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After-effect of foliar-applied herbicides for broad-leaved weeds on the primary germ weight of cotton seeds (*Gossypium hirsutum* L.)

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Abstract: *The trial was carried out during 2013-2015, with twelve cotton cultivars (Gossypium hirsutum L.). Influence of herbicides Bazagran 480 SL (bentazone)- 1.5 L/ha, Pulsar 40 (imazamox) - 1.2 L/ha and Express 50 VG (tribenuron-methyl) - 50 g/ha was studied. These herbicides were used during the budding stage of cotton. From the viewpoint of cotton growing technology, technologically the most valuable are cultivars Helius, Trakia, Viki, Filipopolis, Boyana, Avangard, Natalia, Darmi, Dorina and Nelina, in foliar treatment with herbicide Bazagran 480 SL. Technologically the most valuable are cultivars Chirpan-539, Helius, Viki, Boyana and Natalia in foliar treatment with herbicide Pulsar 40. Technologically the most valuable are cultivars Helius, Trakia, Viki and Nelina in foliar treatment with herbicide Express 50 VG. These variants combine high primary germ weight and high stability of this index during the different years.*

Keywords: cotton, herbicides, foliar treatment, cultivars, primary germ weight

Introduction

Cotton is a crop characterized by long vegetation period and a poor competitive ability to weeds. Because of this, it is highly sensitive to weed spread from the earliest stages of its development. Problems with primary weed spread in cotton are solved to a considerable extent (Hakoomat, 2005; Chachalis and Galanis, 2007; Kahramanoglu and Uygur, 2010). Chemical control is the most effective method of weed control in cotton (Saldzhiev et al., 2008; Delchev, 2015). The issue of secondary weed spread of annual and perennial graminaceous weeds during cotton vegetation is also solved to a great extent by using antigraminaceous herbicides (Boz, 2000; Bukun, 2005; Cardoso, 2011; Jiang, 2012). In the application of vegetative antibroadleaved herbicides in conventional technology, there are often manifestations of phytotoxicity (Barakova and Delchev, 2016; Barakova, 2017).

Effective and selective vegetative herbicides for cotton are still being sought. There is insufficient research on their impact on the sewing characteristics of cotton seeds. The scientific literature does not have enough information on these issues. The aim of this research is to investigate the after-effect of foliar-applied herbicides for broad-leaved weeds on the primary germ weight of cotton seeds (*Gossypium hirsutum* L.).

Material and methods

The trial was carried out during 2013-2015, with twelve cotton cultivars - Chirpan-539, Helius, Trakia, Viki, Filipopolis, IPK-Veno, Boyana, Avangard, Natalia, Darmi, Dorina and Nelina (*Gossypium hirsutum* L.). The experiment was conducted under the block method, in 4 repetitions; the size of the crop plot was 20 m^2. For the control was used the standard for Bulgaria cultivar Chirpan-539.

Influence of herbicides Bazagran 480 SL (bentazone) – 1.5 L/ha, Pulsar 40 (imazamox) – 1.2 L/ha and Express 50 VG (tribenuron-methyl) 50 g/ha was studied. These herbicides were used during the budding stage of cotton. These foliar herbicides were applied after the herbicidal combination Dual gold 960 EC (S-metholahlor) – 1.2 L/ha + Goal 2 E (oxifluorfen) – 1.2 L/ha, which was applied after sowing before emergence for controlling primary weed infestation in cotton. Spraying is done with a knapsack sprayer with a working solution 300 l/ha.

The primary germ weight of cotton seeds was investigated. The index was reported in grams (g). The primary germ weight was reported for 100 seeds per each variant (25 seeds per 1 replication) of twelve cultivars of cotton. The seeds were taken from cotton plants treated during the vegetation with the respective herbicides. Primary germ weight was reported on day 7.

The math processing of the data was done according to the method of analysis of variance (Shanin 1977; Barov, 1982; Lidanski 1988). The stability of herbicides and cultivars for the primary germ weight with relation to years was estimated using the stability variances σi^2 and Si^2 of Shukla (1972), the ecovalence Wi of Wricke (1962) and the stability criterion YSi of Kang (1993).

Results and discussion

Secondary weed infestation with annual and perennial broadleaf weeds is a huge problem for the cotton fields. To combat these weeds 3-4 times of hoeing is done. They are very heavy, labor intensive, and greatly increase the cost of cotton production. Until now, this has made conventional cotton production unprofitable and it could not compete with cheap GMO cotton produced in the major cotton-producing countries outside Europe. We carried out a significant number of studies to find cotton cultivars resistant to foliar-applied antibroadleaf herbicides. For the first time in the world, cotton cultivars resistant to herbicides Basagran 480 SL (bentazone), Pulsar 40 (imazamox) and Express 50 VG (tribenuron-methyl) have been established. These cultivars are Bulgarian

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and have been created in the Field Crops Institute, Chirpan. They produce high and stable yields of raw cotton, cotton fiber and cotton seeds over the years (Barakova and Delchev, 2016; Barakova, 2017). The use of the herbicides bentazone, imazamox and tribenuron-methyl in cotton provides complete control of late spring annual broadleaf weeds *Xanthium strumarium* L., *Amaranthus retroflexus* L., *Amaranthus albus* L., *Amaranthus blifoides* W., *Chenopodium album* L., *Solanum nigrum* L., *Datura stramonium* L., *Polygonum aviculare* L., *Abutilon teophrasti* Medic., *Portulaca oleracea* L., *Polygonum aviculare* L., *Hibiscum trionum* L., *Tribulus terrestris* L.

The herbicides imazamox and tribenuron-methyl also provide complete control of the perennial broadleaf weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L. (Barakova, 2017). The obtained results are of great importance not only for Bulgaria and Romania, but also for the other countries producing cotton in the European Union - Greece, Italy, Spain and Portugal, who cannot use genetically modified cotton cultivars. This requires a study of the quality indicators of the fiber and seeds of these genetically improved cultivars resistant to herbicides.

The herbicide Bazagran 480 SL applied during cotton vegetation, mean for the investigated period, has the highest phytotoxicity on the primary germ weight of the seeds from cultivar IPK-Veno (Table 1). In this herbicide is measured lower value of the indicator compared to the other cultivars – 5.3g. The lowest is the action of Bazagran on cultivars Natalia – 9.0g and Darmi – 8.0g. This is due to the smaller phytotoxicity of the herbicide on the primary germ weight of these cultivars. Cultivar IPK-Veno is characterized as the most sensitive to the herbicide Bazagran 480 SL and cultivars Natalia and Darmi - the most resistant to this herbicide.

Table 1. After-effect of foliar-applied herbicides for broad-leaved weeds on the primary germ weight of cotton seeds, g (2013-2015)

Herbicides	Cultivars	2013	2014	2015	Mean
Bazagran 480 SL	Chirpan-539	6.4	6.5	3.8	5.6
	Helius	7.0	7.1	5.6	6.6
	Trakia	7.0	6.9	4.3	6.1
	Viki	6.7	6.8	4.8	6.1
	Filipopolis	8.3	8.4	4.2	7.0
	IPK-Veno	6.2	6.3	3.3	5.3
	Boyana	8.3	8.4	5.5	7.4
	Avangard	9.0	9.1	4.7	7.6
	Natalia	1.,0	1.,3	6.7	9.0
	Darmi	9.5	9.8	4.6	8.0
	Dorina	7.3	7.4	5.5	6.7
	Nelina	8.5	8.6	2.4	6.5
Pulsar 40	Chirpan-539	7.2	7.3	6.1	6.9
	Helius	7.0	6.9	4.6	6.2
	Trakia	6.5	6.4	3.9	5.6
	Viki	7.7	7.8	4.9	6.8
	Filipopolis	4.3	4.2	2.8	3.8
	IPK-Veno	6.0	6.8	5.0	5.9
	Boyana	7.0	7.1	4.3	6.1
	Avangard	5.8	5.8	2.2	4.6
	Natalia	8.0	8.4	3.4	6.6
	Darmi	6.0	6.2	4.3	5.5
	Dorina	3.6	3.6	3.0	3.4
	Nelina	5.0	2.3	5.1	4.1
Express 50 VG	Chirpan-539	6.3	6.4	3.5	5.4
	Helius	8.0	8.5	5.2	7.2
	Trakia	8.1	8.6	5.3	7.3
	Viki	6.7	6.7	4.7	6.0
	Filipopolis	5.5	5.5	4.0	5.0
	IPK-Veno	5.5	5.4	3.9	4.9
	Boyana	6.7	6.8	3.0	5.5
	Avangard	6.3	6.3	5.2	5.9
	Natalia	7.0	6.9	3.9	5.9
	Darmi	5.3	4.2	5.3	4.9
	Dorina	6.3	6.4	5.6	6.1
	Nelina	7.0	7.3	4.9	6.4

*LSD, g:

F.A	p≤5%=0.07	p≤1%=0.09	p≤0.1%=0.1
F.B	p≤5%=0.07	p≤1%=0.09	p≤0.1%=0.1
F.C	p≤5%=0.1	p≤1%=0.2	p≤0.1%=0.3
AxB	p≤5%=0.1	p≤1%=0.2	p≤0.1%=0.3
AxC	p≤5%=0.2	p≤1%=0.3	p≤0.1%=0.4
BxC	p≤5%=0.2	p≤1%=0.3	p≤0.1%=0.4
AxBxC	p≤5%=0.4	p≤1%=0.6	p≤0.1%=0.7

The herbicide Pulsar 40 has the highest phytotoxicity on the primary germ weight of the seed from cultivars Dorina – 3.4g and Filipopolis – 3.8g. Tested cultivars are defined as the most sensitive to this herbicide. Cultivars Chirpan-539 and Viki have the biggest primary germ weight compared to the other cultivars, respectively 6.9g and 6.8g. Pulsar influences these cultivars less.

The herbicide Express 50 VG has the highest phytotoxicity on the primary germ weight of the seed from cultivars Darmi and IPK-Veno – 4.9g. Cultivars Helius and Trakia have the biggest primary germ weight, respectively 7.2g and 7.3g. Express influences these cultivars less. Cultivars Darmi and IPK-Veno are the most sensitive to this herbicide in terms of the primary germ weight.

Analysis of variance for the primary germ weight of cotton seeds (Table 2) shows that years have influence on the primary germ weight – 41.3% of the variants. The reason for this are the different meteorological conditions during the years of investigation. The strength of influence of herbicides is 9.9% and the strength of influence of cultivars is 9.2%. The influence of years, of herbicides and of cultivars is very well proven at p≤0.01. There is an interaction between herbicides and meteorological conditions of years (AxB) – 2.8 %, between cultivars and meteorological conditions of years (AxC) – 3.2%, and between cultivars and herbicides (BxC) – 21.5%. They are very well proven at p≤0.1. There is interaction between the three experiment factors (AxBxC) – 10.8%. It is also very well proven at p≤0.1.

Table 2. Analyses of variance for after-effect of foliar-applied herbicides for broad-leaved weeds on the primary germ weight of cotton seeds

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean square
Total	215	690.2	100	-
Tract of land	1	4.2	0.6	4.2***
Variants	107	681.0	98.7	6.4***
Factor A - Years	2	284.9	41.3	142.4***
Factor B - Herbicides	2	68.7	9.9	34.3***
Factor C - Cultivars	11	63.7	9.2	5.8***
AxB	4	17.9	2.8	4.5***
AxC	22	22.4	3.2	1.0***
BxC	22	148.6	21.5	6.8***
AxBxC	44	74.8	10.8	1.7***
Pooled error	107	5.0	0.7	0.05

*p≤5%;**p≤1%; ***p≤0.1%

This shows that the meteorological conditions during cotton growing affect both the cotton yield (Barakova, 2017) and the primary germ weight. This should be taken into account when these seeds are used for sowing.

Based on proven herbicide x year interaction and cultivar x year interaction, stability parameters for each variant for primary germ weight of cotton seeds with relation to years were evaluated (Table 3). The stability variances σi^2 and Si^2 of Shukla, the ecovalence Wi of Wricke and the stability criterion YSi of Kang were calculated.

Stability variances (σi^2 and Si^2) of Shukla, which recorded respectively linear and nonlinear interactions, unidirectionally evaluate the stability of the variants. These variants which showed lower values are considered to be more stable because they interact less with the environmental conditions. Negative values of the indicators σi^2 and Si^2 are considered 0. At high values of either of the two parameters - σi^2 and Si^2, the variant is regarded to be unstable. At the ecovalence Wi of Wricke, the higher the values of the index, the more unstable the variant.

On this basis, using the first three parameters of stability, it is found that in foliar treatment with herbicide Bazagran 480 SL stable are cultivars Chirpan-539, Trakia, Viki, IPK-Veno and Boyana. In treatment with herbicide Pulsar 40 stable are cultivars Trakia, Viki, Boyana and in treatment with herbicide Express 50 VG stable are cultivars Chirpan-539, Viki and Nelina. Other variants have high instability - values of stability variance σi^2 and Si^2 of Shukla and ecovalence Wi of Wricke are the highest and mathematically proven. The reason for this high instability is greater variation in primary germ weight during years of experiment as weather conditions affect those most. At part of them there is instability of linear and nonlinear type - proven values σi^2 and Si^2. In another part of them, instability is of linear type - proven values σi^2, the values of Si^2 are not proven.

To evaluate the complete efficacy of each herbicide both its effect on primary germ weight of cotton seeds and its stability - the reaction of cotton to this variant during the years should be considered. Valuable information about the value of the technological value of the variant gives the stability criterion YSi of Kang for simultaneous assessment of weight of the primary germ and stability, based on the reliability of the differences in yield and variance of interaction with the environment. The value of this criterion is manifested that by using nonparametric methods and warranted statistical differences we get a summary assessment aligning variants in descending order according to their economic value.

Table 3. Stability parameters for the variants for after-effect of foliar-applied herbicides for broad-leaved weeds on the primary germ weight of cotton seeds with relation to years

Herbicides	Cultivars	$\bar{x}$	σ_i^2	S_i^2	W_i	YS_i
Bazagran 480 SL	Chirpan-539	5.6	-0.02	-0.03	0.06	9
	Helius	6.6	0.6**	0.06	1.3	20+
	Trakia	6.1	-0.09	0.04	0.07	19+
	Viki	6.1	0.1	0.02	0.3	20+
	Filipopolis	7.0	2.0**	-0.01	3.9	25+
	IPK-Veno	5.3	0.1	-0.06	0.4	5
	Boyana	7.4	0.07	-0.05	0.2	36+
	Avangard	7.6	2.5**	-0.01	4.9	29+
	Natalia	9.0	0.7**	0.07	1.5	31+
	Darmi	8.0	4.8**	0.07	9.2	30+
	Dorina	6.7	0.2*	0.03	0.5	26+
	Nelina	6.5	9.7**	-0.03	18.4	19+
Pulsar 40	Chirpan-539	6.9	1.1**	0.09	2.2	24+
	Helius	6.2	-0.03**	0.04	0.02	23+
	Trakia	5.6	-0.03	0.04	0.02	10
	Viki	6.8	0.07	-0.05	0.2	31+
	Filipopolis	3.8	0.6**	0.03	1.3	-9
	IPK-Veno	5.9	1.0**	0.6**	2.1	5
	Boyana	6.1	0.02	-0.04	0.4	22+
	Avangard	4.6	0.9**	-0.08	1.8	-7
	Natalia	6.6	4.0**	0.1	7.6	21+
	Darmi	5.5	0.3**	0.03	0.6	-1
	Dorina	3.4	2.3**	-0.08	5.0	-10
	Nelina	4.1	14.5**	7.6**	27.5	-8
Express 50 VG	Chirpan-539	5.4	0.07	-0.05	0.2	6
	Helius	7.2	0.3**	0.2*	0.7	26+
	Trakia	7.3	0.3**	0.2*	0.7	27+
	Viki	6.0	0.08	-0.08	0.3	16+
	Filipopolis	5.0	0.6**	-0.08	1.2	-4
	IPK-Veno	4.9	0.5**	0.03	1.1	-6
	Boyana	5.5	1.1**	-0.01	2.3	-1
	Avangard	5.9	1.2**	-0.08	2.4	5
	Natalia	5.9	0.2*	0.05	0.5	9
	Darmi	4.9	6.9**	1.2**	13.1	-5
	Dorina	6.1	2.0**	0.03	3.8	13
	Nelina	6.4	0.02	0.08	0.1	25+

Generalized stability criterion YSi of Kang, taking into account both the stability and value of primary germ weight, gives a negative assessment of cultivars Filipopolis, Avangard, Darmi, Dorina and Nelina, treated by Pulsar 40, and Filipopolis, IPK-Veno, Boyna, Darmi treated by Express 50 SX. They are characterized as the most unstable and with low values.

None of these cultivars receive negative evaluation in foliar treatment with herbicide Bazagran 480 SL. According to this criterion, the most valuable technologically appear to be cultivars Helius, Trakia, Viki, Filipopolis, Boyana, Avangard, Natalia, Darmi, Dorina and Nelina in foliar treatment with herbicide Bazagran. The most valuable technologically appears cultivars Chirpan-539, Helius, Viki, Boyana and Natalia in foliar treatment with herbicide Pulsar. Cultivars Helius, Trakia Viki, and Nelina have the highest evaluation in foliar treatment with herbicide Express. They combine relatively high primary germ weights of cotton seeds with high stability during the different years of the investigation.

Conclusion

It was found that: a) herbicide Bazagran 480 SL has the highest phytotoxicity on the primary germ weight of seeds of cotton cultivar IPK-Veno and the lowest on cultivars Natalia and Darmi; b) herbicide Pulsar 40 has the highest phytotoxicity on the primary germ weight of seeds of cotton cultivars Filipopolis and Dorina and the lowest on cultivars Chirpan-539 and Viki; c) herbicide Express 50 VG has the highest phytotoxicity on the primary germ weight of seeds of cotton cultivars Darmi and IPK-Veno and the lowest on cultivars Helius and Trakia; d) from

the viewpoint of cotton growing technology, technologically the most valuable are cultivars Helius, Trakia, Viki, Filipopolis, Boyana, Avangard, Natalia, Darmi, Dorina and Nelina, in foliar treatment with herbicide Bazagran 480 SL; technologically the most valuable are cultivars Chirpan-539, Helius, Viki, Boyana and Natalia in foliar treatment with herbicide Pulsar 40; technologically the most valuable are cultivars Helius, Trakia, Viki and Nelina in foliar treatment with herbicide Express 50 VG; these variants combine high primary germ weight and high stability of this index during the different years.

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