EFFECT OF PLANT DENSITY ON WINTER SURVIVAL AND SEED PRODUCTION OF AN IMPERATOR TYPE HYBRID CARROT

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ABSTRACT

Two experiments with identical treatments were conducted on one strip of eight-female rows of an Imperator type hybrid carrot on the Madras research site from August 1985 through September 1986. Plants were spring and fall thinned to six- and 12-inches between plants, and to a four-inch block in the spring for comparison to a non-thinned control. From 32.5 to 53.5 percent of the fall thinned plants had heaved compared to 1.1 percent or less for the control plants. The percent winterkill ranged from 14.2 to 21.7 for both fall-thinned treatments but was only 2.8 or less for the control. Obviously, fall thinning is not recommended. Plants of the spring treatments only of experiment I were harvested since treatments of experiment II appeared to be similar and resources were unavailable to handle them. Total seed yield from plants spaced six-inches apart was significantly higher than other treatments except the four-inch block. Individual plant productivity was greatest from plants spaced 12 inches apart but plant population was too low to maximize total yield compared to six-inch spaced plants. Plant spacing had little effect this year on the proportions of each seed size class comprising yield. On the average, the size distribution was 9, 61, and 30 percent for 1/13, 1/16, and 1/19 size seed respectively. The 1,000-seed weight within size class was not altered by plant density. Germination averaged about 90 percent and was not affected by plant spacing or seed size within plant spacings. Therefore, the four-inch block and six-inch spacing between plants produced the highest yield of quality seed.

Many growers produce carrot seed in central Oregon by the seed-to-seed method. Seed is planted in August so the carrot seedlings can make sufficient growth and be hardened for the

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winter. Winter survival varies from year to year. Up to 30 percent stand loss has occurred. As a result the stand in some fields has to be increased by transplanting carrots in the spring. However, questions have arisen about the correct plant density to which a stand should be restored as well as the number of plants to which a field should be thinned for yield of high quality seed. Therefore this study was undertaken to assess the effect of plant density on winter survival, seed yield and quality during the 1985-86 season. This study will be continued for 2-3 years.

METHODS

Plots for the study were in a small Imperator-type hybrid carrot seed production field on the Madras research site of the Central Oregon Experiment Station. This field had spring cereals in 1984 and was summer fallowed in 1985. A broadcast application of N-P-K:16-16-16 (414 pounds/acre) was incorporated into the seedbed before the formation of 30-inch wide beds. Planting began August 6, 1985, but only four female rows were sown because the beds were too soft. Approximately one inch of water by sprinkler was applied to firm the beds. On August 12, the other four female rows of the eight female and four male row pattern for the whole production field were planted. Irrigation was again applied after the entire field was planted and the soil was kept moist to ensure good germination and seedling emergence. Weeds were controlled by an application of Lorox (1 pound ai/acre) on September 20, 1985. Other commercially acceptable practices were conducted in 1986.

The study was located on the strip of four early (August 6) and four late (August 12) female rows because differences in carrot plant height were observed for the two sowing dates. The early and late rows, each with the same treatments, were designated as experiments I and II, respectively. Five treatments (carrots thinned to six- and 12-inches between plants on November 6, 1985 and March 14-17, 1986 plus removing every other four-inch block of plants in the spring) were compared to a non-thinned control. The same six treatments were replicated four times in a randomized complete block design for each experiment. Each treated plot was 18 feet long by 10 feet wide (four 30-inch wide beds). The two center rows 10 feet long were hand harvested September 10 and 11, 1986. The number of plants harvested were counted. All plants from one row were placed in a plastic lined tote box for drying. These plants were handled as the bulk portion of the plot. Plants from the other row were separated and the umbels were clipped and identified according to class (primary, secondary, and tertiary). The number of umbels in each class were counted. Samples were threshed with a belt thresher and scalped before

a second threshing. An M-2B air screen machine was used to condition the seed. Sample identity was maintained from each row of a plot from harvest through conditioning and weighing. However, the total seed yield reported was the sum of seed from both rows.

Quality of bulk-harvested seed

A 40-gram working sample was obtained from each bulk seed sample with a Gamet Precision divider. Since the belt thresher did not accomplish complete debearding, each sample was further debearded to simulate that obtained by commercial debearders. This was done by hand rubbing the seed on a canvas-covered foam pad. The seed was further cleaned with hand screens and a laboratory blower.

Each sample was sized with hand screens into three size fractions: (1) over 1/13, (2) through 1/13 and over 1/16, and (3) through 1/16 and over 1/19. Each size fraction was weighed and the amount reported on a pounds/acre basis.

The 1,000-seed weight of each size fraction was determined. The germination percentage of each size fraction was determined in four replications of 100 seeds each at 20-30^{o} C for 14 days.

Quality of seed from various umbel orders

Seed from each umbel order was cleaned with hand screens and a laboratory blower. Further debearding was not necessary since the seeds were not sized. Germination tests were conducted on seed larger than a 1/19 screen opening. Germination tests were conducted as before, but with only two replications per sample. One thousand-seed weights were determined for each sample.

RESULTS AND DISCUSSION

Significantly more heaving and death occurred among plants spaced six- and 12-inches apart than control populations of 11 and 20 plants per foot of row during the 1985-86 winter (Table 1). Some plants had heaved about two inches above the soil surface. There was no apparent difference for either heaving or winterkill among plants in experiments I and II due to the six-day plant growth differential. At thinning time the leaves were about six- and three-inches tall on plants in experiments I and II, respectively. However, little variation in root diameter (one-half inch) and length (six-eight inches) existed among plants in both experiments. By November 7, 1985, the soil had cracked deeply in line with the carrot plants which exposed up to one quarter of an inch on two sides

of the carrot root. The plants were covered with snow from November 11, 1985, to January 10, 1986, which provided good protection from cold temperatures.

Fall thinning of a carrot stand is detrimental and cannot be recommended. No comparisons were possible on fall vs spring thinning in either experiment I or II because of differences in stand, although plant height, earliness of flowering, number and size of umbels on fall thinned plants appeared to be similar to the same on spring thinned plants.

For the spring thinned treatments, total seed yield from plants six inches apart was significantly higher than all treatments except four-inch blocks (Table 2). However, individual plants were most productive at the 12-inch spacing but plant density was insufficient to maximize total yield. From observation of all treatments it appeared that profuse stem branching was inversely related to low plant population, but no quantitative data were collected. Control and S-4 inch block plants were observed to be about eight inches taller than the six to 12-inch spaced plants. The primary umbels on the two high density populations appeared to flower about a week before plants in other treatments. There were significantly fewer umbels per plant in control and S-4 inch block plants but primary umbels were significantly more numerous and contributed more to yield than the same on plants spaced six and 12 inches. It appears that the high total yield from six-inch spaced plants resulted from more tertiary umbels compared to more primary umbels on S-4 inch block plants.

There was no statistically significant difference in the number of secondary umbels among the four plant densities studied but percent seed yield by umbel class shows that the amount of seed from the secondary umbels increased from the highest to the lowest plant population.

Quality of bulk-harvested seed

The effects of plant density on seed yield of each size class are shown in Table 3. On the average, the 1/16 size class made up 61 percent of the yield, the 1/19 size was 30 percent of the yield, and the 1/13 size was nine percent (Table 4). There was a tendency for more 1/16 size seed to be produced at the 12-inch spacing with less for the 1/13 size. In general, however, plant spacing had little effect this year on the proportions of each size class making up the yield.

The 1,000-seed weight within size classes was affected significantly by plant spacing in only one instance. This would indicate that seed density within size classes was not altered by the density of planting.

Germination percentage averaged about 90 percent and was not affected by plant spacing or seed size within plant spacings.

Quality of seed from various umbel orders

Seed from the primary umbels was the heaviest with seed from the tertiary umbels the lightest (Table 5). Plant spacing did not alter this relationship. As in the bulk-harvested study, six-inch spacing produced lighter seed than four inch blocking.

Seed germination of the primary umbels averaged 65 percent, secondary umbels 62 percent, and tertiary umbels 74 percent (Table 5). Germination of the Control and four-inch blocking was higher than the six-inch and 12-inch spacing.

Since the germination percentages of these seed were considerably lower than of the bulk-harvested seed, no conclusions should be based on these data. On investigating the cause of the low germination of the umbel orders, it was found that the samples contained many empty and undersized seeds. In the bulk-harvested samples, these empty seeds were crushed during the hand-debearding, and the higher germination percentage was obtained because only filled seeds were planted. This conclusion is supported by the fact that the 1,000-seed weight of the bulk-harvested seed was higher than of the seed harvested umbel-by-umbel. We will have to modify our conditioning procedures next year to more closely simulate commercial conditioning results.

Nevertheless, because of the uniformly high germination of all seed sizes in the bulk-harvested samples, all umbel orders undoubtedly were producing good quality seed.

This study did not address the difference in effects that may exist among hybrids, open-pollinated varieties, or between the two types. Therefore, application of these results to other hybrids or open-pollinated varieties is not suggested.

Additional data will be collected in 1987 on plant density effects.

REFERENCE

Simpson, W.R., R.G. Beaver, W.M. Colt, and C.R. Baird. 1985. Carrot, Parsnip and Parsley Seed Production in the Pacific Northwest. A Pacific Northwest Extension Publication (Idaho, Washington, Oregon). PNW272.

Table 1. Effect of plant density on heaving and winter survival of carrot plants at Madras, Oregon, 1985-86

Treatment[1]	Plants			
	Heaved		Dead	
	Exp. I	Exp. II	Exp. I	Exp. II
	%			
F-6" Space	53.5 a	32.5 a	21.7 a	20.8 a
F-12" Space	34.5 a	34.0 a	18.1 a	14.2 a
Control	.4 b	1.1 b	.6 b	2.8 b
Mean	29.5	22.5	13.5	12.6
CV (%)	60.6	71.8	69.4	41.8
LSD (5%)	30.9	28.0	16.2	9.2

1 Treatment: F-6 inch and F-12 inch space -- populations hand thinned November 6, 1985, to a carrot every six and 12 inches, respectively; control -- Exp. I & II populations averaged 20 and 11 plants per linear foot of row, respectively.

Table 2. Effect of plant density on carrot seed production at Madras, Oregon, 1986

Treatment[1]	Seed yield		Umbels	Umbels by class[2]			Seed yield by umbel class[2]		
	Total	per plant	per plant	P	S	T	P	S	T
	(lb/a)	(oz.)	(no.)	%					
Control	1117c[3]	.2c	8.5c	14a	43a	44c	35a	54c	11b
S-4" Block	1305ab	.3c	12.3c	10b	44a	47bc	23b	63bc	15ab
S-6" Space	1389a	1.1b	43.3b	3c	41a	57a	6c	71ab	23a
S-12" Space	1135bc	1.9a	69.0a	1c	46a	52ab	3c	80a	16ab
Mean	1237	0.8	33.3	7	43	50	17	67	16
CV (%)	9	9.9	12.4	35	12	10	38	11	34

1 Treatment: control -- plants about one inch apart; S-Four-inch block -- plants removed from alternate four-inch row lengths on March 13-17, 1986 with about five plants in the four-inch block; S-six-inch and S-12 inch space -- populations thinned to a carrot plant every six and 12 inches, respectively, on March 13-17, 1986.
2 Class: P = primary; S = secondary; T = tertiary.
3 Values within a column with the same letter are not significantly different at the .05 level of probability using Duncan's multiple range test.

Table 3. Effect of plant density on carrot seed quality at Madras, Oregon, 1986

Quality component	Screen size	Plant Spacing Control	S-4" block	S-6"	S-12"	LSD .05
		----------lbs/acre----------				
Seed yield	1/13	88	101	114	62	46
	1/16	580	681	741	620	52
	1/19	288	372	346	287	80
	Total	956	1154	1201	969	
		----------g/1000----------				
Seed weight	1/13	2.405	2.472	2.306	2.334	.081
	1/16	1.796	1.858	1.741	1.847	.074
	1/19	1.285	1.367	1.261	1.370	.108
	Mean	1.829	1.899	1.769	1.850	
		----------% ----------				
Germination	1/13	91	89	92	91	5
	1/16	91	89	92	92	4
	1/19	87	85	89	88	8
	Mean	90	88	91	90	

Table 4. Effect of plant density on percentage of seed in each size category at Madras, Oregon, 1986

Screen size	Plant Spacing Control	S-4" block	S-6"	S-12"	Average
	----------% ----------				
1/13	9.2	8.8	9.5	6.4	8.5
1/16	60.7	59.0	61.7	64.0	61.3
1/19	30.1	32.2	28.8	29.6	30.2

Table 5. Effect of plant density on carrot seed quality by umbel order at Madras, Oregon, 1986

Quality component	Umbel order[1]	Plant Spacing				
		Control	S-4" block	S-6"	S-12"	LSD .05
		g/1000				
Seed Weight	P	1.599	1.682	1.600	1.644	.202
	S	1.444	1.604	1.437	1.447	.140
	T	1.396	1.541	1.299	1.444	.208
	Mean	1.480	1.609	1.445	1.512	
		%				
Germination	P	72	70	58	61	14
	S	65	68	61	54	9
	T	77	79	73	68	13
	Mean	71	72	64	61	

1 Umbel orders: P=Primary, S=Secondary, T=Tertiary