Bulgarian Journal of Agricultural Science, 22 (No 6) 2016, 942–947
Agricultural Academy

EFFECTS OF FILMS ON TABLE GRAPES: ITALIA AND RED GLOBE CULTIVARS

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Abstract

DI VAIO, C., R. RUSSO, S. NOCERINO, I. DI MOLA and F. FAMIANI, 2016. Effects of films on table grapes: Italia and red globe cultivars. *Bulg. J. Agric. Sci.*, 22: 942–947

The new cultivations of table grape are conducted in protected conditions under plastic films, which enable early or delayed harvesting. The aim of this work was to evaluate the effects of three coloured plastic films (white, yellow and red) on vegetative and productive behaviour of two cultivars of table grapes, Italia and Red Globe. The study was carried out in Turi (BA) on vineyards in full production. The parameters evaluated were: PPFD and temperature under the films, index of Huglin, length of shoot, number of leaves/shoot, leaf area yield per vine, cluster and berry weight, soluble solids content, pH, titratable acidity, polyphenols, anthocyanins, ascorbic acid content and total antioxidant activity. The lower transparency to sunlight of yellow and red plastic films caused a slight reduction of light intensity. In both cultivars the reduction of light intensity did not significantly affect vegetative growth and yield. The grapes grown under the yellow and red coloured films had a much higher total antioxidant activity with respect to those grown under the white one (+86 and +91% respectively for cultivars Italia and Red Globe under yellow film and +72 and +48% respectively for cvs Italia and Red Globe under red film).

Highlights

Table grapes of cv Italy and Red Globe were grown under colored plastic films
Plastics films have led to less transparency of light
The colored films did not have negative effects on growth and yield of the two cultivars
The grapes grown under coloured films had higher values of total antioxidant activity

Key words: table grapes, plastic film, PAR, antioxidant activity

Introduction

In Italy, according to official data 2012 ISTAT, table grapes are planted on about 68 000 ha, with a total production of 1 410 000 tonnes. Italy is fourth largest producer after China, Turkey and Iran. The Apulia Region accounts for 66% of the entire national area and about one-third is produced in semi-forced systems (Novello and de Palma, 2008; de Palma et al., 2004). The possibility of higher returns for producers has led to an advance or a lengthening of the harvest date, giving greater competitiveness on national and international markets. The harvest time is advanced or lengthened by semi-forcing, i.e., temporarily covering the vineyard with flexible plastic films. Depending on the purpose and timing, there are essentially two different semi-forcing techniques: "early semi-forcing" and "late semi-forcing". The purposes of using plastic films cover are: to increase the thermal regime to anticipate vegetative growth and, consequently, maturation; to protect the plants from atmospheric agents, in particular rain and hailstorms, in order to preserve the integrity and health of the cluster; and to anticipate or delay the harvest time (Di Lorenzo and Sottile, 1995; Novello et al., 1999). Ethylene-vinyl-acetate (EVA) or polyethylene (PE) films are the best materials for protecting tree crops (Schettini et al., 2009). Polyethylene (PE) film is relative-

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ly economical, has good transparency to sunlight, a long lifetime and good plasticity. In order to further improve the performance of these materials, especially in terms of durability, anti-photo-oxidant (anti-UV) agents are added; to effective drip, surfactants are added, and for thermal effect, mineral fillers are added (Vedrani and Magnani, 1994). Recently, research in the field of roofing materials has been directed toward the development of photo selective film which has the ability to filter specific, different wavelengths of solar radiation. The concept is to develop films with a different transparency to sunlight and increased mechanical strength. Research has not given the same results on the response agronomic and production of grape cultivars (De Souza et al., 2015; Tarricone et al., 2014; Novello and de Palma, 2008) because the genetic component is of significant importance in the response to covering with plastic film (Vox et al., 2014; Schettini et al., 2009; Novello et al., 2000), consequently it was decided to test the behaviour of two of the most popular commercial cultivars of table grapes, Red Globe and Italia. Three different colours of plastic films were used and the vegetative and productive responses of vines were measured. The effect of the plastic films on some nutritional and quality parameters of the grapes was also studied.

Materials and Methods

The tests were conducted in Turi (Bari) (latitude 40°55' North, longitude 17°03' East) on adult plants (12 years old) of cv. Italia, a white grape, and cv. Red Globe, a red grape, both grafted onto rootstock 140 Ruggeri. The vineyards were trained to "pergola type Apulia", with a distance of 2.30 × 2.30 m and a density of 1,890 plants per hectare. Three plastic films of different colours were compared: white (Low Density Polyethylene, thickness 160 micron) used as control and red (Low Density Polyethylene, thickness 200 micron) and yellow (Low Density Polyethylene, thickness 200 micron) photoselective films, having different transparency to sunlight and increased mechanical strength. All plastic films were obtained from Plastik Spa, Bergamo (Italy). The grapes were covered in late winter before bud burst (on March 18). Each treatment consisted of seven rows with 15 plants each. Within each treatment, sensors and data loggers were installed (Tinytag Plus 2) for the continuous acquisition of microclimatic data (maximum, minimum and average temperature and humidity) in order to determine whether there were differences between the different films. The sensors were positioned just below the vegetative wing to monitor the microclimate in the area where the grapes develop. Using the average maximum daily temperature from sprouting, the thermal sum was calculated using the Index of Huglin (IH), with coefficient k equal to 1.02 for the three covers (Huglin, 1986). During the vegetative-productive cycle the following measurements were made on 120 plants (20 × 3 plastic films × 2 cultivars): length of shoots (cm), number of leaves/shoot, leaf area (cm^2), shoot leaf area (cm^2), yield per vine (kg), cluster and berry weight (g). At the end of July and beginning of August measurements of the photosynthetically active photon flux density (PPFD $\mu mol\ m^{-2}\ s^{-1}$) were made during the day, using a PAR sensor (LICOR-190 Quantum Sensor). For each treatment (50 berries per 3 repetitions) the following parameters were determined: soluble solids content (°Brix), titratable acidity (g/l) and pH of the juice. In the final stage of maturation, on the juice of the grapes (300 berries per 3 repetitions), the following parameters were determined: total polyphenols (mg/l gallic acid), anthocyanins (mg/l malvidine-3-glucoside) and ascorbic acid (mg/100 ml) contents and total antioxidant activity (mmol trolox/l). All data were subjected to analysis of variance (ANOVA) and the means were separated using the Tukey test ($P \leq 0.05$), with the statistical software XL-STAT.

Results

PPFD and temperatures measurements under plastic films

The PPFD measurements showed that in the hours of maximum light intensity the plastic films retained a greater amount of light, resulting in lower light transparency than the

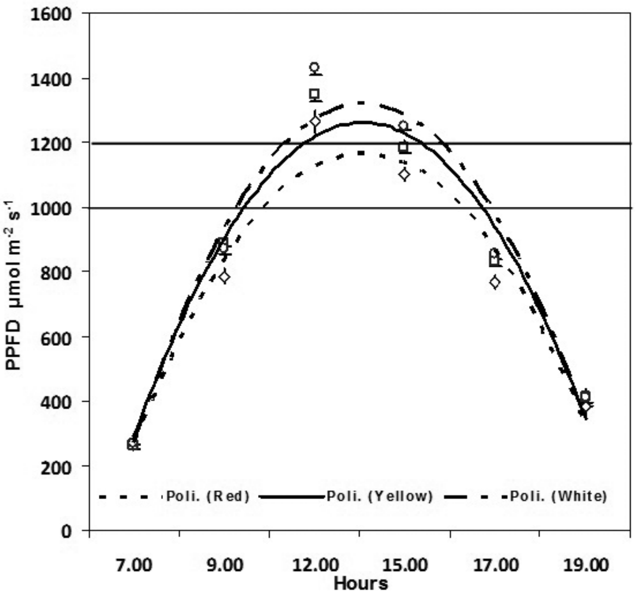

Fig. 1. Effect of plastic films on PPFD (average measurements in July and August) for Italia cultivar. The two horizontal lines indicate the range of the saturation of light

white film. The values of PPFD were slightly lower particularly for the red film. These differences tended to decrease, and almost to disappear, in the first and last hours of the day (Figure 1). Despite the differences in transparency, all the films allowed the light saturation point to be reached in the outer layer of the canopy, thus ensuring maximum photosynthetic activity.

The temperatures under the three plastic films did not appear to be affected by the different transparencies, in fact

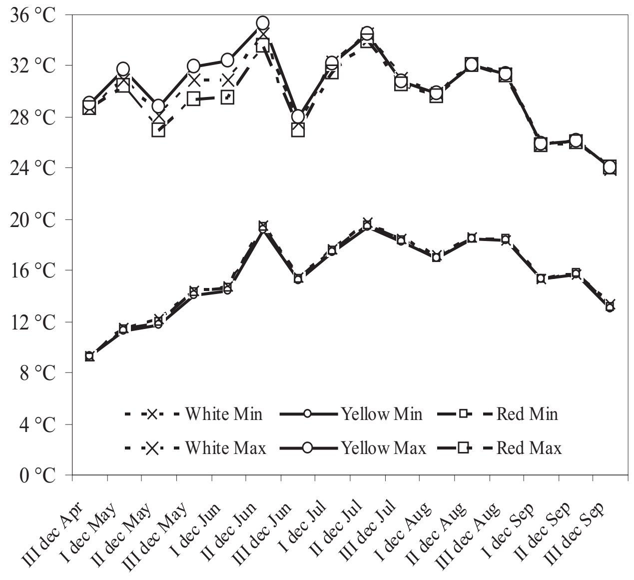

Fig. 2. Daily maximum and minimum temperatures recorded under the three plastic films for Italia cultivar

the curves of the three trends overlap exactly; maximum temperatures showed only slight differences until the second decade of June (Figure 2). This was probably due to the different vegetative cycle of the plants under the cover. In fact, from late April to mid-June, when the canopy was still quite small, the influence of different light transparency of the three plastic films was more evident: the less transparent red film showed lower temperatures, while the white and yellow films had higher values and were similar to one other. In the later stages, the vegetative growth appears to have reduced the heating effect of solar radiation. At the end of the season the accumulation of the thermal sum calculated according to the Index of Huglin was 2814.3 for the yellow film, 2782.7 for the red film and 2712.5 for the white film. There were no significant differences for relative humidity among the different plastic films; the average value for all three plastic films was around 69%.

As expected, the trend for the temperature and humidity data for cv Red Globe was quite similar to the one for cv Italia. At the end of the season the accumulation of degree days calculated according to the Index of Huglin was, respectively: 2633.0, 2628.9 and 2612.8 for the white, yellow and the red films.

Vegetative and productive characteristics

For cv Italia, at the end of the growing season, the length of the shoot and leaf area per shoot under the red film were significantly lower than those under the yellow film, while there was an intermediate response under the white film; there were no significant differences between the treatments in relation to the number of leaves per shoot and leaf area (Table 1).

Table 1
Shoot characteristic for the different plastic films: Italia cultivar. In each line, numbers followed by different letters are statistically different at $p \leq 0.05$

Parameters	White Film	Yellow Film	Red Film
Shoot length (cm)	180.26 ab	183.83 a	176.98 b
Leaves (n° $shoot^{-1}$)	18.04 a	18.77 a	17.78 a
Leaf area (cm^2 $leaf^{-1}$)	313.32 a	312.52 a	311.72 a
Shoot leaf area (cm^2 $shoot^{-1}$)	5652.29 ab	5866.00 a	5542.38 b

For Red Globe, at the end of the vegetative cycle (Table 2), only shoot length showed significant differences, with the white plastic film having the highest values though not statistically different from that of the yellow film. Neither of the other three vegetative parameters were significantly different, although in absolute terms the plants grown under the red cover had the lowest values.

Table 2
Shoot characteristics for the different plastic films: Red Globe cultivar. In each line, numbers followed by different letters are statistically different at $p \leq 0.05$

Parameters	White Film	Yellow Film	Red Film
Shoot length (cm)	211.60 a	208.50 ab	203.80 b
Leaves (n° $shoot^{-1}$)	19.020 a	18.43 a	17.96 a
Leaf area (cm^2 $leaf^{-1}$)	335.43 a	334.76 a	333.92 a
Shoot leaf area (cm^2 $shoot^{-1}$)	6380.31 a	6169.63 a	5995.72 a

For cv Italia, the average production was about 25.0 kg per vine, with no significant differences among the treatments; likewise the average berry and cluster weight was not significantly different, even though the red plastic film gave the absolute lowest values (Table 3). The average values of vine production, for Red Globe, were significantly higher (37.8 kg per vine) than those of cv Italia (24.9 kg). Also in the cv Red Globe there were not differences between the covers for the yield per vine (Table 4). There were only significant differences between the covers for cluster weight: the red film gave the lowest value, even if, with this film, the average number of clusters per vine was higher (32.1 vs. 31.3 and 30.5 for yellow and white film).

Table 3
Production characteristics for the different plastic films: Italia cultivar. In each line, numbers followed by different letters are statistically different at $p \leq 0.05$

Parameters	White Film	Yellow Film	Red Film
Berry weight (g)	8.26 a	8.43 a	8.03 a
Cluster weight (g)	775.6 a	779.0 a	741.0 a
Vine production (kg)	25.0 a	25.4 a	24.4 a

Table 4
Production characteristics for the different plastic films: Red Globe cultivar. In each line, numbers followed by different letters are statistically different at $p \leq 0.05$

Parameters	White Film	Yellow Film	Red Film
Berry weight (g)	11.91 a	11.99 a	11.41 a
Cluster weight (g)	1261.0 a	1226.0 ab	1138.0 b
Vine production (kg)	38.4 a	38.3 a	36.5 a

Regarding soluble solids content, from the beginning of August, the grapes of Italia cv under the red film had the lowest values, even though the trend was similar for all three plastic films, with a phase of rapid accumulation between mid-July and mid-September; the values under all three plastic films were about 17°Brix (Figure 3). In relation to titratable acidity, the three curves showed a similar trend, with a peak in the middle of July followed by a decrease more or less constant from the beginning stage of veraison, reaching to ripening, in all three cases, the values of about 2.5 g/l of tartaric acid (Figure 4).

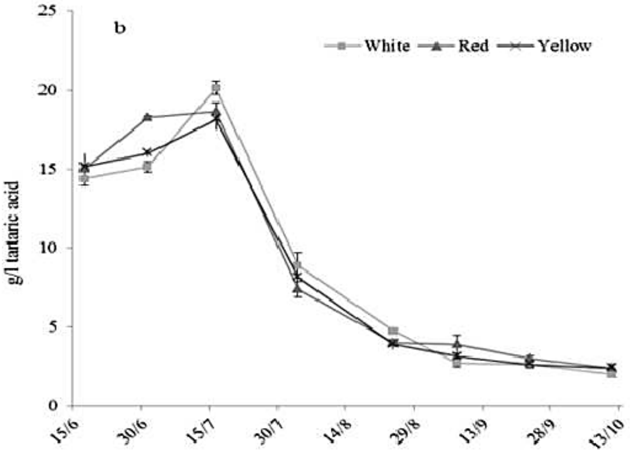

Fig. 4. Titratable acidity of grapes under the three plastic films: Italia cultivar (mean ± S.E.)

The trends of sugar content and titratable acidity of Red Globe were similar to those of Italia: for the first one (Figure 5) the trend increased until the last week of September when it reached a maximum value of 16°Brix, which was slightly lower than that of Italia cv (17.2° Brix); for the second one (Figure 6), the values measured for the juice obtained from plants grown under the white film were initially statistically higher than those of the coloured films, but the pattern of the three covers was similar. The trend was similar to that of the

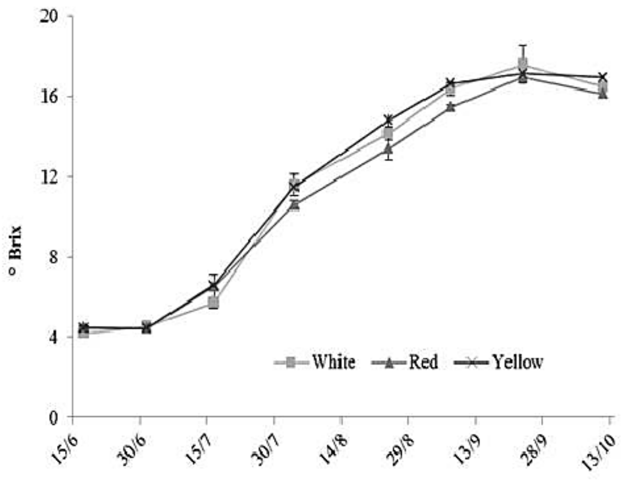

Fig. 3. Soluble solids content of grapes under the three plastic films: Italia cultivar (mean ± S.E.)

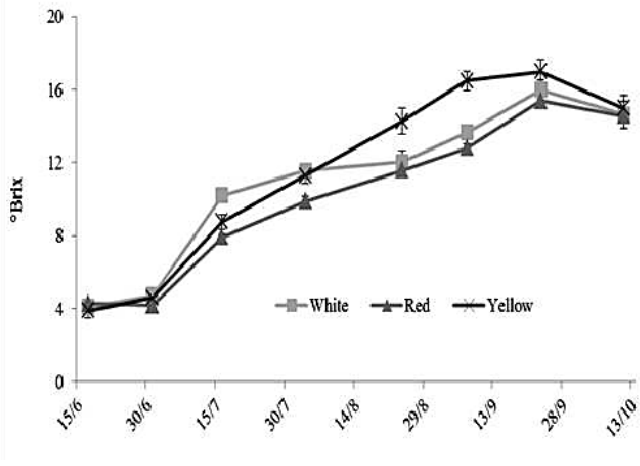

Fig. 5. Soluble solids of grapes under the three plastic films: Red Globe cultivar (mean ± S.E.)

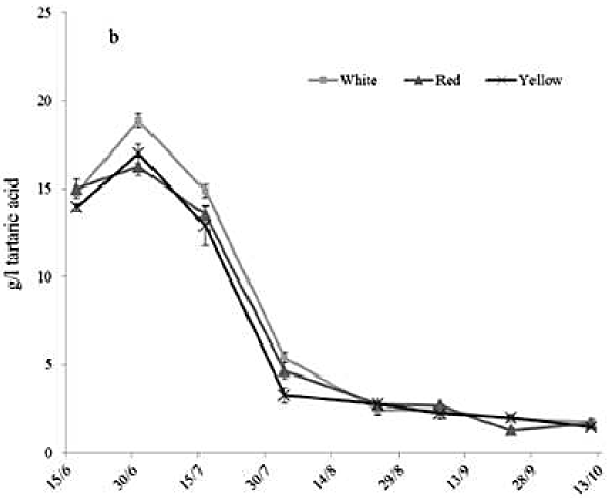

Fig. 6. Titratable acidity of grapes under the three plastic films: Red Globe cultivar (mean ± S.E.)

cv Italia, although the peak was slightly earlier (early July) and the last measurements of titratable acidity were slightly lower, about 1.6 g/l of tartaric acid.

The quality and nutritional characteristics of the Italia grapes determined on the juice are shown in Table 5. There were no significant differences in total polyphenol content and ascorbic acid, while significant differences were found for the total antioxidant activity, in fact, for the latter parameter, the values of yellow and red films were significantly higher than that of the white film.

Table 5
Quality and nutritional characteristics of grapes for the different plastic films: Italia cultivar. In each column, numbers followed by different letters are statistically different at $p \leq 0.05$

Treatment	Total polyphenols	Ascorbic acid	Total antiox. activity
	(mg/l gallic acid)	(mg/100 ml)	(mmol trolox/l)
White Film	103.28 a	3.09 a	7.38 b
Yellow Film	109.62 a	3.12 a	13.75 a
Red Film	105.42 a	3.08 a	12.69 a

Regarding the quality and nutritional characteristics, also for the cv Red Globe the only statistically significant difference was for total antioxidant activity; the white film, having the lowest value from the other two films (Table 6). Averagely for the total antioxidant activity of Red Globe the value was lower than cv Italia (8.51 vs. 11.27 mmol/l, respectively). The total polyphenol content did not differ significantly for the three films, but was significantly lower than the average of cv Italia.

Discussion and Conclusions

The yellow and red plastic films were less transparent than the white film, especially red film, but this condition did not determine a great influence on tested vegetative and productive parameters, as they all slightly decreased, in accord with results of Novello et al. (2005). The effect of lower transparency of coloured films on qualitative characteristic of the two grapes was less evident: the values of soluble solids content, so as that of titratable acid, are perfectly in line with those reported in the literature (de Palma et al., 2004) and with the O.I.V. resolution (2008). As reported for other species (Ordidge et al., 2010), the yellow and red plastic films determined a positive effect on grape nutritional quality, in terms of increased total antioxidant capacity, as the recorded values were lower than those reported by Wang et al. (1996), while the values of total polyphenol contents were similar to the values reported by Moretti et al. (2008).

The results of this study confirm the lower transparency to sunlight of coloured plastic films, especially for the red film. However, none of the three films compromised photosynthetic efficiency, since the radiation level to the leaves always reached the saturation point, thus ensuring the highest photosynthetic activity.

As the different behaviour of the coloured plastic films and different microclimatic conditions under those covers did not induce significant changes in the quantitative parameters of the production for both cultivars, the use of one of three plastic films, in particularly the red one, would seem to be related to the film technical characteristics and especially to their duration in time. Considering

Table 6
Quality and nutritional characteristics of the grapes for the different plastic films: Red Globe cultivar. In each column, numbers followed by different letters are statistically different at $p \leq 0.05$

Treatment	Total polyphenols	Ascorbic acid	Anthocyanins	Total antiox. activity
	(mg/l gallic acid)	(mg/100 ml)	(mg/l malvidine-3-glucoside)	(mmol trolox/l)
White Film	56.62 a	3.01 a	18.67 a	5.78 b
Yellow Film	62.58 a	3.12 a	19.09 a	11.12 a
Red Film	61.22 a	3.11 a	19.41 a	8.63 a

the nutritional profile, a relevant aspect for consumers, it is important to emphasise that the grapes produced in both cultivars under the yellow and red films, showed a higher nutritional value due to higher values of total antioxidant activity. Since no changes in ascorbic acid and total polyphenol content were recorded, the films could have affected the composition of polyphenols, by increasing those having a higher antioxidant activity, and not their total amount.

Acknowledgements

The research was financed with funds from the Apulia Region (Project n. CK7P8F8).

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Received August, 3, 2016; accepted for printing November, 1, 2016