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EFFECT OF POLYPROPYLENE COVER AND PLANT DENSITY ON YIELD AND ASCORBIC ACID CONTENT OF BELL PEPPER FRUITS

SUMMARY

This study aims to evaluate the effect of polypropylene cover and plant density on the marketable yield and ascorbic acid content of bell pepper fruits. Seedlings of cultivar 'Bianca F1' were planted in four plant densities of 21.8, 13.2, 10.9 and 6.6 plants m⁻². The two-factorial experiment in four repetitions was used, where the 1st factor was covering (covered and uncovered) and 2nd factor was plant density in four steps (above mentioned). The polypropylene cover over the plants was laid on plastic hoops, while control plants remain uncovered. Plants were grown on soil covered with black polyethylene mulch film. Mean daily air temperature under the polypropylene cover was 2.3 – 5.8 °C higher than the air temperature in the uncovered crop. Polypropylene cover was removed after eight weeks, when the daily air temperature reached 30 °C. Yield component analysis indicated that fruits from covered plants had greater fresh weight in comparison to fruits from uncovered plants for all plant densities. The marketable yield under polypropylene cover was significantly higher (over 70 %) compared to uncovered control. Increasing plant density enhanced the marketable yield, but the interactions of cover and plant density were not significant. The cover had strong influence on the yield at the second harvest time. Ascorbic acid contents were found significantly higher for bell pepper fruits grown under cover at all plant densities.

Keywords: *ascorbic acid content, Capsicum annuum L., polypropylene cover, plant density, yield component analysis*

INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is a warm-season crop with a high heat-unit requirement (Díaz-Pérez and Carlos, 2010). Bell pepper is an important vegetable used in our daily consumption and represent good sources of vitamins C and E, pro-vitamin A, and carotenoids (Materska and Perucka, 2005). These compounds are antioxidants and can reduce harmful oxidation reactions in human body (Sun et al., 2007). Open field production of bell pepper in central

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Slovenian area is limited, since the unfavourable climatic conditions from April to September. Therefore, planting of developed seedlings is used in commercial vegetable production in order to promote the early fruit harvesting and to improve the yields. Several studies have been conducted to increase the yield and quality of fruits or vegetables (Kacjan Maršić *et al.*, 2009; Usenik *et al.*, 2009; Veberič *et al.*, 2010). To follow these trends in horticultural practice, growers have applied row covers, as a low-cost technique to protect both cool-season and warm-season vegetable crops (Gimenez *et al.*, 2002). The most often used plant cover is the floating row cover made of spun bonded polypropylene (Demšar *et al.*, 2009). The use of polypropylene covers and high plant densities have great potential and economic value for bell peppers production in order to increase the yields (Kasirajan and Ngouajio, 2012).

The number and weight of marketable pepper fruits generally decreases per plant and increases per hectare as plant density increases (Cavero *et al.*, 2001). Enhancement of growth and yield has been attributed to higher daily air temperatures under the covered tunnels, compared with ambient readings (Gimenez *et al.*, 2002). High micro-environmental temperatures under row tunnels early in the season may result in increased vegetative growth and subsequent increased fruit yield (Waterer, 2003). However, if the cover remains over the crop too long the fruits could be impaired and yield reduced. The optimum number of accumulated heat units cannot be precisely calculated, but it is suggested that the optimum is between 650 and 700, using a base temperature of 10 °C (Gerber *et al.*, 1988). The optimum temperature for the vegetative growth of bell peppers ranges between 20 and 25 °C. When temperature falls below 15 °C or exceeds 32 °C, growth is usually retarded and yield decreases (Saha *et al.*, 2010). A reduction in the early yield of bell peppers is thought to be caused by excessively high temperatures under the covers, which result in flower abortion. Pollination and fruit set can be inhibited by maintained continuous daily temperature above 32 °C (Gerber *et al.*, 1989). Thus the removal time of the polypropylene covers is a critical phase. A wide range of different covers have been tested. However, polypropylene covers remain most popular for open field vegetable production in Slovenia. These materials are permeable for water and air, but the transmission of solar energy and the retention of heat energy are both very small (Jolliffe and Gaye, 1995).

The objective of this research was to determine the effects of polypropylene cover material and plant density on the marketable yield of bell pepper cultivar 'Bianca F1' in the central Slovenia as well as ascorbic acid content in fresh fruits. Cultivar 'Bianca F1' is one of the leading cultivars in this area, since the shape and size of the fruits are very acceptable for the fresh vegetable market.

MATERIAL AND METHODS

The experiment was conducted during the 2012 growing season, at the experimental fields of Biotechnical Faculty, University of Ljubljana, Slovenia

(46 °04' N, 14 °31' W, 300 m a.s.l.). Seeds of the bell pepper cultivar 'Bianca F1' were sown in seedling trays filled with fertilized peat. The seedlings were grown under greenhouse conditions, irrigated every day and fertilized once a week with a commercial nutrition solution, "Peters" (0.75 g N, 0.55 g P₂O₅ and 1.45 g K₂O per litre).

The open field experiment was carried out in randomized blocks in four repetitions, where each plot contained 30 plants. The soil type at open field was a heavy clay loam fertilized in early spring with 4 kg of cattle manure per m². A total of 50 g m⁻² of compound fertilizer (N-P-K, 15-15-15) was broadcast-applied and incorporated one week prior the transplanting of developed seedlings with six true leaves. Black polyethylene mulch was laid on soil before planting. The bell pepper seedlings were transplanted by hand at the beginning of June 2012. Various planting distances between plants were used: 30×15 cm (21.8 plant m⁻²), 30×30 cm (10.9 plant/m²), 50×30 cm (6.6 plant/m²), and two plants in parallel 50×30 cm (13.2 plant m⁻²). At the same day after transplanting, plastic hoops were placed over the seedlings and polypropylene cover (17 g m⁻²) was applied. A thermograph was used to record the temperature under the covers. The air temperature was measured 25 cm above the plot surface. In order to supply data for the comparison, temperature recordings were also measured at the same height in the open field with no cover. Cover was removed after eight weeks at the end of July, when the daily temperatures reached 30 °C. Irrigation and disease control were applied regularly according to the standard agronomic practice. The marketable fruits were harvested manually in three technological maturities on August 1 (first harvest), on August 25 (second harvest) and on September 25 (final harvest). Fruit size, number of fruits per plant and weight of fruits per plant were measured.

The content of ascorbic acid was determined in the pericarp of six randomly selected fruits at the end of second harvest. Bell pepper fruit pericarps (10 g) were homogenized with 15 ml of metaphosphoric acid (2% in water) using laboratory homogenizer (Ultraturax T25) and stored at -80 °C until further analysis. Determination was performed on HPLC system (Agilent 1260) with a diode array detector. The separation was carried out on a 100×2 mm i.d., 3µm Scherzo SM-C18 column (Imtakt, Japan) using a flow rate of 0.3 ml min⁻¹. The mobile phase consisted of (A) water and (B) acetonitrile both containing 0.3% (v/v) formic acid; the following elution gradient was used for solvent B: 0-3 min, 0-10%; 3-4 min, 10-100%; 4-6 min, 100%. Concentrations were calculated using external standard and expressed as mg ascorbic acid per 100 g fresh weight (FW). The results obtained during experiment were analysed through a general linear model (GLM) procedure and least-squares mean tests, with a 0.05 level of significance.

RESULTS AND DISCUSSION

With the advance of the growing season, the values of daily mean temperatures under the cover and in open field were increasing and consequently

the differences between covered and no covered treatments were noticed. The mean and maximum decade temperatures during the growing season are presented in Figure 1. From the beginning of June until the end of the second decade of July the mean decade temperature was below 20 °C, while the mean temperature under the cover was 3.6 °C higher. During the period from 20th to 30th July the mean daily temperatures outside the cover were 22.2 °C and the temperatures under cover were 28.0 °C. In general, the air temperatures under the cover were 2.3 °C – 5.8 °C higher compared to outside temperatures. Maximum daily outside temperature reached highest value at the end of July (29.5 °C). This was a critical phase, while temperature under the cover reached 35.4 °C. When temperatures during the growth increased greatly covers were removed due to the risk of flower abortion.

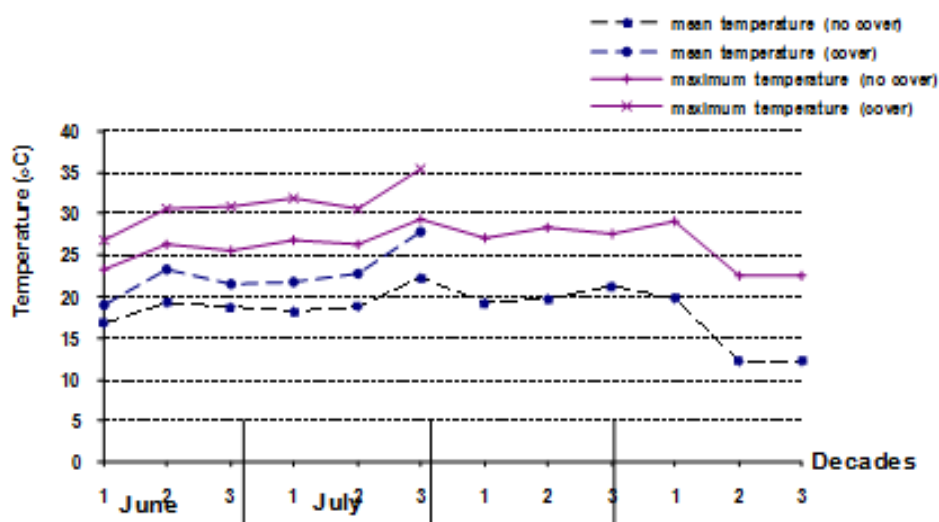


Figure 1. Mean and maximum decade temperatures during the growing season under polypropylene cover and in open field

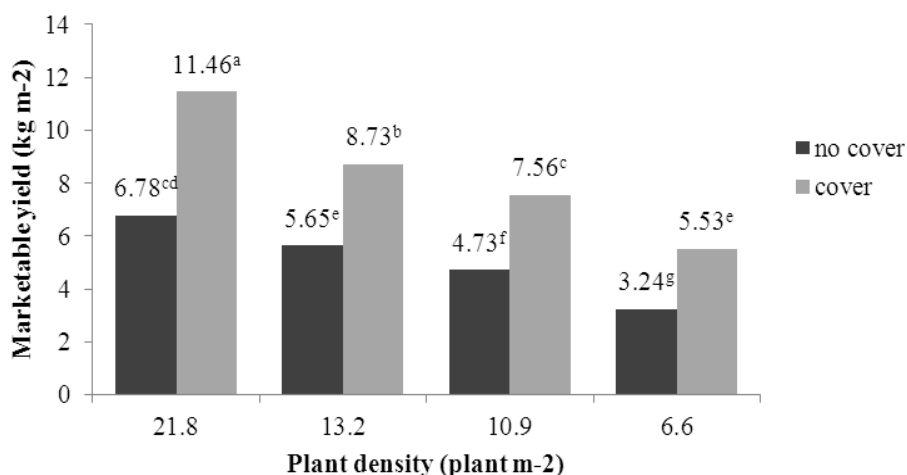
The fruits of bell pepper grown under covers had significantly greater weight compared to the fruits of uncovered control plants for all plant densities; on average fruit weighted 121.2 g and 86.8 g, respectively (Table 1). The effects of plant density on fruit weight were not statistically significant. Not significant cover-by-plant-density interaction was indicated for the fruits weight. The marketable bell pepper fruit numbers increased significantly per plant as plant density decreased. Reducing the distance between plants (21.8 plant m⁻²) resulted in decreases in the number of fruits per plant for covered and uncovered plants. The number of fruits per plant was higher in covered compared to uncovered plants. The increase in total weight of fruits per plant was attributed to a larger number of fruits per plant. This response has been observed by Gaye *et al.* (1992).

Table 1. Effect of covering and plant density on the yield parameters and ascorbic acid content of bell pepper fruits at second harvest

Covering	Plant density (plant m ⁻²)	Fruit weight (g)	Number of fruits per plant	Weight of fruits (g plant ⁻¹)	Ascorbic acid (mg 100g ⁻¹ FW)
No cover	21.8	88.8 ^b	3.5 ^e	310.8 ^e	140.2 ^b
	13.2	89.2 ^b	4.8 ^{cd}	428.2 ^d	139.6 ^b
	10.9	88.6 ^b	4.9 ^{cd}	434.1 ^d	141.5 ^b
	6.6	80.5 ^b	6.1 ^b	491.1 ^{cd}	138.9 ^b
<i>Means</i>		86.8	4.8	416.1	140.1
Polypropylene cover	21.8	122.2 ^a	4.3 ^d	525.5 ^c	165.9 ^a
	13.2	122.4 ^a	5.4 ^c	661.0 ^b	159.6 ^a
	10.9	123.8 ^a	5.6 ^c	693.3 ^b	166.1 ^a
	6.6	116.4 ^a	7.2 ^a	838.1 ^a	158.3 ^a
<i>Means</i>		121.2	5.6	679.5	162.5

Mean values in a column followed by the same superscripts do not differ significantly at $P = 0.05$.

In general, covered bell pepper plants contributed significantly to higher total marketable yields. Total marketable yield had also increased in response to increasing plant density (Figure 2).

**Figure 2.** Effect of plant density and the covering on the marketable yield of bell pepper fruits ($P < 0.05$).

Due to the compensatory effects of higher number of plants per unit area, the total yield per unit area differed significantly. On average, the marketable yield of the first harvest was higher for the covered plants in comparison to the uncovered (Figure 3).

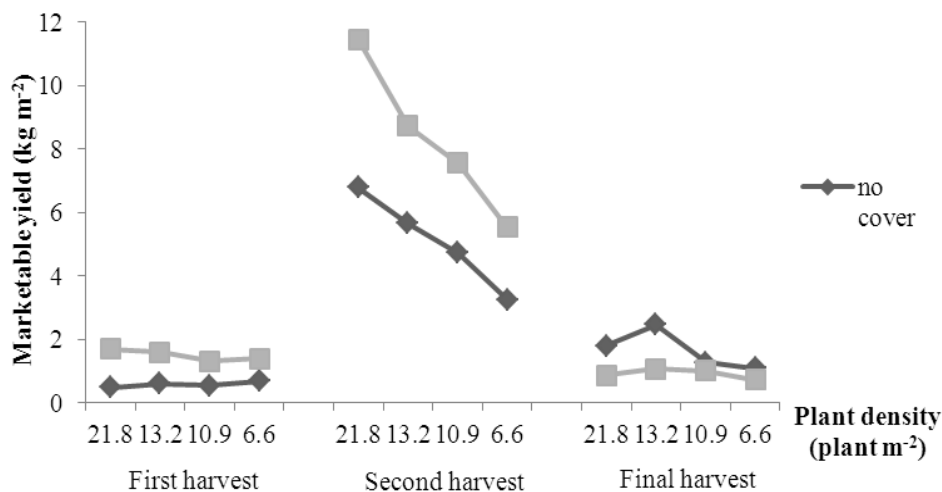


Figure 3. Effect of covering and plant density on the marketable bell pepper yield at different harvest time

These differences, however, were not significant. The increasing plant density did not influence the yield in the first harvest. There was a strong effect of covering plants on the yield in the second harvest. All of the covered plants had a higher yield compared to the uncovered plants (on average: 8.3 kg m^{-2} and 5.1 kg m^{-2} , respectively or 61 % greater yield). The higher temperature under the polypropylene cover might have been the main factor contributing to the yield increase in this harvest period. There was a significant effect of plant density on yields in the second harvest for the uncovered plants. Plant density of $21.8 \text{ plants m}^{-2}$ resulted in significantly higher yields for covered and uncovered plants. At the end of the growing season, the marketable yield under the polypropylene cover was 68.3 % greater than for the uncovered. Ascorbic acid content varied between 138.9 to 166.1 mg/100 g fresh weight among different plant densities (Table 1). The results of the analysis of the ascorbic acid content in the pericarp of the bell pepper fruits showed significantly higher values for covered plants in comparison to uncovered, while plant density had no significant effect. Bae et al. (2014) had reported similar ascorbic acid values for greenhouse-grown bell peppers, wherein the significantly higher contents were found in mature fruits.

CONCLUSIONS

In Slovenia, the earliness and the marketable yield of bell peppers are the decisive factors for determining prices and consequently profit. A comparison of the growth pattern of the bell pepper plants under different growing conditions in the open field showed that the polypropylene cover and the plant density both have a significant effect on the total marketable yield of the bell pepper fruits. On the basis of this data, it can conclude following for the central Slovenian area:

use of polypropylene cover increases the total yield of bell pepper; the production under polypropylene cover influences the higher weight of fruits; total yield per unit area increases in response to increasing plant density; and bell pepper fruits grown under polypropylene cover contain more ascorbic acid.

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