



Influence of planting ratio and plant spacing on hybrid seed yield and quality in tropical carrot (*Daucus carota*) cv. Pusa Vasuda

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ABSTRACT

The present experiment was carried out to investigate the influence of planting ratio and plant spacing on hybrid seed yield and quality in carrot (*Daucus carota* L.) hybrid Pusa Vasuda at SPU, ICAR-IARI, New Delhi during 2014-15 and 2015-16. The experiment consisted of two different planting ratio (1:4 and 1:6) of pollen parent and seed parent and five plant spacing, viz. 60 cm × 20 cm, 60 cm × 30 cm, 60 cm × 40 cm, 60 cm × 50 cm and 60 cm × 60 cm. The results revealed that planting ratio and plant spacing had a significant effect on seed yield. Higher seed yield/ha (380.10 kg) was obtained in a planting ratio of 1:6 with closer plant spacing of 60 cm × 20 cm and it reduced significantly with increasing plant spacing. The planting ratio and spacing had no influence on seed quality trait was at par within the planting ratio and spacing. However, 1000 seed weight was significantly reduced with decreasing plant spacing. Thus, to obtain higher seed yield a planting ratio of 1:6 and a plant spacing of 60 cm × 20 cm should be recommended for hybrid seed production of carrot cv. Pusa Vasuda under Delhi conditions during *rabi* season.

Key words: Carrot hybrid, Plant density, Planting ratio, Pusa Vasuda, Seed yield, Seed quality

Carrot (*Daucus carota* L.) is an important vegetable crop grown in spring, summer and autumn in temperate regions and during winter in tropical and sub-tropical regions of the world. Carrot is an excellent source of carotene (1890 µg/100 g fresh weight), a precursor of vitamin-A and fibre. The deficiency of vitamin A particularly in children causes xerophthalmia, an eye ailment. Although, carrot has been widely cultivated since long, yet its yield per acre remain very low and there is considerable scope to enhance the production potential of carrot using F1 hybrid seed for commercial root production. Considering the demand of hybrid among the farmers, the first public sector tropical hybrid carrot Pusa Vasuda was developed at Division of Vegetable Science, IARI, New Delhi using CMS system. This hybrid is having high yield, uniform maturity and self core coloured roots. Roots are rich in total carotenoids, lycopene, TSS, magnesium, iron, calcium, manganese and zinc. However, a very little knowledge exists about the seed production technology of tropical carrot hybrids with respect to planting ratio and planting density and their affect on seed yield and quality. Many reports suggests that increasing plant densities is useful in obtaining higher

seed yield and quality of carrot as it increase the total number of primary umbels which have better quality (Gray and Steckel 1980, Oliva *et al.* 1988 and Satyaveer *et al.* 1994). Some authors reported that a planting density of 60 cm × 60 cm produced seeds that have higher thousand seed weight (2.0 g) and percentage of seed germination (87.50%) than those planted at 60 × 15 cm, 60 × 30 cm and 60 × 45 cm spacing in carrot cv. Pusa Kesar (Sharma and Singh 1981). Pandita *et al.* (2005) reported that higher processed seed yields (32.6%) was obtained from closer spacing of 40 cm × 10 cm and 40 cm × 20 cm over wider spacing. Seed germination and seedling vigour remained unaffected by spacing differences. However lowest test weight was observed in closer spacing. In hybrid seed production, the planting ratio of seed and pollen parents play an important role in attaining the higher seed yield and quality. To produce hybrid seed, the flowers on the male-sterile line must be visited by pollen loaded nectar seeking pollinators. Several authors have reported that honeybees and other pollinators discriminate between parental lines in hybrid seed production of Brussels sprout (Faulkner 1974 and 1976, Free and Williams 1983) which may be due to differences in parental lines with respect to flower colour, presence or absence of floral rewards such as nectar and pollen and other unknown factors. However, Selvakumar (2006) reported that in cauliflower hybrid seed production plot, honey bees did not discriminate while foraging and more seed yield was obtained with a planting ratio of 4:2 (seed:pollen) than 8:2. Banga *et al.* (1995) reported that a

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higher number of male rows gave higher seed yield in hybrid seed production of Indian mustard which was in the order 2:4>1:2>1:3>1:4 (pollen:seed). Development of successful hybrid seed production scheme in a crop is essential for the extension of hybrid technology to the farmers. Keeping in view of the facts explained above, the following research experiment was undertaken to optimise the planting ratio of pollen and seed parent and planting density of seed parent for higher seed yield and quality.

MATERIALS AND METHODS

An experiment was carried out for two consecutive years during *rabi* season of 2014-15 and 2015-16 in the research field of Seed Production Unit (SPU) at ICAR-Indian Agricultural Research Institute (IARI), New Delhi with randomised block design (RBD) with three replications. The treatment consisted of two planting ratios, viz. 1:4 and 1:6 (pollen parent:seed parent) as main plots and five plant spacing of the seed parent, viz. 60 cm × 20 cm, 60 cm × 30 cm, 60 cm × 40 cm, 60 cm × 50 cm and 60 cm × 60 cm as sub-plots. The seeds of the parental lines of carrot hybrid Pusa Vasuda were obtained from the Division of Vegetable Science, ICAR-IARI, New Delhi and roots were raised separately of seed and pollen parent following 5 m isolation. The medium sized, true to type roots of the pollen and seed parents were selected and prepared the stecklings. The stecklings were transplanted in two different planting ratios at two different locations which had an isolation distance of more than 800 m between them to prevent cross migration of pollen. Under each planting ratio, the seed parent was transplanted suitably at five different plant spacings. The plant spacing of the pollen parent was kept constant spacing of 60 cm × 30 cm across all treatments. Good agronomic practices were carried out to raise the healthy crop. The umbels were handpicked when secondary umbels were fully ripe and tertiary umbels were beginning to turn brown. The observations on plant height, number of productive (primary, secondary and tertiary) umbels per plant were recorded on ten plants selected randomly. Seed yield per plant was calculated by dividing total seed yield/plot by number of plants in that plot. The data were recorded on plot basis for 50% flowering, seed yield per row, seed yield per hectare and seed quality attributes such as seed germination, 1000 seed weight, vigour index 1. Seed quality parameters viz., germination and 1000 seed weight were calculated as per ISTA (2012) procedures. Vigour index 1 was calculated as suggested by Abdul-Baki and Anderson (1973). The two years data were subjected to pooled analysis using Web Based Agricultural Statistics Software Package developed by ICAR-Goa. Data consisting of percentages was transformed in to *arc sine* values wherever required and then statistically analysed.

RESULTS AND DISCUSSION

Effect on flowering and growth attributes

There was no significant effect of plant spacing on

Table 1 Effect of planting ratio and plant spacing on number of days to 50% flowering in pollen and seed parent of carrot cv. Pusa Vasuda

Spacing (cm)	Pollen parent			Seed parent		
	1:4	1:6	Mean	1:4	1:6	Mean
60×20	49.80	47.0	48.40	56.0	55.50	55.70
60×30	50.60	46.80	48.70	56.0	55.0	55.50
60×40	50.80	47.30	49.10	55.80	55.60	55.70
60×50	50.60	46.60	48.60	55.50	55.10	55.30
60×60	51.0	46.80	48.90	55.50	55.0	55.20
Mean	50.60	46.90		55.70	55.20	
	CD @ 5%			CD @ 5%		
Ratio (R)	1.32			NS		
Spacing (S)	NS			NS		
R×S	NS			NS		

NS, Non-significant.

50% flowering of both the parents (Table 1). However, significant difference in flowering in pollen parent was observed in different planting ratios (1:4 and 1:6), whereas in seed parent there was no significant change. In general, the pollen parent completed 50% flowering earlier than the seed parent. The seed parent took an average of 55 days to complete 50% flowering under both planting ratios. However the pollen parent took an average of 50.60 days and 46.90 days to complete 50% flowering in planting ratios of 1:4 and 1:6 respectively.

Plant height of seed parent was significantly affected by plant spacing (Table 2). Higher plant height under both planting ratios in female parent was recorded under closer spacing of 60 cm × 20 cm (113 cm and 115.30 cm in planting ratio 1:4 and 1:6 respectively) and lowest was in wider spacing of 60 cm × 60 cm (97.70 cm and 97.30 cm

Table 2 Effect of planting ratio and plant spacing on plant height (cm) and number of productive umbels in seed parent of carrot cv. Pusa Vasuda

Spacing (cm)	Plant height (cm)			Number of productive umbels		
	1:4	1:6	Mean	1:4	1:6	Mean
60×20	113.0	115.60	114.30	20.10	18.60	19.40
60×30	111.10	108.30	109.70	27.30	25.10	26.20
60×40	106.60	106.0	106.30	29.30	28.10	28.70
60×50	99.80	98.80	99.30	33.0	32.0	32.50
60×60	97.60	97.30	97.50	36.60	33.30	35.0
Mean	105.60	105.20		29.30	27.46	
	CD @ 5%			CD @ 5%		
Ratio (R)	NS			NS		
Spacing (S)	3.02			1.53		
R×S	NS			NS		

NS, Non-significant.

in planting ratio 1:4 and 1:6 respectively). This is because of more competition among plants for sunlight under closer planting which results in less lateral growth. Similar results were also reported by Jaiswal *et al.* (2003).

Effect on seed yield component

Plant spacing had a significant effect on number of productive umbels in both planting ratios (1:4 and 1:6). In both planting ratios, it was highest in wider spacing of 60 cm × 60 cm (36.70 and 33.30 in planting ratio 1:4 and 1:6 respectively) and gradually reduced with decreased spacing (Table 2). Lower number of productive umbels was noted from 60 cm × 20 cm (20.20 and 18.60 in planting ratio 1:4 and 1:6 respectively). This is because at closer spacing there is reduction of secondary and tertiary branches so ultimately there is reduction of number of umbels borne in them. Similar results were also reported by Pandita *et al.* (2005).

There was also significant reduction in seed yield/plant when the plant spacing was decreased (Table 3). Under both planting ratios, highest seed yield/plant was obtained in 60 cm × 60 cm (7.80 g and 7.50 g in planting ratio 1:4 and 1:6 respectively). Under closer spacing, there was more number of plants per plot which resulted in more competition for pollination and nutrient requirements. Also the number of productive umbels decreased under closer spacing as already mentioned. The combined effects of all these factors resulted in lower seed yield/plant under lower spacing.

Planting ratio and plant spacing, both had a significant effect in seed yield/hectare (Table 3). Higher seed yield/ha was obtained from closer spacing 60 cm × 20 cm (332.70 kg/ha and 380.10 kg/ha in planting ratio 1:4 and 1:6 respectively) and it decreased progressively with increased plant spacing. This is because of presence of higher number of plants/hectare under closer spacing of 60 cm × 20 cm as compared to others. Although the seed yield per plant is lower under closer spacing but when seed production is taken at a large scale the effect of number of plants on total seed

Table 3 Effect of planting ratio and plant spacing on seed yield (g) of seed parent of carrot cv. Pusa Vasuda

Spacing (cm)	Seed yield/plant (g)			Seed yield/ha (kg)		
	1:4	1:6	Mean	1:4	1:6	Mean
60×20	6.20	5.90	6.10	332.70	380.10	356.40
60×30	6.70	6.60	6.60	289.50	283.20	286.30
60×40	6.90	6.60	6.80	197.30	229.20	213.30
60×50	7.50	7.20	7.40	161.50	186.70	174.10
60×60	7.80	7.50	7.70	139.80	161.60	150.70
Mean	7.10	6.80		224.20	248.10	
	CD @ 5%			CD @ 5%		
Ratio (R)	0.14			4.70		
Spacing (S)	0.22			7.40		
R×S	NS			10.6		

NS, Non-significant.

Table 4 Comparison of seed yield (g) at different rows of seed parent under different planting ratios and plant spacing of carrot cv. Pusa Vasuda

Spacing (cm)	Planting ratio (1:4)			Planting ratio (1:6)			
	Row 1	Row 2	Mean	Row 1	Row 2	Row 3	Mean
60×20	311.60	187.50	249.50	270.40	165.80	95.80	177.40
60×30	252.50	181.60	217.0	197.90	131.20	67.30	132.10
60×40	165.30	130.70	148.0	160.90	89.0	70.90	106.90
60×50	131.50	110.80	121.20	124.60	77.80	59.0	87.10
60×60	115.50	94.10	104.80	108.0	67.80	50.40	75.40
Mean	195.30	141.0		172.40	106.30	68.70	
	CD @ 5%			CD @ 5%			
Ratio (R)	4.20			4.90			
Spacing (S)	6.70			6.30			
R×S	9.50			10.90			

yield is much more pronounced. It was reported by Gray *et al.* (1983) that seed yield in carrot (Chantenay types) increased by 50-55% when plant density was increased from 10 to 80 plants per meter square.

Effect on seed yield/row

There was significantly higher yield in the seed parent rows that were nearest to the pollen parent row which was row position 1 under both the planting ratio (Table 4). Higher contribution to seed yield by row position 1 can be explained by the fact that in hybrid seed production plot of carrot, bees and other pollinators tend to discriminate among parental lines and they are mainly concentrated in and around the male parent row for floral rewards such as nectar and pollen. So higher percentage of pollinators visit female row position 1 which is just adjacent to the male parent as compared to row position 2 and 3 which is slightly further away resulting in higher pollination and seed set. Similar results were reported by Maity (2012) in hybrid seed production of Indian mustard.

Effect on seed quality traits

From the data presented in Table 5, it can be clearly observed that plant spacing had a significant effect on 1000 seed weight, whereas other seed quality parameters such as seed germination and seed vigour index 1 were not significantly affected. Higher 1000 seed weight was obtained from widest spacing of 60 cm × 60 cm which was 2.44 g and 2.42 g in planting ratio 1:4 and 1:6 respectively. Under closer spacing of 60 cm × 20 cm, the number of plants/plot were higher as compared to 60 cm × 60 cm that produced more competition among plants for resources resulting in lower test weight whereas seeds produced under wider spacing developed under optimum resources and had better accumulation of seed storage products. Seed obtained from wider spacing of 60 cm × 60 cm, had the highest

Table 5 Effect of planting ratio and plant spacing on seed quality parameters of carrot cv. Pusa Vasuda

Spacing (cm)	Seed germination (%)			1000 Seed weight (g)			Vigour Index 1		
	1:4	1:6	Mean	1:4	1:6	Mean	1:4	1:6	Mean
60×20	66.8(41.90)	66.1(41.3)	66.5(41.7)	2.220	2.198	2.209	985.8	987	986.4
60×30	67.0(42.10)	66.5(41.7)	66.7(41.8)	2.273	2.272	2.273	1007.3	1000.8	1004
60×40	67.1(42.10)	66.8(41.9)	67(42.1)	2.332	2.312	2.322	1013.1	1002.5	1007.8
60×50	67.3(42.2)	67.6(42.5)	67.5(42.5)	2.427	2.405	2.416	1023.7	1028.4	1026.1
60×60	67.3(42.3)	67.8(42.7)	67.5(42.5)	2.443	2.422	2.433	1025.7	1025.3	1025.5
Mean	67.1(42.1)	67(42.1)		2.339	2.322		1011.2	1008.8	
	CD @ 5%			CD @ 5%			CD @ 5%		
Ratio (R)	NS			NS			NS		
Spacing (S)	NS			0.02			NS		
R×S	NS			NS			NS		

Figures in parenthesis represents arc sine transformed values. NS, Non-significant.

germination which was 67.3% and 67.8% in planting ratio 1:4 and 1:6 respectively but the results were statistically non significant. Vigour index 1 was highest under plant spacing of 60 cm × 50 cm in planting ratio 1:4 and 60 cm × 60 cm under planting ratio 1:6 but the results were statistically non significant. The seed germination under all different plant spacing was above 60% which is the certified minimum limit of germination as recommended by Indian Minimum Seed Certification Standard.

From the above study, it could be concluded that hybrid seed yield in carrot cv. Pusa Vasuda can be significantly increased by planting the pollen and seed parents in ratio of 1:6 with a closer spacing of 60 cm × 20 cm among the seed parent.

REFERENCES

- Abdul-Baki A A and Anderson J D. 1973. Vigour determination in soybean by multiple criteria. *Crop Science* **13**: 630–7.
- Banga S S, Sandha G M, Gupta and Sohu R S. 1995. Experiments in hybrid seed production in Indian mustard. *Seed Science and Technology* **23**(1): 51–7.
- Faulkner G J. 1974. Factors affecting field scale production of seed of F1 hybrid Brussels Sprout. *Annals of Applied Biology* **77**: 181–90.
- Faulkner G J. 1976. Honeybee behaviour as affected by plant height and flower colour variation in Brussels sprouts. *Journal of Apicultural Research* **15**: 15–8.
- Free J B and Williams I H. 1983. Foraging behaviour of honeybees and bumble bees on Brussels sprout grown to produce hybrid seed. *Journal of Apicultural Research* **22**: 94–7.
- Gray D and Steckel J R A. 1983. Seed quality in carrots: the effect of seed crop plant density, harvest date and seed grading on seed and seedling variability. *Journal of Horticultural Science* **58**(1): 393–401.
- ISTA. 2012. Seed testing rules. *International Seed Testing Association*, Bassersdorf, CH-Switzerland.
- Jaiswal M D, Adpawar R M, Parlwar N D and Yadgirwar B M. 2003. Effect of planting date and spacing on growth, seed yield and quality of carrot. *Annals of Plant Physiology* **17**: 117–9.
- Kishor S, Tomar B S, Singh B, and Munshi A D. 2010. Effect of season, spacing and planting time on seed yield and quality in cucumber. *Indian Journal of Horticulture* **67**(1): 60–9.
- Kumar S, Tomar B S, Jain S K, Singh N, Prasad R and Munshi A D. 2015. Effect of planting time and density on plant growth, seed yield and quality attributes in onion (*Allium cepa*) cv. Pusa Riddhi. *Indian Journal of Agricultural Sciences* **85**(12): 1578–85.
- Maity A, Chakrabarty S K and Yadav J B. 2012. Standardization of planting ratio of parental lines for seed production of mustard (*Brassica juncea* L. Czern & Coss) hybrid NRCHB 506. *Bioinfolet* **9**(3): 299–302.
- Oliva R N, Tissaoui T and Bradford K J. 1988. Relationships of plant density and harvest index to seed yield and quality in carrot. *Journal of the American Society for Horticultural Science* **113**(4): 532–7.
- Pandita V K, Rana S C, Chaudhry D and Kumar V. 2005. Seed productivity and quality in relation to plant spacing in carrot (*Daucus carota*). *Indian Journal of Agricultural Sciences* **75**(11): 722–4.
- Satyaveer S, Nehra B K, Malik Y S and Singh S. 1994. Carrot seed yield and quality as influenced by different order umbels under varying nitrogen, plant density and geometry. *Crop Research Hisar* **8**(3): 543–8.
- Selvakumar P, Sinha S N and Pandita V K. 2006. Abundance and diurnal rhythm of honeybees visiting hybrid seed production plots of cauliflower (*Brassica oleracea* var. *botrytis* L.). *Journal of Apicultural Research* **45**(2): 7–15.
- Sharma S K and I J Singh. 1981. Effect of level of nitrogen and spacing of plants on the yield of carrot seed. *Progressive Horticulture* **13**(314): 97–100.