

Research Article

Consequences of sowing dates and umbel pinching on *Daucas carota* seed production

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Abstract

This research was laid out to examine the effect of sowing dates and umbel pinching on seed production of *Daucas carota*. The experiment was conducted in randomized complete block design (RCBD) with split plot arrangement and replicated three times at Horticulture Nursery of Agriculture University, Peshawar, Pakistan in 2016. Sowing dates (25th October, 9th and 24th November) were assigned to main plot, while umbel pinching levels; secondary + tertiary + quaternary (STQ), primary + tertiary + quaternary (PTQ) and tertiary and quaternary (TQ) umbel pinching were allotted to sub plots. Maximum ($p < 0.05$) days to flowering (111 days), plant height (137.5 cm), days to seed setting (15.6 days), umbel diameter (14.6 cm), days to maturity (151 days), variability in harvest time (34.8 days), seed yield umbel⁻¹ (5.1 g), seed yield plant⁻¹ (34.2 g) and seed yield t ha⁻¹ (3.7 t ha⁻¹) were recorded on 25th October sowing date. Umbel pinching had significantly enhanced plant height (136.4cm), umbel diameter (17 cm), and seed yield umbel⁻¹ (5.7 g) by pinching of STQ umbels. While, maximum seed yield plant⁻¹ (46.9 g), seed yield t ha⁻¹ (5 t ha⁻¹) and variability in harvest time (34.1 days) were observed in TQ umbel pinching. Interaction between sowing dates and umbel pinching (S x U) were found significant in case of seed yield umbel⁻¹, seed yield plant⁻¹, seed yield t ha⁻¹ and variability in harvest time. Based on the present findings it is concluded that sowing on 25th October with pinching of TQ umbels is recommended for maximum seed production in carrot.

Keywords: Carrot; Seed production; Sowing dates; Umbel pinching; Yield

Introduction

Carrot (*Daucas carota* L.) belongs to the family Umbellifereae, cultivated mostly as winter vegetable. It is originated in Asia and Mediterranean regions about 2000 years ago but nowadays cultivated throughout the world [1]. Carrot is considered as a temperate region crop that grows during spring in temperate regions

while grows during winter in tropical and subtropical regions [2]. Carrot is a biennial crop but in tropical regions it is cultivated as an annual crop. An enlarged, high nutritive and fleshy taproot is produced by carrot plant which is edible. Carrot is a rich source of antioxidants, minerals, vitamins, and fibers, contains Vitamin A and β -carotene in large quantity [3].

Daucus carota L. produces rosette of leaves and taproot during the first growing season, while in the second growing season it develop flowers. Stored sugar provides energy to the plant for flowering. Carrot produces hermaphroditic and self-pollinated flowers but cross-pollination also occurs more frequently because stamens mature earlier than the pistils [4, 5]. At the blooming stage, carrot produces an inflorescence on the tip of the stem called primary umbel which upon division makes the secondary, tertiary and quaternary umbels. Carrot seed quality such as size, vigor and germination changed as umbel order changes. The increase in umbel order decreased its size [1]. In carrot seed production, different umbel orders contribute differently. Primary umbel contributes 11%, secondary umbel 58% and tertiary 31% to the over-all seed production. Increase in the order of umbel causes decrease in the seed quality [6]. Seed quality depends on umbel size and its position [7]. Pinching is an important practice for the successful production of flowers. Pinching is actually the removal of terminal portion of stem to inhabit apical dominance. Pinching of growing shoot apex terminates the apical dominance and dry matter is diverted into side buds and branches. The two important factors that have great effect on carrot seed quality and yield are umbel order and umbel pinching. The purpose of umbel pinching is balancing and inducing the nutrients and hormones. When umbel pinching is done, the existing umbels have less competition for nutrients and hormones. Due to umbel pinching more nutrients and hormones are transported to the flowers which in turn grow healthy seeds [8]. The transport of auxin from the tissues might limit cytokinin concentrations as well as maintain apical dominance through hormonal action. Through pinching practice we can adjust plant growth and improve its quality. Apical control is a problem to the commercial growers because it does not allow the lateral buds to grow, which result

in less number of lateral flowers. one can also increase the aesthetic value through pinching because of pinching practice more number of lateral flowers are produce [9]. Growth and yield of a crop are highly affected by sowing dates. The appropriate sowing time depends on cropping model and current environment which is an important factor for seed production of carrot. Being a biennial crop carrot seeds production is greatly affected by temperature [10]. Large size seeds produce heavier individual root weight and more resultant yield [11-14]. Keeping in view the importance of sowing dates and umbel pinching, the present study was conducted to test the hypothesis that sowing time, umbel pinching and their interaction have an influence on seed production in carrot.

Materials and methods

Experimental site

We conducted current experiment at Ornamental Horticulture Nursery, The University of Agriculture, Peshawar, Pakistan in 2016, which is located at 71.5833 ° E longitude and 34.0167 ° N latitude with altitude above sea level is 350-m. The climatic conditions in this location is semiarid, where maximum wind speed is 35 km/h, average annual rainfall is low (300 to 500 mm) 60–70% in summer while 30–40% rainfall occurs in winter [15, 16].

Experimental design

The experiment was designed using RCBD (randomized complete block design) with split-plot arrangement having two factors and replicated three times. Seeds of cultivar “Shan”(collected from horticulture nursery) was sowed on three different dates i.e. 25th October, 09th November and 24th November kept in main plot and different pinching levels i.e. pinching STQ umbels (secondary + tertiary + quaternary), PTQ umbels (primary + tertiary + quaternary) and TQ umbels (tertiary + quaternary) was allotted in sub plot. Twelve treatment combinations were kept, which were replicated three times. Row to row and plant to plant distance was kept 60 cm and

20 cm, respectively. There were 36 sub plots with plot size 1.4 m² each.

Soil preparation

Soil was ploughed up thoroughly and was leveled through cutter. One foot high ridges were made. A soil sample was collected before sowing and was send to soil laboratory for chemical analysis. Fertilization was done in split doses.

Recommended NPK doses were applied @ of 100, 100 and 125 kg ha⁻¹. Half dose of Urea and a full dose of Potash and Phosphorus were applied at sowing time and the rest of the urea was applied after 30 days of sowing. Irrigation was done when needed. Regular cultural practices i.e. weeding, hoeing etc were carried out throughout the experiment (Table 1).

Table 1. Soil analysis results

Physico-chemical Properties	Value	Unit
Soil Texture	Silt loam	---
Bulk density	1.15	g cm ⁻³
Practical density	2.21	g cm ⁻³
pH (1:5 soil water extract)	8.02	---
EC (1:5 soil water extract)	0.26	dS m ⁻¹
Lime content	8.3	%
Organic matter content	1.06	%
Total Nitrogen	0.011	%
Soluble Calcium	24.2	mg kg ⁻¹
Soluble Magnesium	3.01	mg kg ⁻¹

Parameters recorded

Data recorded on different growth and productivity parameters during course of the studies include; Days to flowering, average plant height (cm) and umbel diameter (cm) were recorded by randomly selected five plants in each treatment per replication and their average was calculated. Days to seed setting were counted from the appearance of flower umbel to the date of seed setting, days to maturity were counted from the date of sowing to the seed harvesting maturity, variability in harvest time was calculated by subtracting the number of days to the maturity of first umbel from the number of days required for the maturity of last umbel in each treatment in every replication and their average was calculated. Seed yield per umbel⁻¹ (g) and seed yield plant⁻¹ (g) was taken by weighing the seed collected from five plants randomly in all treatments in each replication and their average was noted [17] while seed yield (tons ha⁻¹) was calculated using following formula;

$$\text{Seed yield (t ha}^{-1}\text{)} = \frac{\text{Plot seed yield (kg)}}{\text{Plot area (m}^2\text{)}} \times \frac{10000}{1000}$$

Statistical analysis

The data noted was subjected to Analysis of Variance (ANOVA) technique appropriate for RCBD split plot design with two factor experiment. Means were compared by using Least Significant Difference (LSD) test at 5% level of significance. Statistical software Statistix (8.1) was used for calculating ANOVA and LSD value [18, 19].

Results and discussion

Days to flowering

The mean data regarding days to flowering is presented in (Table 2). Statistical analysis indicated that sowing dates and umbel pinching had significant effect on days to flowering, while their interaction was found non-significant. Mean data showed that delay in sowing dates significantly decrease days to flowering. Maximum days to flowering (111.0 days) were noted at 25th October, whereas the minimum days to flowering (81.3 days) were recorded at 24th November. Mean data for umbel pinching showed that days to flowering were significantly affected by umbel pinching. Maximum days to flowering (103.3 days)

were observed in case of Pinching PTQ umbels whereas minimum days to flowering (97.1 days) were recorded in case of control. Due to early planting, plants obtained comparatively high temperature also long growth period which results in maximum vegetative growth and delay in flowering. While the delay in sowing eventually reduced the growth period also resulted in early onset of flowering [20]. Similarly, planting time had a marked influence on the number of days required for 50% flowering in onion when planted earlier, because onion bulbs planted in relatively hot condition matured earlier compared to those which were planted in relatively cold season [17]. Pinching delayed the flowering and delay was high in case of sever pinching. The delay might be due to the removal of apical portion. When the apical bud is removed, the source of IAA (indole acetic acid) is removed. Since the IAA concentration is much lower, and the lateral buds can grow due to the elimination of apical dominance. The lateral branches took longer time to become physiologically mature for flowering. Our findings are in line with the results obtained by [21] in okra.

Plant height (cm)

The mean data concerning plant height is given in (Table 2). Its statistical analysis indicated that sowing dates and umbel pinching had significant effect on plant height while their interaction was found non-significant. Data on sowing dates showed that maximum plant height (137.5 cm) was recorded at 25th October sowing whereas minimum plant height (118 cm) was recorded at 24th November sowing. Umbel pinching data showed that plant height was significantly affected by umbel pinching. Maximum plant height (136.4 cm) was observed in case of pinching STQ umbels whereas minimum plant height (124.1 cm) was noted in case of pinching PTQ umbels.

Maximum plant height in case of early sowing might be due to optimum time and environmental conditions especially

temperature that promotes vegetative growth [22]. Increased in plant height might also be the fact that plant gets enough time to complete its vegetative growth due to early sowing and then switch towards reproductive growth [23]. Moreover, [17] reported that onion bulbs planted earlier showed maximum plant height compared to those planted later. The increase could be due to early planting that might have provided plants with relatively cooler condition compared to the later. Thus cooler period stimulates cytokine and gibberellins accumulation in plants, modifying their hormonal balance and leading to increase plants development and elongation of flowering stalk [24]. Maximum plant height was measured in case of pinching STQ umbels because apical buds produce IAA (indole acetic acid) that inhabit the lateral buds growth and promote the plant's vertical growth. The results are parallel with [25] they observed that the decrease in plant height in pinched plants is mainly due to elimination of apical dominance. By the removal of the apical portion of main branch, auxiliary buds become free from correlative inhibition of apical dominance thus diverting plants metabolites from vertical growth to horizontal and start their growth. Moreover, [26], also observed reduction in plant height by pinching in China aster varieties.

Days to seed setting

Data pertaining days to seed setting is presented in (Table 2). Statistical analysis indicated that sowing dates and umbel pinching had significant effect on days to seed setting but have a non-significant interaction. Mean data of sowing dates in (Table 2) showed that delay in sowing dates significantly reduce days to seed setting. Maximum days to seed setting (15.6 days) were noted at 25th October sowing whereas minimum days to seed setting (11.1 days) were noted at 24th November. Mean data for umbel pinching showed that days to seed setting was significantly affected by umbel pinching. Maximum days to seed setting

(15.3 days) were observed in case of pinching PTQ umbels whereas minimum days to seed setting (12.4) were recorded in case of control.

The delay in sowing time results in early flowering and early development of seed. This might be due to the fact that delay in sowing, plants did not get optimum environmental conditions and sufficient time to complete its vegetative growth thus resulted in early flowering and seed setting [22]. In pinched plants delay in flowering and seed setting was observed. This delay

could be due to the removal of apical portion which results in the inhibition of apical dominance and therefore took more time to get mature for flowering and seed setting. The above findings are in line with previous findings of [27] in pinching carnation. Days to seed setting in pinched plant were more because of the delay in shoots for bearing flowers, delay pinching practice and slow growth of auxiliary shoot. Similar results are also in accordance with the findings of [28] in pinching African marigold.

Table 2. Days to flowering, Plant height, Days to seed setting, Umbel diameter and Days to maturity of carrot as affected by sowing dates and umbel pinching

Characters	Days to flowering	Plant height (cm)	Days to seed setting	Umbel diameter (cm)	Days to maturity
Treatments			Umbel pinching (U)		
Control	97.1c	127.6c	12.4d	12.3c	129.9d
Pinching STQ	100.5b	136.4a	13.5c	17.a	133.5c
Pinching PTQ	103.3a	124.1d	15.3a	10.3d	137.4a
Pinching TQ	100.7b	133.2b	14.2b	13.8b	134.7b
LSD (0.05)	0.9	0.9	0.3	0.3	1
			Sowing dates (S)		
25th Oct	111.0a	137.5a	15.6a	14.6a	151a
9th Nov	109.0b	135.5b	14.8a	13.6b	148.3b
24th Nov	81.3c	118c	11.1b	11.9c	102.4c
LSD (0.05)	1.1	0.8	0.9	0.5	0.9
			Interaction		
U×S	NS	NS	NS	NS	NS
LSD (0.05)	NS	NS	NS	NS	NS

*Mean values tag with heterogeneous letters are not similar statistically at $p \leq 0.05$ according to LSD Test. NS stands for Non-significant

Umbel diameter (cm)

In (Table 2), mean data related to umbel diameter of carrot is presented. Statistical analysis of umbel diameter declared that sowing dates and umbel pinching had significant effect on average umbel diameter and their interaction was found to be non-significant. Mean data table on sowing dates showed that maximum average umbel diameter (14.6 cm) was recorded at 25th October sowing whereas the minimum umbel diameter (11.9 cm) was recorded at 24th November. Mean data table of umbel pinching showed that umbel

diameter was significantly affected by umbel pinching. Maximum umbel diameter (17.0 cm) was observed in case of pinching STQ umbels whereas minimum umbel diameter (10.3 cm) was noted in case of PTQ umbels pinching.

Due to early planting, long day length and high temperature add towards the yield contributing characters, while on the other hand slow vegetative growth period results in minimum umbel diameter because of lower temperature and short day length. Our findings agree with that of [29] investigations who reported that umbel

diameter in onion is affected by delay in planting. Early planting increased umbel diameter in onion compared to late planted onions. This might be attributed due to the climatic variability in growing environment [30]. Through umbel pinching practice, nutrients and hormones get balanced and diverted toward the remaining umbels giving a higher umbel size, more numbers of umbellate per umbel and ultimately produces higher yield. Pinching breaks apical dominance and diverts more energy to the production of more number of branches, flowers and ultimately more yield [28]. [31] studied that pinching of tomatoes promoted plant growth, total yield and quality fruit production.

Days to maturity

The data on days to maturity is presented in (Table 2). Its statistical analysis showed that sowing dates and umbel pinching had significant effect on days to maturity while their interaction was found non-significant. Mean data of sowing dates showed that sowing dates had significant effect on days to maturity. Maximum days to maturity (151 days) were observed at 25th October whereas minimum days to maturity (102.4 days) were noted at 24th November. Mean data of umbel pinching showed that days to maturity were significantly affected by umbel pinching. Maximum days to maturity (137.4 days) were observed in case of pinching PTQ umbels whereas minimum days to maturity (129.9 days) were recorded in case of control.

When planting is done earlier, plants receive comparatively high temperature and long day length which might extend vegetative growth period ultimately resulted in delayed seed maturity while, in delayed planting due to short day length and low temperature result in early seed maturity [20]. Maximum days taken to flowering and seed maturity in pinched plant were due to the formation of mature shoots for bearing flowers which took more days. More number of days required to bud appearance due to pinching were observed in Chrysanthemum by [32-34]. [25] also

reported that pinched flowers needed maximum days to start reproductive growth and hence delayed in seed maturity in chrysanthemum.

Variability in harvest time

The data regarding variability in harvest time is presented in figure I. Statistical analysis indicates that sowing dates, umbel pinching and their interaction had significant effect on variability in harvest time. The interaction between sowing dates and umbel pinching (Fig. 1) indicated that maximum (36.6 days) variability in harvest time was recorded at 25th October sowing with pinching TQ whereas the minimum (25.7 days) variability in harvest time was observed at sowing on 24th November in case of control.

Variability in harvest time may be due to variability in seed maturity. Due to early planting, plants received high temperature and long day length which might have extended vegetative growth period ultimately resulted in delayed seed maturity while, in delayed planting due to short day length and low temperature result in early seed maturity [20]. The reason of greater variability in harvest time might be due to the fact that primary umbel matures first because it appears first and located on the top of the flowering stock. The removal of tertiary and quaternary inflorescence diverted the Photosynthate towards the primary and secondary inflorescence which increases their vegetative growth and the umbels remain green for longer time period. Our findings are in line with [35] who obtained similar results in training carrot.

Seed yield umbel⁻¹(g)

The data regarding seed yield umbel⁻¹ is presented in figure 2. Statistical analysis indicated that sowing dates and umbel pinching had significant effect on seed yield umbel⁻¹ and their interaction was also found significant. The interaction between sowing dates and umbel pinching (Fig. 2) indicated that highest seed yield umbel⁻¹ (6.9 g) was noted at 25th October sowing in pinching STQ whereas the lowest seed yield umbel⁻¹ (2.2 g) was recorded at 24th

November sowing date with pinching PTQ umbels.

At early planting seed yield was found maximum because of high light intensity, temperature and long day length preparing more photosynthesis for the plant which add toward more seed yield. Favorable atmospheric conditions could have also promoted vegetative and reproductive growth such as less flower abortion, optimum temperature, efficient pollinators and nutrients availability for all florets in the umbel [36]. Our findings agreed with that of [29] reported that yield of different varieties of onion is influenced by delay in planting. On the other hand, Pinching STQ umbels resulted in maximum seed yield umbel⁻¹. This might be due to the fact that through umbel pinching nutrients and hormones are diverted towards the remaining umbels. Because of pinching the umbels face less competition for nutrients and hormones. More nutrients and hormones are transported to the flowers and they produce bigger, heavier and healthy seeds. Our results are in line with [37] who reported that higher umbel size, number of flower umbel⁻¹, number of seeds/umbel and highest quality of seed was exhibited in only primary umbels.

Seed yield plant⁻¹(g)

The data regarding seed yield plant⁻¹ is presented in figure III. Statistical analysis showed that sowing dates, umbel pinching and their interaction had significant effect on seed yield plant⁻¹. The interaction between sowing dates and umbel pinching (Fig. 3) indicated that maximum seed yield plant⁻¹ (50.1 g) was recorded at 25th October sowing with pinching TQ whereas the minimum seed yield plant⁻¹ (15.2 g) was recorded at 24th November in case of pinching STQ.

Early planting time resulted in higher seed yield per plant in carrot could be the availability of favorable cool temperature for flower development. While, high atmospheric temperature causes early maturity of bulbs before attaining sufficient growth of plant, thereby resulting in low

seed yield in onion [30]. The increased in seed yield per plant might be due to the more number of seed per umbel, cool temperature for flower development in early planting or following favorable temperature that may have increased the seed yield per plant [36]. Similarly, our results are in line with [38] who stated that early planting is always important to obtain higher seed yield and bulb size because yield is significantly reduced with delay in planting. Due to pinching, hormones and nutrients can be balanced. As umbel pinching causes less competition for nutrients and hormones thus more nutrients and hormones are transported to the flowers for healthy seed production and have higher germination percentage. Our results are closely related with [37] who reported that due to umbel pinching the existing umbels are of higher size, produce more number of flowers per umbel, higher number of seeds per umbel and highest quality of seed.

Seed yield (t ha⁻¹)

The data regarding seed yield (t ha⁻¹) is shown in (Fig. 4. Statistical analysis indicated that sowing dates and umbel pinching had significant effect on seed yield t ha⁻¹ and their interaction was also found significant. The interaction between sowing dates and umbel pinching (Fig. 4) indicated that maximum seed yield (5.4 t ha⁻¹) was found on 25th October sowing with pinching of TQ umbel. While minimum seed yield (1.6 t ha⁻¹) was noted in case of 24th November sowing with pinching of STQ umbel.

Maximum seed yield (t ha⁻¹) was observed at early planting which might be due highest seed yield per umbel and seed yield plant⁻¹. Other reason could be the combined contribution of the yield contributing characters affected by comparatively lower atmospheric temperature and short day length. On the other hand, slow vegetative and reproductive growth and minimum yield were observed at late planting because of high temperature and long day length. These findings coincided with that of [39] concluded that seed yield of onion cultivars

was maximum due to early sowing. Due to umbel pinching, nutrients and hormones are balanced and influenced as a result the existing umbels which face less competition for nutrients and hormones. More nutrients and hormones are transported to the existing umbels which produce bigger, heavier and healthier seeds and have higher germination percentage

and vigor index. Seeds become more vigorous and viable. Pinching gathers additional photosynthates which are used for more flowers production. Pinching checked apical dominance and diverted extra energy in to the production of more numbers of branches, flowers and seeds [28].

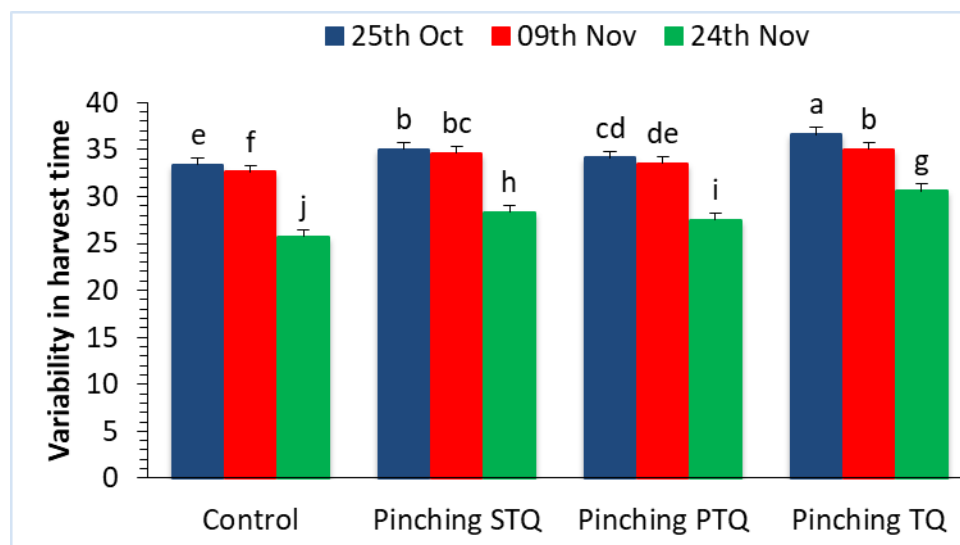


Figure 1. Interaction effect of sowing dates and umbel pinching of carrot as affected by variability in harvest time

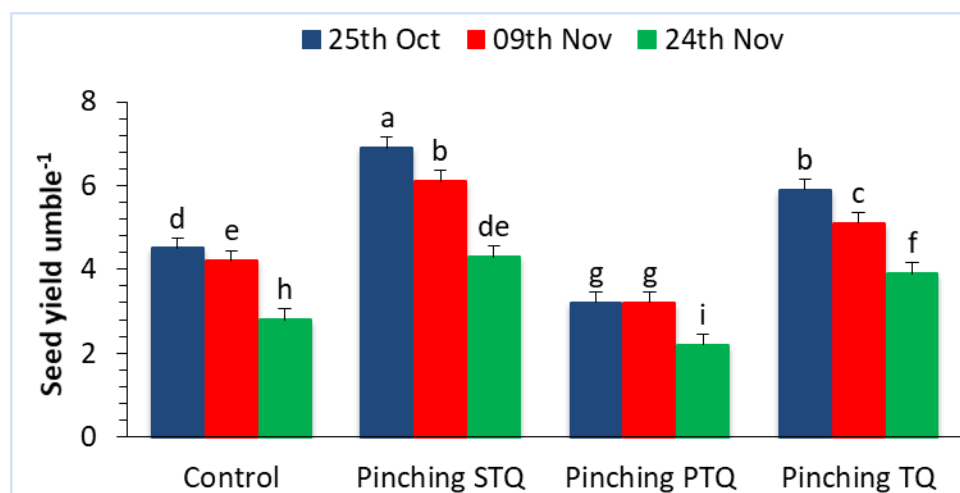


Figure 2. Interaction effect of sowing dates and umbel pinching of carrot as affected by seed yield umbel⁻¹(g)

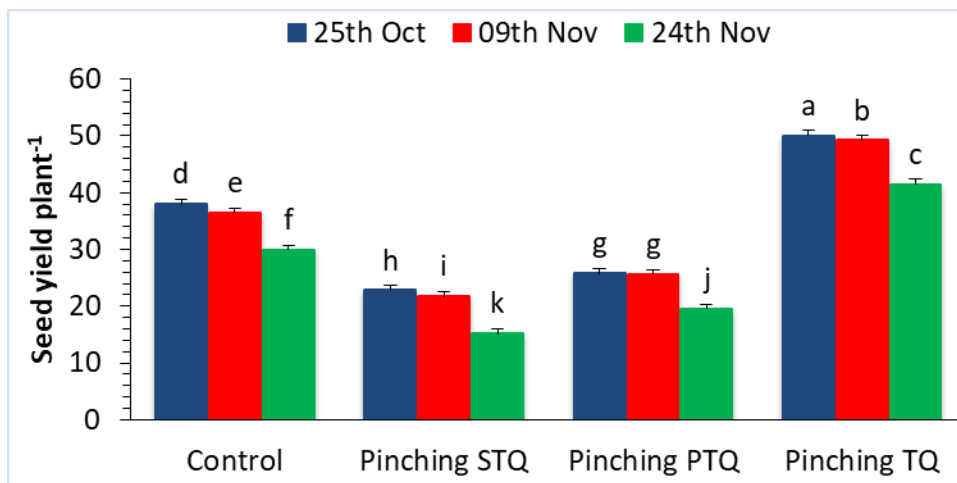


Figure 3. Interaction effect of sowing dates and umbel pinching of carrot as affected by seed yield plant⁻¹(g)

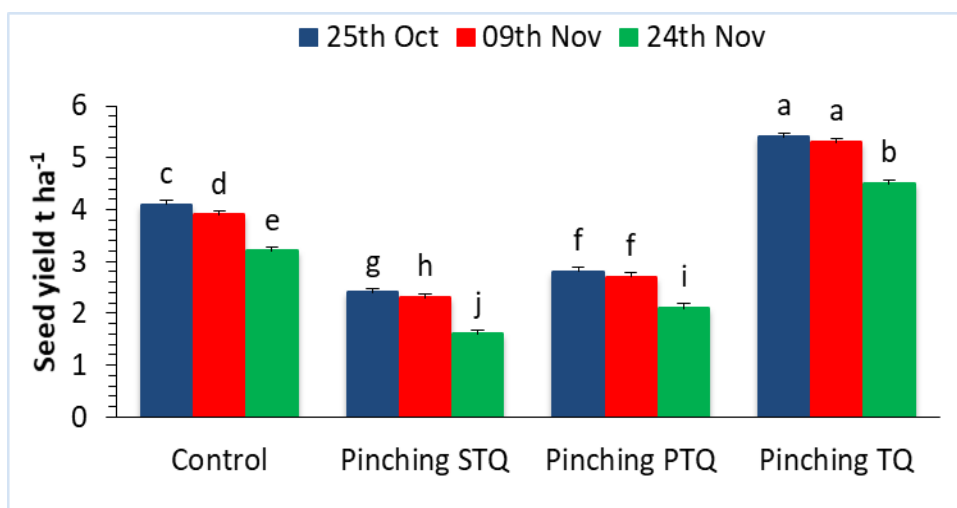


Figure 4. Interaction effect of sowing dates and umbel pinching of carrot as affected by seed yield (t ha⁻¹)

Conclusion

It is concluded that among different sowing dates, sowing on 25th October provided increased seed yield of carrot. Pinching of TQ (tertiary and quaternary) umbels of carrot improved seed production and its quality. Therefore, carrot should be sown on 25th October and pinched its TQ (tertiary + quaternary) umbels for the improved seed production.

Authors' contributions

Conceived and designed the experiments: H Shah, U Shahid & K Shah, Performed the experiments: H Shah, G Ara, U Litaf & B Zainub, Analyzed the data: K Shah, U Shahid, G Ara & H Shah, Contributed

reagents/ materials/ analysis tools: G Ayub & I Ahmad, Wrote the paper: K Shah, U Shahid & H Shah.

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