EFFECTS OF DIFFERENT PLASTIC SHEET COVERINGS ON MICROCLIMATE AND BERRY RIPENING OF TABLE GRAPE CV 'MATILDE'

EFFETS DE DEUX COUVERTURES PLASTIQUES DIFFÉRENTES SUR LE MICROCLIMAT ET LA MATURATION DU RAISIN DE TABLE « MATILDE »

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Abstract: Two types of plastic cover (LDPE + EVA and LDPE + HDPE) were tested to assess their radiometric properties and the influence on the vegetative and reproductive performances of 'Matilde' table grape. Films showed the same transmittance to short infrared waves, but LDPE + EVA had a higher transmissivity to visible, PAR and short infrared wavelength ranges of solar radiation, especially as for the « direct » light component. In comparison to the open field, covering increased GDD accumulation and advanced budbreak by 12 days (LDPE + HDPE) or 20 days (LDPE + EVA). Commercial ripening (14 °Brix) was advanced by 8 and 22 days, respectively. Must acidity was higher in open field than under LDPE + EVA. Yield per vine increased under LDPE + EVA, although not at a significant level; bunch mass was higher under LDPE + EVA than in open field. Berry mass was maximum under LDPE + EVA and progressively decreased under LDPE + HDPE and in open field. Under covering, the pruning cane mass increased by 63% with LDPE + EVA and 43% with LDPE + HDPE.

Résumé : Deux types de couverture plastique à base de polyéthylène à basse densité, associé à du éthylènvinylacétate dans un cas (LDPE+EVA) et dans l'autre à du polyéthylène à haute densité (LDPE + HDPE), ont été testés en Italie du Sud pour connaître leurs caractéristiques radiométriques et leurs effets sur le cycle phénologique et sur la production d'un cépage, « Matilde », à raisin de table précoce. Les deux films ont la même transmittance aux infrarouges longs, mais le type LDPE + EVA transmet mieux la radiation solaire visible, le PAR et les rayons infrarouges courts, surtout en ce qui concerne le composant « direct » de la radiation. Par rapport au secteur du vignoble sans couverture, la somme des températures au-dessus de 10°C a été constamment supérieure jusqu'à la fin du mois d'août. Le bourgeonnement fut avancé de 12 et 20 jours et la maturité commerciale (14 °Brix) de 8 et 22 jours par LDPE + HDPE et par LDPE + EVA respectivement. Le rendement fut augmenté par LDPE + EVA mais ne fut pas modifié de façon significative ; la masse de la baie et de la grappe fut plus élevée dans le secteur couvert avec le film plus transparent par rapport à celui à base de LDPE + HDPE et surtout à l'air libre. Le bois de taille en fin de saison était supérieure de 63 et 43 % (respectivement pour LDPE + EVA et LDPE + HDPE) par rapport au plein champ.

Key words: protected cultivation, plastic radiometric properties, harvesting advance.

Mots-clés : vignobles couverts, caractéristiques radiométriques des couvertures plastiques, avancement de la vendange.

INTRODUCTION

Plastic coverings are mainly utilized in Southern Italy to induce the early ripening of table grapes trained to the tendone system with a flat top trellis. From mid-late winter until blooming, the vineyard is completely covered with plastic sheets. This protective structure has the function of elevating the mean air temperature by limiting both convective and radiative thermic dispersion. This effect is due to the reduction of air movement induced by the closed structure, and to the limitation of thermic radiations emitted as infra-red (IR) long radiations (>3000 nm) by the internal surfaces inside the protected structure (TAKAKURA 1989). The increase of the mean air temperature

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stimulates early budbreak thus promoting most of the earliness of berry ripening which may be obtained under given environmental conditions (LAVEE 1994; NOVELLO *et al.* 1999; DI LORENZO *et al.* 1999).

For agronomical purposes, the thermic effect of a plastic film is conventionally estimated by measuring the light transmission in the IR long 7500-12500 nm radiation range including energy emitted from the soil, vines and other solid bodies at room temperature inside the covering (HANAN *et al.* 1978; UNI 9298, 1988; LA MALFA and MAGNANI 1994). The optimum material for crop protection must have a high transparency to solar radiations (80-90 p. cent) and a minimum transmission of IR long radiations (20-60 p. cent) emitted from surfaces inside the covering (FALLERI and MAGNANI 1991; SCARASCIA MUGNOZZA *et a*l. 1997).

As blooming time approaches, the air temperature rises and overheating may occur under the covering. Air temperatures above 30°C may have a negative influence on vine reproductive processes, such as flower opening and pistil pollination, ovule fertilization and berry cell multiplication (WINKLER *et al*. 1974; KLIEWER 1977). These high temperatures may also negatively affect berry development and the carbohydrate distribution to the cluster; moreover, among other effects of high temperatures on fruit growth and composition, the decrease of juice acidity is also well-known (HALE and BUTTROSE 1974; SEPULVEDA *et al.* 1986). On the whole, viticulturists believe that temperatures above 30°C may lengthen the blooming stage and bloom-ripening period, causing some lost of precocity in berry ripening. When the air temperature becomes too warm, the lateral sheets are wound up to allow a natural ventilation and reduce overheating.

The performance of the covering material is related to its spectroradiometric properties which, in turn, depend upon its chemical composition. Among the plastic materials available, polyethylene is widely used to make cover films for horticultural crops. Polyethylene has some desirable traits, such as high transparency to solar radiation, extended durability, low cost and particular suitability for trade-processing; on the contrary, it has a reduced ability to restrain thermic radiations, and thus other substances are commonly added to the basic polymer, such as mineral agents (silicates, phosphates, silico-aluminates, etc.), vinylacetate (VA) or ethylenvinylacetate (EVA), which have a tendency to limit the losses of thermic radiations (HANRAS 1970; RAVIV and ALLINGHAM 1983).

In the past, plastic films obtained by mixing low density polyethylene and ethylenvinylacetate (LDPE + EVA), or by spreading low density polyethylene onto a texture of high density polyethylene (LDPE + HDPE), have been extensively utilized in Southern Italy. The aim of the present work was to evaluate the radiometric properties of these plastic sheet coverings and their influence on some of the principal microclimatic parameters which may affect the vine growing cycle, the ripening process, the yield components and the berry quality of one of the most important table grapes grown in Southern Italy.

MATERIALS AND METHODS

This trial was carried out in 1997 on three blocks of *Vitis vinifera* L. cv. ‘Matilde’ (‘Italia’ x ‘Cardinal’) grafted onto 775 P in 1992 at a commercial farm in Corato (Bari province, Apulia, Italy). The vineyard was trained to a two-cane pruned tendone system; the plant density was 1736 vines per hectare (2.4 x 2.4 m apart). Each block was 8266 m^2 (84.0 x 98.4 m). In the last week of February, two blocks were completely covered using the following plastics: LDPE + EVA added to other patented substances (main strip 190 µm thick, 210 g/m^2 specific weight), and LDPE + HDPE (main strip 210 µm thick, 145 g/m^2 specific weight); the LDPE is commercially marketed as Orolene® (DANIPLAST s.r.l., Modugno, BA). The third block remained uncovered. The microclimatic conditions of the three blocks at canopy height were automatically recorded by means of an electronic system (CSIA, Cerignola, FG, Italy) composed of a data logger (SM 4000) provided with sensors measuring air temperature (LM 35), relative air humidity (HC 200) and active photosynthetic radiation (C 102 R). In order to compare the effective air temperature in the three blocks, the growing degree days (GDDs: air temperature >10°C) were calculated according to WINKLER and WILLIAMS (1939), starting on March 1.

The radiative properties of the plastic materials were analyzed in the laboratory and in the field as a function of the light wavelength (PAPADAKIS *et al.* 1997). The direct transmissivity of the 200÷1100 nm wavelength range was measured by means of a Perkin-Elmer UV-VIS Lambda 2 spectrophotometer. An integrating sphere was used in order to measure the total transmissivity which included the diffused part of the transmitted radiations. The transmittance was calculated, as an average value, for the wavelength ranges of visible radiations (VR: 380-760 nm), active photosynthetic radiations (PAR: 400-700 nm), and short wave infrared radiations (SWIR: 760-1100 nm). The transmissivity in the 3000-25000 nm infrared range (long wave infrared, LWIR) was measured by means of a Perkin-Elmer FT-IR 1760 X spectrophotometer. The transmittance was calculated, as an average value, for the 7500-12500 nm wavelength interval, according to the standard UNI 9298 (Italian Standard Normative for plastic covering characteristics).

The phenological stages (BAGGIOLINI 1952; EYNARD *et al.* 1978) were periodically evaluated for eight randomly chosen vines per block. As the maximum air temperature under cover was close to 30°C, the lateral sheets were partially wound up during the central part of the day to allow natural ventilation and limit excessive air warming. One week after the end of the blooming stage, a seasonal irrigation volume of 2500 m^3 ha^{-1} was initiated by means of drip irrigation.

From July to mid-August, that is, during the last 35 days preceding the normal date of 'Matilde' harvesting in an open field, the total soluble solid concentration (t.s.s.) was periodically measured on a sample of 50 berries randomly chosen from the same eight single vines previously individuated in each block. Berry ripening was assumed to be 14 °Brix t.s.s., which is the reference point for commercial harvesting of cv. 'Matilde'. At the commercial harvest, titratable acidity (t.a.), berry mass, berry diameters, bunch mass and yield per vine were also measured. After the leaf fall, the pruning cane mass per vine was measured. The fruit yield/pruning cane mass ratio (Ravaz index) was calculated in order to evaluate the vegetative-reproductive efficiency. Data were statistically analyzed by means of GLM and Duncan test procedures of the SAS software package (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

In the open field, 'Matilde' showed a 50% budbreak on April 3 (table I). Vines under LDPE + EVA covering sprouted 20 days earlier than those in the open field and 8 days earlier than those under LDPE + HDPE covering. According to the GDD accumulation curves, the effective air temperatures were higher under the covering than in the open field while, regarding the two types of covering, no relevant difference was observed which could explain the earlier budbreak with LDPE + EVA covering (figure 1). The mean relative air humidity was higher under the covering (60-65 p. cent) than in the open field (55-60 p. cent); this tendency was more evident from late June to late August, that is, during the last part of the berry growth period (figure 2). Agronomical techniques eliciting an increase in relative air humidity tend to produce larger berries (ALJIBURY *et al.* 1975) which might be related to a reduction in berry transpiration (GREENSPAN 1994).

After budbreak, some lost of precocity was expected in vines under the covering due to the negative influence of high air temperatures on grape reproduc-

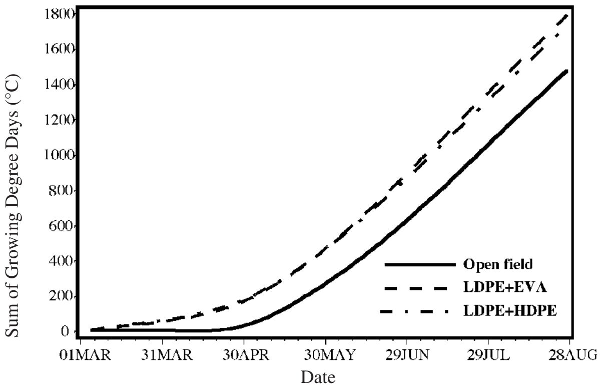

Fig. 1 - Sum of Growing Degree Days under two types of plastic covering and in open field

Fig. 1 – Degrés-jours au-dessus de 10 °C cumulés pendant le cycle sous les deux types de couverture plastique et en plein air

TABLE I
Phenological stages and phenological intervals in 'Matilde' table grape in open field and under two types of plastic covering

Tableau I - Phases phénologiques (bourgeonnement, floraison et maturité) et intervalles entre phases phénologiques du cépage à raisin de table « Matilde », sans abri et avec les deux types de couverture : polyéthylène à basse densité, associé à du éthylenvinylacétate (LPDE+EVA) et à du polyéthylène à haute densité (LDPE + HDPE)

Stages (date)	Open fields	LDPE+EVA	LDPE+HDPE
Covering	—	February 27	February 27
Budbreak	April 3 (0)	March 14 (-20)	March 22 (-12)
Bloom	May 28 (0)	May 11 (-17)	May 19 (-9)
Ripening	August 16 (0)	July 25 (-22)	August 8 (-8)
Intervals (day number)			
Covering-budbreak	—	15	23
Budbreak-bloom	55	58	58
Bloom-ripening	80	75	81
Budbreak-ripening	135	133	139

tion. However, the length of the bloom-ripening interval was shorter under LDPE + EVA covering than in the open field. According to literature, this result was surprising since vines under LDPE + EVA covering experienced the highest air temperature, as can be deduced by the sum of air temperatures exceeding 30°C (figure 3). Possibly, a progressive acclimation of the vegetative and reproductive vine organs to the higher air temperatures might have played a role in determining this result. However, when examining the different responses obtained with the LDPE + HDPE covering, the influence of other factors should be presumed, for example, the effect of a precocious formation of the photosynthetic leaf area.

By analyzing the radiative properties of the two plastic films (table II), almost the same LWIR transmittance was found (about 35 p. cent). LDPE + EVA covering resulted in a higher total transmittance to sunlight, both in the visible and PAR or SWIR wavelength ranges. The latter is known to have no effect on plant growth but provides about 50 p. cent of the sunlight energy (DUFFIE and BECKMAN 1991). The greater LDPE + EVA transparency to sunlight means that a greater amount of solar radiation may reach the surfaces inside the plastic cover, thus increasing the total system energy. A greater « direct » component compared to the « diffused » component of total light transmittance was also observed with LDPE + EVA covering, especially in the PAR wavelength range. The direct sunlight component is known to provide a high light flux density which results in a higher leaf photosynthetic level, while the diffused component is known to provide a lower light intensity but also to reduce the within-vine shade zones and leaf burning during the hottest part of the growing season (SMART 1974; FALLERI and MAGNANI 1991). One might presume that, due to the radiative properties of LDPE

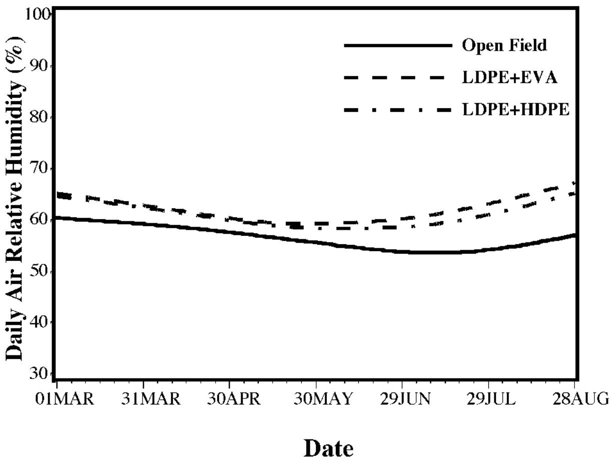

Fig. 2 - Seasonal pattern of the air relative humidity under two types of plastic covering and in open field

Fig. 2 – Cours saisonnier de l'humidité relative sous les deux types de couverture plastique et en plein air

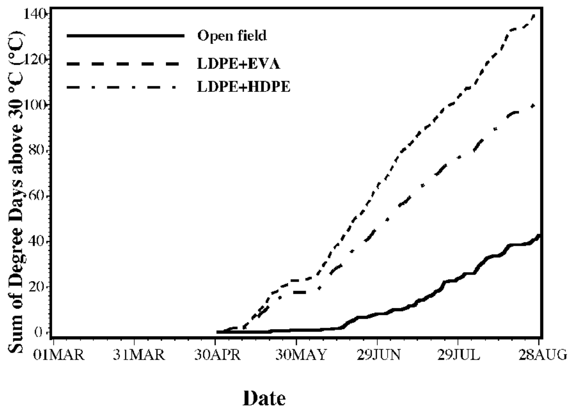

Fig. 3 - Sum of Degree Days above 30°C under two types of plastic covering and in open field

Fig. 3 – Degrés-jours au dessus de 30 °C cumulés pendant le cycle sous les deux types de couverture plastique et en plein air

TABLE II
Radiative properties of the plastic film used as covering for 'Matilde' table grape

Tableau II – Caractéristiques radiatives des films plastique utilisés pour l'essai sur le cépage à raisin de table « Matilde »

Radiation type	Direct Transmittance (%)	Diffused Transmittance (%)	Total Transmittance (%)
LDPE+EVA			
Visible Radiation (380-760 nm)	55.51	30.72	86.23
PAR (400-700 nm)	54.90	31.42	86.32
Short Wave IR (760-1100 nm)	69.00	19.71	88.72
Long Wave IR (7500-12500 nm)	35.23		
LDPE+HDPE			
Visible Radiation (380-760 nm)	25.23	55.13	80.35
PAR (400-700 nm)	24.78	55.50	80.28
Short Wave IR (760-1100 nm)	32.97	47.94	80.91
Long Wave IR (7500-12500 nm)	34.29		

TABLE III
Components of yield and fruit quality of 'Matilde' table grape in open field and under two types of plastic covering

Tableau III – Rendement (kg/cep), masse de la grappe et de la baie (g), longueur et largeur de la baie (mm), ° Brix et acidité (meq/l) du moût et masse de bois de taille (kg/cep) du cépage à raisin de table « Matilde » sous les deux types de couverture plastique et en plein air

Parameters	Open fields	LDPE + EVA	LDPE + HDPE
Yield per vine (kg)	21.98 a	26.56 a	26.94 a
Bunch mass (g)	680.22 b	775.37 a	730.12 ab
Berry mass (g)	6.35 c	8.12 a	7.50 b
Berry length (mm)	2.35 b	2.80 a	2.40 b
Berry width (mm)	2.20 b	2.32 a	2.16 b
Berry length: width ratio	1.06 b	1.18 a	1.11 b
T.s.s. content (°Brix)	14.10 a	14.00 a	14.20 a
Titratable acidity (meq l^{-1})	36.00 a	22.67 b	28.00 ab
Cane mass per vine (kg)	2.36 b	3.84 a	3.38 a
Yield: cane mass ratio (kg kg^{-1})	9.98 a	7.22 a	7.58 a

Within a line, means followed by the same letter are not significantly different at $p = 0.05$ (Duncan test).

+ EVA covering, soil and vine organs under this plastic film were subjected to a higher direct warming before the shoot development stage began. This hypothesis might explain the earlier budbreak observed in vines under LDPE + EVA covering compared to those under LDPE + HDPE covering, given that the air GDD accumulation was similar under the two plastic covers.

Measurements of the photosynthetic photon flux available at the canopy level during the growing season showed a natural PAR increment from March to mid-June in the three blocks (figure 4). Differences between the two types of covers were found during the entire season, but mainly in March and April when the leaf apparatus was rapidly expanding. In these months, the open field PAR rate was about 67 p. cent of the maximum level reached in mid-June. This rate was lowered to 38 p. cent under LDPE + HDPE covering and to only 13 p. cent under LDPE + EVA covering.

By comparing the evolution of the berry t.s.s. concentration from July to mid-August in the three blocks, it was found that berries from uncovered vines showed a typical pattern of sugar accumulation after veraison (MAUJEAN 1983; MATTHEWS and ANDERSON 1988), while berries from covered vines showed only the terminal end of that curve, that is, the portion where the rate of t.s.s. accumulation normally slows down. When 'Matilde' berries reached 14.00 °Brix under LDPE + EVA covering (July 25), the t.s.s. concentration was only 11.50 °Brix under LDPE + HDPE covering and 10.75 °Brix in the open field. Uncovered vines reached 14 °Brix on August 16, as it is normal in that growing area, while 'Matilde' under LDPE + HDPE covering reached 14 °Brix on August 8.

The yield components and the berry composition, assessed in each grape block when reaching commercial ripening, showed a tendency towards an improved production by the covered 'Matilde'. LDPE + EVA covering increased the yield per vine (+21 p. cent compared to the open field), although this difference was not statistically significant (table III). Bunch and berry mass were the greatest under LDPE + EVA covering (775.37 g and 8.12 g, respectively) and progressively decreased under LDPE + HDPE covering (-6 and -8 p. cent, respectively) and in the open field (-12 and -22 p. cent, respectively), while t.a. concen-

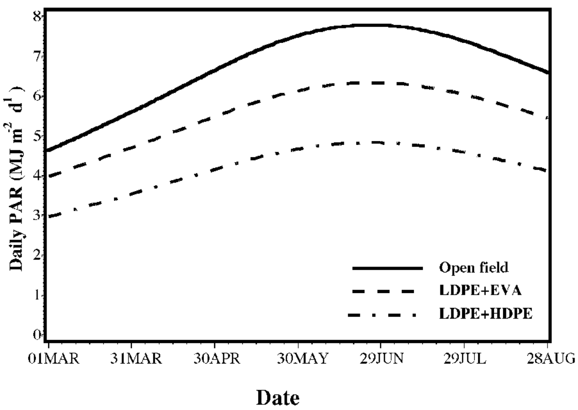

Fig. 4 - Seasonal pattern of the total PAR at canopy level under two types of plastic covering and in open field

Fig. 4 - Cours saisonnier de la radiation photosynthétique active au niveau de la végétation sous les deux types de couverture plastique et en plein air

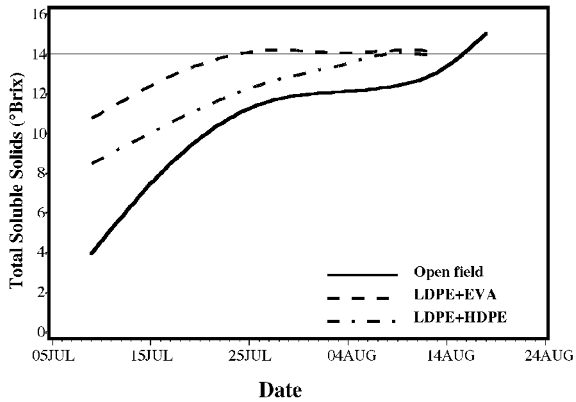

Fig. 5 - Evolution of total soluble solid concentration in berries of 'Matilde' table grape under two types of plastic covering and in open field

Fig. 5 – Evolution de la concentration en matière soluble (°Brix) dans les baies du cépage à raisin de table «Matilde» sous les deux types de couverture plastique et en plein air

tration was higher in open field (36.00 meq l^{-1}) than under LDPE + EVA (-37 p. cent). Changes in berry mass and titratable acidity seemed coherent with the microclimatic changes observed in the three blocks, that is, the berry mass increased with the higher mean relative air humidity and the titratable acidity decreased with the warmer air temperatures. Also the fruit shape, in particular the berry length, was affected by the covering: LDPE + EVA enhanced the elongated shape of the 'Matilde' berry by 18 p. cent.

Covering produced an increase in the cane pruning mass of 63 p. cent under LDPE + EVA and 43 p. cent under LDPE + HDPE. The greater vegetative vigor of 'Matilde' vines grown in protected conditions confirms a tendency observed in a previous work and could be related to the hygrothermic regime which is more favorable to vegetative vine growth (NOVELLO *et al.* 1999). An increment of the vine vigor, to a certain extent, may be considered as a beneficial factor as the vine can support a more elevated grape production. However, vigor and yield are known to be more closely correlated in wine grapes rather than in table grapes (LOUBSER *et al.* 1994). In this trial, vigor and yield did not vary proportionally; the fruit yield/cane pruning mass ratio (Ravaz index) was higher in the open field than under covering, and hence uncovered 'Matilde' showed a higher vegetative-reproductive efficiency.

CONCLUSIONS

The plastic films tested in this trial demonstrated different radiometric properties and induced different effects on microclimatic parameters, and on grape growth and reproduction. LDPE + EVA covering showed the highest light transmissivity to all wavelength ranges of solar radiation and to « direct » sunlight. This plastic film limited the attenuation of the active photosynthetic radiations at the canopy level, and induced a greater rise in air temperature during the blooming and ripening stages. Moreover, these covering advanced 'Matilde' berry ripening by 14 days compared to LDPE + HDPE covering and by 22 days with respect to the open field. The advance of budbreak was confirmed as the responsible factor for most of the berry ripening earliness under covering. However, as the effective air temperatures were similar under LDPE + HDPE and LDPE + EVA covering, another microclimatic factor is presumed to be involved in this response, such as the direct warming of soil and plant organs before shooting. Furthermore, LDPE + EVA covering also prompted an unexpected decrease of the blooming-ripening interval; thus, under the trial conditions, the negative influence of high air temperatures on grape reproductive processes and the length of the berry ripening stage under covering seem less important than commonly believed.

Overall, 'Matilde' grapes grown under LDPE + EVA plastic sheet covering showed the best performance regarding both the advance of berry ripening and the bunch and berry mass. Therefore, vine growing as a « protected cultivation » would seem to be an excellent means to improve both the qualitative and quantitative components of grape production, providing that a high-performance plastic film is used. However, the complex interactions between the microclimatic and ecophysiological factors under covering need to be further investigated to better understand their effects on grape growth and reproduction.

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REFERENCES

ALJIBURY F.K., BREWER R., CHRISTENSEN P.and A.N. KASIMATIS., 1975. Grape response to cooling with sprinklers. *Am. J. Enol. Vitic.*, **26**, 214-217.

BAGGIOLINI M., 1952. Les stades repères dans le développement annuel de la vigne et leur utilisation pratique. *Rev. Rome. Agric. Vitic.,* **8**, 1.

DI LORENZO R., GIUFFRIDA S., FERRANTE S. and G. COLLESANO, 1999. Study on vegetative and productive behavior of table grape cv. 'Matilde' under greenhouse. *Proc. GESCO 11 Meeting*, Marsala, Italy, 6-12 June, 744-750.

DUFFIE J.A. and W.A. BECKMAN, 1991. *Solar engineering of thermal process*. John Wiley & Sons, Inc. 919

EYNARD I., GAY G., ARLUNNO A. and M. BOVIO, 1978. Germogliamento della vite e gelate primaverili. *Atti Acc. It. Vite e Vino,* **30**, 68-86.

FALLERI F. and G. MAGNANI, 1991. Film termici di copertura: valutazione delle caratteristiche principali. *Colture Protette*, **20**, 11, 85-93.

GREENSPAN M.D., 1994. Developmental changes in the diurnal water budget of the grape berry exposed to water deficits. *Master of Science Thesis*, University of California, Davis, U.S.A..

HALE C.R. and M.S.BUTTROSE, 1974. Effect of temperature on ontogeny of berries of *Vitis vinifera* L. cv. Cabernet Sauvignon. *J. Amer. Soc. Hort. Sci.*, **99**, 390-994.

HANAN J.J., HOLLEY W.D. and K.L GOLDSBERRY, 1978. *Greenhouse management*. Ed. Springer-Verlag, Berlin, Heidelberg, New York., 530.

HANRAS M., 1970. Amélioration dans la qualité des films de polyéthylène : film longue durée, film antibuée, film imperméable thermique, film dégradable. *Plasticulture*, **8**, 18-29.

KLIEWER W.M., 1977. Effect of high temperatures during the bloom-set period on fruit set, ovule fertility, and berry growth of several grape cultivars. *Am. J. Enol. Vitic.*, **28**, 4, 215-222.

LA MALFA G. and G.MAGNANI, 1994. I materiali plastici per le colture protette. *Colture Protette*, **23**, 12, 33-40.

LAVEE S., 1994. Training-trellis systems and canopy management of table grapes in Israel. *Proc. International Symposium on Table Grape Production*, Anaheim, CA, 179-188.

LOUBSER J.T., AVENANT J.H. and E.W. LE GRANGE 1994. Grapevine Rootstock Performance in South *Africa. Proc. Int. Symp. on Table Grape Production*, Anaheim, CA, 127-129.

MATTHEWS M.A .and M.M. ANDERSON, 1988. Fruit ripening in *Vitis vinifera* L.: responses to seasonal water deficit. *Am. J. Enol. Vitic.*, **39**, 313-320.

MAUJEAN M., 1983. Étude de la maturation des cépages champenois. *Rev. Fr. Œnol.*, 91.

NOVELLO V., de PALMA L. and L. TARRICONE , 1999. Influence of cane girdling and plastic covering on leaf gas exchange, water potentials and viticultural performance of table grape cv. Matilde. *Vitis*, **38**, 2, 51-54.

PAPADAKIS G., BRIASSOULIS D., STOFFERS J.A., SCARASCIA MUGNOZZA G., VOX G. and P. FEUILLOLEY, 1997. Physical properties and testing methods of greenhouse covering materials. *J. Agric. Engineering Research* (in press).

RAVIV M. and Y.ALLINGHAM, 1983. Films de polyéthylène modifié, caractéristiques. *Plasticulture*, **59**, 3-12.

SCARASCIA MUGNOZZA G., RUSSO G. and G. VOX, 1997. Le caratteristiche spettroradiometriche di materiali innovativi per la protezione delle colture. *Atti VI Convegno nazionale di Ingegneria Agraria*, Ancona, 129-142.

SEPULVEDA G., KLIEWER W.M. and K. RYUGO, 1986. Effect of high temperature on grapevine (*Vitis vinifera* L.). I. Translocation of ^{14}C-photosynthates. *Am. J. Enol. Vitic.*, **37**, 1, 13-19.

SMART R.E., 1974. Photosynthesis by grapevine canopies. *Jour. Appl. Ecol.*, **24**, 997-1006.

TAKAKURA T., 1989. *Climate under cover*. Lab. Environ. Eng., Dept. Ag. Eng., Univ. of Tokyo, 130.

UNI 9298, 1988. Foglie flessibili di materiale plastico trasparente incolore per serre ed analoghi apprestamenti di forzatura e semiforzatura di coltivazioni orto-floro-frutticole - requisiti e metodi di prova.

WINKLER A.J., COOK J.A., KLIEWER W.M. and L.A. LIDER, 1974. *General Viticulture*. University of California Press, Berkeley and Los Angeles, CA., 710 .

WINKLER A.J. and W.O. WILLIAMS, 1939. The heat required to bring « Tokay » grapes to maturity. *Proc. Am. Soc. Hortic. Sci.*, **37**, 650-652.

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