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AUTUMN TERMS OF SOWING OF TURF GRASSES AND LEGUMES AND THEIR INITIAL DEVELOPMENT

J. Ambruz, S. Hejduk

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Abstract

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The most frequent way to establish turfgrass in the climatic conditions of the Czech Republic is sowing during spring period. The seedlings are endangered by lack of soil moisture and by high temperatures if irrigation is no available. One of the possibilities how to increase probability of successful turfgrass establishment in warm areas which suffer by low amount of precipitation is autumn term of sowing. Eight grass species and subspecies and two legumes were sown in three autumn terms (September, October and November) during 2009 and 2010. The shortest time for seedling emergence was found in average of all terms at *Medicago lupulina* and *Trifolium repens* (9 days). *Lolium perenne* (14) *and Festuca arundinacea* (17) were the fastest emerged grasses. On the other hand the longest emergence time was realised at *Poa pratensis* (23), *Festuca rubra ssp. trichophyla* (22) and *Festuca ovina* (21). Plants sown in September emerged in 10 days, in October 12 and in November in 29 days. September term was suitable for all used species but November term underwent most successfully *Festuca rubra* ssp. *commutata* (23% soil cover in April next year) and *Lolium perenne* (19%). November term was not acceptable for legumes.

turfgrass, overwintering, autumn sowing, grasses and legumes

Establishment of turfgrasses by sowing is possible during the whole growing season. In praxis, there is the most common term for turfgrass sowing in spring period. At this time soil moisture is usually sufficient and air temperature is not too high for seedlings growth. If there are drought and high temperatures, supplementary irrigation must be used. In many areas you can easily create high-quality turf when autumn sowing (September to mid October). In autumn, thanks to lower temperatures and shorter day length, compared to the summer period, there is reduced evapotranspiration and sown grass species develop better.

Before the advent of winter plants create a smaller amount of aboveground biomass and in the spring they have deeper root system and will withstand short drought periods without irrigation. This is especially beneficial for species with slow initial development (HRABĚ and KNOT, 2009). TEUTON *et al.* (2009) warn against early summer seeding of *Poa* species as the results are low quality turfgrasses, esp. in warm and dry areas.

Establishment in early November can be risky for some species in years with early onset of below zero temperatures. Given that individual species characterized by different germination rate and initial development, they can be damaged differently. In mixtures can individuals of one species to gain a competitive advantage, resulting in changing the proportion of species in the turfgrass, or loss of any of them.

Plant-plant interactions during seedling establishment can influence composition of turfgrass community. According to SKINNER (2005) emerged seedlings can be influenced by presence of surrounding emerging plants negatively (competition for water, nutrients and space), but also positively (soil shading, lower evaporation).

Emergence rate is influenced by plant species, soil temperature and moisture, but also by cultivar, health status and age of seed (ADAMS and GIBBS, 2004). Many authors emphasize effect of temperature on germination rate of turf species, eg. KNOT (2006) and LARSEN and BIBBY (2005). Minimal and maximum temperatures for germination are genetically given and can be largely influenced by other abiotic factors. Optimal temperatures for germination are species specific. They are usually lower than optimum for growth. At low temperature, there is an imbibition of seed, but no embryo growth. The low temperature damages the embryo so that it will not complete germination. Likewise, high temperatures can lead to water intake, but not as well to grow embryos. Optimum temperature for germination of most species of temperate grasses is between 16 and 25 °C. Minimum temperatures are between 0 °C and maximum around 35 °C (VALVERDE and MINNER, 2008).

The situation is similar with perennial legumes. One method of establishing legumes in order to reduce the negative effects of drought and high temperatures in the spring is sowing on the frozen soil (frost seeding). This method is used in the renovation of pastures in the mid-west of the U.S. (RIDAY, 2008). This is done in early spring after the snow melting on the soil surface. During the cycles of melting and freezing seed comes into contact with the soil. However, in 30–40% of cases, this process ends unsuccessfully.

The aim of this experiment was to compare the suitability of the autumn sowing terms at ten grasses and legumes species used for turfgrass establishment under climatic condition of lowland areas of Central Europe.

MATERIALS AND METHODS

The experiment was established in site Baťov-Otrokovice (49°14‘N, 17°30’E) using randomised block design. Long term sum of precipitation amounts to 711 mm, long term mean annual temperature 8.5 °C, soil type was Fluvisol. Size of plots was 1m^2; each variant was established with four replicates in 2009 and three replicates in 2010. The plots were not fertilised after sowing and the trials were sprayed by a nonselective herbicide (Glyphosate) at the end of July 2010 and in May 2011. The trial was mown by rotary mower on the height 80 mm in following terms: 24. 9. 2009 (1st term of sowing), 22. 4. 2010 (1st and 2nd term), 13. 5. (1st, 2nd and 3rd term), 17. 6. and 15. 7. 2010 (whole trial); the second season terms were as follows: 20. 9. 2010, 19. 4. and 13. 5. 2011.

Soil analysis was made before trial establishment. The results are shown in Tab. III.

Soil surface was loosened by rotary cultivator in the depth of 50 mm and then levelled by rakes. Immediately before sowing, four grams of nitrogen per square meter was applied in a form of ammonium saltpeter with limestone (27.5% N).

I: *Species and cultivars used for the experiment*

Used species	Cultivar	Sowing rate (g m^{-2})
Lolium perenne	Polarstar	25
Festuca rubra ssp. *commutata*	Barborka	25
Festuca rubra ssp. *trichophylla*	Viktorka	25
Festuca rubra ssp. *rubra*	Barustic	25
Festuca ovina	Štěpánka	25
Poa pratensis	Harmonie	15
Agrostis capillaris	Vítek	10
Festuca arundinacea	Barfelix	30
Trifolium repens	Klement	4
Medicago lupulina	Ekola	4

II: *Terms of sowing*

Period	1st season	2nd season
late summer (1)	3. 9. 2009	4. 9. 2010
early autumn (2)	4. 10. 2009	4. 10. 2010
late autumn (3)	3. 11. 2009	3. 11. 2010
spring (4)	4. 4. 2010	

III: *Soil pH and available nutrients [mg.kg^{-1} of dry soil], (Mehlich III)*

pH/$CaCl_2$	P	K	Ca	Mg
7.23	142	197	6 420	206
alkali reaction	high level	satisfactory level	high level	satisfactory level

Sowing was performed by hands using wooden frames which guard surrounding plots against contamination by undesirable seeds. Seed were placed on the soil surface. Soil surface was rolled and irrigated after sowing. Irrigation was applied until seedlings emergence daily in small amount to keep the surface moist.

Meteorological data (air temperature, precipitations and height of snow cover) provided Environmental department of municipality Otrokovice (Tab. IV and Fig. 1).

Measured characteristics

Evaluation of emergence rate: the plots were observed every day after sowing until all species emerged. Emergence time was determined as number of days since sowing when emerged seedlings occurred on 50% of the plot. Assessments were made in the morning after irrigation.

Evaluation of the sward height: measurement was made on five times on each plot by ruler (the distance from the soil surface to the highest part of the closest leaf). The evaluation was made only in one term, 26. 6. 2010.

Evaluation of the sward temperature: the canopy temperature was measured by contactless infrared thermometer OS36-2 (Omega, USA) from the distance c. 800 mm above the canopy surface. Four measurements were made within each plot. Turfgrasses were not mowed before the measurement and period of drought and clear sky was used. The measurement took place between 1 and 2 p.m. The evaluation was made at 13. 7. 2010.

Evaluation of soil cover: plots were assessed in a spring period (April) to judge the differences among the species and terms of sowing after winter.

Statistical analysis

The statistical analysis was carried out using Statistica vers. 8.0. (STATSOFT, 2007). Differences between treatments were analysed by one way ANOVA with multiple comparisons according to Tukey ($p < 0.95$).

RESULTS AND DISCUSSION

Emergence rate

The quickest average emergence rate (just autumn terms) showed both used legumes. As concerns grasses *Lolium perenne* was the first emerged species (Tab. V). Taking into account that the plots were irrigated (water availability was not limiting factor) the differences were caused mainly by temperature. The most problematic turf species for establishment with slow germination and emergence rate is *Poa pratensis* (e.g. STIER *et al.*, 2008). Table IV shows that in warm conditions (September and October) emergence rate of this species is just 14–16 days (7–8 days later then *Lolium perenne*). Plants from November term of sowing emerged 18.5 days later than those sown in September. As *Poa pratensis* is often used in a mixture with *Lolium perenne* (esp. in football pitches), LARSEN *et al.* (2004) suggest to establish pure *Poa* turf three weeks before oversowing by *Lolium* to increase *Poa pratensis* proportion in turfgrass.

Water availability and temperature are ranked among the most important factors limiting the rate of the early stages of seedling development. Low ambient temperature prolongs the germination and slows subsequent growth (LARSEN and BIBBY, 2005). This influence was particularly evident at the November sowings. VRZALOVÁ and KNOT (2011) realized that initial germination rate can be influenced also by seed age. Four years old seed

IV: *Average month's temperatures [°C], sums of precipitations [mm], average height of snow cover [mm], (2009–2011)*

	2009			2010			2011		
month	**temp.**	**precipit.**	**snow cover**	**temp.**	**precip.**	**snow cover**	**temp.**	**precipit.**	**snow cover**
I.	–4.3	31	0	–4.7	48	210.5	–1.0	23.7	0
II.	–0.4	62	0	–1.0	31	150.2	1.9	9.9	0
III.	3.9	62	0	4.2	8	0.5	2.2	39.4	0
IV.	13.4	3	0	8.5	44	0	19.1	63.7	0
V.	14.9	92	0	13.3	200	0	the end of experiment		
VI.	16.8	67	0	18.4	81	0			
VII.	20.7	85	0	21.8	105	0			
VIII.	20.8	37	0	19.3	76	0			
IX.	17.4	21	0	13.1	79	0			
X.	8.7	35	0	6.9	16	0			
XI.	5.8	53	50	6.6	53	0.5			
XII.	0.1	40	190	–4.1	42	75.0			
I.–XII.	9.8	49		8.5	65.3				

had higher germination rate in 7 days after the establishment in comparison with two years old seed. Nevertheless, the total germination capacity and the percentage of germinated seeds at day 13 after establishment were higher at younger seeds.

With decreasing air and soil temperature and shortening the length of the day there is a lengthening of germination time (LARCHER, 2003). SKINNER (2005) found a field emergence of grasses and legumes emergence only 20–41% depending on temperature and soil moisture. The incidence of stress factors during germination and initial growth increase proportion of void areas and thus the subsequent weed occurrence.

Evaluation of the sward height

The highest average canopy height measured 26. 6. 2010 reached *Trifolium repens* (151 mm) followed by *Lolium perenne* and *Festuca arundinacea* (both 143 mm). The lowest height showed *Poa pratensis* (57 mm) and *Festuca rubra* ssp. *commutata* (87 mm). The height of sowed species was strongly influenced also by term of sowing (see fig. 1 and Tab. VI).

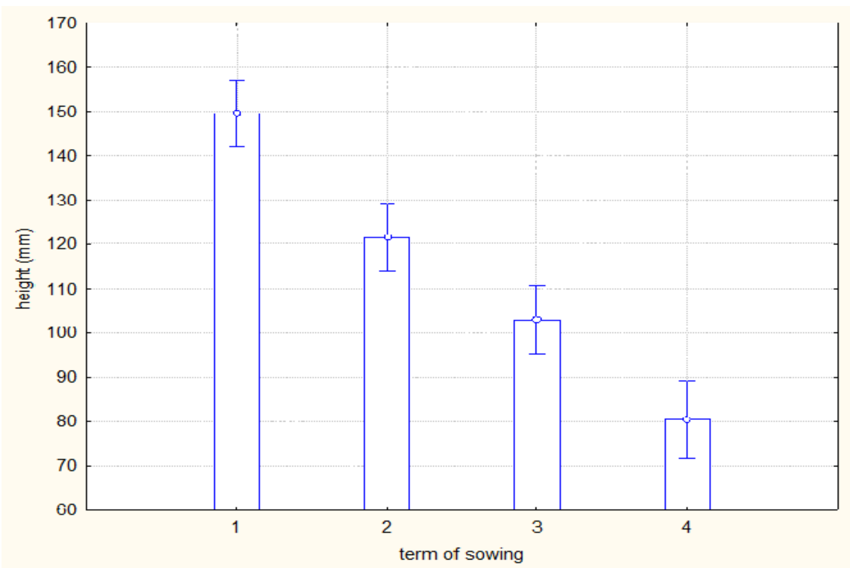
Turfgrass canopy temperature

Temperature of turfgrass surface is mainly influenced by water availability, which plants use for their cooling through transpiration. The amount of water that turfgrass needs during the summer period is often greater than natural rainfall. Once the supply of available soil moisture almost exhausted, the grass begins to wilt and its colour changes from green to grayish-green. Once the apparent lack of soil moisture, plants stop the growth and development and passes into dormant state (JIANG and HUANG, 2000). For this reason, are increasingly used turfgrass species that can draw moisture from the deeper layers of soil and tolerates high

V: *Emergence rate of individual turfgrass species (days from sowing, average of 2009 and 2010)*

Species/Term of sowing	September	October	November	Average*
Trifolium repens	4.4	4.6	17.3	8.8[a]
Medicago lupulina	4.3	4.7	17.3	8.8[a]
Lolium perenne	7.3	8.0	26.9	14.0[b]
Festuca arundinacea	7.1	12.0	31.7	17.0[c]
F. rubra ssp. *rubra*	12.1	13.1	29.6	18.3[d]
F. r. ssp. *commutata*	13.1	14.7	30.6	19.5[e]
Agrostis capillaris	13.7	13.6	21.1	19.8[e]
F. ovina	13.7	15.1	34.0	21.0[f]
F. r. trichophylla	12.9	20.9	30.9	21.5[f]
Poa pratensis	14.4	15.6	37.7	22.6[g]
Average*	**10.3[a]**	**12.2[b]**	**28.8[c]**	**17.1**

*values within the column or row marked with the same letter are not statistically different at the level of significance p = 0.95.



1: *Average height of sward of all evaluated species according to different terms of establishment (evaluated 26. 6. 2010)*

VI: *The height of aboveground biomass [mm], (26. 6. 2010)*

species/term of sowing	September	October	November	April	Average*
Trifolium repens	220	120	104	162	151[ab]
Lolium perenne	173	186	146	69	143[a]
Festuca arundinacea	183	145	138	108	143[a]
F. rubra ssp. *rubra*	161	153	135	89	134[ab]
Medicago lupulina	184	110	115	129	134[abc]
F. r. trichophylla	145	118	92	63	104[bcd]
Agrostis capillaris	109	112	91	53	91[cd]
F. ovina	111	109	90	51	90[d]
F. r. ssp. *commutata*	113	100	83	55	87[de]
Poa pratensis	98	65	39	27	57[e]
Average*	**150[a]**	**122[b]**	**103[c]**	**80[d]**	**125**

*values within the column or row marked with the same letter are not statistically different at the level of significance p = 0.95

temperatures. These properties are typical for tall fescue and C4 grasses (SEVERMUTLU *et al.*, 2011).

In Table VI there are given the surface temperatures of grass and legume leaves, which were measured on a clear day with maximum air temperatures exceeding 30 ° C. The table VII shows that the best cooling capability leaves showed tall fescue and legumes, while a market was chewing fescue leaf temperature by 4 °C higher than of white clover. The highest leaf temperature was measured at fescues with narrow leaves and at perennial ryegrass. The reason is probably the difference in root depth and the greater volume of soil which is available for the plants.

Surprisingly, the lowest temperature of the leaves showed a spring sowing. This is probably associated with somewhat higher soil organic matter content on a bed of soil, which was about 10 meters from the grass of the autumn sowings. Another explanation can be longer period of irrigation after spring sowing resulting in higher soil moisture status. We cannot give an explanation for the highest temperature in October sowings.

The degree of cell damage depends on the time of impact and value of the temperature. The plant damage occurs at plant temperatures above 35 to 40 °C. The plant, when gradually get into period of high temperatures can partially acclimate (HUANG and JIANG, 2002). During long period of high temperatures photosynthesis rate is limited and grasses do not produce enough assimilates to defend against stress and the plant may die.

Winter survival

Results of soil cover assessments after both winter season are shown in tab. VIII. The highest soil cover was stated at September term of sowing. The difference between soil cover at September and November is considerable. During the April evaluation of soil cover, grasses and legumes have experienced adverse conditions for wintering during the 2010/11 winter season, more than in the previous year (Fig. 2). Hard frost without snow cover, alternate thawing and re-freezing of the upper soil layers caused decline of late sown legumes and reduce soil cover for other species.

VII: *The surface temperature of turfgrass sward [°C], (13. 7. 2010)*

species/term of sowing	September	October	November	April	Average*
Trifolium repens	32.1	35.5	33.3	30.3	32.8[a]
Festuca arundinacea	32.4	33.7	32.9	33.0	33.0[a]
Medicago lupulina	31.0	34.4	34.6	32.9	33.2[ab]
F. rubra ssp. *rubra*	34.0	35.5	34.3	30.4	33.6[abc]
Poa pratensis	35.2	33.8	33.1	32.8	33.7[abc]
Agrostis capillaris	33.0	34.9	33.9	34.5	34.1[abcd]
F. ovina	33.7	37.7	34.8	33.3	34.9[bcd]
Lolium perenne	35.6	37.1	34.7	32.5	35,0[cd]
F. r. trichophylla	35.3	37.7	35.6	33.3	35.5[de]
F. r. ssp. *commutata*	37.3	37.8	37.7	34.5	36.8[e]
Average*	**34.0[b]**	**35.7[c]**	**34.6[b]**	**32.7[a]**	**34.4**

*values within the column or row marked with the same letter are not statistically different at the level of significance p = 0.95

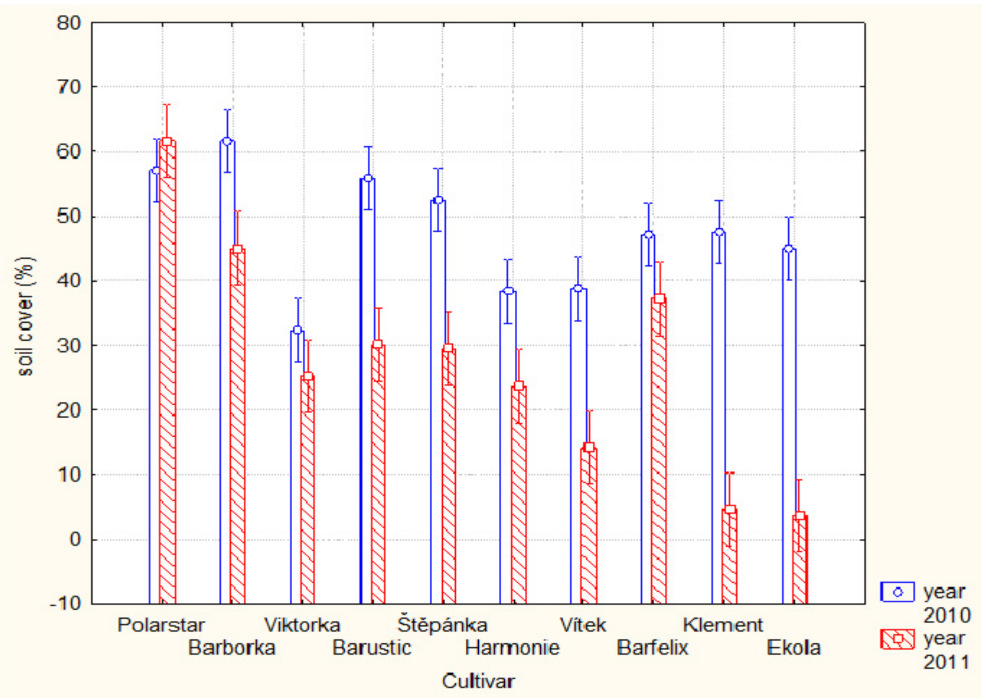
VIII: *Soil cover assessment [%], (average of both years, assessed April 19th 2010 and April 18th 2011)*

species / terms of sowing	September	October	November	average*
Lolium perenne	80.7	77.9	18.6	59.0 [a]
Festuca rubra ssp. *commutata*	71.4	69.3	22.9	54.5 [a]
F. rubra ssp. *rubra*	67.1	54.3	13.0	44.8 [b]
Festuca arundinacea	64.3	50.7	13.6	42.9 [b]
F. ovina	60.0	56.4	11.4	42.6 [b]
Poa pratensis	51.4	42.9	1.9	32.0 [c]
F. r. trichophylla	43.1	40.0	4.7	29.3 [c]
Trifolium repens	50.0	37.4	0	29.1 [c]
Agrostis capillaris	42.1	40.7	1.9	28.2 [c]
Medicago lupulina	47.1	34.7	0	27.3 [c]
Average*	**57.7 [a]**	**50.4 [b]**	**8.8 [c]**	**39.0**

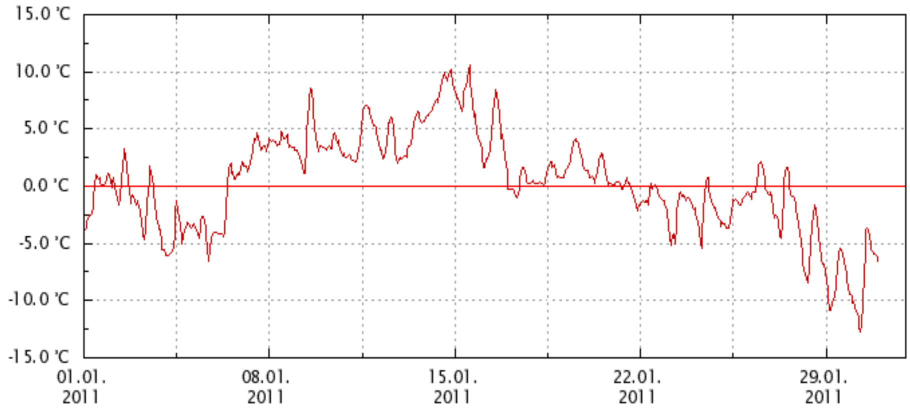
*values within the column or row marked with the same letter are not statistically different at the level of significance p = 0.95

The most suitable turfgrass species for late term of establishment are *Festuca rubra* ssp.*commutata, Lolium perenne* and *Festuca arundinacea*. The advantage of those species is that the minimum (base) temperatures for germination are 3.6 °C for *Lolium perenne* and 3.2–3.6 for *Festuca arundinacea* and even only 2.6 °C for *Poa pratensis* (VALVERDE and MINNER, 2008). According to those authors, suitable parameter for individual years and terms comparison are *growing degree days* (GDD). They are thermal units, which represent a quantity of degrees above a certain minimum or base temperature. It is a sum of daily average temperatures until given growth stage. So the species they can germinate at low temperatures and have low value of GDD are more suitable for late term of sowing.

The main reason for the failure of turfgrass survival during the winter season 2010/2011 was extraordinary air temperature fluctuation during January (Fig. 2) and February (data not shown) and absence of snow cover. Minimum air temperature in January 2011 was −10.1 °C, but maximum +11.1 °C. Similar situation was in February (−10.1 and +10.2 °C, resp.). These changes caused probably movement of topsoil layer and damage of roots. Also hardiness of the plants was reduced by temperatures above threshold for growth. Another reason of plants damage was probably desiccation of leaves as described by LARCHER (2003). The result was considerable reduction of soil cover in April 2011 by 20.1% compared with April 2010 (27.5 vs. 47.6%). Similar values found VEJRKOVÁ



2: *Soil cover in both years according to species (average of assessments in April 2010 and 2011)*



3: *Progress of daily temperatures of air in January 2011*

(2011) at an altitude of 540 m in Bohemian-Moravian upland. The November term for the establishment of turf in lowland in Central European conditions is risky. However, in years when the onset of negative temperatures occurs later and during the winter or/and snow covers the ground plants from late sowings can survive winter well. At higher altitudes snow or frozen soil surface occurs often in early November.

VALVERDE and MINNER (2008) describe a possibility of so called "dormant seeding" of turfgrasses in areas where winter conditions are stable and summer drought is a severe issue. Dormant seeding is made on frozen soil and seed breaks dormancy after temperatures return to within optimal ranges for germination. STIER *et al.* (2008) do not recommend dormant seeding for *Poa pratensis*. They found out the best term for its establishment in late summer (end of August) which provided better turf quality.

Success overwintering of young turfgrass plants depends also on the course of air temperature in winter, the height and duration of snow cover. The period without snow cover during the freeze, which alternate with periods of temperatures above freezing, has a negative impact on winter survival. The worst situation is for the newly established grassland in early spring, when soil is not thawed yet, but air temperature has opened physiological processes and transpiration of aboveground organs.

ELGERSMA and SCHLEPERS (2003) found out that stolons creation of white clover before onset of winter is not essential factor for successful survival of winter period. They sowed white clover in Netherlands at 2. 10. 2005 and though the following winter was severe, 56 to 69% of emerged plants survived at seeding rate 4 kg per hectare. Although legumes from November sowings did not survived in either of the monitored years in our experiment, it was possible to find a considerable amount of spring seedlings, which apparently originated from hard seeds.

High sowing rate can speed up soil cover of sown plants, but it leads to death of seedlings up to two months after sowing (SKINNER, 2005).

SUMMARY

Although spring term of turfgrass establishment is most popular in the territory of central Europe, in warm and dry areas it is easier to create high-quality turf when autumn sowing (September to mid October). In autumn, thanks to lower temperatures and shorter day length, compared to the summer period, there is reduced evapotranspiration and sown grass and legume species develop better and do not need regular irrigation.

The aim of the experiment was to verify the possibility of late summer and autumn sowing terms turf species of grasses and legumes in the lowland areas the central Europe. In 2009 and 2010 ten turf species (*Lolium perenne, Festuca rubra* ssp. *commutata, F. rubra* ssp.*trichophylla, F. rubra* ssp. *rubra, F. ovina, Poa pratensis, Agrostis capillaris, Festuca arundinacea, Trifolium repens* and *Medicago lupulina*) were sown in the beginning of September, October and November and in 2010, also in April.

Term of sowing affects germination time of species as changing the temperature and lighting environments. November sowing terms, although they have ample soil moisture, are limited by low air and soil temperature and the limited duration and intensity of solar radiation. Plants sown in September and October can be threatened by water shortages in the surface layer of soil. The quickest average emergence rate showed both used legumes. As concerns grasses *Lolium perenne* was the first emerged species. It was found out that the legumes are sensitive to late sowing date. In the early onset of negative temperatures and/or during the absence of snow cover during heavy frosts they are not

able to survive the winter unless plants do not develop a leaf rosette. Sward height corresponds with a rate of aboveground organs development. The highest average canopy height reached *Trifolium repens* (151 mm) followed by *Lolium perenne* and *Festuca arundinacea* (both 143 mm). The lowest height showed *Poa pratensis* (57 mm) and *Festuca rubra* ssp. *commutata* (87 mm). The height of sowed species was strongly influenced also by term of sowing (the highest plants at September term of sowing, the lowest at April term). The canopy temperature as a sign of plants stress was measured during day with tropic temperature. The highest temperature had the fine leaved fescues and perennial ryegrass whiles the lowest (4 centigrade lower).

The most important indicator of the ability of species to survive winter season is soil cover assessed in April. September terms had significantly higher soil cover in comparison with later terms and it is possible to recommend it for all species. November terms of sowing tolerated by *Festuca rubra* ssp. *comutata*, *Lolium perenne* and *Festuca arundinacea*. Both the legumes were more sensitive to autumn sowing comparison with grasses.

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Address

Ing. Josef Ambruz, Ing. Stanislav Hejduk, Ph.D., Ústav výživy zvířat a pícninářství, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, e-mail: hejduk@mendelu.cz