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Effect of plant spacing and steckling size length on seed quality parameters of carrot (*Daucus carota* L.)

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Abstract
Carrot (*Daucus carota* L.) with chromosome number (2n) = 18 and belonging to the family Umbelliferae is one of the important root vegetable crops. In India, root to seed is the standard method for the production of high quality seed as this method allows for the selection of healthy and true to type roots for the planting of stecklings. If the seed quality is not good, it may again be difficult to get enough number of uniform roots. This study was conducted at Seed Research Area of Department of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar during spring-summer season of 2018-19. The experiment comprised five treatments of plant spacing (60 x 30 cm (Flat), 60 x 45 cm (Flat), 60 x 60 cm (Flat), 60 x 30 cm (Single row on ridge), 60 x 45 cm (Paired row on ridge)and three steckling size (8 cm, 6 cm and 4 cm) was laid out in Randomized Block Design with three replications. The quality parameters of seed were found better at plant spacing of 60 x 60 cm (Flat) with steckling size of 8 cm.

Keywords: Carrot, plant spacing, steckling size

Introduction
Carrot is a popular cool season vegetable cultivated in tropical region during winter. Carrot (*Daucus carota* L.) with chromosome number 2n=18 belonging to the family Umbelliferae is one of the important root vegetable crops. It produces edible root of high quality in one season and seed in two seasons. Its cultivated forms have been domesticated from wild species. Carrot is grown from seeds and its successful production depends upon a good quality seed (Mcdonald and Copland, 1998) [3]. This vegetable crop is more remunerative, thus, the area under this vegetable crop is increasing every year. Simultaneously, the demand for quality seed is also increasing gradually. Seed is the basic and cheapest input but it is one of the most important means of increasing productivity of any crop (Verma and Phogat, 1994) [8]. In carrot the demand of quality seed especially of Asiatic type is not only within the country but there are possibilities of export to other countries in tropical and subtropical regions where seed production has not yet been commercially exploited. Looking to the importance of crop with regard to nutritional quality, the demand will increase in the coming days, which require more production. If the seed quality is not good, it may again be difficult to get enough number of uniform roots. Carrot is grown from true seeds and its successful production is dependent upon a sustainable and satisfactory supply of good quality seed. However, the seed supply from the domestic production is not adequate and growers depend mainly on imported seeds that demand foreign currency and are of questionable sources with respect to germination and susceptibility to diseases (Mengistu and Charies, 2010) [4]. Thus, to improve the production and productivity of carrot domestically, the availability of quality seed is crucial.

Materials and Methods
The present experiment was carried out at Seed Research Area Department of Vegetable Science and in the Laboratory of the Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana during 2018-19. The general features of this region are semiarid climate with hot and dry winds during summer and dry severe cold in winter. The soil of the experimental field was sandy loam in texture with pH and EC of 8.25 and 0.65 dS/m, respectively. The experiment was laid out in Randomized Block Design with three replications.
The seed production of carrot was done by Root-to-Seed method as used in Hisar condition for quality seed production and brief package of practices given below.

Preparation of roots for planting
Carrot seed of Hisar Gairic variety was sown on 12th October, 2018 and it is the best time for sowing in Hisar condition. Seed was sown on the ridge at spacing of 7-8 cm for better development and quality of root. Recommended dose of fertilizers was applied at ambient time. Two or more hoeing was given at 40 and 65 days after sowing to control the weeds. The recommended plant protection measures, thinning, rouging and monitoring operations were also adopted as and when required for raising healthy roots.

Preparation of stecklings
Fully developed and healthy roots from the selected true to type of the carrot were lifted on 16th January, 2019 (96 days old) with the help of digger. The whole foliage was cut kept back one third only and roots were cut with sharp knife and prepared the stecklings as per treatments.

Transplanting
After 2-3 deep ploughing or hoeing followed by planking and the field was made to a fine, tilth Flat beds of convenient size were made. Land used for seed production of carrot was free from volunteer plants. The carrot stecklings were then transplanted in the main field in spacing of as per treatments.

Nutrition
About 40-50 tonnes of decomposed FYM were applied in the transplanted field. Carrot is a heavy feeder of nutrients, especially of potash. A recommended dose of 40 kg potash along with 80 kg nitrogen and 40 kg phosphorous per hectare were also applied as per Hisar condition. Whole of phosphorous, potash and half of nitrogen were applied at the time of field preparation and the left-over's of half nitrogen dose was applied 30 days after planting.

Irrigation
Soon after transplanting irrigation was given, so that the roots may got established properly in the soil. After that irrigation was given at 7-10 days interval. Flowering and fruit setting are critical period for irrigation; the point was kept in mind. Thereafter, it was stopped to enhance umbel maturity.

Weed control and intercultural operation
First shallow hoeing was done 4 weeks after planting of stecklings. This operation was simultaneously carried out with application of split doses of nitrogen fertilizer. The second intercultural operation was done 3 weeks after the first operation. Carrot normally grows slowly in the beginning and cannot compete with weeds. Stomp (Pendimethalin) @ 2.5 l/ hectare, as a pre-emergence application was applied to check weeds in carrot.

Field inspection A minimum of four inspections have made as follows
1. The first inspection have made before flowering in order to determine isolation, volunteer plants, outcrosses and other relevant factors.
2. The second and the third inspections have made during flowering to check isolation, off-types and other relevant factors.
3. The fourth inspection have made at maturity to verify the true nature of umbel.

Observations recorded
Observations recorded on Test weight (g), Standard germination percentage (%), Vigour index-I (based on seedling length) and Vigour index-II (based on seedling dry weight).

Statistical Analysis
The statistical analysis was carried out by using OPSTAT statistical software developed by Chaudhary Charan Singh Haryana Agricultural University, Hisar to find out the significance of variation resulting from the experimental treatments and the mean differences were evaluated by critical difference (C.D.) test at 5% level of significance (Sheoran, 2010).

Results and Discussion
Effect of plant spacing and steckling size on seed quality parameters
The quality of seed was determined by its boldness (test weight), standard germination percentage (%) and seed vigour was also influenced by various treatments. The plant spacing 60 x 60 cm (Flat) significantly increased the test weight of seed as compared to other plant spacings. The test weight at wider plant spacing was significantly higher as compared to closer spacing. The germination percentage (%) and seed vigour was also recorded maximum under plant spacing 60 x 60 cm (Flat). Similar findings were reported by Gill *et al*. (1981), Singh *et al*. (1994) [7], Kumar *et al*. (2012) [1] and Muhammad and Anjum (2001) [5] who reported that seed produced under wider plant spacing has highest test weight, standard germination percentage (%) and seed vigour as compared to closer plant spacing. This might be due to better conditions of plant growth under wider spacing resulting in bold size seeds having better germination and vigour as compared to closer plant spacing.
The steckling size of 8 cm produced significantly higher test weight which was statistically at par with steckling size of 6 cm. It may be due to better growth and availability of more photosynthates at the time of maturity, while, the growth was poor in case of small steckling size due to less availability of reserve food material. The germination percentage (%) and seed vigour were also significantly affected by steckling size. Steckling size 8 cm recorded maximum standard germination percentage (%) and seed vigour. Similar findings were reported by Nagarajan and Pandita (2001) [6] and Malek *et al*. (2012) [2] in carrot. However, Verma *et al*. (1993) [9] observed no effect of steckling size on 1000 seed weight.
The interaction effect between plant spacing and steckling size showed non-significant influence on test weight. However, the interaction effect between plant spacing and steckling size showed significant influence on germination percentage (%) and seed vigour. Maximum standard germination percentage (%) and seed vigour was recorded under plant spacing 60 x 60 cm (Flat) with the steckling size of 8 cm.

Table 1: Show the treatments of standard germination percentage

Treatments		Test weight (g)	Standard germination percentage (%)	Vigour index-I	Vigour index-II
S_1	60 x 30 cm (Flat)	1.54	74.66	1077.63	0.82
S_2	60 x 45 cm (Flat)	1.99	83.77	1369.70	1.42
S_3	60 x 60 cm (Flat)	2.26	88.00	1509.80	1.87
S_4	60 x 30 cm (Single row on ridge)	1.90	80.44	1269.88	1.15
S_5	60 x 45 cm (Paired row on ridge)	1.75	77.88	1179.71	0.99
C.D.		N.S.	2.69	17.16	0.05
Sz_1	4 cm	1.77	79.33	1204.40	1.12
Sz_2	6 cm	1.93	81.46	1303.02	1.29
Sz_3	8 cm	1.97	82.06	1336.62	1.35
C.D.		1.53	2.08	13.29	0.04

Conclusion

On the basis of present experiment, it may be concluded that the quality of seed was better at plant spacing 60 x 60 cm (Flat) with steckling size of 8 cm which was found to be at par with steckling size of 6 cm.

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