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Scientific paper

Selectivity of Some Herbicides to Standard Wheatgrass (*Agropyron desertorum* (Fisch.) Schultes) During Stand Establishment and Seed Production

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SUMMARY

A study was conducted in the experimental field of the Institute of Forage Crops – Pleven on a slightly leached chernozem soil in 2011-2012 to determine the selectivity of some herbicides to standard wheatgrass (*Agropyron desertorum* (Fisch.) Schultes) during stand establishment and its seed production. The study had the following results: the herbicides Kambio SL (320 g/l bentazone + 90 g/l dicamba) – 1250 ml/ha; Kalam (125 g/l tritosulfuron + 600 g/kg dicamba) – 200 g/ha; Lintur 70 WG (4.1% triasulfuron + 65.9% dicamba) – 150 g/ha, and Axial 050EK (50 g/l pinoxaden) – 600 ml/ha showed high selectivity to standard wheatgrass when applied at the stage of 3-4 leaves during the year of stand establishment; the herbicides Imaspro (69 g/l fenoxaprop-P-ethyl+antidote) and Stelar (50 g/l topramezone + 160 g/l dicamba), each applied at the rate of 1000 ml/ha, caused phytotoxicity (scores from 4 to 6), while Termidor (40 g/l nicosulfuron) – 1250 ml/ha completely destroyed the crop (score 9); the herbicides Kambio SL; Kalam; Lintur 70WG and Axial 050EK applied at the same doses at the stage from spring growth to the beginning of shooting up in the seed production year had a high selectivity to standard wheatgrass and could be applied in seed production stands without negative influence on seed productivity. The herbicide Termidor was very phytotoxic (scores from 3 to 7) and prevented the formation of generative stems.

Keywords: *Agropyron desertorum*; Herbicides; Seeds; Dry biomass

INTRODUCTION

In response to increasingly demanding European standards, new strategies of weed control have to meet the requirements and principles of good plant protection practice. Current agroecological conditions require that methods and means of weed control should improve. Changes in weed associations occur under the influence of different factors and it is necessary to explore new options for weed control. Modern weed control relies in huge part on the chemical method. Treatment with the same active ingredients over long periods of time is the main cause of herbicide resistance that naturally leads to changes in weed species composition. (Nikolova and Konstantinov, 1989; Beckie et al., 2000; Masabni and Zandstra, 2000). Resistance has been reported for most herbicides and for 174 weed species (Heap, 2004).

A typical biological property of standard wheatgrass, and other members of the group of perennial grasses, is slow growth and development during the year of stand establishment. In that period, they are very sensitive to the competitive influence of weeds. That is why establishing stands of good density, persistence of production of high quality forage and seeds require efficient, scientifically grounded and environmentally friendly weed control.

The first Bulgarian variety of standard wheatgrass Morava is suitable for establishment on pastures and meadows, in stands intended to control soil erosion, and for maintaining landscape coverage. The variety was created at the Institute of Forage Crops - Pleven (Katova et al., 2010; Katova, 2012). Weed control during seed production is a priority issue because of its slow growth and development and low competitiveness to weeds, specially during the year of establishment (Dimitrova, 1984; Elgaard and Nancen, 1988). Elimination of weed competition during that period is an important feature for persistence and productivity of perennial grass species (Dong et al., 2005) and another important aspect of annual weed control is the year of stand establishment. In a study by Dimitrova and Chakarov (2004), the highest seed yield of standard wheatgrass (741 kg/ha) was harvested in a stand with 36 cm between rows and oat as the cover crop during the year of establishment. The herbicides Professional (280 g/l bromoxynil octanoate + 280 g/l MCPA) and Topic 080EK (80 g/l clodinafop-propargyl + antidote) are selective and highly effective during seed production years (Dimitrova, 2007).

Relevant studies for this perennial forage species are very scarce, which is why this research was carried out.

The aim of the study was to identify selective herbicides for standard wheatgrass *(Agropyron desertorum* (Fisch.) Schultes) to be applied during stand establishment and its seed production.

MATERIAL AND METHODS

During the period of 2011-2012, a study was conducted in the experimental field of the Institute of Forage Crops – Pleven on a slightly leached chernozem soil. The humus horizon was 60-65 cm. When laying out the grass trails the following contents were found in soil samples: mobile forms of nitrogen (50-87 mg/1000 g), phosphorus and potassium 3-9.3 and 20-34 mg/100 g, respectively, pH_{KCl} 5.4-6.8, and humus 2.6%. Hydrolizable nitrogen supply in soil was medium to good, while the supply of phosphorus was poor to medium and of potassium medium to very good. The soil had a slightly acidic to neutral reaction and low humus content. These soil conditions are favorable for standard wheatgrass growth and development. The experiment was set up using the long plot method in three replicates and the size of the harvested plot of 5 m^2. Variants of the trial are shown in Table 1. The herbicides tested in this study have been registered in Bulgaria for weed control in cereal crops with activity spectra including dicotyledonous (Kambio SL; Kalam; Lintur) and annual monocotyledonous weeds (Axial, Imaspro) and with complex action (Stelar and Termidor).

Standard wheatgrass, variety Morava, was sown in the spring (March) at inter-row distance of 36 cm and sowing rate of 15 kg/ha. Fertilizing was done with P_2O_5 – 100 kg/ha and N – 120 kg/ha (½ in spring + ½ in autumn each year).

Manual removal of weeds was done throughout the vegetative period to eliminate their negative influence on the cultivated plants and to measure only the effects of the herbicides.

Treatments were conducted with 400 l/ha water solutions using a manual Mathaby spreading machine with conic nozzle, pressure P max 3 bar, V max 1.56 l, and Q max 0.6 l/min, at the stage of 3-4 leaves during the year of stand establishment and from springtime emergence until the beginning of shooting up in the seed production year.

The following characteristics were assessed: herbicides phytotoxicity to the cultivated plants 7, 14 and 30 days after treatment (DAT) and during seed harvesting,

using the 1-9 logarithmic scale of the EWRS (European Weed Research Society) (score 1 – no damage and score 9 – completely destroyed crop); structural analysis of the elements of productivity in 60 generative stems for each variant); number of generative stems per m^2, seed yield and dry biomass yield; seed qualities (1000 seed weight and germination). Experimental data were processed by dispersion analysis in Microsoft Excel software.

RESULTS AND DICUSSION

The results of selectivity evaluation (Table 2) showed that the herbicides had different phytotoxic effects on standard wheatgrass. The herbicides Kambio SL – 1250 ml/ha, Kalam- 200 g/ha, Lintur 70 WG – 150 g/ha and Axial 050EK – 600 ml/ha had high selectivity from 7 DAT until the end of vegetation (score 1). Phytotoxic effects of Imaspro – 1000 ml/ha were observed as chlorosis, turning into leaf necrosis from a weak to moderate degree (4 scores). Serious damage, reaching score 6, was caused by Stelar – 1000 ml/ha, manifesting a chlorosis and white spots on leaves and inhibition of growth and development until 14 DAT. Leaf discoloration was restored by the 30th DAT but suppression of growth persisted. The most significant phytotoxic effects were shown by Termidor – 1250 ml/ha, starting as chlorosis and passing into leaf necrosis (score 6) 7 DAT. Exceptionally serious was damage (score 8) 14 DAT, showing necrosis and death of plants until they completely disappeared (score 9) 30 DAT.

Table 1. Trial variants

Variants	Dose of commercial product, ml (g)/ ha	Dose – active ingredient, ml (g)/ha
V_1 – Check - untreated	–	–
V_2 – Kambio SL (320 g/l bentazone + 90 g/l dicamba)	1250	512.5
V_3 – Kalam (125 g/l tritosulfuron + 600 g/kg dicamba)	200	37
V_4 – Lintur 70 WG (4.1% triasulfuron + 65.9% dicamba)	150	105
V_5 – Axial 050EK (50 g/l pinoxaden)	600	30
V_6 – Imaspro (69 g/l fenoxaprop-P-ethyl+antidote)	1000	69
V_7 – Stelar (50 g/l topramezone + 160 g/ l dicamba)	1000	210
V_8 – Termidor (40 g/l nicosulfuron)	1250	50

Table 2. Selectivity of the herbicides to standard wheatgrass (*Agropyron desertorum* (Fisch. Schultes)

Variant**	Damage score (according to EWRS*)					
	Days after treatment (DAT)					
	7		14		30	
	A***	B****	A	B	A	B
V_1	1	1	1	1	1	1
V_2	1	1	1	1	1	1
V_3	1	1	1	1	1	1
V_4	1	1	1	1	1	1
V_5	1	1	1	1	1	1
V_6	4	2	4	3	4	2
V_7	6	2	6	3	6	5
V_8	6	3	8	4	9	7

*EWRS – Logarithmic scale (1-9) – score 1 – no damage; score 9 – completely destroyed crop
** Variants are the same as in Table 1
*** A – during the year of stand establishment
****B – during the seed production year

Table 3. Influence of the herbicides on growth and development of standard wheatgrass during harvesting of 1st cut in the year of stand establishment

Variants *	Characters		
	Height of vegetative stems, cm	Vegetative stems, number/m^2	Fresh stem weight, g/m^2
V_1	26	1529	1033
V_2	26	1517	1017
V_3	25	1540	1013
V_4	26	1533	1023
V_5	25	1553	1040
V_6	22	1520	785
V_7	19	1485	621
V_8**	–	–	–
Average	24	1525	934
Min.	26	1553	1040
Max.	19	1485	621

* Variants are the same as in Table 1
** Termidor herbicide showed strong phytotoxicity (score 9) and destroyed plants completely

Table 4. Influence of the herbicides on dry biomass productivity of standard wheatgrass during the year of stand establishment

Variant*	1st cut		2nd cut		Total	
	kg/ha	% V_1	kg/ha	% V_1	kg/ha	% V_1
V_1	2890	100	2200	100	5090	100
V_2	2820	98	2230	101	5050	99
V_3	2810	97	2180	99	4990	98
V_4	2860	99	2250	102	5110	100
V_5	2970	103	2280	102	5250	103
V_6	2250	78	2160	98	4410	87
V_7	1820	63	2210	100	4030	79
V_8**	–	–	–	–	–	–
GD $P_{5\%}$	480.90		126.16		505.53	
$P_{1\%}$	674.24		176.88		708.76	
$P_{0.1\%}$	952.98		250.01		960.02	

* Variants are the same as in Table 1
** V_8 – Termidor herbicide showed strong phytotoxicity (score 9) and complete plant destruction

Table 5. Influence of the herbicides on seed productivity of standard wheatgrass

Variant*	Seed productivity	
	kg/ha	% V_1
V_1	759	100
V_2	752	99
V_3	757	100
V_4	764	101
V_5	769	101
V_6	748	99
V_7	496	65
V_8**	0	0
GD $P_{5\%}$	84.98	
$P_{1\%}$	119.15	
$P_{0.1\%}$	168.40	

* Variants are the same as in Table 1
**Variant V_8 – no generative stems were formed and seeds were not harvested due to high phytotoxicity of Termidor

Table 6. Influence of the herbicides on structural elements of seed productivity of standard wheatgrass

Variant*	Generative stems		Length of ear, cm	1000 seeds weight, g
	number/m^2	height, cm		
V_1	1411	89.6	5.3	2.30
V_2	1399	89.3	5.2	2.38
V_3	1391	89.3	5.4	2.28
V_4	1424	89.8	5.3	2.28
V_5	1418	90.0	5.4	2.32
V_6	1388	89.1	5.2	2.34
V_7	1172	85.4	5.0	2.32
Average	1365	88.9	5.3	2.32
Min.	1172	85.4	5.0	2.28
Max.	1424	90.0	5.4	2.38

* Variants are the same as in Table 1

Table 7. Dry biomass yield formed as plant residues during the first year of seed production

Variant*	Dry biomass yield – crop residues - straw	
	kg/ha	% V_1
V_1	12320	100
V_2	12180	99
V_3	12370	100
V_4	12270	99
V_5	12380	100
V_6	12030	98
V_7	10740	87
V_8**	–	–

* Variants are the same as in the Table 1
**Variant V_8 – no generative stems were formed and seeds were not harvested due to high phytotoxicity of Termidor

The herbicides' action was reflected on the indexes, describing growth and development of standard wheatgrass (Table 3). Plant height after treatment of the first growth of untreated check plants and those treated by selective herbicides was in the close range of 25 to 26 cm, while values of this character were 19-22 cm as a result of the inhibiting action of Imaspro and Stelar (V_6 and V_7). A reduction in the number of vegetative stems per m^2 was found only for Stelar (1000 ml/ha) – 1485 stems/m^2, while differences between other variants were insignificant and the number of stems was within a close range of 1517-1553 per m^2. Fresh weight of vegetative stems was 789 and 621 g/m^2 for Imaspro (1000 ml/ha) and Stelar (1000 ml/ha) as a result of their phytotoxicity, while the same trait values were between 1013 and 1040 g/m^2 for the selective herbicides and 1033 g/m^2 for the check.

Standard wheatgrass is a winter type crop and during its establishing year two cuts were harvested for forage (Table 4). Dry biomass yield from stands treated with the selective herbicides (V_2, V_3, V_4 and V_5) ranged from 97 to 100%, compared to the untreated check (V_1), and the differences had no statistical significance. Forage productivity in the stands was 22-37% lower as a result of phytotoxicity (V_6 and V_7) with very high significance of differences. Phytotoxicity in the second growth was overcome in the stands treated with Imaspro and Stelar (V_6 and V_7) but the stand treated with Termidor (V_8) was an exception and was completely destroyed. Dry matter yield was between 98 and 102%, compared to the untreated check but differences were not significant. The values of this character in the first year of the stand followed the same tendency as in the first growth. Dry matter yield from the stands treated with selective herbicides was from 4990 to 5250 kg/ha or 98 to 103% compared to the check (V_1). Dry biomass in the stands showing phytotoxicity (V_6 and V_7) was 4030 and 4410 kg/ha, which was lower 21 and 13% than in the untreated stand, while negative differences had high and very high significance.

During the seed production year (second year of stand growing) standard wheatgrass showed higher resistance to the herbicides (Table 2). The herbicides for control of dicotyledonous weeds (Kambio SL; Kalam;

Lintur 70 VG), and Axial 050 EK for control of monocotyledonous weeds had high selectivity in all vegetation (growing) periods. Different degrees of phytotoxic effects were observed for Imaspro, Stelar and Termidor. Imaspro (V6) caused a weak to very weak inhibition (scores 3-2), while Stelar (V7) caused inhibition that was very weak to moderate (scores 2-3-5). These two herbicides made slower heading stage. Termidor (V8) had the highest phytotoxic effect (scores 3-4-7), causing weak, moderate and very serious inhibition of growth and preventing the formation of generative stems.

The herbicides had effect on seed productivity of standard wheatgrass (Table 5). Seed yield in the untreated check was 759 kg/ha, while in variants without expressed phytotoxicity (V_2, V_3, V_4 and V_5) and with very weak one (V_6) the yield had very close absolute values from 748 to 769 kg/ha. These differences had no statistical significance, which was evidence of the herbicides' selectivity to the wheatgrass crop.

As a result of strong phytotoxicity of Stelar (V_7) seed yield was reduced to 496 kg/ha, which was 35 % lower than in the untreated check. This difference had very high negative significance. Seeds were not harvested after treatment with Termidor (V_8) due to very high phytotoxicity and there were no generative stems.

The herbicides had influence on the structural elements of seed productivity (Table 6). The number of generative stems formed in the variants treated with selective herbicides varied between 1388 and 1424 stem/m^2. The phytotoxic herbicide Stelar (V_7) showed a notable deviation regarding this character of standard wheatgrass as the stem number was 1172 per m^2, compared to the average value of 1365 n/m^2. The height of generative stems also had influence of seed productivity. The maximum value of this character was 90 cm, average – 88.9 cm, while Stelar phytotoxicity caused a reduction to 85.4 cm. The last variant stood out with its lowest value for ear length – 5.0 cm, while the range was from 5.2 to 5.4 cm for all other variants. Regarding the thousand seeds weight (TSW), there was no regular trend in the variants and the marginal values were between 2.28 and 2.38 g.

From seed production stands of standard wheatgrass *A. desertorum* a significant quantity of additional dry biomass was obtained, formed from crop residues and aftermath (Table 7). The yield from the stands treated with selective herbicides ranged from 12030 to 12380 kg/ha, which was -2% to equal with the check value. More significant was the deviation (-13%) in the variant treated with Stelar.

There is no other variety of *Agropyron desertorum* registered in EU countries besides this Bulgarian variety. There is a small number of varieties included on the OECD list for 2012 (varieties in total: 2 from USA: Nordan – 1953, Hycrest – 1984; 1 from Canada: AC Goliath – 2001 and 1 from Bulgaria: Morava – 2010 (first Bulgarian, Balkan and European and newest in the world) (Katova, 2012). World seed production is concentrated mainly in Canada and the USA, while in the EU there is now only Breeders' seeds. Plant breeding is focusing on development of high forage and seed productive varieties. For seed production stands of standard wheatgrass in Bulgaria, selective herbicides had first been found (Dimitrova and Chakarov, 2004) and additional quantities of dry biomass after seed harvesting and regrowth were obtained (5010 to 9030 kg/ha), and weed suppression was noted. This variety is characterized by a very high persistence for more than 10 years, winter hardiness, drought resistance, leaf disease resistance and tolerance to high summer temperatures. The average dry matter yield is 9000-10000 kg/ha, and seed yield 500-600 kg/ha. Its biomass has high nutritive value on pastures: crude proteins content is 17-19 %, and *in vitro* dry matter digestibility 60-68 %. The variety is multifunctional, suitable for hay, hay-pasture use, for erosion control and landscape architecture. It can be used as a component of hay mixtures with alfalfa or sainfoin. The variety was registered on the Official Variety List of the Republic of Bulgaria (OVL) for 2012, on the corresponding OECD list for the years 2010, 2011 and 2012, and received a certificate from the Patent Office of the Republic of Bulgaria in 2010 (Katova, 2012).

CONCLUSIONS

The following conclusions were made based on results in the study:

– The herbicides Kambio SL (320 g/l bentazone + 90 g/l dicamba) – 1250 ml/ha; Kalam (125 g/l tritosulfuron + 600 g/kg dicamba) – 200 g/ha; Lintur 70 WG (4.1% triasulfuron + 65.9% dicamba) – 150 g/ha and Axial 050EK (50 g/l pinoxaden) – 600 ml/ha demonstrated high selectivity to standard wheatgrass when applied at the stage of 3-4 leaves during the year of stand establishment;

– The herbicides Imaspro (69 g/l fenoxaprop-P-ethyl+antidote) and Stelar (50 g/l topramezone + 160g/l dicamba), each applied at the dose of 1000 ml/ha, caused phytotoxicity (scores from 4 to 6), while Termidor (40 g/l nicosulfuron) – 1250 ml/ha completely destroyed the crop (score 9);

– The herbicides Kambio SL; Kalam; Lintur 70WG and Axial 050EK applied at the same doses in the stage of spring growth until the beginning of shooting up during the seed production year showed high selectivity to standard wheatgrass and can be applied in seed production stands without negative influence on seed productivity;

– The herbicide Termidor was very phytotoxic (scores from 3 to 7) and prevented the formation of generative stems.

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Selektivnost nekih herbicida prema pirevini (*Agropyron desertorum* (Fisch.) Schultes) tokom zasnivanja useva i produkcije semena

REZIME

U Institutu za krmno bilje Pleven sprovedeno je istraživanje na blago izluženom tipu zemljišta tokom 2011-2012. godine kako bi se utvrdila selektivnost nekih herbicida prema pirevini (*Agropyron desertorum* (Fisch.) Schultes) tokom perioda zasnivanja useva i produkcije semena. Zabeleženi su sledeći rezultati: herbicidi Kambio SL (320 g/l bentazon + 90 g/l dikamba) – 1250 ml/ha; Kalam (125 g/l tritosulfuron + 600 g/kg dikamba) – 200 g/ha; Lintur 70 WG (4.1% triasulfuron + 65.9% dikamba) – 150 g/ha i Axial 050EK (50 g/l pinoksaden) – 600 ml/ha su pokazali visoku selektivnost prema pirevini u fazi 3-4 lista tokom godine zasnivanja useva; herbicidi Imaspro (69 g/l fenoksaprop-P-etil+antidot) and Stelar (50 g/l topramezon + 160g/l dikamba) primenjeni u dozi 1000 ml/ha izazvali su fitotoksičnost (ocene od 4 do 6), dok je Termidor (40 g/l nikosulfuron) – 1250 ml/ha potpuno uništio usev (ocena 9); herbicidi Kambio SL, Kalam, Lintur 70WG i Axial 050EK primenjeni u istoj dozi u fazi od prolećnog nicanja do početka izbijanja izdanka u godini produkcije semena imali su visoku selektivnost prema pirevini, tako da se mogu primenjivati u zasadima za produkciju semena bez negativnog uticaja na produktivnost semena. Herbicid Termidor je pokazao veoma visoku fitotoksičnost (ocene od 3 do 7) i sprečio je formiranje generativnih izdanaka.

Ključne reči: *Agropyron desertorum*; herbicidi; semena; suva masa