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Drying of forage grass seed harvested at different maturity and its utility value in autumn and spring sowing time

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.), red fescue (*Festuca rubra* L.) and cocksfoot (*Dactylis glomerata* L.) are important fodder grasses, but in seed production, they are prone to seed shedding and certain yield losses. In practice, seeds are usually harvested at approximately 20–35% moisture content and then are additionally dried to the moisture content of 12% or lower. However, to prevent shedding, seed was harvested at 45% moisture content. The effects of drying temperatures of 70, 60, 50, 40, 30 and 22 °C on germination and dormancy of tall fescue, red fescue, cocksfoot seeds, harvested at moisture contents of 45, 35 and 25 %, were observed in the present study. The analysis was done immediately upon seed drying, then three, eight and fourteen months later, which corresponds to the autumn and spring sowing time in the continental part of central and south-eastern Europe. In all the three species, drying temperature of 70°C, regardless of the moisture content, and 60°C in the combination with a seed moisture content of 45%, reduced germination. After three months, the highest germination was detected in tall fescue harvested at seed moisture of 25% and dried at 50°C. Furthermore, the greatest germination in red fescue and cocksfoot was determined in seeds harvested with the moisture content of 35% and dried at 50°C. After eight months, the highest germination in tall and red fescue were determined in seeds harvested with the moisture content of 25% and dried at 40–50°C, while corresponding values in cocksfoot amounted to 25% and 22–30°C, respectively. A positive and significant correlation was established between seed germination and seedling vigour.

Key words: *Dactylis glomerata*, drying temperatures, *Festuca arundinacea*, *Festuca rubra*, germination and dormancy, moisture.

Introduction

Plants of the genus dactylis and fescue are important for the production of forage and energy in region of central and south-eastern Europe (Kanapeckas et al., 2011; Samuil et al., 2012; Tilvikienė et al., 2012). However, there has been a decreasing trend of forage grass seed production in Europe (Huyghe, 2010). The main reasons for this are rising prices of cereals (wheat, barley and others). A greater income is obtained by grain production than by seed production of grasses. And therefore, these two productions are competitors for acreages (Jensen, 2010). Due to highly variable yields and low prices of grass seed, on the one hand, and the increased price of wheat, on the other hand, farmers use these areas for the growth of small grains, especially wheat, which has lead to grass seed shortage (Jensen, 2010). For the reason of economic sustainability of fodder grasses production it is necessary to achieve higher and more stable yields. This can partly be accomplished by preventing the loss of seeds resulting from shedding. However, it is often unavoidable since the emergence of generative stems of the same plant is uneven and the differences are even more pronounced in the production plots, leading to uneven seed maturation.

Fodder grasses are harvested when the seed moisture content is 20–35%, whereby seed loss due to shedding can be up to 16.7% (Stanisavljević et al., 2010 b). In order to prevent yield losses by shedding it is possible to harvest seeds with a higher moisture content. In addition to preventing seed shedding, harvest of seeds with a greater moisture content is practiced when the crop is tangled and lodged and when the weather at harvest is cloudy and rainy. After harvesting, seeds are dried to moisture of 12% or lower. It is done either naturally (conventionally) or in dryers at various temperatures.

Drying temperatures in dryers can result in the reduction of seed dormancy (Stanisavljević et al., 2012; 2013), but can also affect protein stability, enzymic activities, damage of cell membranes and mitochondria, which can lead to the seed germination reduction (Bewley, Black, 1994).

Tall fescue is characterised by high adaptability to stress environments (Pecetti et al., 2011), while cocksfoot is particularly tolerant to high temperature stress (Annicchiarico et al., 2011). However, little is known about the effects of temperature stress during drying on the seed of these species. The objectives of the present study were as follows: i) to observe the effects of different drying temperatures on seed germination and dormancy of tall fescue, red fescue and cocksfoot harvested with moisture contents of 45, 35 and 25 %; ii) to test the viability of seeds in different sowing times applied in the continental part of central and south-eastern Europe.

Material and methods

The experiment was set up with commercial seeds of tall fescue (*Festuca arundinacea* Schreb.) cultivar K-20, red fescue (*Festuca rubra* L.) cultivar K-14, and cocksfoot (*Dactylis glomerata* L.) cultivar K-40. All three are summer-active (continental) cultivars and have been developed in Serbia from local populations. Three different seed lots (L) were used from commercial production in eastern (L1), central (L2) and south-eastern (L3) Serbia in 2010 and 2011. Sampling was done during June when the determined seed moisture (M) content amounted to 45, 35 and 25 %. In both years, there was a slow, steady ripening without extreme temperatures or the threat of excessive rainfall. There was up to 10% of the seed mechanically damaged when harvested at 45%. A total of 25% and 9% seeds of tall fescue harvested with the moisture contents of 45% and 35%, respectively were in the milk stage, while seeds with the moisture content of 25% were completely (100%) in the dough stage. On the other hand, 23, 8 and 1 % seeds of red fescue harvested with the moisture content of 45, 35 and 25 %, respectively, were in the milk stage. In cocksfoot, 20, 7 and 1 % of harvested seeds with the moisture content of 45, 35 and 25 %, respectively, were in the milk stage. After sampling, seeds were dried either in the dryer at the following temperatures (T): 70, 60, 50, 40 and 30 °C or conventionally on the floor at an average temperature of 22°C. Drying was performed until the seed moisture content reached 12% and then 1000-kernel weight was determined.

Germination and dormancy were determined after four periods: immediately after drying, three, eight and fourteen months after drying. Three, eight and fourteen months' periods were chosen as they corresponded to the sowing time in autumn of the same year when the harvest was performed, and the sowing time in spring and autumn of the following year when the harvest was done, respectively. Germination and dormancy of seeds were determined in the laboratory of the Institute for Forage Crops, Kru evac, Serbia. In brief, seeds were chilled for five days at the temperature of 5°C, and at the altering temperature (25/15°C light/dark (8/16 h)). Final germination (%) and dormancy (%) of seeds were read in four replicates (4 × 100 seeds) on filter paper after 14 days for tall and red fescue and after 21 days for cocksfoot according to the ISTA rules (ISTA, 2011). Tetrazolium test was performed with ungerminated seeds with the intention of separation dormant from dead seeds. The primary root length (cm), shoot length (cm) and fresh seedling biomass (root + shoot, mg) were also measured after the final count for normal seedlings.

Data were subjected to the analysis of variance, in a factorial arrangement with five factors (year, seed lot, seed moisture, drying temperature and seed maturation (SM) period) for final germination and seed dormancy. The means were compared with the LSD multiple range test at the 5% level of probability. To correct for non-normality the statistical analysis was done on arcsine transformed values. The relationships between final germination and seedling traits were analysed by determining Pearson's correlation coefficients.

Results

On average, for all three species, seeds harvested with the moisture content of 45% had the lowest 1000-kernel weight, while seeds harvested with the moisture content of 25% had the highest 1000-kernel weight. However, the differences were not statistically significant (Table 1).

Table 1. 1000-kernel weight (g) (averaged over lots, years and drying temperatures)

Species	Seed moisture content at harvest		
	45%	35%	25%
Festuca arundinacea	1.92 a	1.99 a	2.03 a
Festuca rubra	1.13 a	1.15 a	1.18 a
Dactylis glomerata	1.15 a	1.19 a	1.22 a

Note. Mean values in a row followed by the same letter are not significantly different (LSD test, $p > 0.05$).

A post-harvest maturation period, seed moisture content, drying temperatures and their interactions significantly affected seed germination and dormancy, while the effects of seed lot, year and their interactions were not significant (Table 2). Hence, in what follows, we present results on seed germination and dormancy as an average of three lots and two years.

Germination and dormancy of seeds harvested with the different moisture contents and immediately after drying at various temperatures are presented in Table 3. The lowest germination and the highest dormancy were determined in seeds of tall fescue and red fescue harvested with the moisture content of 45%, while the corresponding values in cocksfoot were recorded in seeds harvested with the moisture content of 25%. In all three species, regardless of the moisture content at harvest, the lowest germination was recorded after conventional drying (22°C), which was a result of high seed dormancy. Generally, the higher drying temperatures were (60°C and 70°C) the lower seed dormancy and germination were. The highest seed germination immediately after drying was recorded in tall fescue seeds harvested with the moisture content of 45% and dried at a temperature of 60°C and seeds harvested with the moisture content of 35% and 25% and dried at

Table 2. Statistical probabilities of *F*-test for germination and dormancy (%)

Source	d.f.	*Festuca arundinacea*		*Festuca rubra*		*Dactylis glomerata*	
		germination	dormancy	germination	dormancy	germination	dormancy
Seed maturation (SM)	3	**	**	**	**	**	**
Lots (L)	2	ns	ns	ns	ns	ns	ns
Seed moisture (M)	2	**	**	**	**	**	**
Drying temperature (T)	5	**	**	**	**	**	**
Year (Y)	1	ns	ns	ns	ns	ns	ns
SM × L	6	ns	ns	ns	ns	ns	ns
SM × M	6	**	**	**	**	**	**
L × M	4	ns	ns	ns	ns	ns	ns
SM × T	15	**	**	**	**	**	**
L × T	10	ns	ns	ns	ns	ns	ns
M × T	10	**	**	**	**	**	**
SM × L × M	12	ns	ns	ns	ns	ns	ns
SM × L × T	30	ns	ns	ns	ns	ns	ns
SM × M × T	30	*	*	*	*	*	*
L × M × T	20	ns	ns	ns	ns	ns	ns
SM × L × M × T	60	ns	ns	ns	ns	ns	ns
Y × SM	3	ns	ns	ns	ns	ns	ns
Y × L	2	ns	ns	ns	ns	ns	ns
Y × M	2	ns	ns	ns	ns	ns	ns
Y × T	5	ns	ns	ns	ns	ns	ns
Y × SM × L × M × T	60	ns	ns	ns	ns	ns	ns

d.f. – degrees of freedom; * – $p < 0.05$, ** – $p < 0.01$, ns – not significant

Table 3. Germination and dormancy (%) of seed immediately after drying

Seed moisture	Drying temperature °C	*Festuca arundinacea*		*Festuca rubra*		*Dactylis glomerata*	
		germination	dormancy	germination	dormancy	germination	dormancy
45%	70	75 d	2 f	66 d	0 f	65 d	0f
	60	83 a	5 e	69 c	2 e	72 c	3e
	50	80 b	10 d	86 a	7 d	80 b	7d
	40	77 c	21 c	87 a	10 c	85 a	11c
	30	75 d	25 b	78 b	20 b	72 c	19b
	22	67 e	31 a	66 d	28 a	63 e	32a
Mean		76	16	75	11	73	12
35%	70	75 c	2 e	67 c	0 f	66 c	0 f
	60	88 b	7 d	70 b	4 e	75 b	5 e
	50	92 a	7 d	80 a	14 d	88 a	8 d
	40	91 a	8 c	82 a	16 c	89 a	10 c
	30	88 b	10 b	80 a	19 b	77 b	19 b
	22	66 d	30 a	66 c	29 a	61 d	29 a
Mean		83	11	74	14	76	12
25%	70	76 c	4 d	6 e	0 f	71 b	0 f
	60	88 b	7 d	72 d	6 e	78 a	5 e
	50	90 a	9 c	79 b	15 d	79 a	12 d
	40	90 a	9 c	81 a	18 c	69 c	22 c
	30	87 b	11 b	77 c	20 b	62 d	31b
	22	65 d	32 a	65 f	30 a	61 d	33 a
Mean		83	12	63	15	70	17

Note. Different letters within species and treatment combinations indicate significant differences (LSD test, $p < 0.01$).

the temperatures ranging from 40°C to 50°C. The highest germination of red fescue seeds was recorded immediately after drying at the temperatures ranging from 40°C to 50°C, regardless of the moisture content. Moreover, the highest germination of cocksfoot seeds harvested with the moisture content of 45% and 35% was recorded after drying at the temperatures ranging from 40°C to 50°C, while the highest germination of seeds harvested with the moisture content of 25% was recorded after drying at the temperatures ranging from 50°C to 60°C. The absolutely highest germination of tall fescue was recorded for seeds harvested with the moisture content of 35% and dried at

the temperature of 50°C (92%), while the corresponding values in red fescue and cocksfoot were recorded in seeds with the moisture content of 45% and 35% and drying temperatures of 50°C (87%) and 40°C (89%), respectively.

Germination and dormancy of seeds, harvested with different moisture contents, recorded three months after drying at various temperatures are presented in Table 4. Averaged over all three species, germination was the lowest in seeds harvested with the moisture content of 45%. Regardless of the moisture content at harvest, the lowest germination three months after drying was recorded in seeds dried at 70°C, while the highest germination was recorded in seeds dried at the temperature varying from 40°C to 50°C, except for cocksfoot seeds harvested with the moisture content of 25% in which the highest germination was detected in seeds dried at the temperature varying from 50°C to 60°C. The absolutely highest germination of tall fescue three months after drying was recorded in seeds harvested with the moisture content of 25% and dried at the temperature of 50°C (94%), while the corresponding values in red fescue and cocksfoot were recorded in seeds harvested with the moisture content of 45% and 35% and dried at temperatures of 50°C (82%) and 50°C (91%), respectively. Averaged over all temperatures, germination and dormancy after harvest of seeds with the moisture content of 35% and 25% in all three species were slightly higher and lower, respectively, compared to values obtained immediately after drying.

Table 4. Germination and dormancy (%) of seeds three months after drying

Seed moisture	Drying temperature ºC	*Festuca arundinacea*		*Festuca rubra*		*Dactylis glomerata*	
		germination	dormancy	germination	dormancy	germination	dormancy
45%	70	70 c	0 e	62 d	0 e	64 e	0 f
	60	75 b	0 e	76 b	0 e	73 c	2 e
	50	80 a	3 d	80 a	3 d	84 a	4 d
	40	79 a	5 c	79 a	5 c	83 a	8 c
	30	75 b	12 b	79 a	11 b	80 b	12 b
	22	71 c	19 a	65 c	18 a	67 d	21 a
Mean		75	7	74	6	75	8
35%	70	74 d	0 f	65 d	0 e	63 d	0 e
	60	88 bc	2 e	78 dc	2 d	79 b	2 d
	50	92 a	4 d	82 a	6 c	91 a	8 c
	40	93 a	6 c	80 b	6 c	90 a	8 c
	30	89 b	9 b	79 b	9 b	79 b	18 b
	22	78 c	19 a	76 c	22 a	65 c	26 a
Mean		86	7	77	8	78	10
25%	70	75 d	0 f	65 c	0 f	70 c	0 f
	60	89 b	2 e	79 a	3 e	89 a	6 e
	50	94 a	4 d	80 a	5 d	90 a	8 d
	40	93 a	6 c	80 a	10 c	81 b	14 c
	30	90 b	9 b	79 a	18 b	80 b	18 b
	22	79 c	20 a	76 b	23 a	69 c	28 a
Mean		87	7	77	10	80	12

Explanation under Table 3

Germination and dormancy of seeds, harvested with different moisture contents, recorded eight months after drying at various temperatures are presented in Table 5. Averaged over all drying temperatures, germination was the lowest in seeds with the moisture content of 45%, while the highest germination was in seeds harvested with 25% moisture content. Regardless of the moisture content at harvest, the temperatures varying between 30°C and 50°C were the most optimal in the majority of cases in all three species. Seed germination recorded eight months after drying at higher (60–70°C) temperatures tended to decrease in comparison with germination measured after three months or immediately after harvest, especially when combined with high moisture content (45%) in the harvested seed. The absolutely highest germination of tall fescue eight months after drying was recorded in seeds harvested with the moisture content of 25% and dried at the temperature of 40°C (96%), while the corresponding values in red fescue and cocksfoot were recorded in seeds harvested with the moisture contents of 25% and 35% and drying temperatures of 30°C (95%) and 40°C (92%), respectively. The greatest percentage of dormant seeds during this period was recorded after floor drying of seeds harvested with the moisture content of 25% and it amounted to 8%, 9% and even to 20% in tall fescue, red fescue and cocksfoot, respectively.

Germination and dormancy of seeds, harvested with different moisture contents, recorded fourteen months after drying at various temperatures are presented in Table 6. Germination was the lowest in seeds harvested with the moisture content of 45%, while the highest germination was in seeds harvested with 25% moisture content. In the majority of cases, floor drying (22ºC) and drying at 30°C were the most optimal for all three species regardless of the moisture content at harvest. Seed germination recorded after drying at higher (60–70ºC) temperatures tended to decrease in comparison with initial germination measured immediately after harvest.

Table 5. Germination and dormancy (%) of seeds eight months after drying

Seed moisture	Drying temperature ºC	*Festuca arundinacea*		*Festuca rubra*		*Dactylis glomerata*	
		germination	dormancy	germination	dormancy	germination	dormancy
45%	70	68 c	0 c	60 c	0 c	67 c	0 d
	60	77 b	0 c	73 b	0 c	71 b	0 d
	50	79 b	0 c	74 b	0 c	81 a	1 d
	40	82 a	2 b	81 a	0 c	82 a	5 c
	30	84 a	3 b	82 a	2 b	81 a	8 b
	22	85 a	6 a	72 b	5 a	70 b	12 a
Mean		79	2	74	1	75	4
35%	70	74 c	0 d	67 d	0 d	70 e	0 e
	60	90 b	0 d	84 b	0 d	81 c	2 d
	50	94 a	2 cd	89 a	4 c	89 b	3 cd
	40	93 a	3 c	90 a	4 c	92 a	4 c
	30	90 b	7 b	89 a	7 b	80 c	12 b
	22	89 b	9 a	78 c	12 a	74 d	14 a
Mean		88	4	83	5	81	6
25%	70	74 c	0 d	69 d	0 c	72 e	0 e
	60	92 b	0 d	85 b	0 c	82 c	2 d
	50	95 a	2 cd	92 a	1 c	90 a	6 d
	40	96 a	3 c	94 a	4 b	89 a	10 c
	30	91 b	6 b	95 a	4 b	86 b	12 b
	22	90 b	8 a	80 c	9 a	77 d	20 a
Mean		90	3	86	3	83	8

Explanation under Table 3

Table 6. Germination and dormancy (%) of seeds fourteen months after drying

Seed moisture	Drying temperature ºC	*Festuca arundinacea*		*Festuca rubra*		*Dactylis glomerata*	
		germination	dormancy	germination	dormancy	germination	dormancy
45%	70	63 e	0 a	55 e	0 a	66 e	0 a
	60	65 d	0 a	59 d	0 a	70 d	0 a
	50	70 c	0 a	62 c	0 a	82 c	0 a
	40	77 b	0 a	69 b	0 a	85 b	0 a
	30	80 a	0 a	72 a	0 a	89 a	0 a
	22	81 a	0 a	72 a	0 a	88 a	0 a
Mean		73	0	65	0	80	0
35%	70	70 d	0 a	60 d	0 a	69 d	0 b
	60	75 c	0 a	66 c	0 a	80 c	0 b
	50	75 c	0 a	69 b	0 a	90 b	0 b
	40	78 b	0 a	72 a	0 a	91 ab	0 b
	30	82 a	0 a	73 a	0 a	93 a	1 ab
	22	82 a	0 a	73 a	0 a	93 a	2 a
Mean		77	0	69	0	86	0
25%	70	71 e	0 b	61 f	0 b	71 d	0 b
	60	77 d	0 b	68 e	0 b	81 c	0 b
	50	82 c	0 b	70 d	0 b	92 b	0 b
	40	88 b	0 b	72 c	0 b	94 a	1 ab
	30	90 ab	0 b	75 b	0 b	95 a	1 ab
	22	92 a	2 a	78 a	1 a	94 a	3 a
Mean		83	0	71	0	88	1

Explanation under Table 3

In the period between eighteenth and fourteenth month after drying, seeds harvested with the moisture content of 45% were losing germination more quickly than those harvested with the moisture content of 25%, and this difference, on the average for all temperatures, amounted to 10, 14 and 8 % in tall fescue, red fescue and cocksfoot, respectively. The absolutely highest germination of tall fescue and red fescue fourteen months after drying was recorded in seeds harvested with the moisture content of 25% and dried at the temperature of 22°C (92% and

78%, respectively), while the corresponding values in cocksfoot were recorded in seeds harvested with the moisture contents of 25% and dried at the temperature of 30°C (95%). Fourteen months after drying there were no dormant seeds in samples of the species belonging to the genus *Festuca* harvested with the moisture contents of 45% and 35%, while there were still dormant seeds in cocksfoot samples harvested with the moisture content of 35% and dried at temperatures of 22°C and 30°C. A total of 1–3% of seeds harvested with the moisture content of 25% and conventionally dried (22°C) were dormant.

The coefficients of correlation (r) between seed germination and seedling traits are presented in Table 7. Seed germination in tall fescue and cocksfoot was significantly correlated with shoot and root lengths, as well as seedling biomass. However, in red fescue only seedling biomass was significantly related to germination ($p < 0.05$).

Table 7. Coefficients of correlation (r) between germination and seedling traits

Species	Seedling trait		
	shoot cm	root cm	biomass mg
Festuca arundinacea	0.389***	0.395***	0.305**
Festuca rubra	0.245*	0.235*	0.288*
Dactylis glomerata	0.299**	0.326**	0.313**

* – $p < 0.05$, ** – $p < 0.05$, *** – $p < 0.001$

Discussion

Seeds harvested with 25% moisture content had higher 1000-kernel weight in all three species compared to seeds harvested with 45% moisture content, but this increase was not statistically significant. lepetys (2001) has also recorded the increase of 1000-kernel weight in several fodder grasses in seeds harvested with the moisture content of 25% in relation to seeds harvested with the moisture content of 45%. Lots did not significantly affect varying of seed germination and dormancy as it was expected considering that regions of central, eastern and south-eastern Serbia are geographically small, do not differ much in climatic and edaphic conditions, and the applied growing practices were also similar. Although several previous studies of various species showed that differences among consecutive years were larger than differences among test sites within a region of south-east Europe (Rizza et al., 2004; Sudarić et al., 2006; Dodig et al., 2008), the year in the present study did not have a significant effect on the variation of seed germination and dormancy of the three observed species of fodder crops.

Dormancy is a physiological state enabling the plants to survive for a long time without germinating (if the conditions are not favourable for the germination to be completed). The dormancy mechanisms can be divided into those based in the tissues that surround the embryo and those found within the embryo or endosperm (Adkins et al., 2002). In our study, immediately after seed harvest the level of dormancy after conventional drying and drying at 30°C was high, which caused low germination. On the other hand, drying at 70°C reduced dormancy, but also reduced germination, and considering all moisture contents of harvested seeds, germination was high and amounted to 75–76, 65–67 and 65–71 % in tall fescue, red fescue and cocksfoot, respectively. High (70–80°C) drying temperatures stressfully affect seeds of tall fescue, meadow fescue and red fescue, which leads to irreversible germination loss during seed storage (Stanisavljević et al., 2012). High (above 70°C) temperature treatments are used in some fodder grasses such as bread grass (*Brachiaria brizantha* (A. Rich) Stapf) to increase germination (Martins, Silva, 2001). The seed dormancy level immediately after harvest, for instance in tall fescue, depends on temperatures during maturing, whereby the temperature increase leads to the dormancy decrease (Boyce et al., 1976).

Three months after harvest (September–October) is the optimal autumn sowing period for fodder grasses in the region of south-eastern Europe. In this period, a slight decline in germination of all three species in relation to the period immediately after drying occurred after drying at the temperature of 70°C. The negative interaction between the temperature and seed moisture was mostly pronounced in seeds dried at 60°C, whereby germination of seeds harvested with the moisture content of 45% was lower by 3% and 16% (red fescue and cocksfoot, respectively) in relation to seeds harvested with the moisture content of 25%. The significant effect of the combination of seed moisture and drying temperature on seed germination was established in Kentucky bluegrass (*Poa pratensis* L.) (Sveinsson, Björnsson, 1994). According to Probert (2000), the temperature, together with the moisture content, determines the rate of deterioration in dry and moist seeds. Seeds harvested with the moisture content of 45% generally had lower maximum germination, but this moisture content in combination with the optimal (40–50°C) drying temperature results in satisfactory germination (80–84%). However, the most suitable seed for this sowing period is tall fescue seed harvested with the moisture content of 25% and dried at 50°C (germination 94%) and red fescue and cocksfoot seeds harvested with the moisture content of 35% and dried at 50°C (82% and 91%, respectively).

The spring sowing period of fodder grasses in the region of south-eastern Europe begins eight months after harvest (March–April) when there are sufficient precipitation for a successful establishment of meadows and pastures. This is also the period of the greatest consumption of seeds harvested during the previous year. Eight months after harvest there were no dormant seeds in tall fescue and red fescue seeds harvested with the moisture content of 45% and dried at the temperatures ranging from 50°C to 70°C. However, maximum germination was only 79% (tall fescue) and 74% (red fescue), because drying temperatures caused the reduction of both, germination and dormancy. On the other hand, cocksfoot seeds harvested with the moisture content of 45% and dried at the temperatures ranging from 50°C to 70°C had germination of 81%, which points out that this species is less susceptible to higher drying temperatures. Nevertheless, seeds of both cocksfoot and species of the genus *Fescue* harvested with a lower percentage of the

moisture content and dried at lower temperatures are more favourable for this sowing period. Eight months after harvest the highest germination was recorded in seeds of tall fescue (96%) and red fescue (95%) harvested with the moisture content of 25% and dried at temperatures of 40°C and 50°C, respectively. Similar results were obtained in seeds of meadow fescue (*Festuca pratensis* Huds.) (Stanisavljević et al., 2013). Nonetheless, the highest germination (92%) in cocksfoot eight months after harvest was determined in seeds harvested with the moisture content of 35% and dried at the temperature of 40°C. Furthermore, seeds harvested with the moisture content of 25% and conventionally dried (22°C) retained dormancy, especially cocksfoot seeds, even after eight months, which presents a potential increase in germination for the succeeding sowing period.

A period of fourteen months after harvest coincides with the period of autumn sowing in the succeeding year. Seeds dried at 70°C, regardless of the moisture content at harvest, continued to lose germination and none of the species had minimum germination necessary to move seeds into trade (75% according to legislation). This also refers to seeds of all three species harvested with the moisture content of 45% and dried at 60°C. In the case when seeds were harvested with the moisture content of 35% and dried at 60°C, seeds of cocksfoot and tall fescue had a commercial (80%) and limiting (75%) value, respectively, while red fescue seeds lost commercial value (66%). Generally, seeds of tall fescue and red fescue harvested with the moisture content of 25% and dried at 22°C (germination 92% and 78%, respectively) and seeds of cocksfoot harvested with the moisture content of 25% and dried at 30°C (germination 95%) were the most favourable for autumn sowing in the year after harvest.

A high percentage and uniformity of germination with strong vigour of seedlings are an important prerequisite for a successful establishment, rapid initial growth and lucrative production in agriculture (Perry, 1980). The obtained results show that high seed germination is accompanied with strong seedling vigour, which is in accordance with previously gained results on these and other species (Stanisavljević et al., 2010 a; 2011). Tall fescue, red fescue and cocksfoot are mainly grown in the mixture with other grasses and fodder legumes. Therefore, strong seedling vigour provides successful competition with other species during crop establishment and in concurrence with other factors (growing practices, agroecological conditions) provides predicted maintenance of species within the mixture during a long-term utilisation.

Conclusion

Regardless of seed moisture contents, the drying temperature of 70°C reduced seed germination and accelerated deterioration over time. Drying of seeds with the moisture content of 45% at the temperature of 60°C was unfavourable, especially after eight and fourteen months, while dormancy was broken and satisfactory germination was obtained in seeds with the moisture content of 35% and 25%. However, best germination in all three species was determined eight months after harvest of seeds with the moisture content of 25% and dried at temperatures up to 50°C. If it is necessary to harvest seeds with greater moisture content (45%) in order to prevent shedding, drying at the temperature ranging from 40°C to 50°C could provide satisfactory germination (80–84%) three months after harvest of all three species. In order to preserve as long as possible the commercial value (germination ≥75%) of seeds harvested with the moisture content of 45%, drying temperatures should be lower (ranging from 22°C to 30°C).

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Skirtingos brandos nuimtų pašarinių žolių sėklų džiovinimas ir daigumo kitimas saugojimo metu

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Santrauka

Nendrinis eraičinas (*Festuca arundinacea* Schreb.), raudonasis eraičinas (*Festuca rubra* L.) ir paprastoji šunažolė (*Dactylis glomerata* L.) yra svarbios pašarinės žolės, tačiau jas auginant sėklai, yra linkusios byrėti ir todėl patiriami derliaus nuostoliai. Paprastai šių žolių sėklos yra nuimamos joms pasiekus 20–35 % drėgnį ir yra papildomai džiovinamos iki 12 % ar mažesnio drėgnio. Tačiau, siekiant išvengti byrėjimo, sėklos buvo nuimtos 45 % drėgnio. Šio tyrimo metu buvo nustatyta 70, 60, 50, 40, 30 ir 22 °C džiovinimo temperatūrų įtaka nendrinių bei raudonųjų eraičinų ir paprastųjų šunažolių sėklų daigumui ir ramybės būklei, kai sėklos buvo nuimtos 45, 35 ir 25 % drėgnio. Analizės buvo atliktos iš karto išdžiovinus sėklas – po trijų, aštuonių ir keturiolikos mėnesių; tai atitinka rudeninės ir pavasarinės sėjos laiką kontinentinėje Centrinėje ir Pietryčių Europoje. Visų trijų žolių rūšių sėklų daigumą 70 °C džiovinimo temperatūra sumažino, nepriklausomai nuo sėklų drėgnio, o 60 °C džiovinimo temperatūra sumažino daigumą sėklų, nuimtų 45 % drėgnio. Po trijų mėnesių didžiausias sėklų daigumas buvo nustatytas nendrinių eraičinų, kai jos buvo nuimtos 25 % drėgnio ir išdžiovintos 50 °C temperatūroje. Be to, didžiausias raudonųjų eraičinų ir paprastųjų šunažolių sėklų daigumas buvo nustatytas, kai jos buvo nuimtos 35 % drėgnio ir išdžiovintos esant 50 °C temperatūrai. Po aštuonių mėnesių didžiausias nendrinių bei raudonųjų eraičinų sėklų daigumas buvo nustatytas, kai jos buvo nuimtos 25 % drėgnio ir išdžiovintos 40–50 °C temperatūroje, o paprastosios šunažolės – kai jos buvo nuimtos 25 % drėgnio ir išdžiovintos esant 22–30 °C temperatūrai. Tarp sėklų daigumo ir gyvybingumo buvo nustatyta teigiama ir esminė koreliacija.

Reikšminiai žodžiai: *Dactylis glomerata*, daigumas ir ramybės būklė, drėgmė, džiovinimo temperatūros, *Festuca arundinacea*, *Festuca rubra*.