Identification of the Cause of Variation in Carrot Seed Percent Germination Due to Irrigation Method

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Abstract

Yield and germination percentage are determining factors in hybrid carrot seed production profitability. If germination percentage falls below 85 percent, seed companies can discount the price or refuse to purchase the seed entirely. Results show that carrot seed produced under drip irrigation in central Oregon has better germination (around 3-4 percent) than seed grown under overhead sprinkler irrigation. While this small difference may seem unimportant, it is a major quality consideration and vital to the reputation of the seed industry on a global scale. Seed harvested from plants grown under drip irrigation showed an increased germination in all umbel orders, but more specifically in the tertiary level. Increased quality in harvested seed is found in fields when subordinate umbels are allowed to reach maturity (Elballa and Cantliffe 1997). We found that seed from the tertiary umbel was not only higher in harvested number but showed similar germination percentages to those of the primary umbel. Plots grown under drip irrigation produced higher germinated tertiary umbels than other irrigation methods, thus increasing the overall germination of the seed lot. In central Oregon, where 75 percent of North America's hybrid carrot seed is produced, around 45 percent of growers now irrigate their crops using drip irrigation, the remainder using either sprinkler or furrow/flood irrigation.

Introduction

The carrot plant (*Daucus carota* L.) grows in an indeterminate manner, producing seed in umbels that arise from multi-level ordered branches. The center inflorescence, known as the primary umbel, is generally the larger, top-most umbel of the carrot stalk. Subordinate branches of secondary, tertiary, and quaternary umbels, named in relation to their appearance on the plant below the primary umbel, develop throughout the growing season. The size, vigor and germination of carrot seeds, which determine the seed quality, vary according to the umbel order (Hawthorn and Toole 1962, Pereira et al. 2008). Previous research has indicated that seed quality decreased as umbel order increased (Nascimento 1991).

Methods and Materials

Seed-to-seed carrots were sown at Central Oregon Agricultural Research Center, Madras using a commercial planter in early August year?. The trial contained sprinkler- and drip-irrigated blocked fields, and the combination of male and female carrots were the same in both fields over the course of both growing seasons. Initial fall irrigation and early spring irrigation was delivered with sprinkler irrigation until drip tape was installed in May. Irrigation treatments were imposed at the time of extension of the primary umbel and

continued through seed maturity. Planting date, drip irrigation tape installation, and harvest date are presented in Table 1 for both trial years. Standard commercial practices of fertilization, weed control, and pest management were performed according to carrot contractor recommendations. Fungicide applications occurred in coordination with sprinkler irrigation events to reduce bacterial or fungus pathogen loads prior to umbel development. Bees were placed between drip- and sprinkle-irrigated fields in early July and removed in early August. Harvested plot size consisted of 4 1-m rows in 2008; harvested carrots were pulled up by the roots and dried. Two weeks later the samples were separated into umbel order per plot, dried, and weights recorded. In 2009, harvest plot size consisted of 4 3-m rows, harvested carrots were pulled up by the roots and plant umbels were immediately sorted based on umbel order in the field. Umbels were placed into paper bags according to their position (i.e., primary, secondary, tertiary, or quaternary), and the numbers recorded. Umbels were then taken to a room with temperature control to dry for 4 weeks. Once dry, umbels were hand threshed and returned to paper bags. Samples were threshed by hand and then cleaned at the USDA Corvallis seed labs. Plots were first debearded before being run through the seed mill, followed by the indenter, and finally separated with air to remove any remaining light seed. Each machine was set to clean seed as closely to a commercial seed cleaning facility as possible. Seed yield per umbel order and total yield per plot were expressed in grams of clean seeds. Seed samples were then sent to Agri Seed testing (Salem, OR) for 14-day germination tests.

Results

Irrigation delivery method affected germination; seed produced from the drip-irrigated area had 2.6 percent higher germination than that grown under sprinkler irrigation (Fig. 1). Germination differed from year to year but an increased quality of the drip field was consistent over both years (Table 2). Overall, germination was higher in all umbel orders in the drip plots compared to the sprinkled plots (Fig. 1). We hypothesized that the difference in germination percentage is due to a greater proportion of seed coming from the primary umbels of the drip-irrigated carrots, which are thought to have better germination. Yield of cleaned seed of each umbel order showed a greater seed weight for the primary umbel and much lower weights for the quaternary order (Table 4).

Total umbel numbers were similar in the primary and secondary orders but increased in the tertiary and quaternary orders of the sprinkler-irrigation plots (Table 3). Although we saw an increase in numbers, germination percentages were 3-7 percent lower in the sprinkler plots compared to drip plots. We found that seed from the drip-irrigated tertiary umbels were not only higher in harvested number but showed similar germination percentages to those of the primary umbel. Plots grown under drip irrigation produced more germinated tertiary umbels, thus increasing the overall germination of the seed lot.

Plots with germination lower than 84 percent were subjected to a Tetrazolium (TZ) test to identify embryo status. The TZ test can be used for small-seeded species in determining the viability of ungerminated seed at the end of the germination period. Embryo results are categorized as abnormal, dead, or empty (Table 5). We saw no significant differences

in germination response to fungicide treatments (Table 6). Plots were monitored for disease pressure throughout the growing season but showed no distinguishable blighting or loss of seed set. Harvested seed was assayed for bacterial population counts and were determined to have similar levels of infestation. Temperature and relative humidity were measured in each plot from June until August. On average, temperatures in the drip plots were 2-3 degrees higher than those in the sprinkler plots during mid-afternoon. The relative humidity in sprinkler carrot plots was 4-5 percent higher than that in drip plots. Drip-irrigation plots target water delivery to the root zone, which prevents standing water in the field and results in lower humidity within the canopy. Another advantage to drip irrigation is the uninterrupted time for the honey bees to work the carrot crop. Under sprinkler irrigation, honey bees are unable to work the sections of field being watered during that cycle. Seed set and ability of subordinate umbels to reach maturity may be the reason for increased germination of carrot seed fields. Seed companies will have greater confidence in the ability of growers to produce seed lots with a high germination percentage.

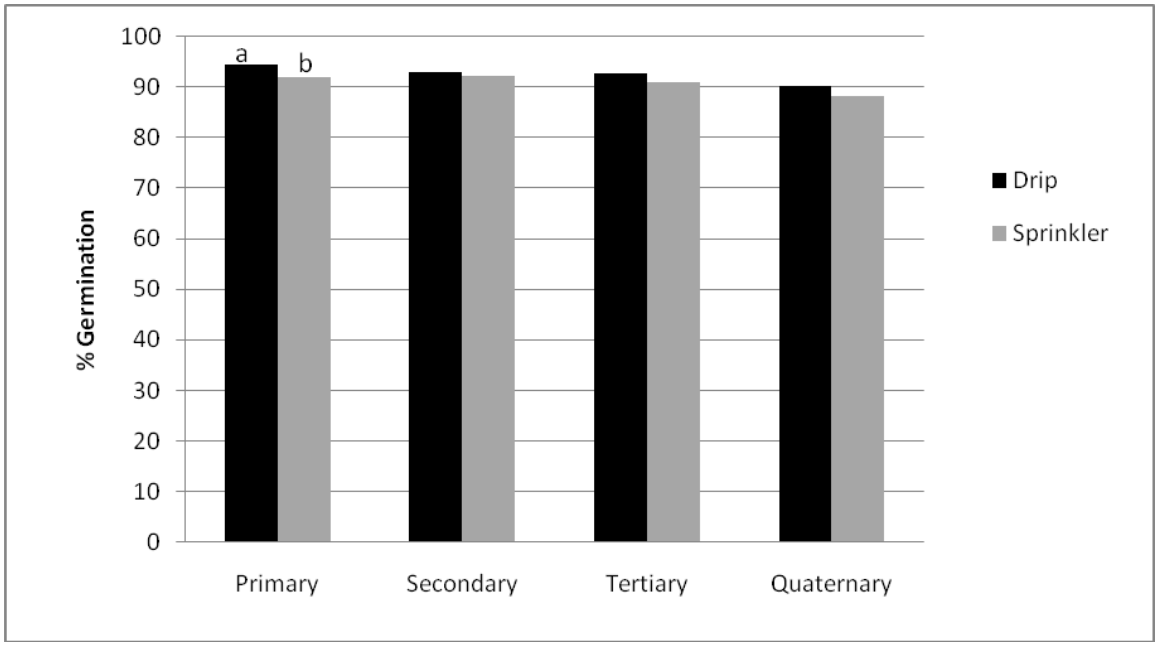

Figure 1. Two-year carrot seed germination results from seed carrots grown under two irrigation treatments, Central Oregon Agricultural Research Center, Madras, OR.

Table 1. Seed carrot planting and harvest dates at Central Oregon Agricultural Research Center, Madras, OR.

	2007-2008			2008-2009		
Field	Planting date	Drip tape installed	Harvest date	Planting date	Drip tape installed	Harvest date
Drip	12-Aug	22-May	16-Sep	14-Aug	20-May	7-Sep
Sprinkler	12-Aug	-	26-Sep	14-Aug	-	14-Sep

Table 2. Carrot seed germination percentage results of umbel order and irrigation practices at Central Oregon Agricultural Research Center, Madras, OR.

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	2007-2008		2008-2009	
Umbel order	Drip irrigation	Sprinkler	Drip irrigation	Sprinkler
Primary	92.8 a	93.2 a	95.4	91.1
Secondary	90.5 ab	89.5 ab	95.8	94.4
Tertiary	93.3 a	85.3 bc	95.7	93.1
Quaternary	89.7 b	81.5 c	94.0	91.9
LSD (0.05)	2.9	4.9		

*Means followed by the same letter are not significantly different at $P \leq 0.05$ according to Fisher's protected least significant difference (LSD) test.

Table 3. Number of harvested umbels from seed carrots grown at Central Oregon Agricultural Research Center, Madras, OR.

	Number of umbels per plot*			
	2007-2008		2008-2009	
Umbel order	Drip irrigation	Sprinkler	Drip irrigation	Sprinkler
Primary	13	13	110	112
Secondary	126	113	501	507
Tertiary	246	253	692	762
Quaternary	59	99	311	428

*Increase in umbel numbers were due to plot size increase in 2008-2009.

Table 4. Plot harvest weights by umbel order.

	Harvest weight (g)			
	2007-2008		2008-2009	
Umbel order	Drip irrigation	Sprinkler	Drip irrigation	Sprinkler
Primary	34	37	202	171
Secondary	136	137	353	426
Tertiary	80	88	276	298
Quaternary	9	14	43 b	64 a

*Means followed by the same letter are not significantly different at $P \leq 0.05$ according to Fisher's protected least significant difference (LSD) test.

Table 5. Hundred- seed Tetrazolium (TZ) results on seed carrot plots with germination below 85 percent.

	Germination %				
Sample	Original germination	Normal seeds	Abnormal seeds	Dead seeds	Empty seeds
1	82	85	4	5	6
2	84	83	3	11	3
3	83.3	81	4	5	10
4	81.3	87	2	7	4
5	84.0	84	2	5	9
6	83.3	78	3	16	3
7	83.5	78	4	8	10

Table 6. Germination percentage results of umbel order between irrigation and fungicide applications in seed carrots, Central Oregon Agricultural Research Center, Madras, OR.

	Germination %			
Umbel order	Drip with fungicide	Drip without fungicide	Sprinkler with fungicide	Sprinkler without fungicide
Primary	93.2 a	92.4 ab	94.1 a	92.3
Secondary	91.1 a	89.9 b	87.7 b	91.4
Tertiary	92.5 a	94.2 a	83.1 c	87.4
Quaternary	86.4 b	91.9 ab	72.9 d	87.3
LSD (0.05)	2.8	3.2	2.2	*NS*

References

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Hawthorn and Toole 1962

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Acknowledgements

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