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Film agents as an effective means of reducing seed shattering in *Festulolium*

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Abstract. In the conditions of the forest steppe of the Central Chernozem region, methods were studied to reduce shatter losses in the pre-harvesting period for *Festulolium* during the period 2009–2011, applying the film forming agents, Elastik (0.8–1.2 L ha^{-1}), Bifaktor (0.8–1.2 L ha^{-1}), and Metylan Universal Premium (1.4–3.8 kg ha^{-1}). The agents were used at seed humidity levels of between 60–65%. Following anti-shattering treatment, seed moisture content gradually decreased. The application of film forming agents prevented seed shattering, and seeds were harvested by direct combining at a humidity of between 20–25% without heavy losses being suffered. Moreover, decreased seed losses due to film forming agents significantly reduced the cost of seed heap drying. In the control treatment, the seed yield amounted to 214.8 kg ha^{-1}, and 360.7 kg ha^{-1} was lost as a result of natural seed shattering in the process of ripening. The Elastik and Bifaktor preparations prevented seed shattering and contributed to the preservation of a seed yield of between 522.1–563.5 kg ha^{-1}. The application of film forming agents contributed to a reduction in losses during harvesting within the range of 9.7–16.8%. Application of the Metylan Universal Premium glue in the studied doses provided a significant increase of seed yield. The highest seed yield (490.1–495.2 kg ha^{-1}) was obtained in the treatment which used a Metylan application at a dose of 3.0–3.4 kg ha^{-1}, where seed shattering was reduced by 14.8–17.6%.

Key words: perennial grasses, shatter losses, film forming agents, seed humidity.

INTRODUCTION

The harvesting of seed herbage for many forms of agricultural crops is the most complicated procedure in the process of cultivation, because it always carries risks that primarily are due to its weather dependence, the blotchy ripening of seeds and their small size, and also due to the ability of many species to shatter seeds (Kulikov, 2010).

Rape, feed legumes, peas, soybean, and other crops are prone to seed shattering during ripening. Under the conditions required to reduce seed loss during ripening and harvesting on a working farm, adhesive preparations are used that are based on synthetic latex. The basic principle of their action is as follows: when they are sprayed onto the plant's surface, their drops spread and merge, creating a uniform elastic film. In the case of rape, this prevents pod shatter, promotes natural ripening, reduces seed humidity, decreases the negative impact of ultraviolet radiation and friction between the pods, and reduces the development of certain fungal diseases which, as a result, leads to higher seed yields and higher oil content in seeds (Fedotov et al., 2008).

Seed shattering (or scattering) is characteristic of most grasses and is one of the stages of the natural process of seed dispersal. The separation of ripe seed from the maternal plant occurs when it is abscised from the rachilla; usually this occurs during the final stage of ripening. In this period all of the inflorescences become straw-coloured, and the endosperm hardens completely (Perepravo et al., 2008).

No data is available on the use of adhesive preparations on perennial grasses. At present, it is recommended that easily-shattering perennial grasses be harvested [(perennial ryegrass (*Lolium perenne* L.) and Italian ryegrass (*Lolium multiflorum* L.), meadow fescue (*Festuca pratensis* L.), etc)] at the seed humidity level of 40–45%, ie. before wholescale seed shattering due to inflorescences begins. Dry matter accumulation in seeds during this period stabilises and reaches its maximum extent (Mikhaylichenko et al., 1994; Shchedrina et al., 2009).

Festulolium (× *Festulolium* F. Aschers. et Graebn.) is an artificially created fodder crop that was obtained by intergeneric hybridisation in the *Lolium sp.* and *Festuca sp.* genera system. The main objective behind the creation of this hybrid was to combine several economically valuable features of its parental forms in one plant. From various ryegrasses, *Festulolium* inherited excellent feeding qualities: high sugar, protein, and exchange energy content, as well as good palatability and the digestibility of feed, and the ability by the plant to intensively form a large number of folious vegetative shoots. During the vegetation period the hybrid quickly regrows after repeated mowing or grazing; at the same time, unlike ryegrass, it is less inclined to the formation of generative shoots and is responsive to the use of mineral nitrogen fertilisers and irrigation. From fescues the hybrid borrowed good winter hardiness, drought resistance, and resistance to long-term grazing and trampling. Depending on the selection of parental forms and their morphotypes, the hybrids that were obtained are being used for the preparation and conservation of various types of feeds, both in pure form and in grass mixtures on cultural hay-producing land and pasture, as well as in the creation of lawns, and the improvement of field aerodromes and sports grounds (Barnes et al., 2014; Kvasnovsky et al., 2014; Schiavon et al., 2014; Kubota et al., 2015).

The VIK-90 *Festulolium* variety was bred in V Williams All-Russian Fodder Research Institute. It is characterised by high productivity levels in terms of green mass (74.3–80 t ha^{-1}), dry matter (14.0–15.5 t ha^{-1}), longevity, good winter hardiness, the evenness of forage mass during the growing season, rapid spring aftergrowing, and after heavy grazing. However, the VIK-90 variety is not free of the shortcomings that are proper to its seed parent, the main being non-simultaneous ripening of seeds and their easy shattering in the pre-harvesting period (Vasko et al., 2010; Perepravo & Ryabova, 2003).

During the study of the dynamics of *Festulolium* herbage ripening with varying degrees of maturity, it has been reported that the delay in harvesting of the VIK-90 variety leads to significant seed loss due to natural seed shattering, starting with humidity levels for the seeds that is less than 40%, and increasing further during the seed herbage ripening process (Kulikov, 2010; Perepravo, 2011). It was revealed that at the stage of complete seed ripeness for the VIK-90 *Festulolium* variety (at seed humidity levels of 20–25%), losses due to seed shattering amounted to 244.6 kg ha^{-1}. The same results were obtained for other grass species (Griffiths et al., 1971; Cherniauskas et al., 1977; Mikhaylichenko, 1987; Lebedeva, 2010).

Therefore, it is obvious that any delay during harvesting leads to excessive seed loss (up to 40–55% of the entire yield). The low actual productivity levels of *Festulolium* seed herbages can be adequately explained by this fact, which is one of the main factors to serve to restrain extensive use of the culture on working farms in the Central Chernozem region (Obraztsov et al., 2013).

It can be seen that, while there are no *Festulolium* varieties that are completely resistant to seed shattering or which undergo simultaneous ripening of the seeds, one of the most important issues in its cultivation technology is the search for ways to reduce shatter loss in the seeds.

The objective of our studies was to develop methods for reducing *Festulolium* seed loss due to natural shattering during the ripening period and harvesting (including delayed harvesting).

MATERIALS AND METHODS

The experimental area of the study was carried out in field trials for the Department of Crop Science, Forage Production and Agricultural Technologies, Voronezh State Agrarian University, on the fields that are run by the 'Agrotechnology' Training, Research and Technological Centre (N51.7140416 E39.21545371) in 2009–2011.

The experimental design included the application of three adhesive preparations: Elastik and Bifaktor in dosages of 0.8, 1.0, and 1.2 L ha^{-1}, and Metylan Universal Premium in dosages of 1.4, 1.8, 2.2, 2.6, 3.0, 3.4, and 3.8 L ha^{-1}. Control crops were treated with clean water. Adhesive preparations were applied at the milk-ripe stage of *Festulolium* weevils when seed humidity was not less than 60–65%. Generative shoots were treated using the Hozelock Professional 4816 manual knapsack sprayer with a volume of sixteen litres. Spray material consumption was 200 L ha^{-1}. The area of the registration plot was 20 m^2. A four-replicate experiment was carried out, the placement of experimental plots was randomised.

Shatter loss in the seeds was defined by the seeds gathering in special containers over a total area of 1 m^2, with these points being located between the rows of the grass stand.

The harvesting of seeds was carried out by direct combining at humidity levels of 22–25%. The clipping height was increased in order to eliminate the cutting of green leaves in the *Festulolium* plants.

A germination test was carried out under the laboratory conditions between two-to-three months after harvesting. It was carried out using the rolling method (Fedotov et al., 2011). A hundred seeds were placed embryo-down on moistened filter paper 12 cm × 100 cm in size on a line drawn between 2–3 cm from the upper edge. They were then covered with a sheet of moistened filter paper of the same size. The strips were loosely rolled up and were placed in a vertical position into germination chambers with 50 mL of water. Seeds were germinated for seven days in the dark in a thermostat at a temperature of 20 °C. A germination test was carried out in four replications. On Day 3 the germinating power was determined. At the end of the germination period, laboratory germination was determined. In addition, the weight of 1,000 seeds was determined.

Mathematical processing of the data obtained was carried out by means of a variance analysis (Dospekhov, 1985). Economic efficiency was calculated on the basis of process flow charts using standard specifications for the prices of 2011.

RESULTS AND DISCUSSION

We offer to change the first paragraph of the Results and discussion.

Following the anti-shattering treatment of *Festulolium* plantings due to the application of adhesive preparations, a thin film was formed on the ears, polymer network with the effect of diffusion covered the entire surface of the plant without stomatal closure and disruption of gas exchange functions of plants. These factors helped to reduce shatter losses in the seeds.

The results indicated that following the anti-shattering treatment of *Festulolium* plantings due to the application of adhesive preparatios, a thin polymer film was formed on the ears and on the surface of each plant without stomatal closure and disruption of gas exchange functions in plants. These findings compare favourably to those reported by Fedotov et al. (2008).

The proposed treatment helped to reduce shatter losses in the seeds.

Additionally, it is worth pointing the fact that the greater part of the leaves of the plantings remained green. A pre-harvesting treatment of *Festulolium* plantings by means of adhesive preparations allowed harvesting to be carried out at lower seed humidity levels and with minimum losses (Table 1).

Table 1. Productivity and *Festulolium* seed shattering rate impacted by the applied adhesive preparations at different concentrations (averaged for the 2009–2011 period). N = 4 observations

Treatment		Productivity, kg ha^{-1}		Seed shattering rate	
Preparation	Dose	Biological	Real	kg ha^{-1}	%
Control (water treatment)		575.6	214.8	360.7	62.0
Metylan	1.4	584.3	284.1	300.1	51.0
Universal	1.8	589.5	342.4	247.1	42.9
Premium,	2.2	581.3	382.3	199.0	35.4
kg ha^{-1}	2.6	585.5	448.9	136.6	24.1
	3.0	578.7	495.2	83.5	14.8
	3.4	590.0	490.1	99.8	17.6
	3.8	593.4	453.9	139.5	24.1
Elastik,	0.8	620.3	522.1	98.3	16.8
L ha^{-1}	1.0	627.2	543.9	83.4	14.0
	1.2	630.2	563.9	66.4	11.2
Bifaktor,	0.8	615.6	524.8	90.8	15.4
L ha^{-1}	1.0	617.4	547.4	70.0	11.9
	1.2	619.7	563.5	56.2	9.7
LSD_{05}		9.8	5.1	3.1	1.8

We registered high levels of efficiency in the preparations that were being studied in regard to *Festulolium* plantings. In the control treatment the real seed yield was 214.8 kg ha^{-1}, and seed shatter losses during the ripening process were at 360.7 kg ha^{-1}.

Elastik and Bifaktor preparations decreased seed shattering and therefore increased the real yield of *Festulolium* seeds to 522.1–563.5 kg ha^{-1}. Film-forming substances decreased harvesting losses from 62% (in the control treatment) to between 9.7–16.8%.

The application of Metylan Universal Premium glue at the recommended rates also provided a significant increase of seed yield. The highest seed yield (490.1–495.2 kg ha^{-1}) was produced under application of the glue at a dose of 3.0–3.4 kg ha^{-1}, which decreased seed shattering by 14.8–17.6%. The spray material of Metylan Universal Premium glue at the maximum dosage (3.8 kg ha^{-1}) was characterised by high viscosity. Its application caused a strong clogging of the sprayer nozzles, which resulted in the poor quality of treatment of generative shoots and increased seed loss (up to 24.1%).

The application of adhesive preparations did not degrade the sowing qualities of *Festulolium* seeds (Table 2). In the control treatment, laboratory germination amounted to 92.2%, whereas in the experimental variants it was at 92.2–95.7%. The average mass of 1,000 seeds reached 2.88–2.92 g.

Table 2. The sowing qualities of *Festulolium* seeds impacted by the applied adhesive preparations (averaged for the 2009–2011 period). N = 4 observations

Treatment		Weight of	Germinating power,	Laboratory
Preparation	Dose	1,000 seeds, g	%	germination, %
Control (water treatment)		2.89	74.6	92.2
Metylan	1.4	2.92	73.7	94.7
Universal	1.8	2.90	76.1	93.4
Premium,	2.2	2.88	74.5	92.4
kg ha^{-1}	2.6	2.94	72.8	92.2
	3.0	2.91	72.1	93.1
	3.4	2.92	76.3	93.6
	3.8	2.90	75.3	93.1
Elastik,	0.8	2.92	70.9	95.7
L ha^{-1}	1.0	2.91	73.9	94.8
	1.2	2.89	69.6	93.5
Bifaktor,	0.8	2.88	73.0	94.1
L ha^{-1}	1.0	2.90	68.5	93.2
	1.2	2.89	72.4	94.2
LSD_{05}		1.6	2.8	4.3

Material and total costs for *Festulolium* cultivation in the control treatment amounted to RUB 29,300 per hectare. When applying adhesive preparations this indicator amounted to RUB 29,900–31,800 per hectare. In economic terms the anti-shattering treatment for *Festulolium* plantings with film forming agents was effective. When applying Elastik and Bifaktor the lowest production costs for 100 kg of seeds (RUB 5,400–5,900 per hectare) and the highest profitability levels (104–123%) were observed (Table 3).

Table 3. The economic efficiency of applying film-forming preparations on seed plantings of *Festulolium* (averaged for the 2009–2011 period)

Treatment		Value of production	Costs per	Cost of	Net income,	Profitability
Preparation	Dose	per 1 ha, RUB	1 ha, RUB	1 c, RUB	RUB	level, %
Control (water treatment)		25,780	29,291	13,634	-3,511	-12.0
Elastik,	0.8	62,648	30,737	5,888	31,911	103.8
L ha^{-1}	1.0	65,264	30,930	5,687	34,334	111.0
	1.2	67,664	30,612	5,429	37,052	121.0
Bifaktor,	0.8	62,980	30,390	5,893	32,050	103.6
L ha^{-1}	1.0	65,692	30,172	5,512	35,520	117.7
	1.2	67,620	30,392	5,393	37,228	122.5
Metylan	1.4	34,096	29,966	10,547	4,130	13.8
Universal	1.8	41,088	30,158	8,808	10,929	36.
Premium,						2
kg ha^{-1}	2.2	45,880	30,351	7,938	15,528	51.1
	2.6	53,872	30,544	6,804	23,328	76.4
	3.0	59,424	30,737	6,207	28,687	93.3
	3.4	58,816	30,930	6,311	27,886	90.2
	3.8	54,468	31,798	7,005	22,670	71.3

The study resulted in the execution of Russian Federation Patent 2420050: 'A method for the pre-harvesting treatment of *Festulolium* seed crops' (Obraztsov et al., 2011).

CONCLUSIONS

On the basis of studies conducted in 2009–2011 during seed harvesting in the conditions of the forest-steppe of the Central Chernozem region, and devoted to the seed productivity of *Festulolium* depending on the application of adhesive preparations, the highest real yield of *Festulolium* seeds was registered when applying Bifaktor, amounting to 524.8–563.5 kg ha^{-1} (averaged across three years of studies).

The application of Metylan Universal Premium glue revealed a significant increase in seed yield due to shatter loss reduction. When applying a dose of 3.0–3.4 kg ha^{-1}, the seed yield amounted to 490.1–495.2 kg ha^{-1} and the seed shattering rate did not exceed 14.8–17.6%.

The pre-harvesting treatment of *Festulolium* plantings by Bifaktor preparation was economically reasonable (the production costs for 100 kg of seeds was RUB 5,500 per hectare with a profitability level of 118%). In the application of Metylan Universal Premium glue, production costs for 100 kg of seeds was RUB 6,200–8,800 per hectare and the profitability level was between 14% and 93%.

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