Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 9 (5): 276-280, 2010
ISSN 1682-3974

Growth and Yield Characteristics of Paprika Pepper (*Capsicum annum* L.) in Response to Plant Density

M.H. Aminifard, H. Aroiee, S. Karimpour and H. Nemati
Department of Horticultural Science, College of Agriculture,
Ferdowsi University of Mashhad, Mashhad, Iran

Abstract: This study was conducted to determine the effects of different plant densities (20×50 cm, 30×50 cm, 20×100 cm, 30×100 cm) on plant growth characteristics and fruit yield of paprika pepper (*Capsicum annum* L.) in open field. Plant height, leaf chlorophyll content, flower number, yield, fruit seed number, 1000 seed weight and vitamin C were assessed at immature and mature. The results indicated that vegetative growth characteristics (plant height, lateral stem length and leaf chlorophyll content) reduced as plant density increased. The highest lateral stem number and leaf number were obtained in plants density 30×100 cm. Plant density affected on flowering factors (node number to first flower, days to 1st flowering and flower number). The days to 1st flowering increased as plant density increased. It was observed that fruit volume, fruit average weight, plant yield and seed number decreased with increasing plant density, but total yield ha^{-1} increased with increasing plant density. The highest and lowest of yield ha^{-1} were obtained by 20×50 cm and 30×100 cm spacing, respectively. Also plant density significantly affected on Vitamin C. The highest and lowest vitamin C were observed in 30×100 cm and 30×50 cm spacing, respectively.

Key words: Plant density, growth, yield, pepper

INTRODUCTION

Pepper (*Capsicum annum* L.) which belongs to Solananceae, is known as a vegetable and consumed both as fresh and dehydrated spices (Bosland and Vostava, 2000). International spices traders use the term paprika for non-pungent red Capsicum powder. Besides being used as colorant, it is also used for flavouring and garnishing of eggs, cheese, meat dishes, sea foods, salads etc. The commercial importance of paprika both as a spice and a vegetable with large scale cultivation in both tropical and sub tropical regions are increasing (Kannan *et al*., 2009). Cultural factors such as transplant age, fertility, plant population and delayed harvest influenced pepper yield (Decoteau and Graham, 1994). Studies on plant density for different types of pepper including bell, cayenne, pepperoncini and Jalapeno have shown that plant density and plant arrangement can influence plant development, growth and the marketable yield of peppers (Khasmakhi-Sabet *et al*., 2009). Plant density is an important determinant of yield. Yield per unit area tends to increase as plant density increases up to a point and then declines (Akintoye *et al*., 2009). An increase in spacing of rice induced vigorous plant growth as well as increased the number of panicles per hill, grain yield per hill, filled grains per panicle and 1000 grain weight (Baloch *et al*., 2002). Nasto *et al*. (2009) reported that increasing plant density resulted in greater yield ha^{-1} of bell pepper. Wider spacing on the other hand led to increase in fruit yield per plant with bigger fruits and more cracked fruits per plant in tomato (Law-Ogbomo and Egharevba, 2009). Decreasing plant density significantly reduced the total yield of radish but markedly enhanced root quality (El-Desuki *et al*., 2005). It was reported with increasing plant density decreased pepper root dry weight and was positive relationship between fruit weight and root weight (De-Viloria *et al*., 2002). Azizi and Kahrizi (2008) reported that plant density affected on Seed yield, biological yield, harvest index and percentage of seed essential oil of cumin. An increasing in yield with higher plant density was a result of increased numbers of fruit ha^{-1} in direct-seeded paprika pepper (Cavero *et al*., 2001). The main aim of this experiment was to determine the influence of plant density on growth, yield and fruit quality of paprika pepper in open filed.

MATERIALS AND METHODS

Plant preparation: The research was conducted from March 9 to November 21, 2006 at Research Farm of Birjand

Corresponding Author: M.H. Aminifard, Department of Horticultural Science, College of Agriculture,
Ferdowsi University of Mashhad, Mashhad, Iran

University, Iran (latitude 32°53' N, longitude 59°13' E and 1470 m elevation). This site represents the range of dry conditions. Annual rainfall ranges is between 91 and 120 mm and mean annual relative humidity is 37%. Soil sample (0-30 cm depth) was taken with auger after the site had been prepared for cultivation. The sample was analyzed for physical and chemical properties using standard laboratory procedures described by Mylavarapu and Kennelley (2002) and data shown in Table 1. The experimental field was cleared, ploughed, harrowed and divided into plots. Phosphorus (P_2O_5) and potassium (K_2O_5) were applied 100 and 50 kg ha^{-1} each at the time of soil preparation. Paprika pepper seeds were established in a greenhouse in large trays with a 1:1 mixture of sand and peat [1:1 v/v]. Irrigation was done after sowing when necessary. Six-week-old pepper plants were hand-transplanted into well-prepared beds in the field on 19 Apr. 2006. Nitrogen fertilizer (urea) was applied at 75 kg ha^{-1} that was splited into three equal parts and applied at ten Days after Transplanting (DAP) as basal and remaining portions were used as top dressing at 30 and 50 DAP. Plots were irrigated when necessary during the growing season. All practical managements included, mulching, weeding and other horticultural operations were done traditionally.

Treatments: Treatments consisted of four levels of population plant (20×50 cm, 30×50 cm, 20×100 cm, 30×100 cm) that achieve planting densities of 100000, 6666, 50000 and 33333 pph, respectively.

Measurements: Ten plants in each replication were used to assess plant height, leaf number, number and length of lateral stem and internodes length at three growing stages including vegetative, flowering and reproductive. Leaf chlorophyll content was measured by a portable chlorophyll meter, SPAD-502 (Minolta Corporation, Ramsey, NJ). Leaf samples were oven dried at 75°C for 72 h to the constant leaf dry weight for each plant was weighed using digital balance and recorded in gram (Ouda and Mahadeen, 2008). The number of days to the first flowering was estimated for each plot and the number of flowers per plant was evaluated based on the method by Remison (1997). Mature fruits were harvested at 10-14 day intervals to assess the volume of fruits (cm^3), average fruit weight (g) and fruit yield per plant (g plant^{-1}). Fruit yield per hectare was obtained through the conversion of the net plot yield. Vitamin C was determined based upon the quantitative discolouration of 2,6-indichlorophenol 6 indophenols (Merck KgaA, Darmstadt, Germany) titrimetric method as described in AOAC methodology No. 967.21 (AOAC, 2000).

Table 1: Soil characteristics of experimental field

Soil factors	Values
N (%)	0.05
P (ppm)	14.0
K (ppm)	270.0
pH	7.1
Clay (%)	19.0
Silt (5%)	41.0
Sand (%)	40.0

Experimental design and statistical analysis: The experiment was arranged in a Completely Randomized Block Design (CRBD) with four treatments and three replications, each replication with ten plants. Data were analyzed using MSTAT-C and means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of confidence.

RESULTS AND DISCUSSION

Data (Table 2-5) showed that plant density significantly affect pepper growth, yield and fruit quality.

Vegetative growth: Results obtained indicated significant differences for Plant height (Table 2). The highest plant height at vegetative and reproductive stages were observed in density 20×100 cm with 21.09 cm and density 30×100 cm with 42.67 cm, respectively and these variables decreased as plant density increased (Table 2), Similar results were also reported by Elattir (2002), De-Viloria *et al.* (2002) and Ara *et al.* (2007). The effects of plant density on the stem characteristics of pepper were significant. Number and length of lateral stems reduced at both vegetative and reproductive stages as plant density increased (Table 2). This result is the same trend with the findings of Jovicich *et al.* (2003a) and Hosseini *et al.* (2006). The reduction in plant height and number and length of lateral stems as plant population density increased might be attributed to the possible competition for soil moisture and nutrients. It is explained that as plant population density increases, competition for available water, mineral nutrients and light increases (Abubaker, 2008). Leaf number at flowering and reproductive stages decreased

Table 2: Effect of plant density on vegetative characteristics of pepper

Treatment	Plant height (cm)		Lateral stem No.		Lateral stem length (cm)	
(cm)	Veg.	Rep.	Veg.	Rep.	Veg.	Rep.
20×50	18.09b	37.26c	10.00b	17.17c	11.00bc	22.84b
30×50	18.51b	38.92c	10.09b	18.00bc	10.34c	23.17b
20×100	21.09a	41.26ab	11.26a	19.24ab	12.51a	25.67ab
30×100	20.92a	42.67a	11.51a	20. 42a	12.09ab	26.92a

Veg.: Vegetative stage; Flower: Flowering stage; Rep.: Reproductive stage. Within each column, same letter indicates no significant difference between treatments at 5% levels with higher planting density (Table 3). The highest leaf number at flowering stage (59.76) and reproductive stages (90.76) were observed in 30×100 cm but there was no significant difference between treatments at leaf number at vegetative stage (Data not shown). This result is in agreement with the findings of Elattir (2002), De-Viloria *et al.* (2002) and Pervez *et al.* (2004). Plant density significantly affected leaf chlorophyll content at flowering and reproductive stages. As data shown, the lower plant density, the higher chlorophyll content (Table 3). The highest leaf chlorophyll content was observed in density 30×100 cm and 20×100 cm (67.30, 65.96 at flowering and reproductive stages, respectively). However, the reduction of leaf chlorophyll content could be explained partially by the effects of shading of the lower canopy, causing poor canopy interception of the photosynthetically active radiation (Brahim *et al.*, 1998). If we look at the plant basis, then at the wider spacing the area for the development of a single plant is larger as well as the possibility for more lush growth and the development of fruitful branches. In high densities, plants compete with each other for nutrients, water and light and therefore develop poorly (Maynard and Scott, 1998). Also, the strong interplant competition due to the crowding and the shallow taproot system of these plants may have prevented the absorption of water and nutrients at deeper soil profiles (Brahim *et al.*, 1998).

Table 3: Effect of plant density on vegetative characteristics of pepper

Treatment (cm)	Leaf number		Leaf chlorophyll	
	Flower	Rep.	Flower	Rep.
20×50	53.51b	86.17b	63.28b	64.07ab
30×50	54.26b	86.09b	63.01b	63.10b
20×100	56.00b	87.51b	66.89a	65.96a
30×100	59.67a	90.76a	67.30a	65.82a

Veg.: Vegetative stage; Flower: Flowering stage; Rep.: Reproductive stage. Within each column, same letter indicates no significant difference between treatments at 5% levels

Table 4: Effect of plant density on reproductive characteristics of pepper

Treatments (cm)	Node No. to first flower	Days to 1st flowering	Flower No. at lateral stem	Fruit No. at lateral stem
20×50	10.00c	47.84a	4.00b	1.67b
30×50	10.34bc	47.51a	4.50b	1.84b
20×00	11.09ab	45.17b	4.67a	2.42a
30×100	11.34a	45.09b	5.00a	2.59a

Within each column, same letter indicates no significant difference between treatments at 5% levels

Reproductive growth: Because of higher vegetative growth by high spacing, the node numbers to the first flowering increased, however the number of days to the first flowering decreased (Table 4). The highest and the lowest node numbers to the first flowering were obtained at the density 20×100 cm with 11.09 nodes and 20×50 cm with 10 nodes, respectively; that was in agreement with Abubaker (2008) and Law-Ogbomo and Egharevba (2009). Flower and fruit numbers in lateral stems were affected by plant density (Table 4). The highest flower and fruit numbers in lateral stems were in the lowest plant density (30×100 cm) with 5 flowers and 2.59 fruits, while the lowest flower and fruit numbers in lateral stems were in the highest plant density (20×50 cm) with 4 flowers and 1.67 fruits, which were in agreement with the findings of Jovicich *et al.* (2003a) and Ara *et al.* (2007). Higher plant density also restricts light penetration and dry matter accumulation, thus reducing flowering bud development (Foster *et al.*, 1993).

Results obtained indicated that plant densities 30×100 cm and 20×100 cm produced the highest weight (74 g) and volumes of fruit (156.3 cm^3) respectively, while the lowest fruit weight (66 g) and fruit volume (142.5 cm^3) was related to plant density 20×50 cm. The similar findings of increased average fruit weight with wider spacing were reported by Miyao (2002) and Jovicich *et al.* (2003b). This is likely due to the competition associated with the higher plant populations resulting in the lower weight and volume mean fruit. It was observed that planting density had remarkable effects on Seed characteristics (Table 5). Seed numbers per fruit and 1000-seed weight increased as plant space increased. The maximum of seed numbers (145) and 1000-seed weight (5.52 g) were observed in the density 30×100 cm and 20×100 cm, respectively. These results confirm earlier observations by Nerson (2005), Dong *et al.* (2005) and Hosseini *et al.* (2006). Increased seed numbers and 1000-seed weight caused by the decreasing in plant population agree with the hypothesis that lower plant population may results in heavier seeds. Heavier seeds may provide superiority in the germination and the establishment as they have more resources to enable them to emerge from greater depth. The production of the heavier seeds by the lowest plant population may be due to the less competition for nutrients and moisture

Table 5: Effect of plant density on yield and fruit quality characteristics of pepper

Treatments (cm)	Fruit F.W. (g)	Fruit vol. (cm^3)	Seed No./Fruit	1000 seed wt. (g)	Vit-C (mL/100 g)		Total yield plant g^{-1}	Total yield (kg ha^{-1})
					Green fruit	Red fruit		
20×50	66.00b	142.5b	127.2c	5.07c	132.4b	199.6b	928.8c	92880a
30×50	66.84b	145.8ab	129.7c	5.10bc	132.3b	199.3c	982.7c	65500b
20×100	72.67a	156.3a	142.3ab	5.520a	135.3a	203.4ab	1082b	54100b
30×100	74.00a	154.2a	145.7a	5.410ab	135.3a	204.7a	1211a	40360c

F.W.: Fresh Weight; Vol.: Volume; W.: Weight; No.: Number. Within each column, same letter indicates no significant difference between treatments at 5% levels

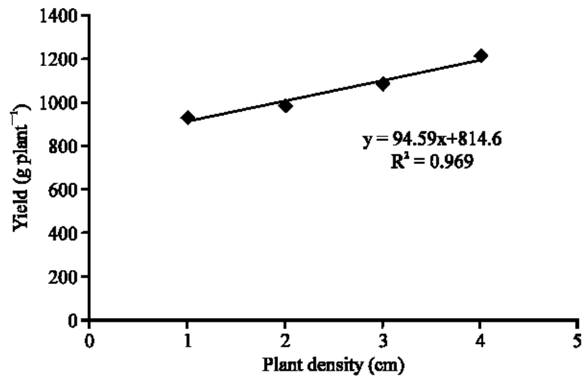

Fig. 1: The correlation between plant density and pepper yield per plant

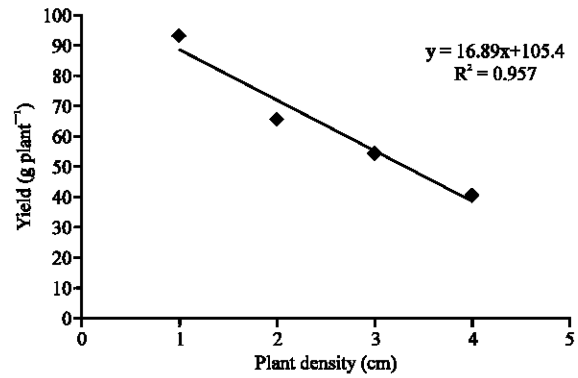

Fig. 2: The correlation between plant density and pepper yield per hectare

between plants which, in turn, influences supply of assimilation of the seeds as reported by Egli (1998).

The total fruit yield plant^{-1} decreased as the planting density increased (Table 5). The lowest and the highest yield (plant^{-1}) were observed in the 20×50 cm with 928.8 g and 30×100 cm with 1211 g, respectively. This result is in conformity with the findings of Cavero *et al.* (2001), Ara *et al.* (2007) and Nasto *et al.* (2009). This might be due to the effect of competition. This arises due to the fact that the competition is less in the low planting density than at the high planting density. The competition might be high for nutrients, physical spaces and water (Law-Ogbomo and Egharevba, 2009). The relationship between plant density and pepper yield is shown in Fig. 1. The equation was: $Y = 94.59 X + 814.65$ where Y is yield in g plant^{-1} and X is levels of plant density.

Results obtained indicated significant differences for yield per hectare (Table 5). Yield (ha^{-1}) increased as plant density increased. The highest density (20×50 cm) produced the highest fruit yield (93800 kg h^{-1}) while the lowest yield per hectare (33420 kg h^{-1}) was recorded at density (30×100 cm). Similarly, Russo (2003), Nasto *et al.* (2009) and Khasmakhi-Sabet *et al.* (2009) reported that greatest fruit yield ha^{-1} of sweet pepper and other plants were obtained from plants grown at the high densities. The lower plant densities per unit area produces more vigorous crops than at the higher population densities, but this could not compensate for the reduced number of plants per unit area. The total yields ha^{-1} increased with the higher plant densities. This was probably due to the increasing in the number of plants per unit area, which might contribute to the production of extra yield per unit area leading to the high yield (Law-Ogbomo and Egharevba, 2009). The relationship between plant density and pepper yield per hectare is shown in Fig. 2. The equation was: $Y = 16.896X + 105.45$ where Y is yield in ha^{-1} and X is levels of plant density. This formula could be used when making a recommendation for pepper plant density application and when the conditions are the same or very close to those in this experiment. A significant difference among the plant density treatments was found on the vitamin C (Table 5). The highest vitamin C at green (135.4 mL/100 g) and ripping stage (204.7 mL/100 g) was observed in the density 30×100 cm, while the lowest vitamin C at green (132.3 mL/100 g) and ripping stage (199.3 mL/100 g) was observed in the density 30×50 cm.

REFERENCES

Abubaker, S., 2008. Effect of plant density on flowering date, yield and quality attribute of bush beans (*Phaseolus vulgaris* L.) under center pivot irrigation system. Am. J. Agric. Biol. Sci., 3: 666-668.

Akintoye, H.A., A.A. Kintomo and A.A. Adekunle, 2009. Yield and fruit quality of watermelon in response to plant population. Int. J. Vegetable Sci., 15: 369-380.

AOAC., 2000. Official Method of Analysis. AOAC., Gaithersburg, USA.

Ara, N., M.K. Bashar, S. Begum and S.S. Kakon, 2007. Effect of spacing and stem pruning on the growth and yield of tomato. Int. J. Sustain. Crop Prod., 2: 35-39.

Azizi, K. and D. Kahrizi, 2008. Effect of nitrogen levels, plant density and climate on yield quantity and quality in cumin (*Cuminum cyminum* L.) under the conditions of Iran. Asian J. Plant Sci., 7: 710-716.

Baloch, A.W., A.M. Soomro, M.A. Javed, M. Ahmad, H.R. Bughio and M.S. Bughio, 2002. Optimum plant density for high yield in rice (*Oryza sativa* L.). Asian J. Plant Sci., 1: 114-116.

Bosland, P.W. and E.J. Vostava, 2000. Peppers: Vegetable and Spice Capsicum. CABI Publishing, New York, USA.

Brahim, K., D.T. Ray and D.A. Dierig, 1998. Growth and yield characteristics of *Lesquerella fendleri* as a function of plant density. Ind. Crops Prod., 9: 63-71.

Cavero, J., R.O. Gill and M. Gutierrez, 2001. Plant density affects yield, yield components and colour of direct-seed paprika pepper. J. Hort. Sci., 361: 76-79.

De-Viloria, Z.A., R. De-Arteaga and L.T.D. Torrealba, 2002. Growing of pepper (*Capsicum annum*) in response to different levels of NPK and sowing density. J. Hortsci., 72: 1062-1066.

Decoteau, D.R. and H.A.H. Graham, 1994. Plant spatial arrangement affects growth, yield and fruit distribution of cayenne peppers. J. Hortsci. 29: 149-151.

Dong, H., D. Zhang, W. Tang, W. Li and Z. Li, 2005. Effects of planting system, plant density and flower removal on yield and quality of hybrid seed in cotton. J. Field Crops Res., 93: 74-84.

Egli, D.B., 1998. Seed Biology and Yield of Grain Crops. CAB International, New York, pp: 108–112.

El-Desuki, M., S.R. Salman, M.A. El-Nemr and A.M.R. Abdel-Mawgoud, 2005. Effect of plant density and nitrogen application on the growth, yield and quality of radish (*Raphanus sativus* L.). J. Agron., 4: 225-229.

Elattir, H., 2002. Plant density effects on processing tomato growing in Morocco. J. Acta Hort., 613: 197-200.

Foster, M.A., G. Kleine and J. Moore, 1993. Impact of Seeding Rate and Planting Date on Guayule Stand Establishment by Direct Seeding in West Texas. In: Advances in New Crops, Janick, J. and J.E. Simon (Eds.). Wiley, New York, pp: 354-355.

Hosseini, M.N., H.M. Alizadeh and H.M. Ahmadi, 2006. Effects of plant density and nitrogen rates on the competitive ability of canola (*Brassica napus* L.) against weeds. J. Agric. Sci. Technol., 8: 281-291.

Jovicich, E., D.J. Cantliffe and P.J. Stofella, 2003a. Spanish pepper trellis system and high plant density can increase fruit yield, fruit quality and reduced labour in hydroponic, passive-ventilated greenhouse crop. Acta Hortic. (ISHS), 614: 255-262.

Jovicich, E., D.J. Cantliffe, P.J. Stoffella and J.J. Vansickle, 2003b. Reduced fertigation of soilless greenhouse peppers improves fruit yield and quality. J. Acta Hortic., 609: 193-199.

Kannan, K., M. Jawaharlal and M. Prabhu, 2009. Effect of plant growth regulators-A review. J. Agric. Rev., 30: 229-232.

Khasmakhi-Sabet, A., S. Sedaghathoor, J. Mohammady and A. Olfati, 2009. Effect of plant density on bell pepper yield and quality. Int. J. Vegetable Sci., 15: 264-271.

Law-Ogbomo, K. and E. Egharevba, 2009. Effects of planting density and NPK fertilizer application on yield and yield components of tomato (*Lecopersicum esculentum* Mill) in forest Location. World J. Agric. Sci., 5: 152-158.

Maynard, E.T. and W.D. Scott, 1998. Plant spacing affects yield of superstar muskmelon. J. Hortsci., 33: 52-54.

Miyao, G., 2002. Influence of plant population on transplanted processing tomatoes in the lower Sacramento valley. J. Acta Hortic., 613: 107-109.

Mylavarapu, R.S. and D.E. Kennelley, 2002. Uf/if as extension soil testing laboratory (ESTL): Analytical procedures and training manual. Instit. Food Agric. Sci., 5: 152-158.

Nasto, T.H., A. Balliu and N. Zeka, 2009. The influence of planting density on growth characteristics and fruit yield of peppers (*Capsicum annuum* L.). J. Acta Hortic., 830: 609-912.

Nerson, H., 2005. Effects of fruit shape and plant density on seed yield and quality of squash. Scientia Hortic., 105: 293-304.

Ouda, B.A. and A.Y. Mahadeen, 2008. Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleracea*). Int. J. Agric. Biol., 10: 627-632.

Pervez, M.A., C.M. Ayub, B.A. Saleem, N.A. Virk and N. Mahmood, 2004. Effect of nitrogen levels and spacing on growth and yield of radish (*Raphanus sativus* L.). Int. J. Agric. Biol., 6: 504-506.

Remison, S.U., 1997. Basic Principles of Crop Physiology. 1st Edn., Sadoh Press, Benin City, Nigeria, pp: 162.

Russo, V.M., 2003. Planting date plant density affect yield of pungent and no pungent Jalapeno peppers. J. Hortsci., 38: 520-523.