ORIGINAL SCIENTIFIC PAPER

Plant population and cultural practices on yield of bell peppers (*Capsicum annuum* L.)

Dragan Žnidarčič[1], Dean Ban[2]

[1]Department of Agronomy, Biotechnical Faculty, University of Ljubljana Jamnikarjeva 101, 1000 Ljubljana (dragan.znidarcic@bf.uni-lj.si)[2]Institute for Agriculture and Tourism, Carla Huguesa 8, 52 440 Poreč

Abstract

A field trial at the Experimental Field of the Biotechnical Faculty in Ljubljana was carried out in 2004 growth season on bell pepper (*Capsicum annuum* L.) cultivar Bianca F1 to investigate the interactive effect of different plant densities (22,000; 16,500 and 10,000 plants/ha) with an in-row spacing of 15, 20, or 30 cm between plants in rows 30 cm apart and different mulch system (PE black mulch, PE white mulch and bare soil) on yield and quality attributes.

Yield component analysis indicated that the fruit size was larger on mulching soil (irrespective of mulch colour) in comparison to bare soil at all population densities. The results revealed that PE black mulch and PE white mulch significantly increased fruit lenght, fruit width and fruit weight which are indirectly related to yield. In addition, results suggest that decreasing plant density significantly reduced the marketable fruit yield. Additionally, use of PE black or PE white mulch generally resulted in earlier and higher yield at the firs harvest compared to plants grown on bare soil.

Key words: bell pepper, PP black mulch, PP white mulch, plant population, yield

Introduction

The production of bell peppers (*Capsicum annuum* L.) for direct marketing to consumer can be a very lucrative enterprise for many growers throughout Slovenia, even though land devoted to peppers is relatively small, ranging from 50-60 ha (Statistical Office RS, 2007). In order to provide high quality peppers for markets, manipulating of growing conditions by cultural practices has the potentiality to improve yield and quality.

Plasticulture (plastic mulches, drip irrigation, fertigation, high tunnels, row covers ...) is one of good cultural practices for the favorable manipulation of microclimate. Following the trends in plasticulture practice, many growers have employed mulching and the commonly used mulching materials is the black polyethylene (PE) mulch (Goreta et al., 2005).

The use PE mulches is recomended to decrease runoff and soil erosion (Sur et al., 1992), protect nutrients from leaching and conserve soil moisture (Gajri et al., 1994) and retard weeds (Lamont, 1996). PE mulches also help in better utilization of soil nutrients meeting up the need of irrigation and warms the soil (Aguyoh et al., 1999) which can stimulate early plant growth resulting in early and better yields (Bhella, 1998) and fruit quality (Perry and Sanders, 1986) over bare ground culture.

Although many studies have been published on plant populations for bell peppers (Stoffella and Bryan, 1988; Ali and Kally, 1992; Jollife and Gaye, 1995) specific recommendations for optimal plant population density vary. One reason may be that, plant population density consists not only of plant number, but also plant vigor.

Only few studies (Žnidarčič and Osvald, 1999) of the effect of cultural management and plant density on the yield of bell pepers in Slovenian growing environment are reported.

Material and methods

Sweet pepper (*Capsicum annuum* L. cv. Bianca F1) were pre-germinated at 25-30 ^{o}C in a growth chamber and sown with 2-3 mm emerged radicle. The seedling were grown in styrofoam flats with 72 cavities per flat which were filled with a commercial Klasmann Tray® potting media, for a period of 8 weeks. After seedling emergence, the transplants were uniformly overhead trrigated as needed, and wheen they reached 2-3 leaves fully expanded leaves, were fertigated with soluble fertilizer (Peters 75 g N, 0.55 g P_2O_5 and 1.45 g K_2O L^{-1}) twice weekly.

After establishing the mulch (plastic) and bare ground beds, the pepper plants were transplanted to the field (Field of the Biotehnical Faculty in Ljubljana) by hand on May 20, 2004. Pre-plant nutrients applied at land preparation in kg per ha were: 8N, 26P and 26K. Starting two weeks after transplanting, plants were fertigated weekly with soluble fertilizer (15N-15P_2O_5-15K_2O).

The experimental design was a split-plot design with three replications. The main plot treatments consisted of three mulch system (PE black mulch, PE white mulch and bare soil) and each subunit consisted of three spacing densities. The above spacing resulted in plant population of 22,000, 16,500 and 10,000 plants/ha, respectively. Within-row spacing for transplants was 30 cm. In-row spacing used were 15 cm, 20 cm and 30 cm. The experimental unit consisted of three rows within ten plants in each row.

Peppers were harvested manually as soon as they reached technological maturity on August 10 (First harvest), on August 25 (Second harvest), on September 10 (Third harvest) and on September 25 (Final harvest). Peppers from each plot were separated into categories of marketable or unmarketable (sunscald, small, mishapen, and damaged) and the counted and weighed. Only plants from central rows were considered for measurment.

The results was subjected to an analysis of variance, and least significant differences were used to ascertain mean differences.

Results and discussion

Growing (meteorological) conditions for peppers were quite good in 2004 (data not shown) and we obtained some of the highest yields ever recorded at the Experimental Field.

The interaction for the yield characteristics between plant density and mulch system was found to be non-significant. Ther were significant differences between fruit length and width (Table 1) at the closest density (22,000 plants/ha) compare to the wider density (16,500 and 10,000 plants/ha). The fruit lenght ranging from 91.6 mm (22,000 plants/ha) to 104.8 mm (22,000 plants/ha). The similar trends were observed by fruits width.

From average results it was concluded that the lowest plant population of 10,000 plants/ha produced significantly large fruits (230.6 g) followed by 16,500 plants/ha (214.8 g) against minimum from 201.5 g at the highest plant population (22,000 plants/ha). From average data it was observed that both mulch systems gave significantly larger fruits against bare soil. No significant weight differences existed between black and white mulch. Higher pepper fruit yields under PE mulches may be partly due to low weed population, which resulted in reduced competition for nutrients and water.

Based on the result, it was found out that there is no significant difference in fruit wall thickness between treatments. Statistically the three density; 30cm x 15 cm, 30 cm x 20 cm and 30 x 30 cm perform equality good and so with the different mulch system.

Table 1. Main effects of plant density and mulch system on fruit characters of bell peppers

Treatment	Fruit			Fruit wall thickness (mm)
	Lenght (mm)	Width (mm)	Weight (g)	
Plant density (plants/ha)				
22,000	91.6 a	76.3 a	201.5 a	6.4
16,500	102.5 b	81.5 ab	214.8 b	6.1
10,000	104.8 b	84.2 b	230.6 c	6.5
Significance	*	*	*	ns
CV (%)	24.7	18.2	34.8	-
Mulch system				
PE black mulch	108.2 b	86.7 b	228.6 b	6.2
PE white mulch	101.9 b	85.2 b	225.2 b	6.1
Bare soil	85.6 a	74.3 a	196.3 a	6.4
Significance	*	*	*	ns
CV (%)	20.8	16.1	29.4	-

ns = non significant; * = significant (P<0.05)
Means followed by the same letter(s) are not significantly different at 5% level.

Marketable yield (t/ha) was inversely related to plant density and had shown similatr trends to the weight of fruits for all plant densities and mulch systems. Marketable yield were highest at 22,000 plants/ha (27.5 t/ha), followed by 16,500 plants/ha (22.6 t/ha), and lowest at 10,000 plants/ha (16.4 t/ha). Marketable yield were significantly highest in pepper mulched with PE black and PE white mulch compared to bare soil. Cooper (1973) found that vegetables grown under mulches consistently improved root development owing to increased soil temperatures. The incident radiation absorbed by mulches can be readily transmitted to the soil surface. The air near the soil surface is relatively immobile with a low thermal conductivity. Thus, mulches applied on or near the soil surface cause a consistent increase in soil temperature.

The number of fruits per plant was affected by plant density. At lowest plant density (10,000 plants/ha), the number of fruits per plant was less than at higher plant densities (16,500 plants/ha and 22,000 plants/ha). Mulch system did not influence the number of fruits per plant.

Corresponding with number of fruits per plant increased the fruit weight per plant. Pepper plants grown on mulch produced higher fruit weight per plant than plants grown on bare soil. We found no differences between PE black and PE white mulch for pepper fruit weight per plant.

Table 2. Main effects of plant density and mulch system on yield and yield components of bell peppers

Treatment	Yield (t/ha)		No fruits/plant		Fruit weight/plant (kg)	
	Market.	Nonmark.	Market.	Nonmark.	Market.	Nonmark.
Plant density (plants/ha)						
22,000	27.5 a	10.2 a	6.2 a	2.3 b	1.3 a	0.5
16,500	22.6 b	8.5 a	6.4 a	2.4 b	1.4 a	0.5
10,000	16.4 c	3.7 b	7.1 b	1.6 a	1.6 b	0.4
Significance	*	*	*	*	*	ns
CV (%)	12.4	6.2	8.3	5.7	4.2	-
Mulch system						
PE black mulch	33.3 b	3.7 b	6.8	2.2	1.5 b	0.5
PE white mulch	35.5 b	3.7 b	7.0	2.1	1.6 b	0.5
Bare soil	28.8 a	2.9 a	6.7	2.0	1.3 a	0.4
Significance	*	*	ns	ns	*	ns
CV (%)	17.4	12.8	-	-	3.6	-

ns = non significant; * = significant (P<0.05)
Means followed by the same letter(s) are not significantly different at 5% level.

Table 3. Main effects of plant density and mulch system on percent of the marketable yield of bell peppers at different harvest time

Treatment	Harvest time			
	August 10	August 25	September 10	September 25
Plant density (plants/ha)				
22,000	11.8	25.6	31.8	30.8
16,500	10.9	27.4	34.2	27.5
10,000	11.6	24.8	33.0	30.6
Significance	ns	ns	ns	ns
CV (%)	-	-	-	-
Mulch system				
PE black mulch	20.4	30.5	35.6 b	13.5 a
PE white mulch	21.8	32.6	33.1 ab	12.5 a
Bare soil	12.3	30.8	28.3 a	28.6 b
Significance	*	ns	*	*
CV (%)	12.3	-	17.7	20.4

ns = non significant; * = significant (P<0.05)
Means followed by the same letter(s) are not significantly different at 5% level.

The strongest influence in terms of an earlier yield has the PE black and PE white mulch at the first harvest on August 10. Acording to Tindal et al. (1991) the soil warming effects of mulches are important early in the season because cool soil temperatures have a number of adverse effects on plant root growth such as reduced nutrient uptake. This increase in production occurs at a time when bell prices are high because domestic peppers (fruits from local farmers) have not yet come onto the market.

Conclusions

It could be concluded that lowering plant density increase bell pepper fruit quality in terms of fruit weight and marketable yield. In addition both PE mulch system increased fruit and marketable yield as compared wit production on bare soil.
There is need for further research to determine the upper limit for plant density. Additional work will be needed to careful analysis of the influence of different mulch colours in comparison to the standard black or white PE films on fruit yield, as well as insect and disease occurence.

References

Ali A.M., Kelly W.C. (1992). The effects of interfruit competition on the size of sweet pepper (Capsicum annuum L.) fruits. Sci. Hortic., 52: 69-76.

Aguyoh J., Taber H.G., Lawson V. (1999). Maturity of fresh market sweet corn with directseeded plants, transplants, clear plastic mulch and rowcover combinations. Hort Tech., 9(3): 420-425.

Bhella H.S. (1998). Tomato response to trickle irrigation and black polyethylene mulch. J. Am. Soc. Hort. Sci., 113: 543-546.

Cooper A.J. (1973). Root temperature and plant growth. Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, England.

Gajri P.R., Arora V.K., Chaudhary M.R. (1994). Maize growth responses to deep tillage, straw mulching and farmyard manure in coarse textured soils of N.W. India. Soil Use Manage., 10: 15-20.

Goreta S., Perica S., Dumičić G., Bučan L., Žanić K. 2005. Growth and yield of watermelon on polyethylene mulch with different spacings and nitrogen rates. HortSci., 40, 2: 366-369.

Jollife P.A., Gaye M.M. (1995). Dynamics of growth and yield component responses of bell peppers (*Capsicum annuum* L.) to row covers and population density. Sci. Hortic., 62: 153-164.

Lamont W.J. (1996). What are the components of a plasticulture vegetable production system. HortTech., 6(3): 150-154.

Nielson K.F. 1974. Roots and root temperature. pp. 293-333. in: E.W. Carlson (ed.). The plant root and its environment. Univ. Press of Va. Charlottesville.

Perry B.K., Sanders D.C. 1986. Tomato yield as influenced by plants protection system. HortScience, 21: 238-239.

Shrivastava P.K., Parikh M.M., Parikh N.G., Sawani N.G., Raman S. (1994). Effect of drip irrigation and mulching on tomato yield. Agric. Water Manage., 25: 179-184.

Soltani N., Anderson J.L. Hamson A.R. (1995): Growth analysis of watermelon plants with mulches and row covers. J. Am. Soc. Hort. Sci., 120: 1001-1009.

Statistical Office RS (2007). Rapid Reports - provisional data. Ljubl., No. 548, Nov. 14. 2008.

Stoffella P.J., Bryan H.H. (1988). Plant population influences growth and yields of bell pepper.- J. Am. Soc. Hortic. Sci., 113: 835-839.

Sur H.S., Mastana P.S., Hadda M.S. (1992). Effect of rates and modes of mulch application on runoff, sediment and nitrogen loss on cropped and uncropped fields. Trop. Agric., 69: 319-322.

Tindall J.A., Beverly R.B., Radcliff D.E. (1991). Mulch effect on soil properties and tomato growth using micro-irrigation. Agron. J., 83: 1028-1034.

Žnidarčič D., Osvald J. (1999) The influence of plant density and covering on yield of bell peppers (*Capsicum annuum* L.) Zb. Bioteh. fak. Univ. Ljubl., Kmet., 73(1): 59-64.