Effects of Planting Density and System on Growth and Flowering of Spray Carnations[*]

Soner KAZAZ[1][**], Faik Ekmel TEKİNTAŞ[2], Mehmet Atilla AŞKIN[1]

[1]*Süleyman Demirel University, Faculty of Agriculture, Horticulture Department, 32260 Isparta, Turkey*
[2]*Adnan Menderes University, Faculty of Agriculture, Horticulture Department, Aydın, Turkey*

Abstract

This study was conducted to determine the effects of different planting systems and densities on yield and quality of spray carnations. There were eight different treatments consisting of different planting densities and planting systems [(S_1: 40 plants m^{-2} with 4 rows), (S_2: 45 plants m^{-2} with 5 rows), (S_3: 50 plants m^{-2} with 5 rows), (S_4: 48 plants m^{-2} with 6 rows), (S_5: 54 plants m^{-2} with 6 rows), (S_6: 54 plants m^{-2} with 6 rows), (S_7: 44 plants m^{-2} with a triangular shape) and (S_8: 59 plants m^{-2} with a triangular shape)], and 8 spray carnation cultivars belonging to *Dianthus caryophyllus* L. species were used as the plant materials. The longest stem was determined in S_8 (74.88 cm) and the shortest stem was in S_1 (69.92 cm) among the planting densities and systems, whereas the longest stem was recorded in Optima (79.42 cm) and the shortest stem was found in Scarlette cultivar (67.03 cm) among the cultivars. The highest yield per plant was determined in S_1 (4.31 stems) and the lowest yield per plant was found in S_8 (3.03 stems). Among the cultivars, the highest yield per plant was recorded in White Natila (4.26 stems), while the lowest yield per plant was in Isabella (3.48 stems). Days to flowering (day of 50 % flowering) in S_1 (140.62 days) was found about 7.5 days earlier than in S_8 (148.06 days).

Key words: *Carnation, days to flower, flower yield, plant spacing, quality, stem length,*

INTRODUCTION

In Antalya, the center of carnation export in Turkey, the carnation export is interrupted between May and October especially due to climate conditions (high temperature and humidity etc.). It is necessary to create alternative production regions in order to eliminate this interruption, in order for foreign markets not to shrink, and in order to provide an opportunity for carnation export throughout the year. Among these regions, Isparta in particular has gained importance with its proximity to Antalya (125 km), high altitude (1050 m) and favorable ecology in summer months. For the above-mentioned reasons, the carnation production, which was launched for export in an area of 2 ha in Isparta in 2000, soon spread rapidly and reached approximately 50 ha in 2010.

Cultural treatments, such as planting density, planting date, pinching method, cultivar, irrigation, and fertilization, and ecological factors, such as temperature, light, and CO_2, play a significant role in the flowering time, yield and quality of carnation (Besemer 1980; Whealy 1992; Sawwan

1998). Planting density varies depending on planting date, cultivar, light, and pinching date and method. Leaf width and length as well as the number of shoots to be left on the plant are also of importance for planting densities. It has been reported that high planting densities are generally used in annual cultivation, while low planting densities are generally used in biennial cultivation (Garibaldi and Volpi 1977; Holley and Baker 1991; Whealy 1992).

Studies to enhance yield and quality are required in Isparta so as to perform more profitable carnation cultivation. The fact that the vegetation period is limited to 7 months (between April-November) in Isparta primarily features the studies to be made on productivity. One of the important cultural treatments affecting yield and quality is the planting density and system in carnation cultivation, like with other greenhouse crops. Therefore, in this study, it was aimed to determine the effects of different planting systems and densities on yield and quality parameters in spray carnations.

MATERIALS AND METHODS

The study was conducted in a plastic-covered greenhouse located at Yakaören (latitude: 37° 47' N, longitude: 30°30' E, altitude: 1019 m) in Isparta, Turkey between 2003 and 2004. Totally 8 treatments [(S_1: 40 plants m^{-2} with 4 rows), (S_2: 45 plants m^{-2} with 5 rows), (S_3: 50 plants m^{-2} with 5 rows), (S_4: 48 plants m^{-2} with 6 rows), (S_5: 54 plants m^{-2} with 6 rows), (S_6: 54 plants m^{-2} with 6 rows), (S_7: 44 plants m^{-2} with a triangular shape) and (S_8: 59 plants m^{-2} with a triangular shape)] consisting of different planting densities and systems were investigated in the study. Eight spray carnation cultivars (Optima, Isabelle, Berry, Scarlette, Orange Isabelle, Natila, Evita ve White Natila) belonging to *Dianthus caryophyllus* L. species were as the plant materials.

The rooted cuttings of carnation were planted in plots (25 m in length and 1 m in width) on April 21 in the 1st year (2003) and on April 17 in the 2nd year (2004). Some characteristics of the greenhouse soil (in 0 to 20 cm depth) in the study area were as follows: texture: sandy-loam, lime: 1.6 %, pH: 7.5, and organic matter: 1.7 %. The plants were single-pinched above the fifth leaf pair from the bottom (Whealy 1992; Kazaz et al. 2009). To maintain straight stems, carnation plants were supported by four layers of mesh. Water and nutrients were supplied through a drip irrigation system. When the terminal buds on the plants colored, the terminal buds were removed by hand (Besemer 1980; Whealy 1992). Harvest was performed above the second node from the base when flowers were fully open (Kazaz et al. 2009). The following data were recorded: stem length, stem diameter, stem fresh weight, number of flowers per stem, dry matter content, days to flowering (day of 50 % flowering), yield per plant, and yield per m^{-2}.

The experiment was set up according to randomized plots in factorial design with three replications. 1-m^2 plots were formed for each replication. Data were subjected to analysis of variance using MINITAB software (Minitab Inc., State College, PA), and mean values were compared using Duncan's multiple range test at p = 0.05 level (Düzgüneş et al. 1983). The results obtained in the research were given as the averages of both years (2003-2004) of the study.

RESULTS AND DISCUSSION

Stem Length
Both the planting densities and systems and the cultivars statistically significantly affected the stem length. Among the planting densities and systems, the longest stem was determined in S_8 (74.88 cm), while the shortest stems were found in S_1 (69.92 cm), S_2 (70.86 cm) and S_7 (71.00 cm) (Table 1). In the study, stem length increased with increasing planting density. The obtained results are in agreement with the results of Altan and Altan (1982), Sakai and Kojima (1988), and Kitamura et al. (1990). Among the cultivars, the stem lengths also varied depending on the

planting densities and systems and the stem lengths ranged from 66.88 to 79.42 cm (Table 1). The differences in stem length among the cultivars might result from the different growth and development characteristics of the cultivars. This was also stated in the cultivar catalogues of the firms, to which the cultivars belonged.

Stem Diameter
The thickest stems among the planting densities and systems were recorded in S_1 (4.27 mm), S_7 (4.16 mm) and S_2 (4.14 mm); however, the difference in stem diameter among these three planting densities was statistically insignificant. On the other hand, the thinnest stem was determined in S_8 (3.78 mm). The stem diameters ranged from 3.83 to 4.16 mm among the cultivars (Table 1). In the study, with increasing planting density, the stem diameter decreased and the stem diameters varied among the cultivars. Holley and Baker (1991) reported that a high planting density reduced the flower quality, whereas Mastalerz (1983) stated that high light increased the stem diameter.

Stem Fresh Weight
The planting densities and systems and the cultivars significantly affected the stem fresh weight. The stem fresh weights ranged from 39.37 to 48.46 g among the planting densities and systems and from 36.38 to 49.40 g among the cultivars (Table 1). In the research, the stem fresh weight was found to decrease with increasing planting density. Similar results were reported by Mastalerz (1983), Sakai and Kojima (1988), and Sakai and Asano (1990).

Number of Flowers per Stem
The number of flowers per stem ranged from 4.37 to 4.92 buds $stem^{-1}$ among the planting densities and systems and from 3.99 to 5.64 buds $stem^{-1}$ among the cultivars (Table 2). Garibaldi and Volpi (1977) reported that the effects of different planting densities (33, 50 and 66 plants m^{-2}) on the number of flower buds were insignificant and that the numbers of flower buds significantly varied among the cultivars. Minimum 3 flowers per stem are required in the cultivation of spray carnations for export. In the study, the number of flower buds was found to be more than three in both all planting densities and cultivars. Rejman et al. (1982) reported that the numbers of flower buds ranged from 2.4 to 9.8 in 7 different spray carnation cultivars.

Dry Matter Content
The dry matter content decreased with increasing planting density. The dry matter content ranged from 18.87 to 20.69 % among the planting densities and from 19.08 to 21.16 % among the cultivars (table 2). The low dry matter content in high planting densities might result from the failure of plants to receive adequate light due to the high leaf density in high planting densities. Bunt and Powell (1982) reported that under a high planting density, the rate of photosynthetic active light was less as compared to the

low planting density, while Mastalerz (1983) stated that dry weight decreased under a high planting density or low light.

Table 1. Effects of treatments on stem length, stem diameter and stem fresh weight

Variation sources Planting density and system (PD)	Stem length (cm)	Stem diameter (mm)	Stem fresh weight (g)
S_1	69.92 d	4.27 a	48.46 a
S_2	70.86 cd	4.14 ab	45.73 b
S_3	71.92 bc	4.01 bc	42.84 de
S_4	71.81 bc	4.02 bc	43.63 cd
S_5	72.86 b	3.91 c	41.64 e
S_6	72.76 b	3.92 c	41.36 e
S_7	71.00 cd	4.16 a	45.37 bc
S_8	74.88 a	3.78 d	39.37 f
Cultivar (C)			
Optima	79.42 a	4.16 a	48.79 a
Isabelle	73.76 b	4.08 ab	46.23 b
Berry	73.39 b	3.89 cd	44.78 b
Scarlette	67.03 c	3.83 d	38.23 cd
Orange Isabelle	74.07 b	4.12 ab	49.40 a
Natila	67.21 c	4.05 ab	38.40 c
Evita	74.26 b	4.07 ab	46.19 b
White Natila	66.88 c	4.00 bc	36.38 d
PD x C	ns	ns	ns

Means within a column followed by different letter are significantly different at P<0.05, Duncan's multiple range test. ns: not significant.

Table 2. Effects of treatments on number of flowers per stem, dry matter and days to flowering

Variation sources Planting density and system (PD)	No. of flower per stem	Dry matter (%)	Days to flowering (day of 50 % flowering)
S_1	4.92 a	20.69 a	140.62 e
S_2	4.86 ab	20.50 a	141.93 de
S_3	4.68 c	20.06 ab	144.77 bc
S_4	4.73 bc	20.19 ab	143.45 cd
S_5	4.51 d	19.49 bc	146.64 ab
S_6	4.51 d	19.51 bc	146.93 a
S_7	4.85 ab	20.57 a	142.37 de
S_8	4.37 d	18.87 c	148.06 a
Cultivar (C)			
Optima	4.12 e	19.96 bc	137.58 e
Isabelle	5.16 b	19.89 bc	153.04 b
Berry	5.19 b	21.16 a	139.68 d
Scarlette	4.79 c	20.44 ab	136.81 e
Orange Isabelle	5.64 a	19.88 bc	156.56 a
Natila	3.89 f	19.63 bc	140.68 d
Evita	4.63 d	19.82 bc	139.72 d
White Natila	3.99 ef	19.08 c	150.70 c
PD x C	ns	ns	ns

Means within a column followed by different letter are significantly different at P<0.05, Duncan's multiple range test. ns: not significant.

Days to Flowering (Day of 50 % Flowering)

In terms of days to flower, the difference among the planting densities and systems was found statistically significant, the planting density and system x cultivar interaction was found insignificant, and the difference among the cultivars was also significant. The periods until

days to flowering ranged from 140.62 to 148.06 days among the planting densities and systems and from 136.81 to 150.70 days among the cultivars (Table 2). In the study, the period until days to flowering was found to be delayed with increasing planting density. The obtained results are in agreement with Mastalerz (1983), who reported that in carnations, days to flowering were delayed with increasing planting density. Bunt (1978) reported that intra-plant competition increased with increasing planting density and that days to flower were further delayed with increasing competition, while Arreaza (2000) stated that the amount of

light among the plants decreased with increasing planting density.

Flower Yield per Plant (stems plant^{-1})

The average flower yield per plant was significantly affected by planting density and system, cultivars, and the interaction of planting densities and cultivars. Among the planting densities and systems, the highest average flower yield per plant was determined in S_1 (4.31 stems), and the second group consisted of S_7 (4.12 stems) and S_2 (4.06 stems). On the other hand, the lowest average flower yield per plant was recorded in S_8 (3.03 stems) (Figure 1).
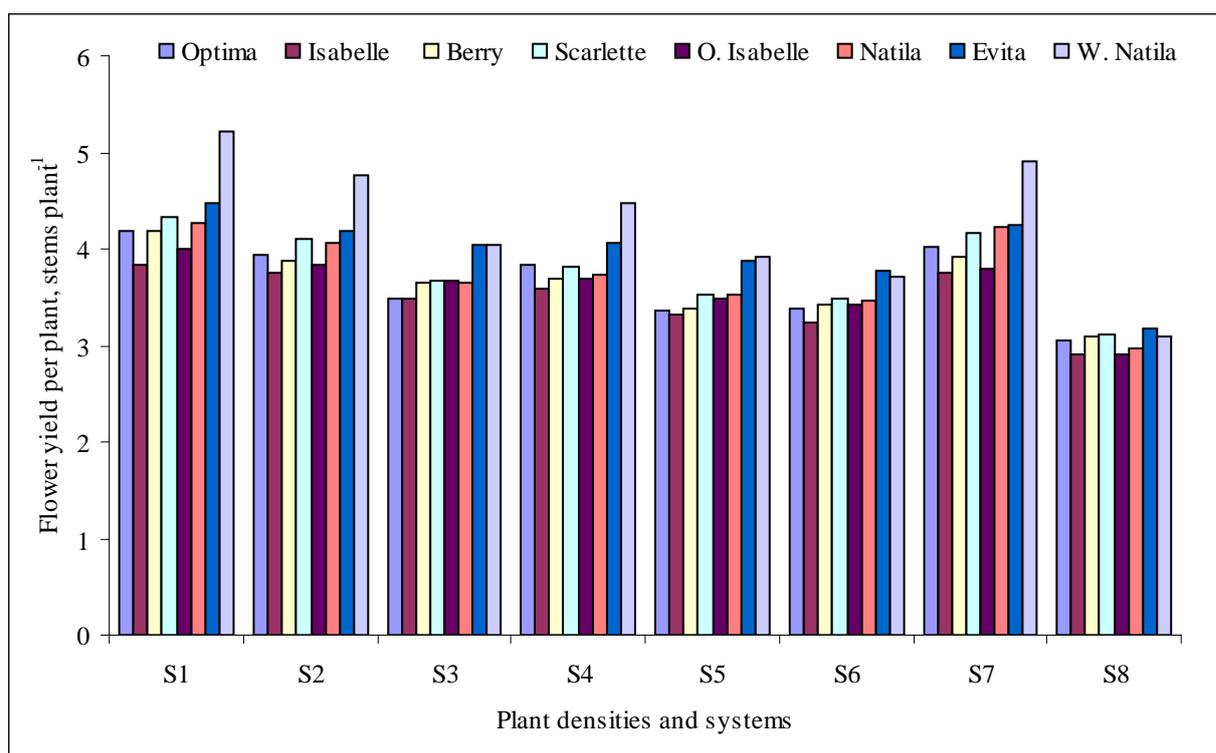

Figure 1. Effects of plant density and system with cultivars on flower yield per plant

Among the cultivars, the highest average flower yield per plant was in White Natila (4.26 stems) and the lowest average flower yield per plant was obtained from Isabelle cultivar (3.48 stems). In the planting density and system x cultivar interaction, the highest flower yield per plant was determined in S_1 in White Natila cultivar (5.22 stems), while the lowest flower yields per plant were found in S_8 in Isabelle and Orange Isabelle (2.91 stems) cultivars (Figure 1).

In the study, flower yield per plant decreased with increasing planting density. The obtained results are in agreement with Hanan and Heins (1975), Heins (1975), Spithost (1977), Garibaldi and Volpi (1977), Yonemura and Higuchi (1977), Altan and Altan (1982), Bunt and Powell (1982), Mastalerz (1983), Powel and Bunt (1983), and

Khanna et al. (1986), who reported that yield per plant decreased with increasing planting density in carnation.

Flower Yield per m^2 (stems m^{-2})

The planting densities and systems were found to significantly affect total flower yield per m^2. Although the highest total flower yield per m^2 was found in S_5 (191.54 stems), the difference between it and S_6 (188.54 stems) was statistically insignificant. On the other hand, the lowest flower yield per m^2 was recorded in S_1 (172.29 stems). The cultivars were also determined to significantly vary in terms of total flower yield per m^2. The highest total flower yield per m^2 was found in White Natila cultivar (206.35 stems), followed by Evita cultivar (193.83 stems). On the other hand, the lowest total flower yield per m^2 was determined in Isabelle cultivar (169.81 stems) (Table 3). The planting density and system x cultivar interaction also significantly

affected the total flower yield per m^2. In the interaction, the highest flower yield values per m^2 were recorded in White Natila cultivar in S_7 (215.67 stems), S_4 (215.17 stems) and S_2 (214.67 stems), respectively.

However, these three planting densities were included in the same group in terms of total flower yield. On the other hand, the lowest flower yield per m^2 was determined in S_1 in Isabelle cultivar (153.33 stems) (Table 3).

In the study, the values of total flower yield per m^2 were found to increase in all planting densities and systems except for S_8 with increasing planting density.

Table 3. Effects of plant density and system with cultivars on flower yield per m^2

Plant density and system	Cultivars								
	Optima	Isabelle	Berry	Scarlette	O. Isabelle	Natila	Evita	W. Natila	Mean
S_1	167.00 m-q	153.33 q	167.50 l-q	173.33 h-p	159.67 pq	170.50 j-p	178.50 g-o	208.50 ab	172.29 e
S_2	177.50 g-o	169.00 k-q	173.83 h-p	184.50 f-m	172.50 i-p	183.33 g-n	188.17 d-j	214.67 a	182.93 cd
S_3	174.33 h-p	174.00 h-p	182.33 g-o	183.67 g-n	183.33 g-n	182.17 g-o	202.00 a-e	202.50 a-d	185.54 bc
S_4	184.67 f-l	171.83 j-p	177.67 g-o	182.67 g-n	177.50 g-o	179.33 g-o	194.83 b-g	215.17 a	185.45 bc
S_5	181.17 g-o	179.17 g-o	183.00 g-n	190.17 c-i	188.00 d-j	190.33 c-h	209.33 ab	211.17 a	191.54 a
S_6	183.17 g-n	174.50 h-p	185.00 f-l	188.00 c-j	185.67 e-k	187.17 d-j	204.17 abc	200.67 a-f	188.54 ab
S_7	176.67 h-o	165.00 opq	172.00 j-p	183.17 g-n	166.67 n-q	185.67 e-k	186.33 d-k	215.67 a	181.39 cd
S_8	180.17 g-o	171.67 j-p	182.33 g-o	183.33 g-n	171.83 j-p	174.67 h-p	187.33 d-j	182.50 g-n	179.22 d
Mean	178.08 de	169.81 f	177.95 de	183.60 c	175.64 e	181.64 cd	193.83 b	206.35 a	

Values within the same column and rows followed by the different letter are significantly different at P<0.05, Duncan's multiple range test.

It has been reported by many researchers (Hanan and Heins, 1975; Heins, 1975; Spithost, 1977; Garibaldi and Volpi, 1977; Yonemura and Higuchi, 1977; Bunt and Powell, 1982; Mastalerz, 1983; Powel and Bunt, 1983; Khanna et al., 1986; Sakashita et al., 1987; Os and Weel, 1988) that with increasing planting density, the yield per plant decreased but the total yield per m^2 increased. It is thought that the decrease in total yield under the highest planting density and system (S_8) was caused by the development of disease in plants as a result of inadequate penetration of light, excessive leaf density and reducing air movement among the plants. A similar case was reported by Arreaza (2000).

CONCLUSION

The effects of different planting densities and systems on flower yield and some quality parameters of spray carnation cultivars were investigated in the study. It was concluded that it would be appropriate to use S_1, S_2, S_3 and S_4 planting densities and systems in carnation cultivation in the Isparta region in terms of both flower yield and quality and the easiness of cultural treatments. Among the cultivars, it is necessary to prefer especially the early cultivars with a high flower yield as the vegetation period is short in the region. Nevertheless, it is also inevitable to produce highly demanded cultivars in the market. Therefore, it was concluded that late cultivars should be planted under a low planting density (S_1), while cultivars with a low flower yield should be planted under S_2, S_3 and S_4 planting densities.

REFERENCES

Altan T, Altan S, 1982. Karanfil bitkisinde dikim aralıklarının çiçeklenme zamanı, verim ve kaliteye etkisi. Çukurova Üniversitesi, Ziraat Fakültesi Yıllığı, Yıl: 13, sayı: 1, Adana, Türkiye, s: 47-57

Arreaza P, 2000. Tecnicas Basicas del Cultivo del Clavel (In: Clavel, Editor: Marta Pizano) Edicones HortiTecnia Ltd, Bogota, Colombia, p: 15-40

Besemer ST, 1980. Carnations. In: Larson RA (ed) Introduction to floriculture, Academic Press. Inc. New York.

Bunt AC, 1978. Yield and cropping patterns of the carnation (*Dianthus caryophyllus* L.) with respect to plant density and planting date. Journal of Horticultural Science 53 (4): 339-347

Bunt AC, Powell MC, 1982. Carnation yield patterns: The effects of plant density and planting date. Scientia Horticulturae 17: 177-186

Düzgüneş O, Kesici T, Gürbüz F, 1983. İstatistik Metodları-I. Ankara Üniversitesi, Ziraat Fakültesi Yayınları: 861, Ders Kitabı: 229, Ankara, Türkiye.

Garibaldi EA, Volpi L, 1977. Effect of planting date, plant densities and pinching on the production of mediterranean and miniature carnation. Acta Horticulturae 71: 57-62

Hanan JJ, Heins R, 1975. Effect of plant density on two years of carnation production. Colorado Flower Growers Association Inc., Bulletin: 302

Heins R, 1975. Effect of plant density on first year's production of carnations. Colorado Flower Growers Association Inc., Bulletin: 296, 1-3

Holley WD, Baker R, 1991. Carnation Production II. Kendall/Hunt Publishing Company, Iowa, USA, 151p

Kazaz S, Yılmaz S, Sayın B, 2009. Comparison of soil and soilless cultivation of carnation in Isparta province. Acta Horticulturae 807: 547-552

Khanna K, Arora JS, Jaswinder S, Singh J, 1986. Effect of spacing and pinching on growth and flower production of carnation (*Dianthus caryophyllus* L.) cv. Marguerite Scarlet. Indian Journal of Horticulturae 43 (1-2): 148-152

Kitamura H, Yoshizawa K, Hasegawa K, Mori S, 1990. Studies on improvement of planting system of carnation (2). Improvement of planting system based on cultivar characteristics of carnation. The Shiga Prefecture Agricultural Experiment Station, Shiga, Japan, 31: 35-45

Mastalerz JW, 1983. Supplementary irradiation or dusk to dawn lighting for cropping carnations at several population densities. Acta Horticulturae 141: 157-163

Os EA Van, Weel PA Van, 1988. Soilless Culture. Isnt. Agric. Eng. Wageningen, 4 (1): 31-39

Powell MC, Bunt AC, 1983. The Effect of plant density and day-length on growth and development in the carnation. Scientia Horticulturae 20 (2): 193-202

Rejman S, Mynett K, Owczarek,M, 1982. Ocena kılku odmian gozdzikow miniaturowych. Prace Instytutu Sadownictwa I Kwiaciarstwa, Seria B, Poland, 7: 41-49

Sakai K, Asano M, 1990. Effects of plant density of pot culture prior to planting, numbers of lateral shoots per plant, and planting systems on growth and flowering. Research Bulletin of The Aichi-Ken Agricultural Research Center, Nagakute, Aichi, Japan, 22: 191-198

Sakai K, Kojima H, 1988. Influences of cold storage duration of cuttings, lighting and planting density on growth and flowering. Cultivation of spray carnation without pinching II. Research Bulletin of The Aichi-Ken Agricultural Research Center, Nagakute, Aichi, Japan, 20: 293-299

Sakashita T, Morioka K, Yonemura K, 1987. Effects of planting density, ıts arrangement and the number of secondary shoots on the yield and quality of sim carnation. Research Bulletin of The Aichi-Ken Agricultural Research Center, Nagakute, Aichi, Japan, 19: 236-241

Sawwan J, 1998. Carnation production and quality of three cultivars as affected by plant density. Dirasat, Agricultural Sciences 25 (3): 375-379

Spithost S, 1977. The Effects of spacing on the yields of glasshouse spray carnations. Acta Horticulturae 71: 63-68

Whealy A, 1992. Carnations. In: Larson RA (ed) Introduction to floriculture, second edition, Academic Press. Inc. New York.

Yonemura K, Higuchi H, 1977. The Effect of plant density on sim carnation production. Research Bulletin of The Aichi-Ken Agricultural Research Center, Series B (Horticulture) No: 9, Nagakute, Aichi, Japan.