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EFFECTS OF SUBSTRATES AND TEMPERATURES ON *CYNARA CARDUNCULUS* L. SEED GERMINATION

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ABSTRACT

The aim of this study was to determine the effects of substrates and temperatures on *Cynara cardunculus* seed germination. The tests encompassed the following substrates - filter paper, sand and compost. The following temperature regimes were applied on each substrate used for germination tests: 20/30°C (T_1), 20°C (T_2) and 25°C after 10-day chilling at 10°C (T_3). The analysis of variance showed that there were statistically significant differences between the first counts and the total seed germination, depending on the substrate type, temperature regime and medium × temperature regime interaction The highest germination was detected on filter paper, whereas the lowest was on sand. Furthermore, the highest germination was determined at a constant temperature of 20°C (T_2), while the lowest, at a temperature regime of 25°C after 10-day chilling at 10°C (T_3).

Key words: *Cynara cardunculus,* seed, germination, medium, temperature.

INTRODUCTION

Cynara cardunculus (Fam. *Asteraceae*) is an important Mediterranean species that is grown for its large, immature inflorescences. Its commercial production is mainly based on the perennial cultivation of vegetatively propagated clones (Sonnante et al., 2007), but lately seed-propagated artichokes have been gaining in economic importance (López Anido et al., 1998). Farmers are looking at modifying this garden crop to a field crop (Hammer, 2003), hence the potential of seed-propagated *Cynara cardunculus* appears to be high.

The temperature and the substrate are important factors that affect germination and germination capacity. The temperature affects seed germination in the following three ways: a) the determination of capacity and the rate of germination, b) the breaking of seed dormancy and c) the induction of seed dormancy (Bewley and Black, 1994). Regardless of its well-substantiated effect on dormancy break and induction, temperature is very important for germination. When temperature impacts on seeds are analysed, the effect of constant and alternating temperatures is usually observed (Fenner and Tompson, 2006). The temperature range within which each seed germinates differs from one species to another and, very often, even among varieties of the same species.

The germination tests are carried out under constant temperatures, but seeds of many species require alternating temperatures, as seeds of the majority of plant species in nature are exposed to alternating, and not constant temperatures (Goedert and Roberts, 1986; Pons and Schröder, 1986; Pegtel, 1988; Probert, 2000).

The increase in the difference between low and high temperatures in conditions of alternating temperatures affects the increase of germination (Morinaga, 1926). Pons and Schröder (1986) stated that the maximum effect of alternating temperatures was reached at an amplitude of 12°C. Tests of the effects of alternating temperatures on seeds showed that germination also increases with a swifter

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rate of temperature growth (van Assche and van Nerum, 1997).

Different substrates are used for seed germination testing - paper, sand, soil, and compost (ISTA, 2009a). Filter paper is suitable for small seeds, but sand and compost are more suitable as they do not need additional watering during tests, as is often the case with filter paper. Substances released by seeds during swelling and germination (sugars, amino acids, germination inhibitors, etc.) are more easily neutralised in sand and compost than on filter paper, where they encourage the development of microorganisms that affect germination.

The ISTA Rules concerning the germination of *C. cardunculus* seeds prescribe two types of substrate: filter paper and sand, and two temperature regimes: alternating temperatures of 15-20°C or a constant temperature of 20°C. The duration of testing is 21 days, and the first count is determined on the seventh day from the day the seeds were placed to germinate (ISTA, 2009b).

The objective of the study was to observe the effects of different substrates and temperatures on seed germination, as well as to find out on which substrate and within which temperature range *C. cardunculus* seeds would have the highest germination.

MATERIAL AND METHODS

Mature achenes of *C. cardunculus* (the Romaneschi group), which are usually called seeds, were manually colleted in the experimental fields of the Institute for Medicinal Plant Research in Pančevo (Serbia) (44°52`20``N, 20°42`25``E) in September of 2008. The seeds were cleaned and placed in glass containers and stored for 10 months at a temperature of 20°C ± 2°C. Seed testing was performed in 2009. The mass of 1000 seeds weighed 19.8 g.

Seed germination was tested on three substrates - filter paper, sand and compost. The seeds were placed between two sheets of filter paper (type: Macherey Nagel, 80 g m^{-2}) that were rolled into scrolls and placed in the germination cabinet. Quartz sand (originating from Serbia) was the second substrate and its dimensions ranged from 0.3 to 0.8 mm. The artichoke seeds were placed in the sand. Compost, originating from Germany (Floragard, type: floradur b-fine), served as the third substrate for germination testing.

Three temperature regimes were applied in the course of germination testing. The first temperature regime (T_1) meant seed exposure to a temperature of 20°C for 16 h (in the dark), and a temperature of 30°C for 8 h under a light of 750 lux. The second temperature regime (T_2) consisted of a constant temperature of 20°C. The third temperature regime (T_3) involved chilling at 10°C for 10 days and then germination testing at 25°C.

The germination test on the paper substrate was done in the following way: the seeds were placed on a sheet of filter paper that was moistened with water up to saturation, and then a second moist sheet of filter paper was placed over the seeds. These two sheets of filter paper with the seeds between them were rolled into a scroll in such a way as to allow the seeds a sufficient amount of oxygen.

Then, the rolls were wrapped in double filter paper, over which a plastic bag was placed. The germination test in sand was performed in the following way: moist sand, which was 10 mm deep, was placed in plastic containers; the seeds were evenly spread over the sand. Then, another 10 mm-thick layer of moist sand was placed over the seeds and the containers were closed. The germination test in the compost did not differ from the test in the sand. In the course of testing, the substrate was sufficiently moist so that the seeds could germinate freely. After the first count (7^{th} day), the seedlings were removed each day and, after 21 days, germination was established.

Descriptive and analytical statistics were performed with the statistic package SPSS 10.0 for Windows. The significance of the differences between the calculated mean values of the observed factors (substrates and temperature regimes) was tested by applying the model of factorial analysis of variance. All evaluations of significance were performed on the basis of the F-test and the LSD-test at the 5% and 1% probability levels.

RESULTS

Based on the analysis of variance, statistically significant effects of substrate type, temperature regime and medium × temperature regime interaction were determined both for the first count and the total seed germination (Table 1).

The highest values of the first count and the total germination of artichoke seeds were obtained on filter paper and compost. The first count (49.6%) and the total germination (70.3%) on sand were significantly lower ($P \leq 0.01$) in relation to the corresponding values on the two previously mentioned substrates (Table 2). The highest (80.7%) and lowest (73.9%) values of the first count were recorded in the T_2, and T_1 temperature regimes, respectively. There were no significant differences between the first counts in the temperature regimes T_2 and T_3, while the first count in sand was significantly higher ($P \leq 0.05$) in the temperature regime T_3 (80.1%) than T_1 (73.9%).

Table 1. Mean values of grain yield (g plant^{-1}) of the generations of studied hybrids

Source of variation	Df	Mean squares MS		F value	
		First count	Total germination	First count	Total germination
Replication	3	3.778	13.481	0.113	0.684
Substrate (S)	2	7407.194	2250.528	222.447**	114.178**
Temperature (T)	2	167.861	121.444	5.041*	6.161**
S × T	4	94.403	56.028	2.835*	2.842*
Error	24	33.299	19.711		
Total	35				

*P ≤ 0.05, **P ≤ 0.01

Table 2. Effects of substrate (P), temperature (T) and P × T interaction on germination of *Cynara cardunculus* L**.** seed

First count (%)									Total germination (%)								
Filter paper (S_1)			Sand (S_2)			Compost (S_3)			Filter paper (S_1)			Sand (S_2)			Compost (S_3)		
T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
94.0	94.0	94.0	42.0	64.0	41.0	89.0	97.0	88.0	97.0	96.0	94.0	80.0	82.0	56.0	92.0	100.0	89.0
91.0	95.0	94.0	35.0	58.0	56.0	92.0	91.0	91.0	93.0	98.0	94.0	71.0	71.0	62.0	95.0	95.0	91.0
98.0	95.0	95.0	38.0	41.0	55.0	87.0	96.0	93.0	98.0	95.0	95.0	68.0	65.0	60.0	91.0	97.0	93.0
91.0	92.0	95.0	41.0	55.0	69.0	89.0	90.0	90.0	90.0	94.0	95.0	82.0	76.0	71.0	91.0	93.0	90.0
Average of substratum × temperature (S × T) interaction																	
93.5	94.0	94.5	39.0	54.5	55.2	89.2	93.5	90.5	94.5	95.7	94.5	75.2	73.5	62.2	92.2	96.2	90.7
Average over substrates (S)																	
94.0(S_1)			49.6 (S_2)			91.1 (S_3)			94.9 (S_1)			70.3 (S_2)			93.1 (S_3)		
Average over temperatures (T)																	
73.9 (T_1)			80.7 (T_2)			80.1 (T_3)			87.3 (T_1)			88.5 (T_2)			82.5 (T_3)		
$LSD_{0.05}$																	
S			T			S × T			S			T			S × T		
4.862			4.862			8.421			3.741			3.741			6.479		
$LSD_{0.01}$																	
S			T			S × T			S			T			S × T		
6.589			6.589			11.410			5.069			5.069			8.781		

The highest seed germination of 88.5% was determined in the temperature regime T_2. The difference between germination values in the regimes T_2 and T_1 was not statistically significant, but it was significantly ($P \leq 0.01$) lower in the temperature regime T_3 (82.5%).

The results on total germination points to the changes that occurred in the sand in the temperature regime T_1, where the total seed germination was significantly ($P \leq 0.05$) higher than the germination in the temperature regime T_3 (Table 2).

DISCUSSION

Shamsi and Whitehead (1974), who tested seeds of *Epilobium hirsutum* and *Lythrum salicaria* found lower germination of seeds tested in sand and soil in comparison to filter paper. Their study showed that the final seed germination in sand occurred several days later than in filter paper. Seeds of *L. salicaria* and *E. hirsutum* were on the substrate surface (sand), hence, the differences in germination were not the result of any other factor (poor aeration) but the substrate. In testing seeds of *Conium maculatum*, Baskin and Baskin (1990) established higher seed germination on soil, which is in accordance with the results obtained in the present study. Seeds of *Digitalis purpurea* at 20°C had a greater germination on filter paper than on soil (van Baalen, 1982). *C. cardunculus* seed had higher germination in the regime with constant temperatures than in regimes with alternating temperatures and these results are in accordance with the ones obtained by Conner and Conner (1988).

CONCLUSIONS

The seeds of *C. cardunculus* tested on filter paper and compost had higher germination than the seeds tested in sand. There were no statistically significant differences in the seed germination obtained on filter paper and compost.

The highest germination of *C. cardunculus* seed was achieved in the temperature regimes T_2 (20°C const) and T_1 (20°C, 16 h; 30°C, 8 h), while the lowest germination was detected in T_3 (chilling at 10°C for 10 days, germination testing at 25°C).

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