

CARROT SEED GERMINATION AND VIGOR IN RESPONSE TO TEMPERATURE AND UMBEL ORDERS

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ABSTRACT: Several factors may influence carrot (*Daucus carota* L.) crop establishment. High temperatures (35 - 40°C), for instance, may delay or inhibit carrot seed germination in the field and so compromise the stand establishment. Carrot seeds from superior umbel orders usually have better physiological quality than those of lower umbel orders. These seeds from superior umbel orders may also show a better performance in adverse conditions. In addition, seeds from different ages show differences in vigor, which affect the stand establishment, mainly under adverse conditions. The aim of this study was to verify the germination at high temperatures and the carrot seed vigor of different umbel orders of 'Brasília', as well as the different 'Alvorada' seed lots. Preliminarily, 'Brasília' seeds were incubated at temperatures ranging from 20 to 36°C. Also, seeds from the primary, secondary and tertiary umbel orders harvested separately from a basic seed production field and seeds from lots harvested in 1998, 1999 and 2000 were analyzed to the following tests: germination at 20°C (optimum) and 35°C (adverse), accelerated aging, cold test, seedling emergence in greenhouse and mass of 100 seeds. High temperatures reduced carrot seed germination. Seeds germinated better at 20°C than 35 or 36°C. Seeds from primary and secondary orders, as well as less aged seed lots, had higher vigor and germination at high temperature.

Key words: *Daucus carota* L., thermo-inhibition, physiological quality

GERMINAÇÃO E VIGOR DE SEMENTES DE CENOURA EM RESPOSTA A TEMPERATURA E ORDENS DE UMBELA

RESUMO: Vários fatores podem influenciar no estabelecimento da cultura da cenoura (*Daucus carota* L.). Altas temperaturas (35 - 40°C), por exemplo, podem retardar ou inibir a germinação das sementes de cenoura no campo, comprometendo assim o estabelecimento de plântulas. Sementes oriundas de umbelas de ordem superior geralmente apresentam melhor qualidade fisiológica do que aquelas de menor ordem. Estas sementes podem apresentar uma melhor performance no campo, principalmente sob condições adversas. Lotes de sementes armazenados por diferentes períodos podem também apresentar diferenças de vigor o que poderá afetar o estabelecimento de plântulas no campo, principalmente em condições adversas. O presente trabalho teve como objetivo estudar a germinação em condições de altas temperaturas e o vigor das sementes de diferentes ordens de umbelas de cenoura cv. Brasília, bem como de diferentes lotes da cv. Alvorada. Sementes de cenoura 'Brasília' foram incubadas em temperaturas variando de 20 a 36°C. Ainda, sementes da primeira, segunda e terceira ordens colhidas separadamente em um campo de produção de sementes básicas e sementes provenientes de lotes produzidos nos anos de 1998, 1999 e 2000 foram analisadas quanto a germinação a temperaturas de 20°C (ótima) e 35°C (adversa), envelhecimento acelerado, teste de frio, emergência de plântulas em casa de vegetação e massa de 100 sementes. Temperaturas elevadas reduziram a germinação das sementes de cenoura. As sementes germinaram melhor a temperatura de 20°C do que a 35 ou 36°C. Sementes oriundas de ordens primária e secundária, bem como lotes mais novos, apresentaram maior vigor e germinação em temperatura elevada.

Palavras-chave: *Daucus carota* L., termo-inibição, qualidade fisiológica

INTRODUCTION

The carrot (*Daucus carota* L.) plant in its blooming stage produces a central floral stem that contains at the tip a central inflorescence, known as primary umbel, which ramifies and originates the secondary, tertiary and quaternary umbels. The umbel size

decreases as the number of the order increases. The size, vigor and germination of carrot seeds, which determine the seed quality, vary according to the umbel order (Hawthorn & Toole, 1962; Castro & Andrews, 1971; Gray & Steckel, 1983; Krarup & Villanueva, 1977; Viggiano, 1984; Nascimento, 1991; Rodo et. al., 2001).

The contribution of each umbel order to the carrot seed production depends on both cultivar and edaphoclimatic conditions. Nascimento (1991), observed that primary umbel of 'Brasília' carrot contributed to 11%, secondary to 58% and tertiary to 31% of the total seed production. Seed quality decreased as the umbel order increased (Nascimento, 1991). Superior umbel orders also produced seeds of higher size or mass (Castro & Andrews, 1971; Castellane, 1982; Krarup & Duran, 1982; Cardoso, 2000). In open pollinated cultivars, as 'Brasília', there is still a high genetic diversity, which is one of the reasons why seed quality standards do not seem to be very well defined, with a high variation in seed quality in terms of germination and vigor (Bittencourt, 1991). These traits may compromise the crop establishment under some conditions. High temperatures (35 - 40°C) for example, can delay or inhibit carrot seed germination and compromise the stand establishment in the field (Carneiro & Guedes, 1992; Cantliffe & Elballa, 1994; Pereira & Nascimento, 2002; Pereira et al., 2007; Nascimento & Pereira, 2007). The aim of this study was, therefore, to verify the germination at high temperature and vigor of carrot seeds from different umbel orders of 'Brasília' and from different lots of 'Alvorada'.

MATERIAL AND METHODS

Study 1: Evaluation of 'Brasília' carrot seed germination at different temperatures

In this preliminary study, four replications of 50 seeds of 'Brasília' carrot were placed in plastic box containing two germination papers wetted with 15 mL of fungicide solution (iprodione + thiram 3:1 - 4 g L⁻¹ distilled water). Seeds were incubated in an NKSystem type chamber to germinate under artificial light, at the constant temperatures of 20, 24, 28, 32 and 36°C. Evaluations were performed after 14 days of incubation and the results expressed in average percentage of germinated seeds (primary root protrusion). Data were submitted to variance analysis, and the averages were compared by Tukey test ($P < 0.05$). Percentage data had previously been transformed according to $\sqrt{\text{arc sign}}$.

Study 2: Vigor and germination of 'Brasília' carrot seeds from different umbel orders

This study was carried out in Brasília, DF, Brazil, between January 2003 and February 2005. Roots of 'Brasília' carrot produced during the summer and then vernalized in a cold storage room at 4°C and 90 - 95% RH for 35 days, were used to obtain seeds. After this period, the roots were transplanted into the

greenhouse, 24 hours after being taken out of the storage room. Distances of 0.80 m between rows and 0.30 m between plants were used. During the flowering, bees (*Trigona spinipes*) and flies (*Musca domestica*) were used for pollination. Primary, secondary and tertiary umbels were harvested separately, dried in an oven at 35°C for 24 hours, and then, threshed and processed manually. Seeds were analyzed by the following tests:

Germination test: Four replications of 50 seeds were placed in plastic box containing two germination papers wetted with 15 mL of fungicide solution (iprodione + thiram 3:1 - 4 g L⁻¹ distilled water). Seeds were incubated in a BOD type chamber at 20 (optimum) and 35°C (adverse). Evaluation occurred after seven and 14 days of incubation, and the results were expressed as an average percentage of germinated seeds (primary root protrusion).

First-count test: Carried out with the germination test, by calculating the average percentage of germinated seeds (primary root protrusion) after seven days of incubation.

Seed mass (g): Four replications of 100 seeds were weighted on an analytical scale, to a three decimal point.

Accelerated aging: Firstly, the seed moisture content was determined according to the Rules for Seed Analysis (Brasil, 1992). Seed samples of 3.0 g for each umbel order were placed over a screen into the gerbox with 40 mL of distilled water, for 72 hours at 42°C. Then, four replications of 50 seeds were incubated at 20°C, following the same methodology of the germination test, and the evaluation after seven days of incubation.

Cold test: Four replications of 50 seeds were placed in plastic box containing two germination papers wetted with 15 mL of fungicide solution (iprodione + thiram 3:1 - 4 g L⁻¹ distilled water) and incubated for seven days in a BOD type chamber, at 10°C, then transferred to 25°C, where they were evaluated after 24 hours (primary root protrusion).

Emergence of seedlings in greenhouse: Four replications of 50 seeds were sowed on February 14, 2005 in multi-cellular expanded polystyrene trays containing the commercial substrate and placed in a greenhouse, where the temperature between 10h00 and 14h00 ranged from 35 to 40°C. Evaluations occurred after seven and 14 days of sowing, and the results were expressed as an average percentage of emerged seedlings.

The data obtained was submitted for variance analysis, and the averages of treatments were compared by Duncan test ($P < 0.05$). The data in percentages had previously been transformed through the $\sqrt{\text{arc sin}}$.

Study 3: Vigor and germination of 'Alvorada' carrot seeds from different seed lots

Basic seed lots of 'Alvorada' carrot produced by Embrapa Vegetables, Brasília, DF in 1998, 1999 and 2000, and stored in a cold chamber at 5°C and 40 - 45% RH, were evaluated through the germination test, first count test, cold test, emergence of seedlings in a greenhouse and seed mass, as described in the Study 1.

The experimental design was entirely randomized, with four replications, and the averages were compared by the Duncan test ($P < 0.05$). Data in percentage had previously been transformed according to $\sqrt{\text{arc sin}}$.

RESULTS AND DISCUSSION

Study 1: Evaluation of 'Brasília' carrot seed germination at different temperatures

Seeds incubated at temperatures ranging from 20 to 32°C had the same germination pattern (Figure 1). At 20°C, seed germination was 85%; whereas at 36°C, only 27% of seeds germinated. Temperature is considered an important factor affecting the rate and percentage of germination and emergence (Nascimento, 2000). High temperatures have a strong influence on carrot seed germination. For example, in some genotypes no germination is observed; and in others, germination is drastically reduced (Pereira et al., 2007). In a similar study, 'Brasília' carrot seeds germinated 91% at 25°C, while at 35°C, germination decreased to 47% (Carneiro & Guedes, 1992).

Study 2: Vigor and germination of 'Brasília' carrot seeds from different umbel orders

After harvesting, seed moisture content from primary, secondary and tertiary umbels was 7.7; 6.0 and 7.6%, respectively. Differences were observed in

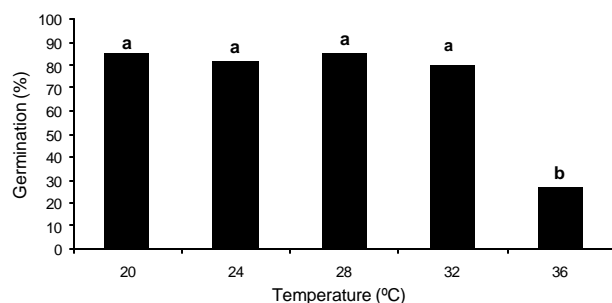


Figure 1 - Brasília carrot seed germination at different temperatures, under light. (CV = 6.6%). Brasília, DF, Brazil, 2005. Means followed by the same letter were not different (Tukey test, $P < 0.05$).

seed germination at different temperatures, with superiority at 20°C. Germination at 20°C was higher for all umbel orders, which varied between 91 and 95% (Figure 2). Carrot seeds germinate well between 8°C and 30°C, in which the ideal range for obtaining the maximum potential is between 20 and 30°C (Lima Júnior, 1999). At 35°C, there was a reduction in seed germination (Figure 3). Carrot seeds of 'Kuronan' and 'Brasília' showed low germination at 35°C (Carneiro & Guedes, 1992; Pereira & Nascimento, 2002). In the present study, no differences were observed among

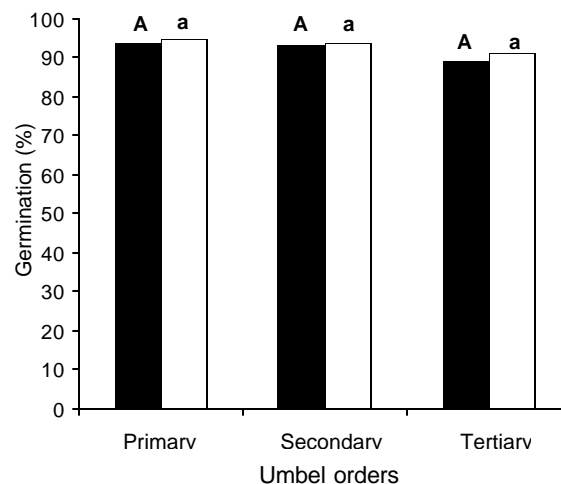


Figure 2 - Germination after 7 (■) and 14 (□) days at 20°C of 'Brasília' carrot seeds from different umbel orders (CV = 4.7% and 3.6% respectively). Brasília, DF, Brazil, 2005. Means followed by the same upper case letter and the same lower case letter were not different (Duncan test, $P < 0.05$).

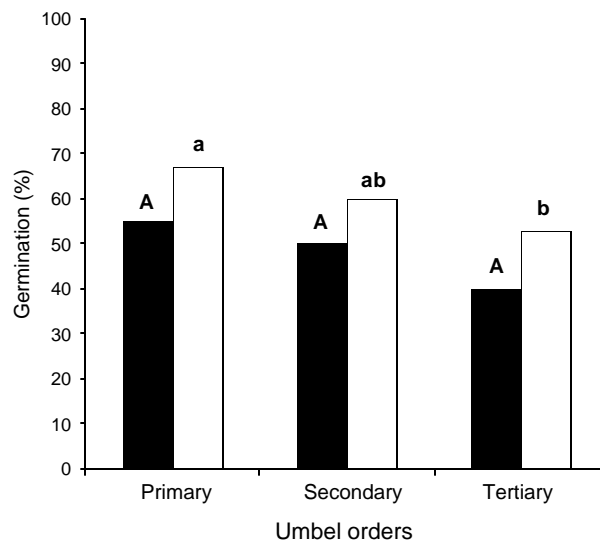


Figure 3 - Germination after 7 (■) and 14 (□) days at 35°C of 'Brasília' carrot seeds from different umbel orders (CV = 13.3% and 11.9% respectively). Brasília, DF, Brazil, 2005. Means followed by the same upper case letter and the same lower case letter were not different (Duncan test, $P < 0.05$).

the umbels orders for the first count germination. However, there was a difference in seed germination percentage at 35°C. Seeds from primary and secondary umbels, although did not show any difference, had a higher germination than the seeds from tertiary umbels (Figure 3). Using 100 progenies from a 'Brasília' carrot population, Pereira et al. (2007) found a better performance at 35°C in seeds from primary umbels when compared to those from secondary ones.

Seeds from superior umbel orders have higher size and density, presenting a better seed development. Seeds with fully mature embryos and high amounts of reserves are potentially the most vigorous ones (Carvalho & Nakagawa, 1983). In addition, vigor of seeds is closely related to performance under adverse conditions (Heydecker, 1972). Differences among the umbel orders were observed in the emergence on the seventh day at greenhouse. On the 14th day, seeds from primary umbels performed better than the other umbel orders (Figure 4). As previously mentioned, high temperatures were observed during the test, which might have influenced the results. Seeds from primary umbel showed high vigor by accelerate aging test in relation to the other umbel orders (Figure 5). Also, the cold test revealed a difference among the treatments; seeds from primary, secondary and tertiary umbel orders germinated in this test, 73, 58 and 50%, respectively (Figure 5). The thermo stress conditions to which seeds of different umbel orders were submitted caused a decreasing of seed vigor.

The statistical analysis revealed differences in seed mass among umbels, with a decrease of mass as the umbel order increased (Figure 6). These results

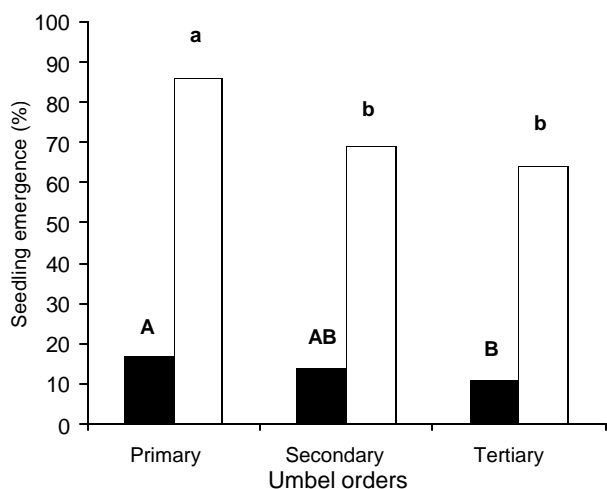


Figure 4 - Seedling emergence in greenhouse after 7 (■) and 14 (□) days of 'Brasília' carrot seeds from different umbel orders. (CV = 7.8% and 6.1% respectively). Brasília, DF, Brazil, 2005. Means followed by the same upper case letter and the same lower case letter were not different (Duncan test, $P < 0.05$).

have been similarly observed by Castro & Andrews (1971), Szafirowska (1994) and Cardoso (2000). Nascimento (1991), however, did not observe any difference in this trait among the different umbel orders using the same genotype. Using 'Brasília' carrot, Cardoso (2000) obtained a mass of 1,000 seeds of 2.18 g, 1.63 g and 1.45 g for seeds from primary, secondary and tertiary umbel orders, respectively. These differences may occur, as the mass of carrot seeds also varies according to the seed lot and the production timing (Gray et al., 1988).

As superior umbels usually produce seeds with higher germination and vigor, the primary and secondary umbels could be harvested separately and used in regions and/or at sowing times where conditions of more stress, including high temperatures, occur.

Study 3: Vigor and germination of 'Alvorada' carrot seeds from different seed lots

Seed lots from 1998, 1999 and 2000 had moisture content of 9.0; 9.5 and 11.0% respectively, after

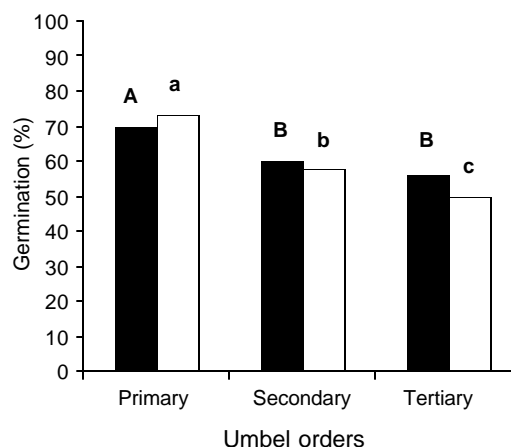


Figure 5 - Accelerate aging test (■) and cold test (%) (□) of seeds from different umbel orders of 'Brasília' carrot. (CV = 6.0% and 6.8% respectively). Brasília, DF, Brazil, 2005. Means followed by the same upper case letter and the same lower case letter were not different (Duncan test, $P < 0.05$).

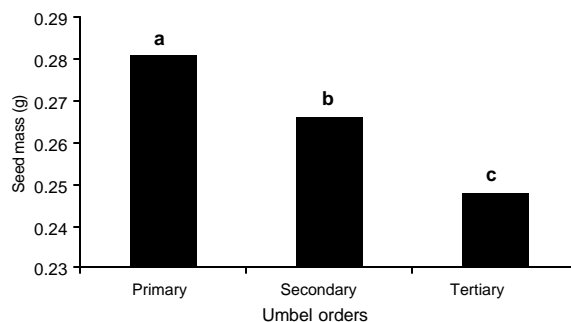


Figure 6 - Mass of seeds from different umbel orders of 'Brasília' carrot. (CV = 2.1%). Brasília, DF, Brazil, 2005. Means followed by the same letter were not different (Duncan test, $P < 0.05$).

Table 1 - First counting of germination at 20°C (FC 20) and 35°C (FC 35), total germination at 20°C (TG 20) and 35°C (TG 35), seedling emergence (SE), cold test (CT) and seed mass (M) from different lots of 'Alvorada' carrot. Embrapa Vegetables, Brasília, DF, 2005.

Lots	FC 20	TG 20	FC 35	TG 35	SE	CT	M
	----- % -----						g
2000	79 a	83 a	14 a	23 a	35 a	70 a	0.212 a
1999	72 a	75 ab	5 b	19 a	22 b	60 ab	0.188 b
1998	70 a	71 b	4 b	11 a	9 c	57 b	0.185 c
CV (%)	8.3	7.9	14.2	18.6	20.3	10.6	5.2

Means followed by the same letter were not different (Duncan test, $P < 0.05$).

being taken out from the cold storage room, and immediately before carrying out the tests. At 20°C, seed lots did not differ, although the seed lot from 2000 showed numerically a higher germination (Table 1). At 35°C, in the first germination counting, the seed lots showed differences. The 2000 lot had the best performance at high temperatures, despite the high reduction in germination observed in this study (Table 1). In another study, different carrot seed lots of 'Orlando Gold' cultivar had also considerable reduction in germination at 35°C (Cantliffe & Elballa, 1994).

When the lots are stored for long periods, seed vigor tends to decrease, which can affect negatively their potential for field establishment, mainly under high temperatures (Table 1). The 2000 seed lot showed the higher emergence, followed by the 1999 and 1998 seed lots. The high vigor of seeds is a fundamental factor for crop establishment, required to tolerate environmental stress (Heydecker, 1972), including high temperatures. The cold test at 10°C was very efficient for the separation of different vigor levels (Table 1), compared to the seedling emergence in the substrate. This test was more comprehensive than the germination test at 20°C for the separation of carrot seed lots (Hegarty, 1971; Peluzio, 1999). The mass of 100 seeds obtained in the seed lots from 2000, 1999 and 1998 showed significant differences: 0.212 g, 0.188 g and 0.185 g, respectively (Table 1). Several factors, such as edaphoclimatic conditions and seed maturation, may have contributed to these differences and affected seed vigor.

In another study, carrot seed lots from 1992 displayed better performance in vigor tests, compared to those produced in 1989 and 1990, where germination was reduced to zero (Andrade et al., 1995). These authors observed that the application of the vigor test facilitated the comparison of the seed lots. This might be of high relevance for decision making as regards to the seed storage, commercialization and use. For example, in the present study, lots from 1998 and 1999, even when showing elevated germination levels in the laboratory germination test, displayed a lower vigor in

different tests, which will certainly affect the establishment of seedlings under conditions of stress in the field.

In order to obtain a better performance in the field, mainly under adverse conditions of high temperatures, it would be advisable to use seeds from primary and secondary umbels, as well as higher vigor seeds.

CONCLUSIONS

The increase of the temperature to 35 - 36°C drastically reduced carrot seed germination. Seeds from primary and secondary umbel orders showed better performance at high temperatures than those from tertiary umbels. Seed lots with higher vigor displayed a better performance at high temperatures.

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