Drying of meadow fescue seeds of different moisture contents: Changes in dormancy and germination

R. Stanisavljević[1], J. Milenković[1], D. Djokić[1], D. Terzić[1], M. Petrović[1], L. Đukanović[2], D. Dodig[3]

[1]*Institute of Forage Crops, Kruševac, Serbia*
[2]*Department of Seed, High School for Agriculture, Šabac, Serbia*
[3]*Maize Research Institute Zemun Polje, Belgrade-Zemun, Serbia*

ABSTRACT

In the past few years in Europe grass seed production declines. This tendency is especially pronounced in meadow fescue. Seed shedding and therefore yield losses are the problem in seed production. This can be reduced if seed of higher moisture contents is harvested. The impacts of drying temperatures of 70, 60, 50, 40 and 22°C on changes in dormancy and germination of seed harvested with moisture contents of 45, 35 and 25% were observed in the present study. The analysis was done immediately after seed drying, then three months later and eight months later. Seeds with the moisture content of 45% that were dried at 70°C were not dormant at all after harvest, but seeds were damaged, which resulted in reduced germination. Drying temperatures of 40°C and 50°C resulted in maximum germination of seed harvested with 45% moisture after three months. After eight months the best germination of all seeds was obtained at 22°C and 40°C. The seed ageing test confirmed faster deterioration of seeds harvested with higher moisture contents. Seed harvested with 25% moisture and dried at 22°C is the most suitable seed for longer storage.

Keywords: *Festuca pratensis*; germination ability; post-harvest maturation; seed viability; seed storage

Meadow fescue (*Festuca pratensis* Huds.) is one of the most important fodder grasses in central and south-eastern Europe (Wilkins and Humphreys 2003, Hejduk and Knot 2010, Samuil et al. 2012). However, in general, areas under seed production of grasses were reducing in Europe during the last five years (Huyghe and Tabel 2010). Due to highly variable yields and low prices of grass seed, on 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).

Seed shedding and yield losses are one of main the reasons for variable yields in grass seed production. Namely, generative stalks occur in fodder grasses in different periods, and therefore, shooting, flowering and pollination occur in different periods. In addition, flowering, pollination, grain filling and grain maturation is uneven in the same inflorescence. All these lead to uneven seed maturation and seed harvest at physiological maturity may result in seed shedding and therefore in yield losses. However, there is a possibility of earlier harvest, when moisture of grain is greater, which will prevent seed shedding and provide a higher yield (Jensen 1976). After harvest, seeds are compulsorily dried either naturally-conventionally or in dryers with the application of various temperatures with the aim to decrease moisture under 12%. Temperature treatments are useful for dormancy breaking and germination increase, but too high temperatures can adversely affect enzymic activities, damage cell membranes and mitochondria, and degrade storage proteins, which can lead to the seed germination reduction (Bewley and Black 1994).

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Seeds of annual fodder grass were used to study the effects of drying temperatures on seed germination (Eichelberger et al. 2002, 2003). However, there is little data on drying temperature impacts on germination of seed of perennial fodder grasses. Therefore, the objective of the present study was to observe the drying temperature effects on dormancy and germination of meadow fescue seeds with different moisture contents at harvest. The traditional accelerated ageing test was used to predict viability of seed lots during storage.

MATERIAL AND METHODS

The experiments were set up with seeds of summer-active (continental) cultivar K-21 of meadow fescue (*Festuca pratensis* Huds.), which has been developed in Serbia from local populations. In the first experiment, three different seed lots (L) were used from commercial production in eastern (L1), central (L2) and south-eastern Serbia (L3). Seeds were hand-harvested to ensure that collected seeds are of high purity. Sampling was performed when determined moisture content (MC) in seeds amounted to 45, 35 and 25%. Seeds were then dried either in the dryer at the following temperatures (T): 70, 60, 50 and 40°C or conventionally on the floor at the average temperature of 22°C. Drying was performed until the seed moisture content reached 12% and then 1000-seed weight was determined. Germination and dormancy were determined after three periods of seed maturation: immediately after drying (SM1), three (SM2) and eight months later (SM3). 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 according to the ISTA Rules (ISTA 2011).

In the second experiment, the traditional accelerated ageing test was applied to all seed samples with temperature of 41°C and relative air humidity of 100%, while exposure times were 24, 48 and 72 h. The test was conducted on 400 seeds, which were arranged in even layers and approximately at the same inter-distance on wire trays (10 cm × 10 cm × 3.5 cm) placed in a water bath. Seed water content was determined before and after each ageing period (ISTA 2011). After accelerating ageing, the seeds were placed on the filter paper for germination at the temperature of 20°C for 10 days. Germination of seeds (%) was read after 10 days.

Data were subjected to the analysis of variance, in a factorial arrangement with four factors (seed lots, seed moisture, drying temperatures and maturation period) for final germination and seed dormancy, and the regression analysis (StatSoft Statistica 8.0, Inc., Bedford, UK). The *LSD* multiple range test was used to detect significant differences among lot means at the 5% level of probability. To correct for non-normality the statistical analysis was done on arcsine transformed values for final germination and seed dormancy.

RESULTS AND DISCUSSION

Averaged over lots, 75, 92 and 100% of tested seeds reached the hard dough stage of development when moisture content in seeds at harvest amounted to 45, 35 and 25%, respectively (Table 1). The optimum time for grass seed harvest is the hard

Table 1. Maturity stage (%) of seeds at harvest and 1000-seed weight (g) after drying with different moisture contents (averaged over temperatures)

Lot	Seed moisture content (%)											
	45				35				25			
	harvest date	maturity stage		1000-seed weight	harvest date	maturity stage		1000-seed weight	harvest date	maturity stage		1000-seed weight
		milk	dough			milk	dough			milk	dough	
L1	June-15	24	76	1.84^{aA}	June-18	9	91	1.99^{aA}	June-24	0	100	2.02^{aA}
L2	June-16	25	75	1.85^{aA}	June-19	8	92	1.98^{aA}	June-25	0	100	2.01^{aA}
L3	June-15	26	74	1.83^{aA}	June-18	8	92	1.97^{aA}	June-24	0	100	2.03^{aA}

Mean values in a column (upper case) and in a row (lower case) followed by the same letter are not significantly different (*LSD*, $P < 0.05$). L1 – eastern; L2 – central; L3 – south-eastern Serbia dough and mature stage. Seed harvested in these stages tends to be filled, will survive the curing process and will germinate after planting. Also, if a seed crop is more uniform in seed maturity level and seed size, then such seed usually shows a higher seed quality. Generally, the best germination and seedling vigor is usually attained with sufficiently large seeds (Moles and Westoby 2006).

Average 1000-seed weight over different temperatures for three lots after drying of seeds with different moisture contents until the seed moisture content reached 12% is presented in Table 1. The analysis of variance showed there was no significant difference in 1000-seed weight between the lots. This was expected as 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. In all lots, the higher moisture content in seeds after harvest means the lower 1000-seed weight, but these differences were not significant. This is in accordance with the results for meadow fescue seeds obtained by Šlepetys (2001) – 1000-seed weight when grain was harvested with moisture contents of 45% and 23% amounted to 2.02 g and 2.17 g, respectively.

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

Seeds harvested with the moisture content of 45% and dried at 70°C were not dormant at all immediately after harvest, but this temperature damaged seeds, which resulted in seed germination of only 71% (Figures 1a–b). Drying temperatures of 60°C and 50°C resulted in slightly higher seed dormancy compared to 70°C (about 2% and 3%, respectively) but the germination was increased (up to 81% and 87%, respectively), which points out to considerably lesser seed damage by temperature. The drying temperature of 70°C applied to seeds with the moisture content of 35% and 25% also resulted in complete breakage of dormancy immediately after harvest. However, the germination of 84% and 89%, respectively, points out that a certain number of damaged seeds still existed. It seems that drying temperature of 50°C was the most suitable for the harvested seeds with the moisture content of 35% and 25% as the dormancy was broken (not higher

Table 2. Statistical probabilities of *F*-test

Source	*df*	Seed dormancy (%)		Seed germination (%)	
		F	*P*	*F*	*P*
Maturation period (SM)	2	944.2	0.000	83.6	0.000
Lots (L)	2	1.4	0.244	2.1	0.124
Seed moisture (MC)	2	237.4	0.000	167.7	0.000
Drying temperature (T)	4	1060.7	0.000	210.3	0.000
SM × L	4	1.6	0.166	0.7	0.578
SM × MC	4	41.2	0.000	21.6	0.000
L × MC	4	0.3	0.892	0.2	0.936
SM × T	8	234.2	0.000	143.7	0.000
L × T	8	1.0	0.403	1.7	0.097
MC × T	8	53.1	0.000	39.6	0.000
SM × L × MC	8	0.2	0.991	0.6	0.802
SM × L × T	16	0.1	0.473	0.4	0.990
SM × MC × T	16	10.5	0.000	1.4	0.139
L × MC × T	16	0.2	0.999	0.6	0.856
SM × L × MC × T	32	0.3	0.999	1.1	0.289

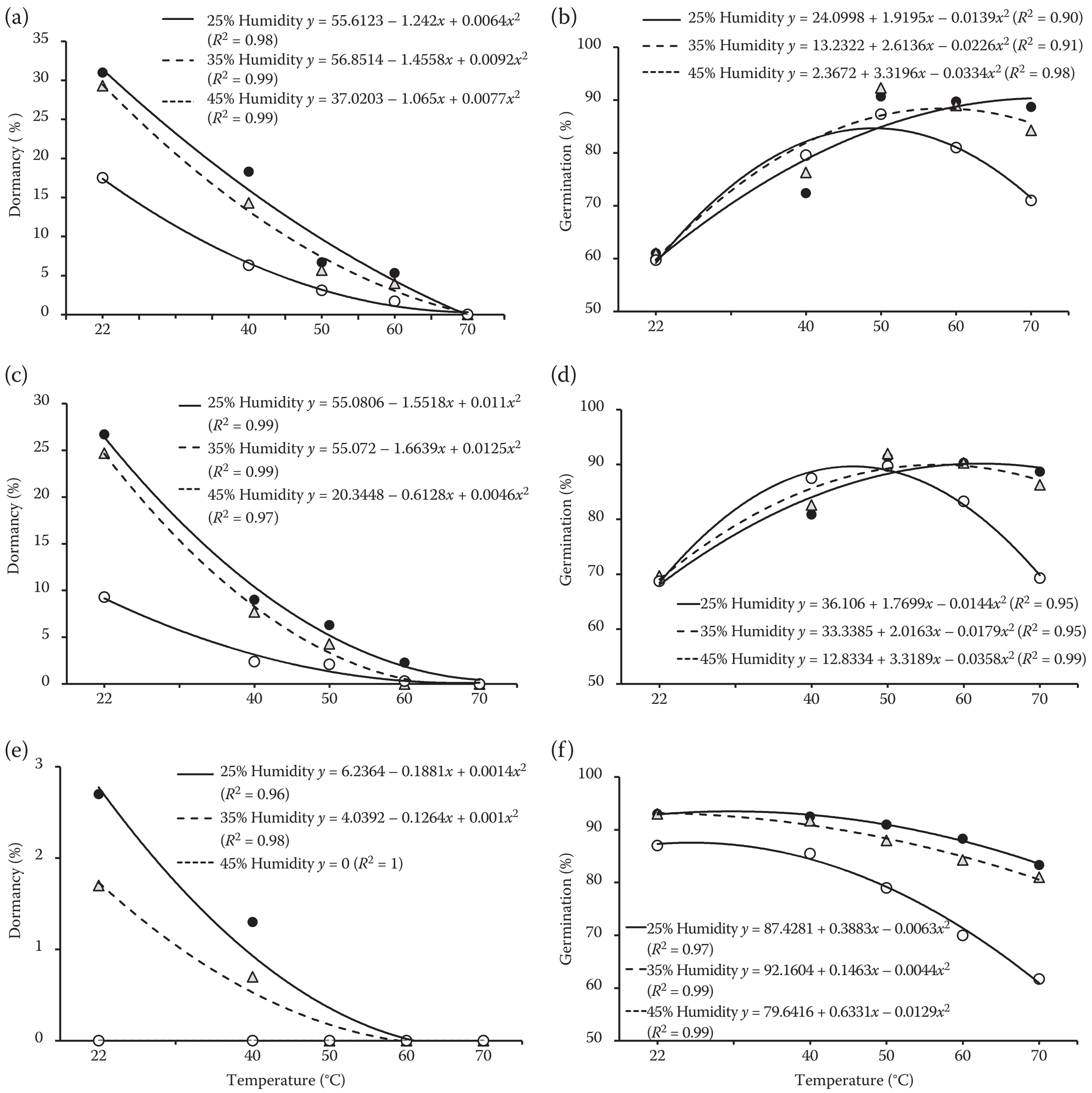

Figure 1. Effects of drying temperature on meadow fescue seeds with moisture of 25, 35 and 45% and changes in germination and dormancy immediately after harvest (a, b); three (c, d) and eight months after harvest (e, f)

than 6–7%), while germination was high (92% and 91%, respectively) immediately after harvest. On the other hand, seeds with moisture contents of 45, 35 and 25% conventionally-floor dried were dormant immediately after harvest (over 15%), which resulted in poor germination of 60, 61 and 61%, respectively (Figures 1a–b). Dormancy causing reduced germination immediately after harvest was also present in seeds of other fodder grasses conventionally dried. For instance, 31% of dormant seeds present in *Arrhenatherum elatius* resulted in germination of 57% (Stanisavljević et al. 2010b), while seed germination in *Lolium multiflorum*, *Dactylis glomerata* and *Phleum pretense* amounted to 58, 52 and 62%, respectively (Stanisavljević et al. 2011). Very low seed germination (about 50%) was recorded in *Brachiaria brizantha* (Dias and Toledo 1993), but the dormancy in these seeds if exposed to the temperature of 70°C for 10 and 15 min would be reduced and germination would be increased without adverse effects on physiological quality of seeds (Martins and Silva 2001).

The autumn sowing period of fodder grasses in the continental part of south-eastern and central Europe begins after 3- to 4-month storage. Autumn sowing (September–October) provides significantly higher fodder yield or grain yield in relation to sowing in spring of the succeeding year. Three months after harvest the dormancy of meadow fescue seeds harvested with the moisture contents of 45, 35 and 25% and then naturally-floor dried was reduced by 8, 5 and 4%, respectively, while germination was increased by 6–8% (Figures 1c–d). In this period, dormancy was fully broken or was on minimum in seeds with moisture contents of 35% and 25% that were dried at 60°C. This resulted in high seed germination (90%). Moreover, high germination (90%) was recorded in seeds with the moisture content of 45% dried at the temperature of 50°C (Figure 1d). On the other hand, germination of seeds with the moisture content of 45% dried at 70°C was decreased below 70% and had no commercial value due to trade regulations.

Autumn sowing can be unsuccessful due to insufficient precipitation sums or later precipitations, which result in late seed germination and the insufficient development of seedlings prior to stronger frosts. Seed dormancy is a biological property of seed by which plants regulate germination and the development of seedlings under environmental conditions normally favourable for germination. In agriculture, this trait is generally unfavourable as it reduces seed germination, but it can provide higher germination of perennial fodder grasses under environmental conditions in spring, when there is no danger of frosts (Stanisavljević et al. 2010c).

Eight months after harvest is a period of spring sowing (March–April) and it is a main sowing period for perennial fodder grasses in south-eastern Europe. During this period, only 1% to 3% of dormant seeds were recorded in seeds with the moisture contents of 35% and 25% that were floor-dried and in those dried at 40°C (Figure 1e). Medium germination (80% to 90%) was recorded in seeds dried at 50, 40 and 22°C (conventional drying). High germination (> 90%) was recorded in seeds with the moisture content of 25% dried either conventionally or at the temperatures of 40°C and 50°C. Furthermore, high germination was determined in seeds with the moisture content of 35% dried either conventionally or at the temperature of 40°C (Figure 1f). Seeds with the moisture content of 45% dried at the temperatures

Table 3. Germination (%) evaluated by the accelerated ageing test for periods of 24, 48 and 72 h in three lots of meadow fescue[1]

Moisture content in seed (%)	Lot	Temperatures of seed drying (°C)														
		70			60			50			40			22		
		24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h	24 h	48 h	72 h
45	L1	62^{c}	48^{b}	32^{d}	71^{c}	52^{c}	39^{d}	80^{b}	68^{a}	44^{c}	81^{a}	68^{a}	44^{c}	82^{a}	70^{a}	44^{c}
	L2	61^{c}	50^{b}	31^{d}	70^{c}	52^{c}	38^{d}	82^{ab}	68^{a}	44^{c}	80^{a}	67^{a}	44^{c}	81^{a}	70^{a}	43^{c}
	L3	63^{c}	51^{b}	36^{d}	73^{c}	53^{c}	41^{d}	82^{ab}	70^{a}	47^{bc}	81^{a}	68^{a}	47^{bc}	82^{a}	71^{a}	47^{bc}
	mean	62	62	50	33	71	52	39	81	69	45	81	68	45	82	70
35	L1	76^{b}	52^{b}	41^{c}	78^{b}	59^{b}	49^{c}	83^{ab}	66^{a}	48^{b}	84^{a}	67^{a}	48^{abc}	83^{a}	68^{a}	48^{abc}
	L2	78^{ab}	54^{b}	42^{c}	78^{b}	60^{b}	48^{c}	84^{ab}	66^{a}	48^{b}	83^{a}	68^{a}	47^{bc}	84^{a}	68^{a}	48^{abc}
	L3	77^{ab}	53^{b}	47^{b}	80^{b}	60^{b}	53^{b}	84^{ab}	68^{a}	51^{ab}	84^{a}	68^{a}	51^{ab}	84^{a}	69^{a}	51^{ab}
	mean	77	77	53	43	79	60	50	84	67	49	84	68	49	84	68
25	L1	80^{ab}	75^{a}	52^{ab}	85^{a}	79^{a}	60^{a}	84^{ab}	68^{a}	50^{ab}	85^{a}	69^{a}	51^{ab}	85^{a}	69^{a}	50^{ab}
	L2	82^{a}	77^{a}	52^{ab}	86^{a}	78^{a}	61^{a}	85^{a}	67^{a}	50^{ab}	84^{a}	68^{a}	50^{ab}	85^{a}	68^{a}	50^{ab}
	L3	81^{ab}	77^{a}	56^{a}	86^{a}	80^{a}	63^{a}	85^{a}	69^{a}	53^{a}	85^{a}	69^{a}	53^{a}	85^{a}	70^{a}	53^{a}
	mean	81	81	76	53	86	79	61	85	68	51	85	69	51	85	69

[1]means in the same column followed by the same letter are not significantly different at the 0.05 probability level; L1 – eastern; L2 – central; L3 – south-eastern Serbia

of 70°C and 60°C had no commercial values (due to germination of 62% and 70%, respectively).

High seed germination in perennial fodder grasses is accompanied with high seedling vigour, which is a prerequisite for a successful establishment of meadows and pastures (Jakobsson and Eriksson 2000, Stanisavljević et al. 2010a,b, 2011). The seed ageing test is applied to seeds of vegetables and field crops. However, its application on seeds of fodder crops is insignificant (Wang et al. 2004), which might be a result of a lower price of the seed or a smaller scope of seed production. Hence, we have applied the accelerated ageing test on seed lots of meadow fescue with different moisture contents and dried at different temperatures (Table 3).

The seed ageing test showed poor germination of seeds with the moisture content of 45% that were dried at high temperatures (70°C), which is in accordance with data presented in Figure 1. On the other hand, the seeds harvested with lower moisture contents (25% and 35%) had higher germination after the 24-h ageing test, and especially after the 48- and 72-h ageing test, pointing out to better maintenance of seed germination during storage. According to Tunes et al. (2011) by using of the ageing test it is possible to evaluate quality of fodder grass seed lots (*Lolium multiflorum* Lam.), and therefore to evaluate whether a lot can be stored for a longer period of time or not. Our results obtained on three seed lots of meadow fescue showed that there were no significant differences among lots after the application of the 24- and 48-h ageing test, while the third lot had significantly higher ($P < 0.05$) germination after the 72-h ageing test in almost all drying temperature/moisture content combinations. This suggests that the accelerated ageing test for 72 h was sensitive to detect differences in the physiological quality of meadow fescue seeds.

In conclusion, seeds of meadow fescue harvested with the moisture content of 45% had maximum germination if dried at 50°C and 40°C three months after harvest (period of autumn sowing). If the seeds are intended for spring sowing (eight months after harvest) it is better to apply conventional-floor drying (22°C). Seeds harvested with the moisture contents of 35% and 25% to be used in autumn sowing should be dried at 50°C or 60°C, and in spring sowing should be floor-dried or dried at the temperature of 40°C. The accelerated ageing test confirmed that seeds harvested with the moisture content of 45% and dried at higher temperatures are not suitable for longer storage. Seeds harvested with the moisture content of 35% and 25% and dried at temperatures of up to 40°C had a better potential for longer storage. The accelerated ageing test conducted with exposure periods of 72 h presents enough sensitivity for the storage potential evaluation of meadow fescue seeds.

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Corresponding author:

Dr. Dejan Dodig, Maize Research Institute Zemun Polje, Slobodana Bajica 1, 11185 Zemun Polje, Belgrade, Serbia
e-mail: dejanza@yahoo.com