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Research Article

Using plastic house shading in the summer improves eggplant and sweet pepper yield[1]

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ABSTRACT

Shading is a way of cooling in hot and sunny areas to modify the microclimate and improve crop growth. This study aimed to evaluate the effect of shading treatments on eggplant and sweet pepper growth, under plastic house conditions, at the beginning of the summer, when there are high temperatures and solar radiation intensity. The plastic covers were lifted at the beginning of April and the shading nets used in May and June. The shading treatment improved the plant height, vegetative weight, number of fruits per plant, fruit weight, plant yield and total yield per plastic house for both crops, especially for the sweet pepper. The sweet pepper hybrid (Charisma) and the local variety of eggplant showed the highest values for most of the studied characteristics.

KEYWORDS: *Solanum melongena* L., *Capsicum annum* L., protected cultivation.

RESUMO

Sombreamento melhora a produtividade de berinjela e pimentão em casa-de-vegetação no verão

O sombreamento é uma forma de resfriamento em áreas quentes e ensolaradas para modificar o microclima e melhorar o crescimento das culturas. Objetivou-se avaliar o efeito de tratamentos de sombreamento no crescimento de berinjela e pimentão, em condições de casa-de-vegetação, no início do verão, quando ocorrem elevadas temperaturas e intensidades de radiação solar. Os filmes plásticos foram recolhidos no início de abril e as malhas de sombreamento utilizadas nos meses de maio e junho. O sombreamento melhorou a altura de planta, peso vegetativo, número de frutos por planta, peso de frutos, rendimento por planta e rendimento total por casa-de-vegetação para ambas as culturas, especialmente para o pimentão. O híbrido de pimentão (Charisma) e a variedade local de berinjela apresentaram os maiores valores para a maioria das características estudadas.

PALAVRAS-CHAVE: *Solanum melongena* L., *Capsicum annum* L., cultivo protegido.

INTRODUCTION

Eggplant (*Solanum melongena* L.) and sweet pepper (*Capsicum annuum* L.) are economically important summer crop vegetables belonging to the Solanaceae family, which includes more than 75 genus and 2,000 plant species spread all over the world (Daunay & Hazra 2012, Krasnow & Ziv 2022).

Eggplant is grown in many areas of Iraq in open fields. It is also one of the main vegetable crops grown under protected cultivation, as well as early cultivation at the end of the winter in low tunnels. It is grown for its high nutritional and medicinal value. Eggplant is rich in antioxidants and vitamins (especially vitamin C), in addition to substances that enhance the health of the heart and arteries, regular blood pressure, lowering cholesterol in the blood, resisting some infections (including bronchial tubes) and ridding the body of toxic metals such as mercury and lead. It also helps in treating diabetes, gout and sclerosis of blood vessels (Diop et al. 2020).

Peppers of the sweet and hot varieties differ in colour, shape, taste, biochemical content, uses and benefits in many areas such as food, medicine, cosmetics and plant insecticides. Pepper is easy to grow and harvest, and this makes it suitable for use in poverty reduction and food security improvement programs (Dagnoko et al. 2013). It contributes significantly to providing the human body with important compounds, as well as a high content of vitamin C. In addition, it contains a good amount of vitamin A and other types of vitamins necessary for growth, and mineral elements such as calcium, iron and phosphorous (Sadoon & Al-Abrahimi 2011). The

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appropriate temperatures for pepper plant growth range from 21 to 33 ºC (Saha et al. 2010).

The average eggplant and sweet pepper yields in Iraq, in 2018, were about 10,442 and 23,473 t, respectively (Iraq 2018). For eggplant, China ranked first in the world (34,102,735 t), followed by India (12,826,000 t), Egypt (1,409,202 t) and Turkey (836,284 t) (FAO 2018). The reasons for the production decline in Iraq are the lack of interest in appropriate methods for cultivation and the failure to choose the appropriate varieties for protected cultivation, in addition to the negative impact of high temperatures at the end of the growing season as a result of high solar radiation, which greatly affects the increase in respiration and transpiration and results in a high consumption of irrigation water.

Johkan et al. (2011) indicated that high temperatures lead to physiological disturbances in some crops, meaning lower incomes for farmers and agricultural countries. Photosynthesis and fruit set ratio are among the most sensitive physiological factors to stress processes resulting from high temperatures, and heat sensitivity varies among crops and among different growth stages in the same crop.

In addition, the air temperature could increase at the end of this century at a rate of 0.3-4.8 ºC (IPCC 2013), and this would lead to major problems, threatening the global food security. The photosynthesis rate decreases under heat stress conditions, and this process may stop when heat stress intensifies (Yamamoto et al. 2008).

Despite the importance of light as one of the main environmental factors affecting plant survival, crop yield and dry mass distribution (Janda et al. 2014, Zoratti et al. 2014), the use of shading in conditions of high solar radiation is very important to reduce negative effects and improve growth and production. López-Marín et al. (2012), Zhu et al. (2012) and López-Marín et al. (2013) proved that the sweet pepper crop is able to adapt well to shaded environments, as the shading protects the pepper from sunburn, reduces the water use and increases the crop yield. Also, shading affects the growth of eggplant seedlings, as observed by Aied et al. (2017) in a study with three shading percentages (30, 50 and 70 %) on the growth of eggplant seedlings, in which the shading treatments significantly affected the seedling height and weight.

Thus, this study aimed to evaluate the shading effect, in May and June, on two hybrids of sweet pepper and three varietes of eggplant, in order to identify the best pepper hybrid and eggplant variety, as well as the optimum interaction for achieving the highest growth rate and the best yield under Tikrit conditions.

MATERIAL AND METHODS

The experiments were conducted at yellow plastic houses (Quonset greenhouse model) of the Tikrit University, in Tikrit, Iraq, during the 2019-2020 agricultural season (two experiments, being one for each kind of vegetable), in order to evaluate three eggplant varieties: black [local variety (E1)], purple [Malaysian variety (E2)] and elongated black [Turkish variety (E3)]. Also, two hybrids of sweet pepper [Olympus (P1) and Charisma (P2)] were evaluated, when planted under an unheated plastic house (9 x 50 m), to find out their response to shading (50 %) by using saran (green shade net) after lifting the plastic cover at high temperatures. The plastic cover was lifted at the beginning of April, then the saran was placed during the months of May and June only, put on the top of the greenhouse at a distance of 1 m from the ground. The experiment was conducted in sandy loam soil (Table 1).

The measurements were taken as an average of 5 plants of the experimental unit. The plant height, vegetative weight and percentage of fruit dry matter were measured at the end of the experiments, while the yield characteristics (number of fruits, fruit weight, yield and total yield) were measured on the basis of the aggregate yield. The crops received bright sunshine, in terms of daily minimum, maximum and average temperature, during May and June, which varied from 19.48 to 19.67 ºC, 39.76 to 39.94 ºC and

Table 1. Some soil properties of this study.

Parameters	Sand	Silt	Clay	Textural class	CEC	pH	N	P	K	EC	OM
Unit	%	%	%		Meq 100 g^{-1}		%	%	%	Mmho cm^{-1}	%
Value	76	22	2	Sandy loam	6	7.55	0.26	0.13	0.15	1.12	0.275

CEC: cation exchange capacity; N: nitrogen; P: phosphorus; K: potassium; EC: electrical conductivity; OM: organic matter.

29.62 to 29.81 ºC, respectively. A total evaporation of 7.82 mm, maximum wind speed of 9.89 m s^{-1}, average wind speed of 2.20 m s^{-1}, total solar radiation of 24.50 MJ m^{-2} day^{-1}, minimum relative humidity of 16.25 % and maximum relative humidity of 67.68 % were received in May, and 7.88 mm, 9.86 m s^{-1}, 2.20 m s^{-1}, 24.65 MJ m^{-2} day^{-1}, 16.60 % and 67.35 % in June, respectively. There was no rainfall in these two months.

The experiment was carried out using a randomized complete block design, with three replications. The seedlings were planted at a distance of 40 cm between plants on both sides of the ridge, which had 10 plants with width of 60 cm and length of 2 m. The analysis of variance (Anova) was derived from the common diverse model for a randomized compelete block design. All measured parameters were assumed to be generally distributed, and a numerical analysis by Anova was carried out using the SAS software (version 9). The importance of the differences among the treatments was approximated using the Duncan's test at $p \leq 0.05$.

RESULTS AND DISCUSSION

The shading had a positive effect on the sweet pepper growth and yield (Table 2). The plant height and vegetative weight under shading increased significantly (59.428 cm and 475.35 g, respectively), when compared to the treatment without shading (52.083 cm and 249.51 g, respectively). Also, the shading treatment resulted in the highest values for number of fruits per plant (16.110), fruit weight (31.663 g), yield per plant (478.91 g plant^{-1}) and total yield per plastic house (0.533 t plastic house^{-1}), when compared to the treatment without shading: 15.825 fruits plant^{-1}, 18.880 g, 298.20 g plant^{-1} and 0.330 t plastic house^{-1}, respectively.

At the same time, the Charisma hybrid had the highest values for number of fruits per plant (21.655), plant yield (516.27 g plant^{-1}) and plastic house total yield (0.576 t plastic house^{-1}), when compared to the Olympus hybrid (10.280 fruits plant^{-1}, 260.84 g plant^{-1} and 0.286 t plastic house^{-1}). Meanwhile, there were no significant differences between the hybrids for plant height, vegetative weight and fruit weight.

On the other hand, the results showed that there are significant differences between the interaction treatments. The highest values for plant height, number of fruits, plant yield and plastic house yield, which reached 59.137 cm, 22.044 fruits plant^{-1}, 630.68 g plant^{-1} and 0.706 t plastic house^{-1}, were observed for the interaction treatment of the Charisma hybrid with shading. But there was no difference in relation to the no-shading treatment for the same hybrid, concerning the number of fruits, while the shading treatment with the Olympus hybrid had the highest values for plant height (59.720 cm), vegetative weight (493.75 g) and fruit weight (32.527 g). But there were no significant differences for the shading treatment with the Charisma hybrid. These results clearly indicate the significant positive effect of shading in improving the sweet pepper growth and yield, although the shading treatment lasted for only two months.

Table 2. Effect of shading, hybrid and interaction between them on sweet pepper growth and yield.

Characteristics		Plant height (cm)	Vegetative weight (g)	Number of fruits (plant^{-1})	Fruit weight (g)	Plant yield (g plant^{-1})	Plastic house yield (t house^{-1})
Shading effect							
Without shading		52.0830 b*	249.51 b	15.825 a	18.880 b	298.20 b	0.330 b
With shading		59.4280 a	475.35 a	16.110 a	31.663 a	478.91 a	0.533 a
Hybrids effect							
Olympus		56.9017 a	368.19 a	10.280 b	25.893 a	260.84 b	0.286 b
Charisma		54.6100 a	356.67 a	21.655 a	24.650 a	516.27 a	0.576 a
Interaction effect							
Olympus	Without shading	54.0830 b	242.64 b	10.380 b	19.260 b	194.54 c	0.213 c
	With shading	59.7200 a	493.75 a	10.180 b	32.527 a	327.14 b	0.360 b
Charisma	Without shading	50.0830 b	256.39 b	21.270 a	18.500 b	401.86 b	0.446 b
	With shading	59.1370 a	456.94 a	22.044 a	30.800 a	630.68 a	0.706 a
CV (%)		18.8300	6.48	9.700	15.230	16.13	13.860

* Different letters in the same column show a significant difference using the Duncan's multiple range test ($p \leq 0.05$).

The shading had a positive effect on the eggplant growth characteristics (Table 3). The shading treatment was significantly superior for plant height (73.174 cm) and vegetative weight (884.21 g), when compared to the control treatment (58.230 cm and 484.21 g, respectively). On the other hand, there were no significant differences for the other studied characteristics.

The local variety had the highest values for most of the studied characteristics: vegetative weight (1,041.67 g), number of fruits per plant (13.325), fruit weight (255.83 g), plant yield (2,919.8 g plant^{-1}) and total yield per plastic house (5.295 t plastic house^{-1}), while the Turkish and the Malaysian varieties showed the highest values for plant height and fruit dry matter percentage (73.872 cm and 6.541 %, respectively) (Table 3).

The shading treatment for the Turkish variety resulted in a significant increase for plant height (80.830 cm), when compared to the other interaction treatments (Table 3), whereas the shading treatment for the local variety showed the highest values for vegetative weight (1,363.33 g plant^{-1}), number of fruits per plant (14.453), fruit weight (307.36 g), plant yield (3,447.8 g plant^{-1}) and total yield per plastic house (3.878 t plastic house^{-1}), when compared to the other treatments, while the Turkish variety without shading had the lowest total yield per plastic house (0.602 t plastic house^{-1}). This shows the positive effect of shading in improving the eggplant growth and yield by reducing the negative effects of high heat and solar radiation, thus reducing the evaporation rate and the moisture loss for both plants and fruits, and this is confirmed by the results of the Table 3, with the low percentage of dry matter under shading, when compared to the control treatment.

The results clearly indicate the significant effect of shading in improving and increasing the growth and yield of sweet pepper and eggplant. This positive effect is due to the role of shading in reducing the negative effects of high solar radiation that causes heat stress on the plant, as the heat stress affects the structure of cells, enzymes, proteins and DNA (Suzuki et al. 2012). The heat stress also affects the process of stomata opening and closing, thus reducing the water content of the leaves, as well as the cell content of CO_2 (Greer & Weedon 2012). Also, high temperatures lead to physiological disorders, as photosynthesis and fruit set rate are among the most sensitive physiological factors to heat stress (Johkan et al. 2011).

Alam & Salimullah (2021) indicate that temperatures above the optimum temperature lead to reduced eggplant plant growth, increased fall of flowers and reduced yield and quality. These results agree with those by Kittas et al. (2009), who pointed out the importance of using shading in preserving plants from high solar radiation during the summer, and that the use of partial shading by plastic nets provides protection for agricultural crops and improves growth and yield.

These results are in agreement with López-Marín et al. (2012), Zhu et al. (2012), López-Marín

Table 3. Effect of shading, variety and interaction between them on the eggplant growth and yield.

Characteristics		Plant height (cm)	Vegetative weight (g)	Number of fruits (plant^{-1})	Fruit weight (g)	Plant yield (g plant^{-1})	Plastic house yield (t house^{-1})	Fruit dry matter (%)
Shading effect								
Without shading		58.230 b*	484.21 b	10.189 a	112.47 a	1,177.9 a	1.325 a	6.496 a
With shading		73.174 a	884.21 a	11.301 a	161.31 a	1,670.7 a	1.879 a	5.091 a
Variety effect								
Local variety (Black)		66.125 ab	1,041.67 a	13.325 a	255.83 a	2,919.8 a	3.284 a	5.295 b
Malaysian variety (Purple)		57.110 b	366.39 c	11.820 a	69.72 b	761.1 b	0.856 b	6.541 a
Turkish variety (Black)		73.872 a	645.15 b	7.090 b	85.13 b	592.0 b	0.665 b	5.545 ab
Interaction effect								
Local variety (Black)	Without shading	56.167 cd	720.00 b	12.197 ab	204.29 ab	2,391.8 b	2.690 b	5.620 bc
	With shading	76.083 ab	1,363.33 a	14.453 a	307.36 a	3,447.8 a	3.878 a	4.970 bc
Malaysian variety (Purple)	Without shading	51.610 d	255.55 d	11.067 b	55.28 c	606.6 c	0.682 c	7.426 a
	With shading	62.610 bcd	477.33 c	12.573 ab	84.17 c	915.6 c	1.030 c	5.656 bc
Turkish variety (Black)	Without shading	66.913 abc	477.08 c	7.303 c	77.84 c	535.3 c	0.602 c	6.443 ab
	With shading	80.830 a	813.22 b	6.877 c	92.42 c	648.7 c	0.729 c	4.646 c
CV (%)		10.950	14.79	14.260	16.05	25.59	25.610	12.980

* Different letters in the same column show a significant difference using the Duncan's multiple range test ($p \leq 0.05$).

et al. (2013), Aied et al (2017), Ilić et al. 2017, Nagy et al. (2017), Ibrahim (2021) and Zisis et al. (2019), who proved the positive role of shading in improving the growth and yield of sweet pepper and eggplant crops.

On the other hand, there were differences between hybrids or varieties for growth and yield charactersitcs. These results could be due to the difference in response to shading, due to the genetic differences of each hybrid or variety (Abu Dahi & Muayyad 1988, Al-Shammari 2017, Koley et al 2019). As Alam & Salimullah (2021) pointed out, there are many eggplant varieties and genotypes resulting from breeding work carried out in the last thirty years, in order to obtain varieties with high yields, to withstand biotic and abiotic stresses or to improve the quality of fruits. Cultivated genotypes may have different and insufficient levels of resistance to biotic and abiotic stresses.

CONCLUSION

Shading showed to be very important under high summer temperatures to improve the growth and yield of sweet pepper and eggplant, especially for *Capsicum annuum* L., when applied for just two months. Subsequently, by using shading throughout the summer, when the sun radiation is high, the plant yield will be fully better.

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