COMPARISON OF GERMINATION OF SELECTED ENERGY GRASSES SPECIES WITHIN DIFFERENT WATER REGIMES

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Abstract

Grasslands in the landscape fulfil not only a number of important functions but they are also relevant in terms of production. One of the ways how to utilize biomass effectively is its use in power engineering. Currently, several technologies which are able to obtain energy from phytomass are known. Anaerobic digestion and direct combustion belong among the most common ones. Due to the phytoenergetic development, there are monocultural grasslands established. Grasslands appear to be the most appropriate for these proposes. Selection of species and varieties depends on many factors. The energy obtaining technology is the most important. Also the growing method and harvesting dates are dependent on it. With an assumed climate change, also the grass drought resistance is becoming more important. This property is important not only in the vegetation period but especially during seed germination and seedling emergence. In this article, based on the results of laboratory experiments, the germination of seeds of selected grass species within two water regime types is assessed and compared. Experiments were carried out in a laboratory at a constant room temperature (21 °C) without the influence of direct sunlight and 16 repetitions were taken. The monitored species were orchard grass (*Dactylis glomerata* L.) - Padania species, reed canary-grass (*Phalaris arundinacea* L.) - Chrastava species and Szarvasi (*Agropyron elongatum* L). One of the water regime variants was the simulation of water stress during germination. This way, the seed drought resistance was verified and compared. The highest germination under conditions of water stress was achieved with *Agropyron elongatum* L. seed. The germination of this seed always reached values of ≥ 70% in all 16 repetitions. The difference in germination between different seed kinds within the variant simulating water stress ranged from ≥ 22% to ≤ 80% in all 16 repetitions. Germination of seeds in the second permanently irrigated variant does not drop below 78% with *Agropyron elongatum* L., 68% with *Dactylis glomerata* L. and 30% with *Phalaris arundinacea* L.

Key words: drought resistant, water stress, germination, energy grasses

Grasslands make up a significant part of agroecosystems (Kohoutek et al, 2002). They perform many ecological functions. They have a positive effect in areas of soil, water and climate protection (Nitsch H. et al, 2012). Protection of soil against rainstorms and wind is ensured all the year round thanks to the grasslands (Mrkvička J. et al, 2007). Grasslands protect the soil from erosion due to their rich root system and dense vegetation cover (Skládanka J., 2007). These areas simultaneously slow down the rainwater drainage. Thus, they partly reduce eutrophication of water flows in the landscape (Mrkvička J. et al, 2007). If grasslands are used extensively, they form highly species-rich communities (Nitsch H. et al., 2012). On the contrary, the increase of mineral fertilizer rate causes the biodiversity loss (Susan F. and Ziliotto U., 2008). In the past, the production function of grasslands was concentrated only on assurance of feed base for livestock. Recently, the alternative use of grass biomass has become more important. The ecoenergetic field is suitable for these purposes. Biomass can be used for example for the biogas production or for combustion (Jasinskas A. et al, 2008). During their energetic use, only as much carbon dioxide is released to the atmosphere as it was fixed before in the photosynthesis process (Osadolor O.O., 2009). Specifically grown grass species for ecoenergetics are for example *Phalaris arundinacea* L. or orchard grass (*Dactylis glomerata* L.) (Skládanka J., 2007). We estimate, there will be an increase of agricultural land aridity, especially in the summer seasons (Rožnovský J., 2011). Drought is considered to be a major threat for ecosystems within global climate changes. It also changes living conditions of agricultural diseases and pests that will be able to extend from today's warmer areas (Fuksa I., 2011). Nevertheless, we cannot state that the climate change influence on

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terrestrial ecosystems is accurately known (Qiu J., 2014). The lack of rainfall may be only local but it can also affect larger territorial areas (Bláha L., 2008). In Europe and the Mediterranean areas, there are more frequent dry seasons accompanied by heat waves expected (Schar C. et al, 2004). In the ever-growing and more frequent weather changes and especially during periodic dry and wet seasons, efficient use of water not only by plants during the growing season but also by seeds in the process of germination plays an important role (Bláha L., 2006). To maintain the stability and quality of crop production, there will be necessary to use varieties that are resistant to these adverse conditions (Bláha L., 2008). Water stress reduces biomass yields more than any other biotic and abiotic factors together (Bláha L., 2003). Plant drought resistance is the ability to adapt in certain periods of ontogenesis to conditions of permanent or temporary soil or atmospheric drought and thus survive in these conditions (Šebánek J. et al., 1983). If there is a drought stress at the beginning of germination, the overall species germination is negatively affected (Martinek J. et al, 2009a). Genetics of drought resistance is a very sophisticated and complex matter that has not been fully unravelled with many species (Bláha L., 2008). Plants with resistance to water stress have seeds with high germination energy, there is the rapid development of the root system and growth in biomass (Bláha L., 2008).

MATERIAL AND METHOD

The study was based on monitoring and evaluation of seed germination of three grass species potentially suitable for power use. The subjects were szarvasi (*Agropyron elongatum* L.), reed canary grass (*Phalaris arundinacea* L.) and *Dactylis glomerata* L. Germination tests were based on a simple laboratory methodology. The first step was distribution of 50 grain pieces of one species on a moistened sheet of filter paper (diameter 150 mm) placed in a Petri dish and subsequently closed with a lid. We recommend putting grains on the filter paper with gaps between them for their easy subsequent evaluation. Because germination monitoring consisted in comparing two different water regimes, there were always two Petri dishes of each species based. The first water regime, called "wet variant", was irrigated regularly every 24 hours. The principle of each watering was to keep the filter paper still damp. The second water regime, called "dry variant", was watered intermittently during monitoring. The intermissions of watering with "dry variant" (i. e. from irrigation to irrigation) was 72 hours in total while for 48 hours, there was the lid opened on the dish. Watering was interrupted when the seed started to germinate. After a period of interruption, we continued with the process of watering. Watering was repeated (every 24 hours) until the germinated plants have reached a height of 4-5 cm. Then, the share of germinated seeds of particular species and varieties was recorded. During the germination experiments in the laboratory, there was a constant room temperature (21 °C) ensured using a thermostat. Repeated establishment of Petri dishes with grains were carried out 16times for each grass species in wet and dry variant. Particular repetitions were established every 22 days. Germination experiments lasted for 8 months (March-September).

RESULTS AND DISCUSSIONS

The basic prerequisite for the optimal stand establishment is the quality seed. Laboratory germination is considered to be the main value that defines the seed quality (Pazderů, 2009). Although, the seed germination is evaluated under standard optimal laboratory conditions, in some cases, different results can be obtained (Gottwaldová, Bláha, 2009). Germination tests described in this paper were performed on the basis of the set methodology. The result is a summary of the numbers of germinated seeds of monitored species from 16 repetitions within a variant without water stress ("wet variant") and with water stress ("dry variant"). According to Fay and Schultz (2009), this method also simulates the state of rotation of dry and wet conditions that are usually caused by the episodic precipitation characteristic. However, Cipriotti et al. (2008) adds that due to the dynamics of the soil water, a reduced amount of precipitation does not affect the availability of water for germinating seeds, even in arid sandy areas. The average seed germination monitored in 16 repetitions is shown in *figure 1* and *table 1*.

Different values of irrigation intensity caused different values of germination. With most species, dehydration reduced germination as compared to a constant state of hydration (Fay, Schultz, 2009; Cipriotti et al., 2008). The reduction of germination due to water stress occurs not only within one species but also between different varieties (Martinek, Svobodová, Králíčková, 2011). In addition to changes in the water regime, germination is influenced by numerous other factors which include, for example, light regime and germination periodicity during the year. Martinek, Svobodová, Králíčková (2009a) state that the effect of the light on germination is not fully clarified. Still, there are species that have demonstrably higher germination in the light. On the contrary, Ahmadi, Hosseini, Zeidali (2013) carried out experiments with little seed canary grass (*Phalaris minor* L.) and there was the influence of light time period described. With the reduced duration of sunshine, the percentage of germinated seeds rises. According to Gottwaldová, Bláha (2009), there is a period with most plant species when seeds germinate in different quantity and intensity. The period of minimum germination may have a significant impact on the results of testing seeds. Accodring to Bláha, Hnilička (2006), the speed and quality of seed germination is strongly influenced by the inherited properties. The response of seeds to the water presence, the rate of uptake and utilization efficiency of water taken for germination is also important. The water use efficiency by germinating seeds decreases with varieties that are less resistant to water stress (Bláha, Hnilička, 2006).

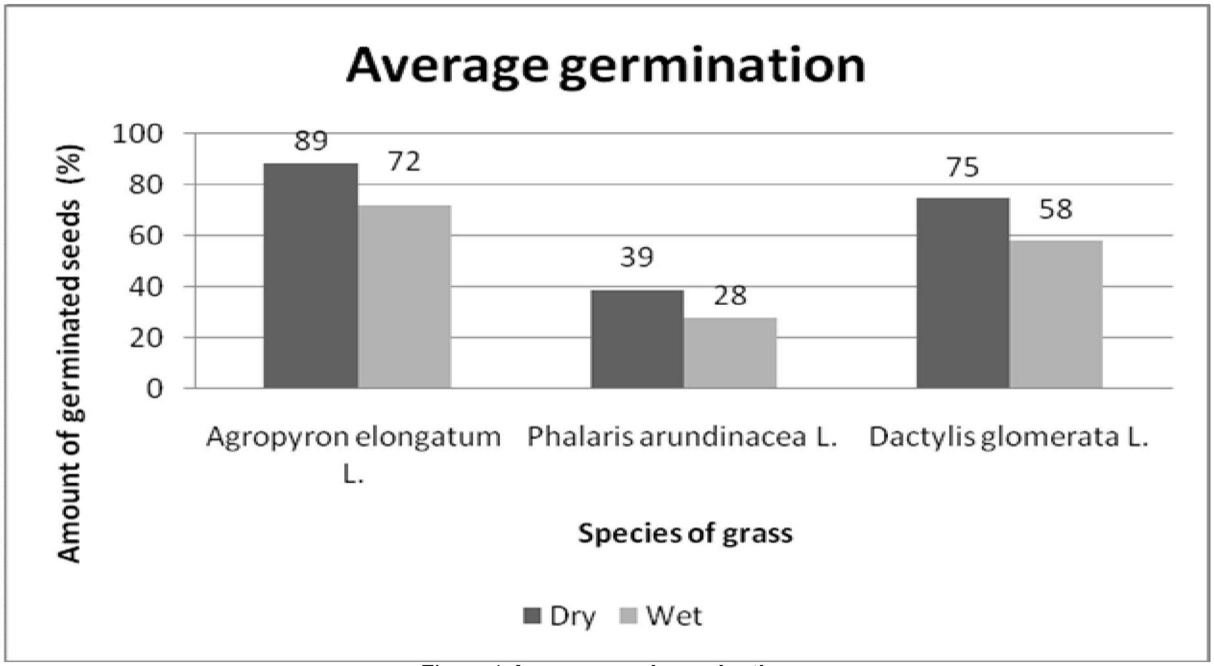

Figure 1 **Average seed germination**

Table 1

Table of seed germination

	Percent of germination						
Species	***Agropyron elongatum* L.**		***Dactylis glomerata* L.**		***Phalaris arundinacea* L.**		
Variant »	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Number of recurrecnce**
	78	72	72	68	40	28	*1*
	82	70	80	70	36	26	*2*
	90	72	68	50	44	26	*3*
	90	74	76	48	38	28	*4*
	94	74	72	56	40	26	*5*
	92	76	74	56	44	24	*6*
	86	80	80	68	36	30	*7*
	88	74	78	68	36	28	*8*
	92	78	82	58	42	32	*9*
	96	70	76	60	40	28	*10*
	94	70	76	64	42	34	*11*
	86	64	80	46	38	32	*12*
	76	62	64	66	34	24	*13*
	92	64	78	48	32	32	*14*
	88	76	72	50	40	26	*15*
	96	78	72	54	44	24	*16*
Average	**89**	**72**	**75**	**58**	**39**	**28**	

During germination tests, there are seeds sometimes treated with stimulant for germination improvement (Knot and Vrzalová, 2011).

Germination of the *Agropyron elongatum* L. seed was in average 89 % within the "wet variant". Germination interval within the "wet variant" during 16 repetitions varied in the range of 76-96%. The *Agropyron elongatum* L. seed within the "dry variant" always achieved the germination value of ≥ 62%, 72% in average. The percentage difference in average germination between these two variants was 17%. Bláha, Hnilička (2007) state that seeds of some species are able to use water during germination better and they also have higher germination energy which was proved with the *Agropyron elongatum* L. seed. This seed achieved significantly higher germination than other types, both in the "wet" and "dry variant". During all 16 repetitions, a constant room temperature (21 °C) was maintained. As reported by Rawlins et al. (2012), seeds of most grass species show high germination (> 50%) in the experiments exposed to constant temperatures and this is already at 5 °C.

The *Phalaris arundinacea* L. seed (Chrastava variety) has variable and unbalanced germination as compared with the *Agropyron elongatum* L. seed. The lowest germination of the *Phalaris arundinacea* L. seed was 32% within the "wet variation" and 24% within the "dry variation". The overall average germination of the *Phalaris arundinacea* L. seed was 28% within the "dry variation" and 39% within the "wet variation".

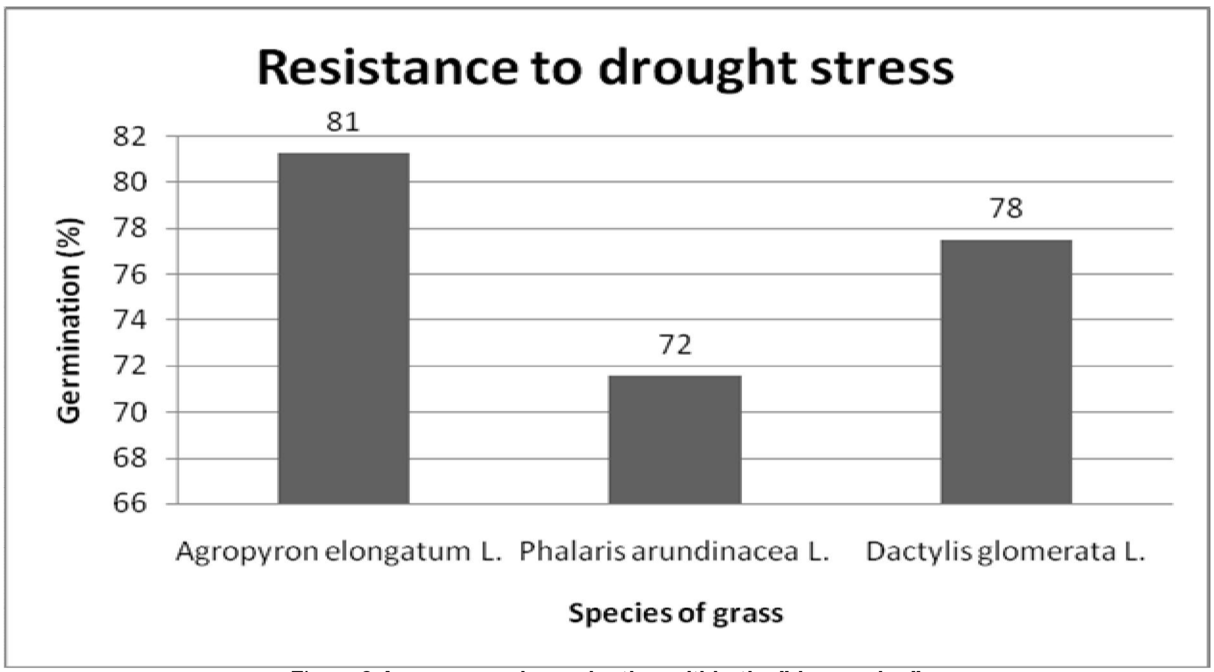

Figure 2 **Average seed germination within the "dry version" (germination within the "wet version" is taken as 100%)**

The germination success of the *Dactylis glomerata* L. seed reached 64-82%, 75% in average, within the "wet variant". Within the "dry variant" simulating water stress, the average germination was 39% while it was ≥ 32% in all repetitions. Experiments with *Dactylis glomerata* L. were carried out in 2003 and 2004 by Qiu et al. (2008). It was found that the percentage of plant germination with daily watering was in 2003 in the range of 47-92% and in 2004 between 47 and 91%.

Chart 2 shows the drought resistance of particular species during germination. The values show the amount of seeds (in percent) that germinated within the "dry version". As a basis for the calculation (100%), the number of seeds germinated within the "wet version" is taken. Thus, the difference in germination between the "wet and dry variant" is 28% with *Phalaris arundinacea* L. With this species, the assumption of Martinek, Svoboda, Králíčková (2009b) was proved. They stated that when there is a lack of water in the germination stage, which is already associated with cell division, volume growth and growth of the germ, there will be a violation of the clavicle. This can lead to drying of germinated plants. Lelièvre et al. (2011) states that *Dactylis glomerata* L. has by 10-20% higher drought resistance as compared with other grass species. The experiment confirmed the lower drought resistance of *Phalaris arundinacea* L. However, *Dactylis glomerata* L. has slightly lower drought resistance as compared with *Agropyron elongatum* L.

CONCLUSIONS

In the case of the grassland establishment, it is necessary to know the habitat conditions and the seed which would be sown there. Due to possible water condition changes in a habitat that are expected due to climate changes in the whole territory of the Czech Republic, it is necessary to choose such seeds which will germinate with some certainty and subsequently come up well in these conditions. Germination tests published in this paper can contribute to the proper selection of seeds for the grassland establishment in habitats with a higher risk of spring drought. Compared grass seeds germinate in varying quantities during monitoring. In terms of comparison of the "wet variant", there was the highest germination repeatedly observed with the *Agropyron elongatum* L. seed. The germination with this seed ranged was in the range of 78-96% within 16 repetitions. Germination of *Dactylis glomerata* L. within the "wet variant" reached maximum values of 80% and with *Phalaris arundinacea* L., it was only 44%. For other evaluation, this variant was taken as a control one. Within the "dry variant" where water stress was simulatedf during germination (for 72h), the seed germination in comparison with the "wet variant" was considerably lower. As compared with the "wet variant", the germination decreased by 17% with the *Agropyron elongatum* L. and *Dactilis glomerata* L. seed and by 11% with the *Phalaris arundinacea* L. seed. In terms of comparing the impact of water stress on the seed germination, the *Agropyron elongatum* L. seed has the best results. The average seed germination of this grass within the "dry variant" was 72% (*Phalaris arundinacea* L. 28%; *Dactylis glomerata* L. 58%). The *Agropyron elongatum* L. seed showed the highest germination within the "dry variant", even when the basis (100%) was the percentage germination of the "wet variant" (see *figure 2*) (*Agropyron elongatum* L. 81%; *Phalaris arundinacea* L. 72%; *Dactylis glomerata* L. 78%). Simulated-72-hour-water stress (within the "dry variant") may not always be clear in terms of comparing drought resistance. The *Phalaris arundinacea* L. seed showed the lowest germination within the "dry variant", even when the basis (100%) was the percentage germination of the "wet variant" (see *figure 2*) (germination of 72%). On the basis of this one-year monitoring, the *Phalaris arundinacea* L. seed can be regarded as the least drought resistant. On the other hand, the *Agropyron elongatum* L. seed showed the best drought resistance during germination as stated above. Despite the fact that the grass species may seem drought resistant with specific water stress intensity, we have to count on the fact, that resistant or tolerant genotypes may not actually exist if the stress boundary was higher.

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REFERENCES

Ahmadi A., Hosseini M., Zeidali E., 2013 - *Study of ecological characteristics of canary grass (Phalaris minor)*, TJEAS Journal, vol. 16, i. 3, p. 1835.

Bláha L., 2003 - *Rostlina a stres*, Praha: Výzkumný ústav rostlinné výroby, 156 p.

Bláha L., 2006 - *Současné změny klimatu ovlivní zemědělskou produkci*, In: Úroda, Profi press, Praha, vol. 6, i. 53, p. 36-38.

Bláha L., 2008 - *Biologické metody boje se suchem, In: Sborník příspěvků ze semináře ke světovému dni výživy*, Výzkumný ústav potravinářský, Praha, p. 3-6.

Bláha L., Hnilička F., 2006 - *Význam vlastností kořenů a semen pro odolnost rostlin vůči abiotickým stresorům*, In: HNILIČKA, F., 2006 - Vliv abiotických a biotických stresorů na vlastnosti rostlin, Praha, Výzkumný ústav rostlinné výroby, 300 p.

Bláha L., Hnilička F., 2007 - *Růst významu vlastností kořenů v měnících se klimatických podmínkách střední Evropy*, In: Vliv abiotických a biotických stresorů na vlastnosti rostlin, Česká zemědělská univerzita, Praha, p. 12-13.

Cipriotti P. A., Flombaum P., Sala O. E., Aguiar M. R., 2008 - *Does drought control emergence and survival of grass seedlings in semi-arid rangelands?,* Journal of Arid Environments, vol. 72, i. 3, p. 162-174.

Fay P. A., Schultz M. J., 2009 - *Germination, survival, and growth of grass and forb seedlings: Effects of soil moisture variability*, Acta Oecologica, 2009, vol. 35, p. 679-684.

Fuksa I., 2011 - Zemědělství a změna klimatu, Praha: Ministerstvo zemědělství, 26 p.

Gottwaldová P., Bláha L., 2009 - *Klíčivost semen - změny v průběhu roku*, In: ŠVACHULA, V. 2009 - Osivo a sadba. Praha, Česká zemědělská univerzita v Praze, 164 p.

Jasinskas A., Zaltauskas A., Kryzeviciene A., 2008 - *The investigation of growing and using of tall perennial grasses as energy crops*, Biomass and Bioenergy, vol. 32, i. 11, p. 981-987.

Knot P., Vrzalová J., 2011 - *Vliv teploty na klíčivost a počáteční vývoj vybraných trávníkových druhů trav*, Praha, Zahradnictví, Profi Press, vol. 9, i. 7, p. 50 - 51.

Lelièvre F., Seddaiu G., Ledda L., Porqueddu C., Volaire F., 2011 - *Water use efficiency and drought survival in Mediterranean perennial forage grasses*, Field Crops Research, vol. 121, i. 3, p. 333-342.

Martinek J., Svobodová M., Králíčková T., 2011 - *Stres suchem a dynamika klíčení vybraných trávníkových odrůd lipnice luční*, In: BLÁHA, L.; HNILIČKA, F. 2011 - Vliv abiotických a biotických stresorů na vlastnosti rostlin, Praha: Výzkumný ústav rostlinné výroby, v.v.i. Praha - Ruzyně

Česká zemědělská univerzita v Praze, vol. 1, p. 246-250.

Martinek J., Svobodová L., Králíčková T., 2009a - *Dynamika klíčení trávníkových druhů trav při vodním stresu*, In: Aktuální poznatky v pěstování, šlechtění, ochraně rostlin a zpracování produktů, Praha: Výzkumný ústav pícninářský, spol. s r.o. Troubsko a Zemědělský výzkum spol. s r.o. Troubsko, p. 18 - 23.

Martinek J., Svobodová M., Králíčková T., 2009b - *Vliv vodního stresu na klíčení vybraných druhů trav*, In: Vliv abiotických a biotických stresorů na vlastnosti rostlin, p. 35 - 41.

Mrkvička J., Veselá M., Niňaj M., 2007 - *Trvalé travní porosty - jejich funkce v krajině*, Sborník z konference ,,Ekologické zemědělství", p. 188.

Nitsch H., Osterburg B., Roggendorf W., Laggner B., 1998 - *Cross compliance and the protection of grassland - Illustrative analyses of land use transitions between permanent grassland and arable land* in German regions: Lecture Notes from the 2nd ERCOFTAC Summerschool hel in Stockholm, 10-16 june, Land Use Policy, vol. 29, i. 2, p. 440-448.

Osadolor O. O., 2009 - *Availability of grasses, weeds and leaves as energy resource*. Renewable Energy, vol. 34, i. 3, p. 486-491.

Pazderů K., 2009 - Význam *energie klíčení pro hodnocení kvality osiva*, In: ŠVACHULA, V. 2009 - Osivo a sadba, Praha, Česká zemědělská univerzita v Praze, 164 p.

Qiu J., 2014 - *Land models put to climate test*, Nature, vol. 510, i. 7503, p. 16-17.

Qui J., Bai Y., Coulman B., Romo J., 2008 - *Mechanisms regulating seedling emergence of orchardgrass (Dactylis glomerata L.) and western wheatgrass (Pascopyrum smithii [Rydb.] L.): Dormancy change, seed fate and seeding date*, Environmental and Experimental Botany, Elsevier Science, vol. 62, i. 2, p. 185 - 194.

Rawlins J. K. et al., 2012 - *Predicting germination in semi-arid wildland seedbeds. I. Thermal germination models*, Environmental and Experimental Botany, vol. 76, p. 60-67

Rožnovský J., 2011 - *Možné dopady měnícího se klimatu na zemědělství v ČR*, Bio, vol. 2, p. 19-20.

Schär C., Vidale P. L., Lüthi D., Frei C., Häberli C., Liniger A., Appenzeller M. C., 2004 - *The role of increasing temperature variability in European summer heatwaves*. Letters to nature, vol. 427, p. 332 - 336.

Skládanka J., 2007 - *Biologie trávníkových druhů*, In: HRABĚ, F. 2007 - Zelené vzdělávání: souborný studijní materiál, V Brně: Mendelova zemědělská a lesnická univerzita, vol. 1, p. 22-28.

Skládanka J., 2007 - *Druhová diverzita travních porostů a její vztah k produkčním a mimoprodukčním funkcím*, In: Travní porost jako krajinotvorný prvek, Brno: Mendelova zemědělská a lesnická univerzita, p. 24-32.

Susan F., Ziliotto U., 2008 - *Long-term effects of N, P and K fertilization on specific biodiversity in a permanent mountain meadow, Biodiversity and animal feed: future challenges for grassland production*, Proceedings o f the 22nd General Meeting of the European Grassland Federation, p. 943 - 945.

Svobodová M., 1998 - *Trávníky, V Praze*: Česká zemědělská univerzita, vol. 1, 81 p.

Šebánek J. et al., 1983 - *Fyziologie rostlin*, SZN, Praha, 588 p.