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Effect of Different Shading Levels on Growth and Yield Parameters of a Hot Pepper (*Capsicum annuum* L.) Cultivar 'Beldi' Grown in Tunisia

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ABSTRACT

Pepper is one of the main vegetable crops grown and consumed in Tunisia and is therefore of economic importance. In Tunisia, 19400 ha were dedicated to this crop and its production amounted to 304000 t in 2010. Pepper production (crop yield and quality) in some Mediterranean regions is negatively affected by the high radiation, temperature and relative humidity particularly during spring-summer harvesting period. The use of shading screen is thought to be an efficient solution to overcome this problem and to improve pepper growth and yield. Therefore, the aim of this study was to evaluate the effect of different levels of shading on growth and yield parameters of the hot pepper (*Capsicum annuum* L.) cv 'Beldi'. For this reason, two shading levels were evaluated in order to attain 50% and 100% shading which compared to open field conditions (control 0% shading). The 50% and 100% shading levels, respectively increased total plant height by 15% and 30%, internode length by 31% and 47%, leaf area by 30% and 40%, and plant yield by 5% and 24% relative to non-shaded conditions. However, 50% and 100% shading decreased the incidence of blossom end rot by 30% and 69%, respectively relative to non-shaded pepper plants. A microclimate may have been created by the shading conditions, particularly under 100% shading, during the hottest summer period (June, July and August), has improved the vegetative growth and by extending plant physiological activity.

Keywords: growth and yield parameters, hot pepper, shading

INTRODUCTION

The pepper (*Capsicum annuum* L.) is one of the main vegetable crops grown and consumed in Tunisia and is therefore of economic importance. In fact, in 2010, 19,400 ha were dedicated to this crop and its production amounted to 304,000 t (GIL 2010).

During the growth cycle of pepper, many unfavourable environmental conditions occur such as high temperature and high radiation in particular during late spring and summer. These particular conditions may exert a negative effect on plant growth and yield (López-Marín *et al*. 2011). According to Schwarz *et al*. (2010), the main negative effects exerted by high temperature and radiation are a reduction in growth, a decrease in photosynthetic rate, increased respiration, and reduced water and ion uptake. Therefore, the use of different shading screens is thought to be an alternative to overcome this problem. Shading screens reduce incoming radiation, reduce the heat load inside the greenhouse and maintain a good level of humidity around plants (López-Marín *et al*. 2012). Schoch (1972) reported that under high solar radiation conditions, shading at an early stage of plant development increased cell division and volume in leaves and whole plant dry matter, and also positively affected fruit growth and yield. Rylski and Spigelman (1986) studied also the effect of shading on plant development, yield and fruit quality of sweet pepper grown under conditions of high temperature and radiation. These authors found that when light was reduced, plant height, number of nodes and leaf size increased. The shading also affected fruit set, number of fruit per plant, fruit development and yield. It has been reported that the response of pepper plants to shading will probably vary in different geographical areas, seasons and cultivars, and from different geographical areas, seasons and cultivars and from different agricultural practices (Rylski and Spigelman 1986; López-Marín *et al*. 2011, 2012). In addition, data regarding the effect of shading on pepper growth and yield concerns primarily sweet pepper (*Capsicum annuum* L.) cultivars (Rylski and Spigelman 1986; López-Marín *et al*. 2012)

Therefore, and based on these facts, the aim of this study was to evaluate the effect of 2 different shading levels (50% and 100% shading) with regard to a control (0% shading) placed in open field conditions on growth and yield parameters of the hot pepper (*Capsicum annuum* L.) cultivar ('Beldi') grown in Tunisia. Cultivar 'Beldi' was selected for this experiment due to its large scale use by Tunisian farmers, its high productivity, its good fruit set at both higher and lower temperatures and its high pungency preferred by both Tunisian consumers and processors (Hamza and Rhim 2008).

MATERIALS AND METHODS

Plant culture

The experiment was carried out in the Sahline experimental plot of the National Agricultural Research Institute of Tunisia during the growing seasons 2003 (March-August). The hot pepper cultivar ('Beldi') was used in this experiment. 'Beldi' is a local variety selected by the National Agricultural Research Institute of Tunisia with dark green immature fruit and dark red mature fruit and a high pungency. Seeds were sown in plug-seedling trays (Makrolon multi UV IQ-Relax Generation, Bayer Sheet, Europe Darmstadt, Germany) on January 2003. Transplanting was carried out in March 2003. The experiment surface was 1500 m² divided into 3 elementary plots for the different applied treatments and the studied pepper cultivar was grown in three replicates. Briefly, 1000 kg/ha of a basic organomineral fertilizer (Fertil Agreste Start, Scam) was spread. Post-transplant nitric nutrition with ammonium

Received: 31 December, 2012. Accepted: 28 February, 2013.

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nitrate (fertilizer Leon, Hydro Agri), 600 kg/ha, was given when required. Propamocarb hydrochloride, a fungicide, Confidor Supra (Bayer), an insecticide, and metallic copper were used for pest control. Drip irrigation may run for 1–2.5 h, at 1-2 day intervals, depending on potential evapo-transpiration, climate data and crop coefficient.

The characteristics of the different applied treatments are:

Control: 0% shading, plants placed in open field conditions. The shading conditions were applied using a shading screen (Aluminet, Polysack, Nir-Yitzak-Sufa, Israel) in order to attain 50% shading level: plants grown under the screen and receiving in this case only 75% of the global radiation and 100% shading level: plants grown under and completely surrounded by the screen. The screens were more than 2.5 m above the ground to ensure good ventilation and were large enough to fully cover the corresponding shaded plots. All the polyethylene screens were installed one week after planting in order to eliminate effects of the different screens on plant establishment as suggested by Rylski and Spigelman (1986).

Measurements

Fifteen plants per shading level repeated 3 times were used to measure different growth and yield parameters. Fruits were picked at the red-ripe stage counted and weighed. Growth parameters include plant height (cm), internode length (cm), and leaf area (cm²). Yield parameters include fruit yield (g) and the blossom-end rot incidence (%).

1. Growth parameters

Plant height was measured at the end of the experiment. Measurements were considered from the base to the highest apex of the plant. Internode length was determined only for the fourth bifurcation. This parameter was expressed in mm. Finally, leaf area was measured at the end of the experiment using a planimeter (LI 3000A, LI-COR, Nebraska, USA).

2. Yield parameters

Plant yield was expressed in grams fresh weight per plant. The percentage of blossom-end rots (% BER) was expressed as the ratio between the number of rotten fruits and the total number of fruits:

% BER = (Number of rotten fruits/Total number of fruits)*100.

Statistical analysis

The analysis of variance was carried out according to the General Linear Models (GLM) procedure developed by the Statistical Analysis Systems Institute (SAS, V6.0, Cary, NC). Means and standard errors were calculated. LSD test was also used for testing significant differences between means with a confidence level of 95%.

RESULTS AND DISCUSSION

Radiation and temperature evolution

After positioning the screens, the average daily radiation intercepted in open field conditions (0% shading) was 3900 J/cm². This value decreased under 50% shading to attain 2857 J/cm². The decrease continued under 100% shading conditions and attained only 1965 J/cm² (**Fig. 1A**). The presence of different screen also decreased the maximum daily temperature compared to open field conditions (**Fig. 1B**). At 100% shading conditions plants were exposed to 35°C for more than 2 h per day. However, this lap of time was doubled (4 h) and tripled (6 h) under 50% shading and open field conditions, respectively.

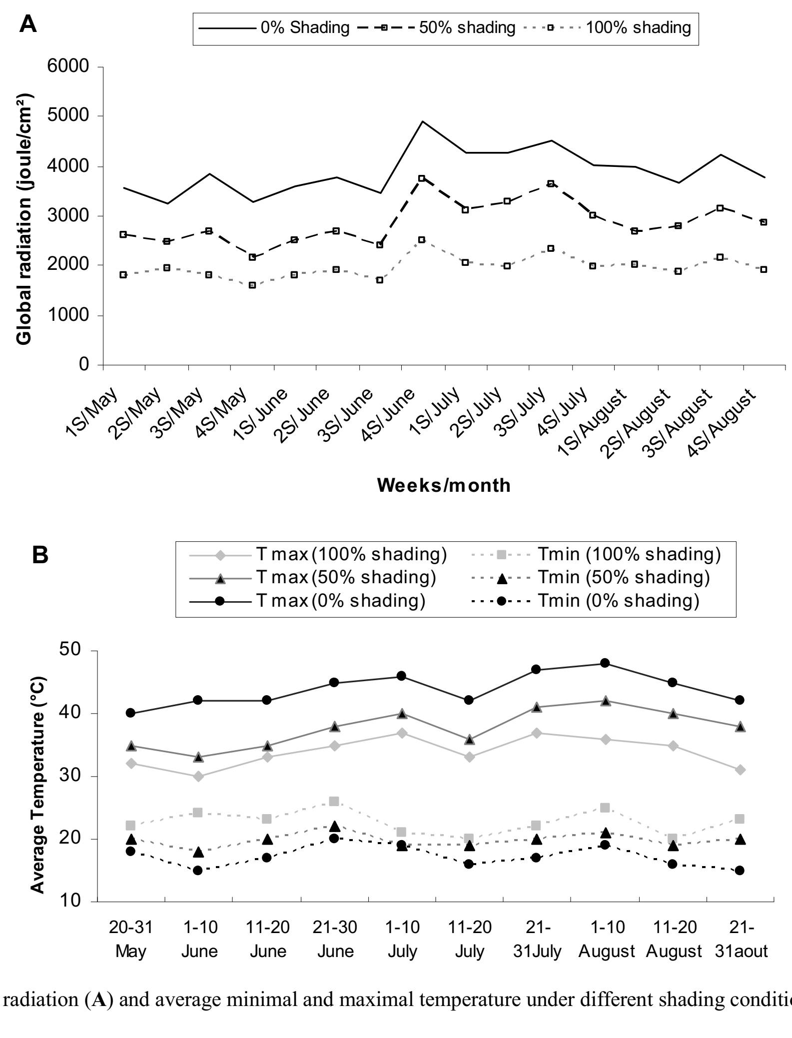

Fig. 1 Evolution of daily global radiation (**A**) and average minimal and maximal temperature under different shading conditions (**B**).

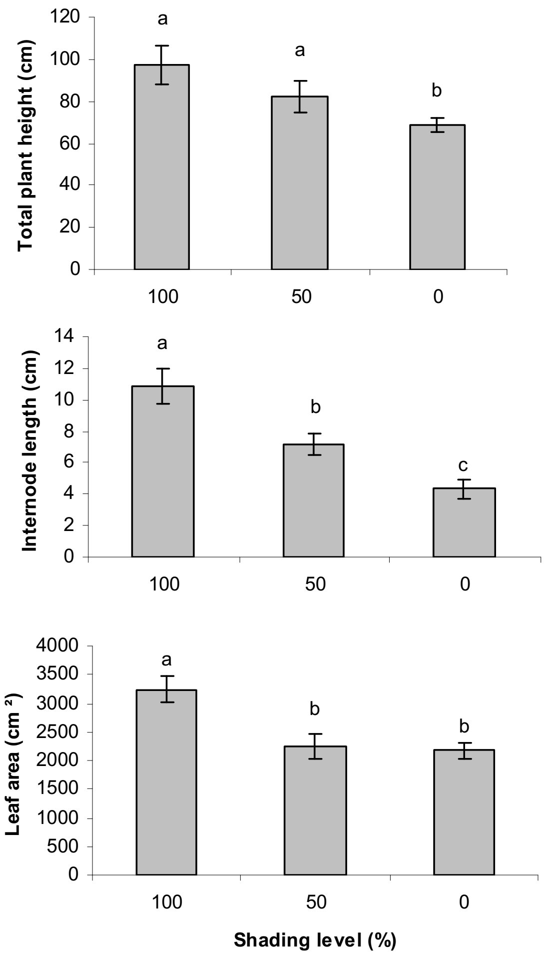

Fig. 2 Plant height, internode length and leaf area of the hot pepper cultivar 'Beldi' under different shading conditions. Data are means of three replicates ± standard error. Bars marked with the same letters are not significantly different (LSD test, $P<0.05$).

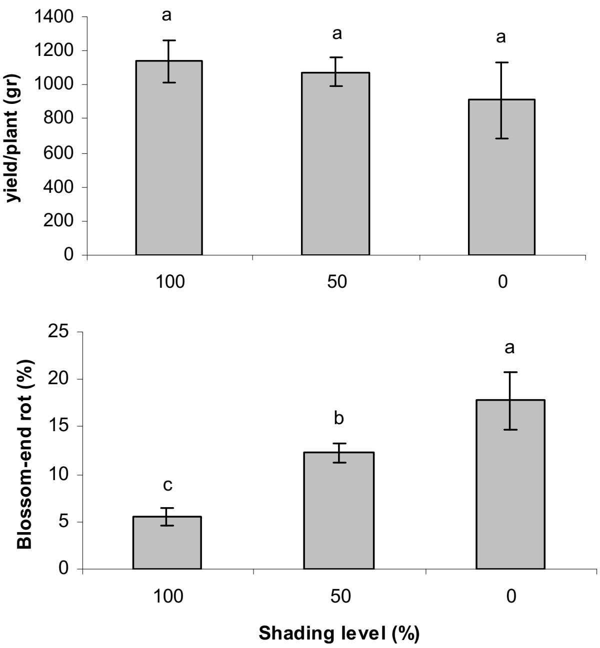

Fig. 3 Fruit weight per plant and the percentage of blossom-end rot of the hot pepper cultivar 'Beldi' under different shading conditions. Data are means of three replicates ± standard error. Bars marked with the same letters are not significantly different (LSD test, $P<0.05$).

Growth parameters

Different growth parameters including plant height, internode length and leaf area are shown in **Fig. 2**. For all the studied shading levels, plant height, internode length and leaf area varied significantly between the applied shding levels ($P < 0.01$). Values ranged from 97 cm under 100% shading to 68.67 cm under 0% (open field condition). Under 100% shading, the increase was 15% and 30% higher compared to 50% and 0% shading respectively. Regarding internode length, values ranged from 10.83 cm under 100% shading to 4.33 cm under open field conditions. The increase under total shading conditions compared to 50% and 0% shading was 31% and 47% higher respectively. Leaf area values also ranged from 3244 cm² under 100% shading to 2174 cm² under 0% shading. The increase under 100% shading was 36% and 50% higher than those obtained under 50% and 0% shading respectively. In this subject, Rylski and Spigelman (1986), studying the effect of shading on plant development, yield and fruit quality of the sweet pepper cv 'Maor' grown under conditions of high temperature and radiation, reported that plant development records taken under different levels of shading reported that plant height values ranged from 29.9 cm under 0% shading to 40.2 cm under 47% shading which means 35% higher compared to open field conditions. Similarly, the number of flower ranged from 5.6 under 0% shading to 6.2 under 47% shading. They also attributed the increase in plant height of shaded plants to both the internode elongation and node number. López-Marín *et al*. (2012), studying the grafting as an efficient alternative to shading screens to alleviate thermal stress in greenhouse-grown sweet pepper reported that plant height of the pepper cv 'Herminio' ranged from 173.63 cm under non-shaded conditions to 227.5 cm under shaded conditions. Similarly, leaf area values ranged from 15.14 cm² under non-shaded conditions to 18.30 cm² under shaded conditions. Finally total leaf fresh weight ranged from 482 g under non-shaded conditions to 528.23 g under shaded conditions. Taken together these data demonstrate that shading alleviate heat stress for the pepper cv 'Beldi'. This was revealed by higher plant vegetative growth.

Yield parameters

Different yield parameters including fruit yield and blossom-end rot incidence are shown in **Fig. 3**. Although, fruit yield under total shading conditions was quantitatively higher than that obtained in open field conditions, no statistical differences were obtained between all the applied shading conditions. However, regarding blossom-end rot incidence, 5.5% of rotted fruit was obtained under total shading conditions. This value attained attained 12.25% under 50% shading conditions and 17.75% under open field conditions. Rylski and Spigelman (1986) reported that fruit total yield and marketable yield, using the spacing 5 plants/m², was highest under 26% shading and attained 4.1 and 3.7 kg/m² respectively. Top grade quality expressed as percentage of total yield was also highest under 26% and 47% shading and attained 79% and 77%. However sun-scalded fruits were the lowest at the same shading levels with 8% and 2% under 26% and 47% shading respectively. They reported also that under shading conditions, individual fruits were characterized by a higher weight and larger length and diameter and thicker pericarp. López-Marín *et al*. (2012) reported that total yield for the sweet pepper cv 'Herminio' ranged from 3.7 kg/plant under non-shaded conditions to 3.42 kg/plant under shaded conditions. Commercial yield also ranged from 2.55 kg/plant under non shaded conditions to 2.53 kg/plant under shaded conditions. Unmarketable yield varied from 1.15 kg/plant under non-shaded conditions to 0.9 under shaded conditions. Finally sun-scald affected yield varied from 0.69 kg/plant under non-shaded conditions to 0.18 kg/plant under shaded conditions. Therefore, total yield, unmarketable yield and sun-scald affected yield were the lowest under shaded conditions.

However, there was no significant differences between shaded and non-shaded conditions in commercial yield of the sweet pepper cv 'Herminio'. Many authors studied the effect of shading on many horticultural crops (Gent 2007; Demirsoy *et al*. 2007; Xiao *et al*. 2012). Gent (2007) focused on the effect of degree and duration of shade on quality of greenhouse tomato and reported that total yield decreased linearly with increasing shade but there was no significant difference among shade treatments in marketable yield. The authors also found that marketable fruit fraction was greatest for plants grown under 50% shade. They have also reported that among crackling sensitive cultivars, up to 35% of the fruit produced in greenhouse with no shade had cracked skin, whereas in greenhouse covered with 50% shade only 24% and 26% of the tomatoes had cracked skin. In addition there was no consistent trend for shade density in the fraction of fruit with green shoulder, blossom end rot or irregular shape. Demirsoy *et al*. (2007) studied the effect of different of shading on growth and yield in 'Sweet Charlie' strawberry. They have reported that there was no effect of shading on the crown and leaf number in the experiment and that leaf area of the plants in the constant shading treatment was generally larger than that in the other treatments during spring and summer periods. They have also reported that the petiole length of the plants in the absence of shading and constant shading was higher that that of the plant in open field during spring and summer periods. Recently, Xiao *et al*. (2012) studying the effect of low light on the characteristics of photosynthesis and chlorophyll a fluorescence during leaf area development of sweet pepper reported that under low light chlorophyll content, net photosynthetic rate, photosynthetic apparent quantum efficiency and carboxylation efficiency of sweet pepper leaves increased gradually and decreased after reaching the maximum level. In addition, Devoktal and Kumar (2010) studied the effects of different light levels (0% of sun light, 30, 50 and 70% of solar radiation interception) on the growth traits and yield of *Centella asiatica*. The authors reported significant variation in many vegetative growth traits and yield of *C. asiatica* along different levels of light intensity they have also reported that *C. asiatica* plants showed better development when exposed to 30% shading. The shading also can affect health promoting compounds in horticultural crops. In this context, Krumbein and Schwarz (2013) focused on the use of grafting as an alternative to enhance health-promoting and flavour compounds in tomato fruits of shaded plants. The authors concluded that although grafting onto 'Brigeor' and 'Maxifort' enhanced titratable acid levels and three volatiles, grafting was unable to raise the decreased concentrations of sugars, β-carotene and five volatiles in shaded tomato plants.

CONCLUSIONS

The use of shading screens reducing 25% and 50% of the incoming global radiation may have created a microclimate different from this in open field conditions. This microclimate obtained mainly for 100% shading level during the hottest months of the year (June, July and August) insures a better vegetative growth and a prolongation of the main physiologic activities. Although, no differences were obtained for yield, this effect was clearly reflected in growth parameters and rotted fruit incidence.

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