The effectiveness of PC in decreasing weight loss may be due to the relative increase in the firmness of covered fruits, especially in Flame, which has a thinner peel than Superior berries.

Table 5. Effect of plastic covering on physico-chemical parameters of Flame and Superior grapevines during 2021 and 2022.

Characteristics	2021		P value	2022		P value
	Covered	Uncovered		covered	Uncovered	
			Flame			
Cluster no./ vine	52.3	92.3	0.006**	49.7	83.2	0.002**
Cluster weight (g)	412.7	454.1	0.450	419	380	0.304
Weight of 10 berries (g)	38.8	43.5	0.251	38.3	42.0	0.130
Small berries (%)	1.26	1.98	0.682	1.34	2.20	0.454
Berries diameter (mm)	19.8	19.1	0.562	19.5	18.8	0.687
TSS (%)	16.5	15.4	0.352	17.0	16.1	0.424
Tartaric acid (%)	0.58	0.61	0.381	0.58	0.60	0.542
Anthocyanin (mg/L)	552.3	801.2	0.015*	528.2	795.0	0.018*
Firmness	12.4	10.8	0.017**	12.3	10.6	0.036**
Weight loss (%)	11.66	14.35	0.003**	10.02	15.48	0.001**
			Superior			
Cluster no./ vine	42.2	55.2	0.004	42.3	58.4	0.002
Cluster weight (g)	457	521	0.366	437	534	0.227
Weight of 10 berries (g)	59.2	52.3	0.123	61.0	50.0	0.155
Small berries (%)	0.95	1.07	0.226	1.20	1.49	0.139
Berries diameter (mm)	21.53	19.40	0.218	21.41	19.33	0.109
Berries length (mm)	21.2	22.7	0.198	22.0	23.5	0.169
TSS (%)	16.0	14.9	0.371	15.7	14.3	0.492
Tartaric acid (%)	0.612	0.770	0.155	0.632	0.752	0.195
Firmness	13.0	12.1	0.029*	14.2	12.4	0.004**
Weight loss (%)	12.23	14.14	0.096	13.04	15.88	0.065

*** Statistically significant at $P \leq 0.05$** **** Statistically significant at $P \leq 0.01$**

CONCLUSION

This study indicates that plastic covering demonstrated greater efficacy in accelerating phenological stages (such as budburst, blooming, veraison, and ripening time). Additionally, using plastic covering caused additional abiotic stress, as evidenced by increased levels of soluble sugar, total phenols, proline and MDA content in vine leaves in addition to a significant decrease in carbohydrate content and polysaccharides. Furthermore, applying plastic covering helped maintain fruit quality and reduce fruit weight loss during shelf life. Conversely, using plastic covering reduced anthocyanin concentration within the berries of the colored variety (Flame). Hence, additional studies are necessary to enhance the pigmentation of grapes grown under plastic to have a favorable appearance for consumers. The utilization of a periodic system between covering and uncovering intervals should be considered and examined to maintain vine health and increase total income.

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التغطية البلاستيكية تسرع المراحل الفينولوجية وتسبب إجهادًا لاحيويًا في عنب المائدة في مصر

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الملخص

تواجه مصر، مثل غيرها من دول العالم، تغيرات مناخية تهدد اقتصادها وأمنها الغذائي. ويلجأ مزارعو العنب والمصدرون لحماية كروم العنب من المناخ المحلي غير الملائم باستخدام التغطية البلاستيكية. أجريت هذه الدراسة لتقييم تأثير التغطية البلاستيكية المبكرة من منتصف يناير إلى نهاية أبريل، على المراحل الفينولوجية، والمحصول، وجودة الثمار لعنب المائدة الخالي من البذور صنف فليم وسوبريور. أيضًا، لمعرفة ما إذا كان التغطية يمكن أن تسبب ضغوطًا إضافية على كروم العنب من خلال تقييم تأثيرها على النمو الخضري، ومحتوى الكلوروفيل، وكفاءة التمثيل الضوئي، وكذلك الكربوهيدرات، والبرولين، والفينولات الكلية، وبيروكسيد الدهون، والكاتاليز، ومحتوى بيروكسيديز الأسكوربات في الأوراق. تشير نتائج أبحاثنا إلى أن التغطية البلاستيكية المبكرة تسرع جميع المراحل الفينولوجية؛ بالإضافة إلى ذلك، فإنها تسبب إجهادًا غير حيوي، مما يؤدي إلى زيادة محتوى السكر القابل للذوبان، والفينولات الكلية، والبرولين في أوراق العنب المغطى. عند الحصاد، لم يؤثر التغطية البلاستيكية على معظم صفات جودة الثمار، مثل وزن العنقود، ونسبة الحبات الصغيرة (%)، ونسبة المواد الصلبة الذائبة الكلية، والحموضة القابلة للمعايرة (%). ومع ذلك، فقد أدى استخدام البلاستيك إلى خفض محتوى الأنثوسيانين في حبات العنب الفليم بنسبة ٣١,١٪ و٣٣,٦٪ في الموسمين الأول والثاني على التوالي، مقارنة بالمجموعة غير المغطاة.وفي الختام، يمكن التوصية باستخدام البلاستيك كاستراتيجية جيدة لمكافحة تغير المناخ وتسريع حصاد العنب. الا انه مازال هناك حاجة إلى مزيد من البحث لتحسين تصبغ العنب المزروع تحت البلاستيك لتوفير مظهر جذاب للمستهلكين.

الكلمات الدالة: Vitis vinifera؛ النضج؛ المناخ المحلي؛ إنزيمات مضادة للأكسدة؛ البرولين