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Original scientific paper

Impact of storage conditions on seed germination and seedling growth of wild oat (*Avena fatua* L.) at different temperatures

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SUMMARY

The influence of seed storage conditions and different temperatures (5°C, 10°C, 15°C, 20°C, 25°C, 30°C and 26°C/21°C) during germination and seedling development on seed germination, shoot length and germination rate of wild oat (*Avena fatua* L.) was examined. Germinated seeds were counted daily over a period of ten days and shoot length was measured on the last day, while germination rates were calculated from those measurements. The results showed that seed storage under controlled conditions (T_1: temperature 24±1°C, humidity 40-50%; T_2: temperature 26±1°C, humidity 70-80% and T_3: temperature 4°C) for periods of 3 (t_1) and 12 (t_2) months had a significant influence on germination of wild oat seeds. The percentage of germinated seeds under all examined temperatures was higher when they were stored for 12 months under controlled temperature and humidity. The results also showed that temperature had a significant effect on the percentage of germination and germination rate of *A. fatua* seeds. The highest total germination occurred at 15°C temperature (T_1: t_1 - 41.25%, t_2 - 44.37%; T_2: t_1 - 28.13%, t_2 - 34.37%; T_3: t_1 - 10.63%, t_2 - 12.50%). Germination percentage under an alternating day /night photoperiod at 26°C/21°C temperature was higher in all treatment variants (T_1: t_1 - 8.13%, t_2 - 10.00%; T_2: t_1 - 11.87%, t_2 - 13.13%; T_3: t_1 - 2.42%, t_2 - 2.70%) than germination in the dark at 25°C, 30°C and 5°C.

Keywords: Germination; Seed storage; Temperature; Wild oat

INTRODUCTION

Avena fatua L. (wild oat) is considered the 13th most important weed worldwide (Holm et al., 1991). Wild oat spreads tremendously in fields after heavy rains and in well-irrigated areas of Serbia, as well as elsewhere in the world. It is an annual grass which is difficult to eradicate because its seeds disperse before crop maturation. Also, many of its seeds get plowed under and back again onto soil surface. Walia et al. (1998) found that wheat yield decreased exponentially when wild oat populations varied from 0 to 100 plants per m^2

with the loss approaching 50-60% at 100 plants of wild oat plants per m^2. High seeding rates of wheat reduced the impact of this weed on crops in a number of previous studies (Lajos et al., 2000; Khan et al., 2007). Also, Stougaard and Xue (2004) confirmed wheat yield losses of 47-58% resulting from competition with this weed species. Scursoni and Satore (2005) similarly reported that wild oat density of 70 plants/m^2 reduced oat yield up to 25%. The influence of crop density on wild oat competitiveness was also confirmed by Armin and Asghripour (2011), who found yield to decrease 42, 39 and 18% at crop densities of 300, 450 and 600 plants/m^2, respectively.

Effective management of a weed species in agricultural systems requires an understanding of that species' population dynamics (Cousens & Mortimer, 1995) in which seed fate is a critically important component. Seed dynamics depend on the rate of seed viability and dormancy (Venable & Brown, 1988) which alter other processes, such as mortality in the seedbank, including senescence and decay (Pakeman et al., 2012), predation (Westerman et al., 2003) and fatal germination (Davis & Renner, 2007). The time of weed germination and emergence in the field is influenced by a variety of environmental factors, such as light, soil temperature, soil moisture and soil atmosphere (Forcella et al., 2000).

Temperature is considered one of the crucial factors for the process of germination (Forcella, 1998). Besides, seed germination of some species requires temperature fluctuation (Baskin & Baskin, 1998). One of the significant characteristics of seeds that has an immediate impact on their germinating capacity is seed dormancy. It is the most important factor for *A. fatua* survival and spread in agroecosystems. Highly distinct seed dormancy is a typical characteristic of the species, which is why it has been used as a model plant for testing dormancy as a phenomenon (Foley, 1992). Nitrogen fertilization increases considerably the compatitiveness of wild oat in wheat crops (Ross & Acker, 2005), but it also reduces its seed dormancy, which is especially evident after spring plowing (Hilton, 1984). Callow et al. (1999) came to a similar conclusion regarding the effect of potassium fertilizers on wild oat compatitiveness.

An ability to predict the time of seedling emergence is an important step towards increasing the timeliness and efficiency of chemical and cultural weed control measures (Forcella et al., 1993). Data about the effects of environmental factors on germination and emergence can be very useful in that context. The purpose of this study was to investigate the effects of variable temperatures and storage conditions on seed germination and seedling growth of *A. fatua*.

MATERIALS AND METHODS

Seed germination was studied at the following temperatures: 5°C, 10°C, 15°C, 20°C, 25°C and 30°C. The experiment was set up under controlled conditions. Three treatments differing in manipulation with seeds that preceded the germination study were tested per each temperature: T_1 - seeds were stored in a climate room under the following conditions: temperature 24±1°C, humidity 40-50%; T_2 - seeds were stored in the climate room at: temperature 26±1°C, humidity 70-80%; and T_3 - seeds were stored at 4°C. The seeds were stored in paper bags. Seed germination under all three treatments was checked after two time intervals: t_1 – after being stored for three months under conditions described; t_2- after being stored for 12 months under conditions described. A data logger device was used for temperature and humidity measurements in the climate room. The same procedure was used for testing the germination of wild oat seeds under white light illumination and fluctuating temperature in the climate room. The conditions included: 14h/10h photoperiod, 26°C/21°C (day/night) temperature and 300 μE/m^2s light intensity.

Twenty seeds of *A. fatua* were placed in each Petri dish and 5 ml of distilled water was added. Germination took place in an incubator (Binder CE). Germinated seeds were counted daily over a ten-day period and the length of seedlings was measured on the final day. All trial variants were performed in four replications and the trial was repeated twice.

Germination rate (GR, sum of germination per day) was calculated using a formula described by Maguire (1962):

$$GR = n1/t1+n2/t2+....+nx/tx, \quad [1]$$

where n1, n2, ...nx are the numbers of germinated seeds at times t1, t2, ...tx in days.

Data analysis

Data were analysed by a two-factorial analysis of variance (ANOVA) using STATISTICA 8.0. software package. When F values were statistically significant ($p < 0.05$) treatments were compared using the LSD test.

RESULTS AND DISSCUSION

Seed germination depends on various factors, including temperature, humidity, type of soil, seed size, dormancy, etc. (Benvenuti, 2007). Our data show that seed storage conditions ($F = 20.92$; $p < 0.05$), duration of seed storage ($F = 5.38$; $p < 0.05$) and their interactions ($F = 2.02$; $p < 0.05$) had significant impact on the germination of wild oat seeds. Data on their germination at temperatures from 5 to 30°C (at 5°C intervals) are presented in Figure 1.

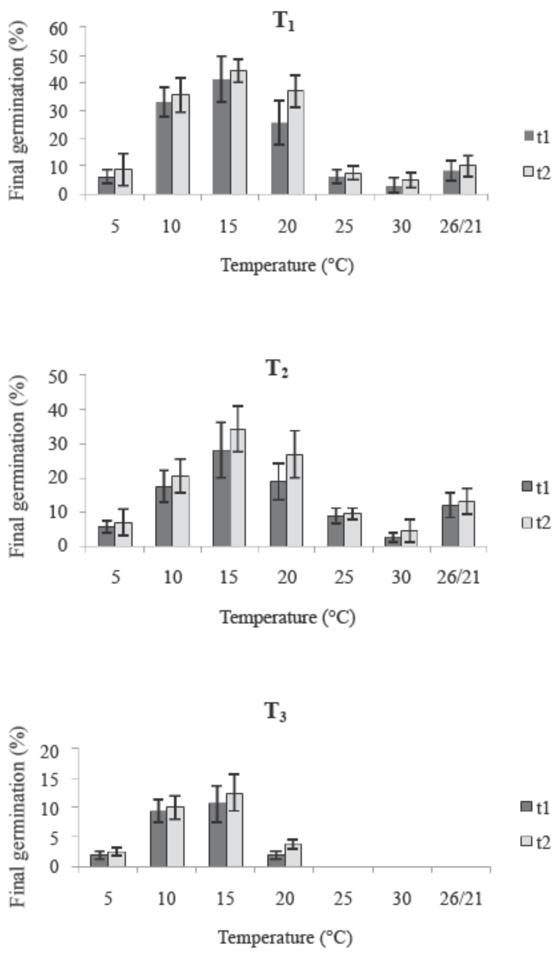

Figure 1. Final percentage of seed germination (%) of *A. fatua* at different temperatures; a, b – differences between treatments (LSD test, $p < 0.05$); T1 - seeds were stored in a climate room under following conditions: temperature 24±1°C, humidity 40-50%; T2 - seeds were stored in a climate room under following conditions: temperature 26±1°C, humidity 70-80%, and T3 - seeds were stored at 4°C; t1- after being stored for three months; t2- after being stored for 12 months.

Our data showed that the highest total germination of *A. fatua* seeds was at the temperature of 15°C in all treatments (T_1: t_1 - 41.25%, t_2 - 44.37%; T_2: t_1 - 28.13%, t_2 - 34.37%; T_3: t_1 - 10.63%, t_2 - 12.50%). Conversely, germination was at the minimum when temperature was 30°C in treatments T_1 and T_2 (T_1: t_1 - 3.13%; t_2 - 5.00%; T_2: t_1 - 2.50%, t_2 - 4.38%), while no seeds germinated at 25°C and 30°C temperature in treatment T_3 (Figure 1). Similar to our results, Fernandez-Quinantila et al. (1990), and Foley (1994) had also reported that seed germination of wild oat depended on temperature conditions. Fernandez-Quinantila et al. (1990) examined the influence of temperature on seed germination of *A. fatua* and *A. sterilis* and found that *A. fatua* seeds had lower germination at temperatures below 10°C and better above 20°C, compared to *A. sterilis*. Božić et al. (2013) reported that the percent of germinated seeds of *A. fatua* was highest at 10°C (90%), and lowest at 35°C (6.87%). Based on our results, we inferred that the percentage of germinated seeds at all temperatures in all treatments was higher after storage for 12 months than after 3 months, comparing the same temperatures and humidity (Figure 1). An exception is treatment T_3 at temperatures 25°C, 30°C and 26°C /21°C in which no seed germination occurred. Statistically significant differences ($p<0.05$) between seed germination after the two periods of storage (t_1 and t_2) were detected only at 20°C (T_1, T_2) (Figure 1).

The percentage of germinated seeds under day/night photoperiod at the respective temperatures of 26°C/21°C in two treatments (T_1: t_1-8.13%, t_2-10.00%; T_2: t_1-11.87%, t_2-13.13%) was higher than the percentage of those germinating at 25°C, 30°C and 5°C (Figure 1).

Germination rates were calculated based on daily data for germinated wild oat seeds (Table 1), and they showed the dynamics of seed germination. The highest germination rates were detected at 15°C in all treatment variants, ranging from 3.90 to 7.59, while the minimum rates (0.00-1.90) were found at 30°C temperature. Božić et al. (2013) reported the highest germination rate at 25°C (7.9) and lowest at 30°C (0.79).

The growth of weed seedlings is affected by various factors, such as temperature, light, depth of seed embedment in soil, seed storage conditions, soil bacteria and seed vigour (Bekker et al., 1998). The effects of different temperatures and humidity on germination rate and seedling length of *A. fatua* seeds in our experiment are presented in Table 1. The length of seedlings after ten days of the experiment was the highest at 15°C temperature and ranged from 4.87 to 9.93 cm. Conversely, seedling length was the lowest (0.09-1.97 cm) at 25°C and 30°C.

Table 1. Impact of seed storage conditions and different germination temperatures on germination rate (no. day^{-1}) and seedling length (cm) of *A. fatua*

Parameter			Temperature (°C)						
			5	10	15	20	25	30	26d/21n
Germination rate (no.day^{-1})	T_1	t_1	0.60±0.14	2.70±1.26	6.77±2.28	2.85±1.44	0.40±0.26	0.39±0.15	0.41±0.14
		t_2	0.55±0.27	3.73±0.87	7.59±2.39	3.75±1.23	0.58±0.46	1.90±1.40	0.94± 0.51
	T_2	t_1	0.86±0.25	3.95±2.85	4.69±2.16	1.95±0.87	0.47±0.21	0.32±0.21	0.72± 0.59
		t_2	0.75±0.26	2.42±1.61	6.85±3.04	2.01±1.32	0.70±0.52	0.83±0.51	0.86 ±0.32
	T_3	t_1	0.21±0.15	1.08±0.53	4.64±1.12	1.83±0.49	0.00±0.00	0.00±0.00	0.00±0.00
		t_2	0.16±0.10	1.19±1.06	3.90±1.34	2.43±0.69	0.00±0.00	0.00±0.00	0.00±0.00
Seedling lenght (cm)	T_1	t_1	0.31±0.13	4.68±3.44	4.87±2.61	4.71±1.44	1.57±0.93	0.09±0.03	0.00±0.00
		t_2	0.28±0.15	4.71±0.68	9.31±1.04	5.29±1.18	1.97±0.81	0.13±0.10	2.13± 0.68
	T_2	t_1	0.42±0.26	2.97±0.87	7.16±2.01	4.47±2.20	0.48±0.28	0.25±0.15	0.51± 0.22
		t_2	0.36±0.21	3.56±1.79	9.93±0.81	3.63±1.57	0.56±0.18	0.45±0.13	0.67± 0.28
	T_3	t_1	0.30±0.24	3.41±1.08	5.65±2.67	1.21±1.0	0.00±0.00	0.00±0.00	0.00±0.00
		t_2	0.45±0.35	6.06±3.32	7.67±4.17	2.78±1.51	0.00±0.00	0.00±0.00	0.00±0.00

T_1 - seeds were stored in a climate room with the following conditions: temperature 24±1°C, humidity 40-50%; T_2 - seeds were stored in a climate room with the following conditions: temperature 26±1°C, humidity 70-80% and T_3 - seeds were stored at 4°C; t_1- after being stored for three months; t_2- after being stored for 12 months.

In agricultural practice, the primary and permanent source of new weed growth is the seed bank in soil. Many biological characteristics of seeds and the processes normally occurring in them help plants to maintain a permanent reserve of seeds in soil, and an ensuing weediness of agricultural fields. Better understanding of seed ecology can be helpful in predicting the potentials of weed species for spreading, predicting their invasiveness, and developing more effective weed management strategies. Seed germination is a key event in determining the success of a weed species in any agroecosystem, and several environmental factors, such as temperature, light, pH and soil moisture, are known to affect seed germination. Temperature is one of the most important factors deciding seed germination and seedling emergence. Our results make a contribution to better understanding of *A. fatua* germination and emergence, and can be useful in developing programmes for control of this species.

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Uticaj uslova čuvanja i temperature na klijanje semena i rast klijanaca divljeg ovsa (*Avena fatua* L.)

REZIME

Ispitivan je uticaj različitih temperatura (5 ˚C, 10 ˚C, 15 ˚C, 20 ˚C, 25 ˚C, 30 ˚C i 26/21 ˚C), svetlosti i vlage na klijanje semena, dužinu klijanaca i stopu klijanja divljeg ovsa (*A. fatua* L.). Svakodnevno, u periodu od deset dana, prebrojavana su proklijala semena, a poslednjeg dana su izmerene dužine klijanaca, nakon čega je izračunata stopa klijanja semena. Dobijeni rezultati ukazuju da temperatura značajno utiče na procenat klijanja semena *A. fatua*, dužinu i stopu klijanja, pri čemu je optimalna temperatura za klijanje semena ove vrste, 15˚C

(T1: t1- 41.25%, t2- 44.37%; T2: t1-28.13%, t2-34.37%; T3: t1– 10.63%, t2 – 12.50%). Takođe, dobijeni rezultati ukazuju da skladištenje semena u kontrolisanim uslovima (temperatura 24±1°C, vlažnost 40-50%; temperatura 26±1°C, vlažnost 70-80% i semena izložena temperaturi od 4°C) u trajanju od 3 i 12 meseci ima značajan uticaj na klijanje semena divljeg ovsa. Procenat klijalih semena na svim rađenim temperaturama je veći u slučaju kada su bila skladištena 12 meseci pri određenoj temperaturi i vlažnosti vazduha. Takođe, procenat klijalih semena koji je praćen pri smeni dana i noći sa temperaturama 26ºC/21ºC u svim tretmanima (T1: t1-8.13, t2-10.00; T2: t1-11.87,t2-13.13; T3: t1-2.42, t2-2.70) je bio veći u odnosu na klijanje u mraku na temperaturama od 25ºC, 30ºC i 5ºC.

Ključne reči: Klijanje; Uslovi čuvanja; Temperatura; Divlji ovas