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Agronomic response of winter melon (*Cucumis melo inodorus* Naud.) to biodegradable and polyethylene film mulches, and to different planting densities

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SUMMARY – The winter melon is widely grown in the open field in Sicily on about 6000 hectares. Plants are grown in the countryside without irrigation as the annual rain precipitation provides sufficient water for the crop. In the last decades the use of plastic mulches has enhanced early winter melon and total yields. However, disadvantages of plastic mulches are the need to remove and dispose of them after use. The objective of this research was to evaluate effects of polyethylene (PE) and biodegradable films (transparent or black) in combination with two planting densities, 2667 plants/ha (1 plant/hill) or 5334 plants/ha (2 plants/hill) on yield, fruit size, quality and earliness of winter melon. All mulches markedly increased early and total yields in comparison to unmulched plots. The best results were obtained with the highest plant density and by mulching with either transparent PE film or transparent biodegradable film. This study demonstrated that the transparent biodegradable film is an efficient environmentally friendly alternative to plastic mulching.

Key words: Winter melon, mulching, biodegradable, planting density.

RÉSUMÉ – *"Réponse agronomique du melon d'hiver (*Cucumis melo inodorus *Naud.) à un paillage en film biodégradable et en polyéthylène, et à différentes densités de plantation". La culture du melon d'hiver en Sicile s'étend sur une surface de 6000 hectares. Le cycle cultural a lieu sans irrigation entre le printemps et l'été. La technique du paillage a été introduite dans les derniers dix ans ; elle utilise principalement du polyéthylène (PE) transparent qui permet un remarquable accroissement de la production. Par la présente recherche on a essayé de confronter des pellicules conventionnelles pour le paillage en PE noir ou transparent avec des pellicules biodégradables en couleur noire ou transparente (Mater-Bi™). On a voulu évaluer aussi la réactivité du melon d'hiver à deux densités d'installation différentes (2667 ou 5334 plantes par hectare). Les pellicules pour le paillage ont produit de remarquables effets positifs sur la précocité et sur la productivité de la culture par rapport à la terre nue. Les meilleurs résultats ont été obtenus avec les pellicules transparentes et la densité maximale des plantes. Le Mater-Bi™ transparent a donné des productions comparables à celles du PE transparent et, grâce à sa biodégrabilité, a permis l'emploi de la technique du paillage avec un impact faible sur l'environnement.*

Mots-clés : *Melon d'hiver, paillage, biodégradable, densité des plantes.*

Introduction

Plastic mulching, introduced in the last three decades, is currently used in many areas of the world especially for warm-season crops such as tomatoes, peppers, melons and water melons. Plastic mulches, depending on their properties, provide many benefits for the crops. For example, higher soil temperatures compared to bare soil, earlier and higher yields, weed control, reduced evaporation and fertilizer leaching, reduced soil compaction (Lamont, 1993). The winter melon is widely grown in Sicily on about 6000 hectares. The species is grown in the open field in the hilly countryside during the spring-summer months. Plants are grown without irrigation as the annual rain precipitation (500-600 mm) provides sufficient water for the crop. Several studies have investigated the production effects of plastic mulch on melons (Incalcaterra and Curatolo, 1991; Taber, 1993; Schales and Sheldrake, 1996). However, the disadvantage of plastic mulches is that they have to be removed and disposed of after use (Wittwer and Castilla, 1995). To resolve these problems, photodegradable plastic films and more recently biodegradable starch-based materials have been developed (Bastioli, 1998). The purpose of this research was to evaluate the effects of polyethylene and biodegradable films (transparent or black) in combination with two planting densities, 2667 plants/ha (1 plant/hill) or 5334 plants/ha (2 plants/hill) on yield, fruit size, quality and earliness of winter melon.

Materials and methods

The trial was conducted on vertic xerochrept soils near San Cipirrello in the province of Palermo, 325-m elevation. The soil was prepared before planting by ploughing in the summer and tilling in the fall at 25-30 cm depth. Fertilizers were incorporated during the tillage to meet the local culture recommendation of 50 kg N/ha, 100 kg P_2O_5/ha and 80 kg K_2O/ha . Five to six seeds of the Sicilian winter melon landrace 'Purceddu' were sown by the hill system on May 10, 2000. Plants were thinned, at the four leaf stage (15 cm height) to one or two per hill and spaced at 150 x 250 cm. The cultivation techniques were those commonly used in the area. The previous crop was wheat. The experiment was arranged in a split-plot design with mulching materials as main plots and plant densities as sub-plots. The five mulch treatments were: (i) bare soil; (ii) transparent polyethylene (PE) film (50 μm); (iii) black PE film (50 μm); (iv) transparent biodegradable Mater-Bi™ (18 μm) film; and (v) black biodegradable Mater-Bi™ film (18 μm). Mater-Bi™ is a class of biodegradable starch-based material (Novamont S.p.A., Novara, Italy). The two planting densities were 2667 plants/ha (1 plant/hill) and 5334 plants/ha (2 plants/hill). There were four replications and individual experimental plots measured 37.5 m^2. All mulches were 1.2 m wide. Soil temperatures were measured at hourly intervals during the growing period using thermocouple probes positioned 5 cm below the soil surface in the middle of the mulched bed and connected to a microprocessor logging thermometer (Hanna Instruments, R.I., USA). Data were collected on number of leaves per plant 20, 30 and 40 days after sowing. Cumulative marketable yields were recorded by August 8 (early yield) and by August 29 (total yield) for each treatment. A random sample of 10 melons was taken from each replicate-treatment and total soluble solids (TSS) were evaluated in an Atago N 1 refractometer (Atago Co. Ltd, Tokyo). All data were subjected to analysis of variance (ANOVA) and mean separation was performed by Duncan's multiple range test.

Results and discussion

All mulches increased soil temperatures in comparison to the bare soil plots (Fig. 1). Maximum soil temperatures (ranging from 25.8 to 33.8 °C) were measured under transparent PE and transparent biodegradable Mater-Bi™ films between 7:00 and 17:00 h. During this day period soil temperatures of these plots were from 3.7 to 8.6 °C higher than those in the bare soil. Night and pre-dawn soil temperatures in the soil plots covered with black PE film were higher (from 4.2 to 5.5 °C) than those in the bare soil. Whereas, during the same day periods, soil temperatures in the transparent PE film plots were from 0.9 to 1.6 °C higher than those in the bare soil. Pre-dawn soil temperatures in the plots covered with transparent or black biodegradable Mater-Bi™ films, although higher than those in the bare soil, were much lower than those under black PE film and comparable to those measured in the transparent PE plots.

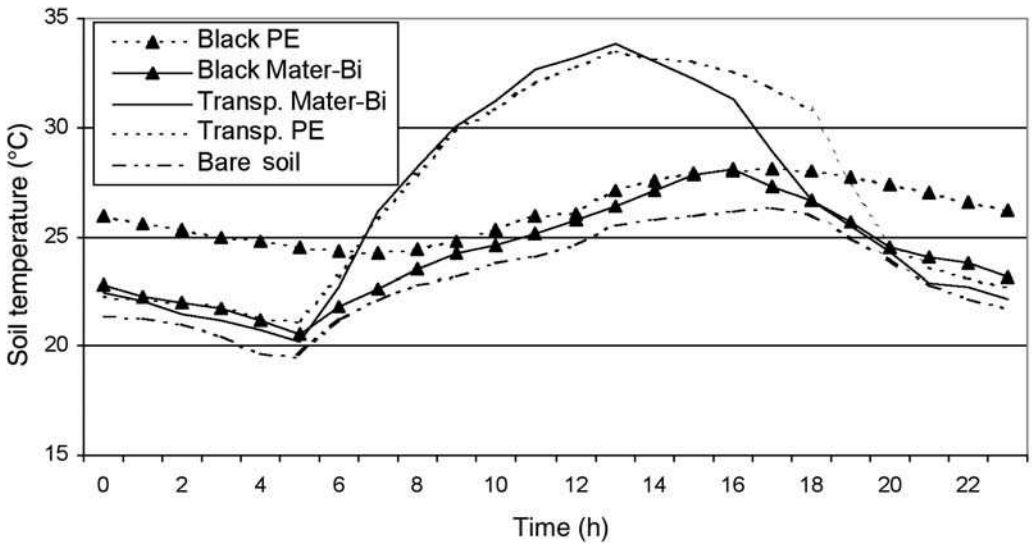

Fig. 1. Diurnal patterns of soil temperature at the 5 cm depth. Data are shown for each of the plastic mulches and the bare soil plot.

Black PE film has a high short wave absorbance; the incoming radiation is first absorbed by the plastic and then transmitted to the soil by conduction. We can speculate that in absence of solar radiation, heat loss due to long wave infrared radiation was higher in the plots covered with black and transparent Mater-Bi^{TM} films, and transparent PE as compared to that of black PE film. All mulches induced an earlier plant emergence (about 4 days) in comparison to bare soil plots (data not shown). Vegetative growth at 20, 30 and 40 days after sowing was affected by the treatments tested (Table 1).

Table 1. Number of leaves per plant of winter melon grown with different soil mulch and plant density combinations

Plant density (plants/ha)	Mulch	Days after sowing		
		20	30	40
2667	Bare soil	6.2d	11.3e	22.2d
	Black PE	10.6bc	25.8bc	44.7b
	Transp. PE	12.4a	28.7a	48.3a
	Black Mater-Bi	9.7c	23.6cd	44.7b
	Transp. Mater-Bi	12.5a	26.3b	47.5a
	Mean	10.3a	23.1a	41.5a
5334	Bare soil	6.2d	10.7d	21.3d
	Black PE	10.5bc	23.8cd	42.5c
	Transp. PE	12.0a	26.7ab	45.8b
	Black Mater-Bi	9.5c	22.6d	43.0c
	Transp. Mater-Bi	11.8ab	25.4bc	44.6b
	Mean	10.0a	21.8 b	39.4b
Average	Bare soil	6.2d	11.0d	21.8d
	Black PE	10.6b	24.8b	43.6c
	Transp. PE	12.2a	27.7a	47.1a
	Black Mater-Bi	9.6c	23.1c	43.9c
	Transp. Mater-Bi	12.2a	25.9b	46.1b

[a,b,c,d,e]Values within columns that are followed by the same letter are not significantly different at P = 0.01 using Duncan's Multiple Range Test.

Regardless of the planting density, the number of leaves per plant in the plots covered with transparent PE or transparent biodegradable Mater-Bi^{TM} films was significantly higher than that recorded in the other treatments. Plants in the unmulched plots had the lowest number of leaves per plant. Regardless of the mulches tested, at 30 and 40 days after sowing, plots with one plant per hill had more leaves per plant as compared to those with two plants per hill. Mulch treatments and plant density significantly interacted. The highest number of leaves per plant was recorded by growing one or two plants per plot and by using transparent PE or transparent biodegradable Mater-Bi^{TM} films. All mulches dramatically increased early yields in comparison to bare soil plots (Table 2). Fruit yield at August 8, in the transparent PE and transparent biodegradable Mater-Bi^{TM} mulching treatments over the two planting densities averaged 19.9 and 20.1 t/ha respectively. These data were significantly higher than those recorded in the plots covered with black PE and black biodegradable Mater-Bi^{TM}. Regardless of the mulch treatments, growing two plants per hill resulted in higher early yields. The interaction mulch treatment x plant density was highly significant. Early yields in the plots with two plants per hill and covered either with transparent PE or transparent biodegradable Mater-Bi^{TM} films were approximately 88% higher than those in the unmulched treatment. Although the greatest differences in fruit yield among the treatments tested were observed by August 8, total fruit production was also affected by mulching and to a lesser extent by plant density. The highest total yields were obtained by growing two plants per hill in the plots covered with transparent PE film (25.4 t/ha). Fruit yields obtained in the plots covered with transparent biodegradable Mater-Bi^{TM} film at the highest plant density (23.6 t/ha) did not significantly differ from those obtained by growing one plant per hill and by mulching either with transparent PE or transparent biodegradable Mater-Bi^{TM} films. Both main and secondary treatments significantly affected mean fruit weight. This led to a significant mulching x planting density interaction. The highest mean fruit weight was recorded by growing one plant per hill in the plots covered with transparent PE film; whereas, the lowest mean fruit weight was observed by growing two plants per hill in the plots covered with black biodegradable Mater-Bi^{TM} film (Table 2).

Table 2. Early and total yields, and mean fruit weight of winter melon grown with different soil mulch and plant density combinations

Plant density (plants/ha)	Mulch	Early yield (t/ha)	Total yield (t/ha)	Mean fruit weight (g)
2667	Bare soil	2.2g	14.7f	2229cd
	Black PE	16.5ef	19.6d	2340b
	Transp. PE	19.6bc	23.3b	2494a
	Black Mater-Bi	15.9f	18.7d	2204ef
	Transp. Mater-Bi	19.3cd	22.7b	2207ce
	Mean	14.6b	19.8b	2295a
5334	Bare soil	2.5g	17.1e	2157df
	Black PE	17.1e	20.4c	2147df
	Transp. PE	20.2b	25.4a	2239c
	Black Mater-Bi	18.7d	19.7c	2010g
	Transp. Mater-Bi	20.8a	23.6b	2103g
	Mean	15.9a	21.2a	2131b
Average	Bare soil	2.4c	15.9c	2193c
	Black PE	16,8b	20.0b	2243b
	Transp. PE	19.9a	24.4a	2366a
	Black Mater-Bi	17.2b	19.2b	2107c
	Transp. Mater-Bi	20.1a	23.2a	2155c

[a,b,c,d,e,f,g]Values within columns that are followed by the same letter are not significantly different at P = 0.01 using Duncan's Multiple Range Test.

Planting density did not affect fruit TSS. However, all mulches significantly increased fruit TSS in comparison to bare soil plots (data not shown). In the climatic conditions of the trial, the Mater-Bi^{TM} films showed good rates of degradation. Visual observation at the final harvesting date indicated a partial degradation of the material. However, two weeks after soil tilling Mater-Bi^{TM} films appeared totally degraded.

Conclusions

In this study all mulches markedly increased early and total yields in comparison to unmulched plots. The best results were obtained with the highest plant density and by mulching with both transparent films. The higher soil temperatures produced by the transparent films in combination with the use to maximize available water resources, played a major role in increasing early winter melon and total yields. In this study, regardless of the planting density, plots with transparent PE mulch and transparent Mater-Bi^{TM} mulch had similar marketable early and total yields. The Mater-Bi film adds the advantage of rapid degradation to many of the desirable effects of plastic mulch and, therefore, it represents an environmentally friendly alternative to PE film mulching.

Acknowledgements

The authors contributed equally to this work.

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