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EFFECT OF SOME HERBICIDES AND THEIR MIXTURES WITH GROWTH REGULATOR AND FOLIAR FERTILIZER ON FAT CONTENT IN COTTON (*GOSSYPIUM HIRSUTUM* L.) SEEDS

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Abstract

The research was conducted during 2013-2015 with two cotton cultivars - Helius and Darmy (*Gossypium hirsutum* L.). It was investigated five herbicides: Goal 2 E (oxyfluorfen) - 800 ml/ha; Linuron 45 SC (linuron) – 2 l/ha; Wing-P (pendimethalin + dimethenamid) – 4 l/ha; Merlin 750 WG (isoxaflutol) - 50 g/ha; Bazagran 480 SL (bentazone) – 1.5 l/ha. They were treated separated or combined with growth regulator Amalgerol 5 l/ha or foliar fertilizer Lactofol O – 8 l/ha in the budding stage of the cotton. It has been found that investigated herbicides and their combinations with growth regulator and foliar fertilizer do not have a phytotoxic effect on the fat content of the cotton seed cultivar Helius. These herbicides and tank mixtures reduce the fat content in the seeds of cultivar Darmy. The decrease is greatest in the Linuron 45 SC herbicide and its combination with Amalgerol. For the first time, it has been established that, from the point of view of the technology for cotton growing of cultivar Helius, technologically the most valuable are all herbicides and their combinations with growth regulator and foliar fertilizer. Technologically the most valuable in cotton cultivar Darmy are tank mixtures of herbicides Wing-P and Bazagran 480 SL with growth regulator Amalgerol. They combine high values and high stability of fat content in cotton seed during different years. The alone use of herbicide Linuron 45 CK and its combination with Amalgerol receives negative assessments and should be avoided. The most economically effective are tank mixtures of herbicides Wing-P and Bazagran 480 SL with growth regulator Amalgerol.
Keywords: Cotton, foliar-applied herbicides, growth regulator, foliar fertilizer, fat content.

1. 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.

In cotton growing, weed control is critical to yield and production quality (Stoychev, 2010). Problems with primary weed spread in cotton are solved to a considerable extent (Chachalis and Galanis, 2007; Cardoso, 2011). 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 (Gao, 2005).

A problem with modern cotton growing is the secondary wed infestation (Boz, 2000; Nikolova, 2001; Economou, 2005: Gozgu and Uludag, 2005). Data on herbicides for efficient control of secondary emerging annual and perennial broadleaf weeds in conventional cotton growing technology are rather scarce even on a global scale. Effective herbicides for their control in cotton are still being sought. In the application of vegetative antibroadleaved herbicides in conventional technology, there are often manifestations of phytotoxicity (Barakova and Delchev, 2016; Barakova, 2017).

Information on glyphosate-tolerant and glufosinate-tolerant cotton cultivars is presented (Gaylon et al., 2015; Spielman et al., 2015). In them control of all weeds – graminaceous and broadleaf, annual and perennial is completely solved by the use of total herbicides based on glyphosate (Roundup Ready technology) or glufosinate (Liberty Link technology). These two technologies are widely used in major cotton-producing countries. However, these cultivars are GMOs and are banned within the territory of the European Union. This makes the present study particularly relevant for all cotton producing countries within the European Union.

Cotton is one of the most valuable oil crops in the world.The seeds of cotton are quite rich in fat - 17-23%. Cotton oil is one of the most important semi-dry oils in the world used for alimentary and technical purposes.Worldwide, there are many studies on the fat content in cotton seed, its quality and its purpose (Ataullaev et al., 1982; Constantin, 2007; Saldzhiev et al., 2008; Saldzhieva et al., 2009; Uzunova G., 2008). Scientific literature does not yet know whether treatment with herbicides during cotton growing affects the fat content of cotton seeds.

The purpose of this study is to investigate the effect of vegetative treatment with some herbicides and their mixtures with growth regulator and foliar fertilizer on the fat content of seeds of two Bulgarian cottoncultivars.

2. Materials and Methods

In the period 2013-2015 a field experiment was carried out in the experimental field of the Field Crops Institute, Chirpan, under non-irrigated conditions of a soil type leached vertisol with two Bulgarian cotton cultivars - Helius and Darmy (*Gossypium hirsutum* L.). The experiment is based on the block method in 4 replications with a plot size of 20 m^2.

Table 1. Investigated Herbicides and Herbicide Combinations

№	**Variants**	**Active Substance**	**Doses**
1	no treated control	-	-
2	economic control	-	-
3	Goal 2 E	oxifluorfen	800 ml/ha
4	Linuron 45 SC	linuron	2 l/ha
5	Wing-P	pendimethalin + dimethenamid	4 l/ha
6	Merlin 750 WG	izoxaflutole	50 g/ha
7	Basagran 480 SL	bentazone	1.5 l/ha
8	Amalgerol	growth regulator	5 l/ha
9	Goal 2 E + Amalgerol	oxifluorfen + growth regulator	800 ml/ha + 5 l/ha
10	Linuron 45 SC + Amalgerol	linuron + growth regulator	2 l/ha + 5 l/ha
11	Wing-P + Amalgerol	pendimethalin + dimethenamid + growth regulator	4 l/ha + 5 l/ha
12	Merlin 750 WG + Amalgerol	izoxaflutole + growth regulator	50 g/ha + 5 l/ha
13	Basagran 480 SL + Amalgerol	bentazone + growth regulator	1.5 l/ha + 5 l/ha
14	Lactofol O	foliar fertilizer	8 l/ha
15	Goal 2 E + Lactofol O	oxifluorfen + foliar fertilizer	800 ml/ha + 8 l/ha
16	Linuron 45 SC + Lactofol O	linuron + foliar fertilizer	2 l/ha + 8 l/ha
17	Wing-P + Lactofol O	pendimethalin + dimethenamid + foliar fertilizer	4 l/ha + 8 l/ha
18	Merlin 750 WG + Lactofol O	izoxaflutole + foliar fertilizer	50 g/ha + 8 l/ha
19	Basagran 480 SL + Lactofol O	bentazone + foliar fertilizer	1.5 l/ha + 8 l/ha

In both cultivars five herbicides were studied - Goal 2 E, Linuron 45 SC, Wing P, Merlin 750 WG and Basagran 480 SL They were applied both individually and in combinations of each of them with the growth regulator Amalgerol and the foliar fertilizer Lactofol O applied during bud formation phase of cotton. The active substances of the herbicides and the treatment dosages are given in Table 1.

The applied herbicides are applied against the background of the herbal combination Dual gold 960 EC 1.2 l/ha + Goal 2 E – 1.5 l/ha applied after sowing pre-emergence for control of primary weed spread in cotton. Spraying was done with hand back sprayer with working solution of 300 l/ha. Weeds in the economic control were removed by digging - 3 times during cotton vegetation.

Fat content in cotton seeds was determined by extraction - SR ISO 6492. The seeds were taken from cotton treated during vegetation with the relevant herbicides.

The math processing of the data was done according to the method of analyses of variance (Shanin 1977; Barov, 1982; Lidanski, 1988). The stability of herbicides and tank mixtures for fat content in cotton seeds with relation to years was estimated using the stability variances σ_i^2 and S_i^2 of Shukla (1972), the ecovalence W_i of Wricke (1962) and the stability criterion YS_i of Kang (1993).

3. Results and Discussion

None of herbicides has any phytotoxic effect on the fat content of cottonseed in cultivar Helius average for the period of study.They account for values around and above that of the commercial control where the fat content is measured - 29.8% (see Table 2). The highest is the fat content of the seeds in the herbicides Linuron 45 SC and Basagran 480 SL - 31.4 %.

In their combinations with growth regulator and foliar fertilizer, the same tendency is observed. All herbicidal mixtures show values exceeding those of the commercial control. The exception is the Merlin 750 WG + Lactofol O combination, which measures a value close to the control - 29.2 %.

In cultivar Darmy, all herbicides and herbicide combinations have a phytotoxic effect on the fat content of the seeds. The measured values are lower than those of the economic control - 30.7 %. The most phytotoxic effect on this indicator is the Linuron 45 CK - 22.5 % herbicide, and its combination with Amalgerol - 22.3 %. In alone use of herbicide Merlin 750 WG, it also accounts for a lower value than the economic control and another herbicides - 25.6 %. The highest fat content in the seeds is measured with the herbicide Goal 2 E - 29.1% and tank mixtures Wing-P + Amalgerol - 29.6 % and Basagran + Amalgerol - 29.3 %. This indicates that they have a poor phytotoxic effect on the indicator.

The growth regulator Amalgerol lowers the phytotoxicity of Merlin 750 WG compared with alone use in cultivar Darmy. In combination Merlin + Amalgerol account of fat content in seeds - 28.0 %. But Amalgerol does not reduce the phytotoxic effect of the Linuron 45 SC herbicide. Combination Linuron + Amalgerol has a strong phytotoxic effect on the fat content of the seeds.

The foliar fertilizer Lactofol O reduces the phytotoxic effect of herbicides Linuron 45 CK and Merlin 750 WG in cultivar Darmy compared to the alone use of these two herbicides. The values for Linuron + Lactofol O - 27.3 % and Merlin + Lactofol O - 27.2 % are reported, which are also the highest of all herbicide combinations with Lactofol O.

In cultivar Helius, the herbicides and herbicide combinations applied during its vegetation do not have a phytotoxic effect on the fat content of the seeds. In cultivar Darmy each of the herbicides and herbicidal mixtures act phytotoxically to a lesser or greater extent on this index. These results show cultivar’s sensitivity. This is proved by the analyses of the variance for fat content.

The variance analysis with regard to fat content in cotton seeds (see Table 3) established that herbicides and herbicide combinations have the greatest impact on that indicator – 42.9 % of the total variation. The reason for this is the phytotoxic action of some of the herbicides on cotton plants during vegetation. Cultivars also have great influence – 27.6 %, which is due to the different genetic origin of the two cotton cultivars - Helius and Darmy. The power of effect of years is 1.0 %. The effect of years, cultivars and herbicides is very well demonstrated at $p \leq 0.1$. There is proven interaction of varieties with the conditions of years (AxB) – 2.6 % and of cultivars with preparations (BxC) – 20.6 %. They are very well proven at $p \leq 0.1$. The effect of years with herbicides (AxC) is 1.1 % and is not proven. There is an interaction among the three factors in the experiment (AxBxC) - 1.1 %. It is also not proven.

Table 2. Fat Content in Cotton Seeds of Vegetation Treatment with Herbicides, % (2013-2015)

Cultivars	Variants	2013	2014	2015	Mean
Helius	no treated control	27.3	26.3	27.3	26.9
	economic control	29.5	29.5	30.5	29.8
	Goal 2 E	29.4	29.4	30.4	29.7
	Linuron 45 SC	31.1	31.1	32.1	31.4
	Wing-P	30.3	30.4	31.4	30.7
	Merlin 750 WG	29.2	29.2	30.2	29.5
	Basagran 480 SL	31.1	31.2	32.1	31.4
	Amalgerol	30.5	30.5	31.5	30.8
	Goal 2 E + Amalgerol	30.8	30.8	31.8	31.2
	Linuron 45 SC + Amalgerol	31.7	31.7	32.7	32.0
	Wing-P + Amalgerol	31.4	31.5	32.4	31.8
	Merlin 750 WG + Amalgerol	31.7	31.7	32.7	32.0
	Basagran 480 SL + Amalgerol	31.0	31.0	32.0	31.3
	Lactofol O	31.6	31.6	32.6	31.9
	Goal 2 E + Lactofol O	31.1	31.2	32.1	31.5
	Linuron 45 SC + Lactofol O	29.9	29.9	30.8	30.2
	Wing-P + Lactofol O	30.8	30.8	31.8	31.1
	Merlin 750 WG + Lactofol O	29.2	29.2	29.2	29.2
	Basagran 480 SL + Lactofol O	30.6	30.7	31.6	31.0
Darmy	no treated control	23.9	22.9	22.8	23.2
	economic control	31.3	30.3	30.3	30.7
	Goal 2 E	29.4	29.0	28.9	29.1
	Linuron 45 SC	26.6	20.6	20.3	22.5
	Wing-P	28.2	27.5	27.2	27.6
	Merlin 750 WG	26.2	25.2	25.2	25.6
	Basagran 480 SL	29.3	28.3	28.3	28.6
	Amalgerol	29.9	29.0	28.9	29.3
	Goal 2 E + Amalgerol	29.4	28.4	28.4	28.7
	Linuron 45 SC + Amalgerol	23.0	22.0	22.0	22.3
	Wing-P + Amalgerol	30.3	29.3	29.3	29.6
	Merlin 750 WG + Amalgerol	28.6	27.6	27.6	28.0
	Basagran 480 SL + Amalgerol	30.0	29.0	29.0	29.3
	Lactofol O	29.6	28.6	28.6	28.9
	Goal 2 E + Lactofol O	26.5	25.5	25.5	25.8
	Linuron 45 SC + Lactofol O	27.9	26.9	26.9	27.3
	Wing-P + Lactofol O	26.5	25.5	25.5	25.8
	Merlin 750 WG + Lactofol O	27.8	26.9	26.8	27.2
	Basagran 480 SL + Lactofol O	26.8	25.8	25.8	26.1

LSD, %:

F.A	$p \leq 5\% = 0.2$	$p \leq 1\% = 0.3$	$p \leq 0.1\% = 0.4$
F.B	$p \leq 5\% = 0.2$	$p \leq 1\% = 0.3$	$p \leq 0.1\% = 0.4$
F.C	$p \leq 5\% = 0.5$	$p \leq 1\% = 0.7$	$p \leq 0.1\% = 0.9$
AxB	$p \leq 5\% = 0.3$	$p \leq 1\% = 0.4$	$p \leq 0.1\% = 0.5$
AxC	$p \leq 5\% = 0.9$	$p \leq 1\% = 1.2$	$p \leq 0.1\% = 1.5$
BxC	$p \leq 5\% = 0.7$	$p \leq 1\% = 1.0$	$p \leq 0.1\% = 1.3$
AxBxC	$p \leq 5\% = 1.3$	$p \leq 1\% = 1.7$	$p \leq 0.1\% = 2.2$

Based on the proven interactions cultivar x year and cultivar x herbicide, the stability of manifestations of each variant with respect to fat content in cotton seeds has been evaluated (see Table 4). Shukla's stability variances σ_i^2 and S_i^2, Wricke's ecovalence W_i and Kang's stability criterion YS_i have been calculated.

Table 3.Analyses of Variance for Fat Content

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean squares
Total	455	1695.0	100	-
Tract of land	3	1.0	0.1	1.0
Variants	113	1645.0	97.1	14.6***
Factor A - Years	2	16.4	1.0	8.2***
Factor B - Cultivars	1	730.4	42.9	730.4***
Factor C - Herbicides	18	467.3	27.6	26.0***
AxB	2	44.0	2.6	22.0***
AxC	36	17.9	1.1	0.5
BxC	18	351.8	20.8	19.5***
AxBxC	36	19.1	1.1	0.5
Pooled error	339	47.0	2.8	0.4

*p≤5% **p≤1% ***p≤0.1%

Shukla's stability variances (σ_i^2 and S_i^2), which take into account both linear and non-linear interactions, uniquely assess the stability of the variants. These variants, which show lower values, are considered to be more stable because they interact less with the environmental conditions. The negative values of the indicators σ_i^2 and S_i^2 are assumed to be 0. With reliably high values of either parameter - σ_i^2 or S_i^2, the variants are considered unstable. With Wricke's ecovalence W_i, the higher the values of the indicator, the more unstable the relevant variant.

By using these three stability parameters it has been established that in both cotton cultivars, all of the applied herbicides and herbicide combinations are stable, with the exception of Linuron 45 CK in cultivar Darmy. Herbicide Linuron in Darmy has high instability. In it the values of the Shukla σ_i^2 and S_i^2 stability variances and Wricke's ecovalence W_i are high and mathematically proven. Instability is mainly due to the significant differences in fat content in cotton seed in these variants throughout the years of the experiment, since this herbicide exhibits the most phytotoxic effect on cultivar Darmy. In some of the variants there is instability of linear and non-linear type - proven values of σ_i^2 and S_i^2. In another part, there is only linear type of instability - proven value of σ_i^2, whereas the S_i^2 values are unproven.

In order to make an overall assessment of the effectiveness of each herbicide and herbicide combination, both its effect on fat content and its stability - the reaction of the crop to it throughout the years has to be taken into account. Very valuable information about the technological value of the variants gives Kang's YS_i indicator for simultaneous evaluation of the fat content in seeds and stability based on the reliability of differences in fat content and the variance interaction with the environment. The value of this criterion is that by using non-parametric methods and statistical proof of differences, we obtain generalized assessment ranking the variants in descending order according to their economic value.

The summarizing Kang's stability criterion YS_i, taking into account both stability and fat value in cotton seeds, gives negative assessment of herbicide Linuron and herbicide combinations Linuron + Amalgerol in cultivar Darmy. They are characterized as the most unstable or the most sensitive to herbicides in terms of fat content in cotton seeds. In cultivar Helius, none of the herbicides and herbicide mixtures has negative assessment. According to that criterion, technologically the most valuable in cultivar Helius are all tank mixes except Merlin + Amalgerol.

Table 4. Stability Parameters for the Variants for Fat Content with Relation to Years

Cultivars	Variants	$\bar{x}$	σ_i^2	S_i^2	W_i	YS_i
Helius	no treated control	26.9	0.1	0.06	0.3	5
	economic control	29.8	0.7	1.3	1.4	25+
	Goal 2 E	29.7	0.7	1.3	1.4	24+
	Linuron 45 SC	31.4	0.7	1.3	1.4	35+
	Wing-P	30.7	0.7	1.3	1.4	29+
	Merlin 750 WG	29.5	0.7	1.3	1.4	21+
	Basagran 480 SL	31.4	0.7	1.3	1.4	35+
	Amalgerol	30.8	0.7	1.3	1.4	30+
	Goal 2 E + Amalgerol	31.2	0.7	1.3	1.4	32+
	Linuron 45 SC + Amalgerol	32.0	0.7	1.3	1.4	40+
	Wing-P + Amalgerol	31.8	0.7	1.3	1.4	38+
	Merlin 750 WG + Amalgerol	32.0	0.7	1.3	1.4	40+
	Basagran 480 SL + Amalgerol	31.3	0.7	1.3	1.4	34+
	Lactofol O	31.9	0.7	1.3	1.4	39+
	Goal 2 E + Lactofol O	31.5	0.7	1.3	1.4	37+
	Linuron 45 SC + Lactofol O	30.2	0.7	1.3	1.4	27+
	Wing-P + Lactofol O	31.1	0.7	1.3	1.4	32+
	Merlin 750 WG + Lactofol O	29.2	0.2	-0.04	0.4	18
	Basagran 480 SL + Lactofol O	31.0	0.8	1.5	1.6	31+
Darmy	no treated control	23.2	0.4	0.9	0.8	0
	economic control	30.7	0.3	0.6	0.8	28+
	Goal 2 E	29.1	0.1	0.2	0.3	17
	Linuron 45 SC	22.5	23.5**	27.9**	44.7	-9
	Wing-P	27.6	0.4	0.8	0.8	8
	Merlin 750 WG	25.6	0.3	0.6	0.7	1
	Basagran 480 SL	28.6	0.3	0.6	0.7	12
	Amalgerol	29.3	0.3	0.5	0.5	19
	Goal 2 E + Amalgerol	28.7	0.3	0.6	0.7	13
	Linuron 45 SC + Amalgerol	22.3	0.3	0.6	0.7	-2
	Wing-P + Amalgerol	29.6	0.3	0.6	0.7	23+
	Merlin 750 WG + Amalgerol	28.0	0.3	0.6	0.7	10
	Basagran 480 SL + Amalgerol	29.3	0.3	0.6	0.7	20+
	Lactofol O	28.9	0.3	0.6	0.7	16
	Goal 2 E + Lactofol O	25.8	0.3	0.6	0.7	2
	Linuron 45 SC + Lactofol O	27.3	0.3	0.6	0.7	7
	Wing-P + Lactofol O	25.8	0.3	0.7	0.7	2
	Merlin 750 WG + Lactofol O	27.2	0.3	0.6	0.7	6
	Basagran 480 SL + Lactofol O	26.1	0.3	0.6	0.7	4

Technologically valuable is the alone use of applied herbicides.In cultivar Darmy high obtained herbicide combinations Wing-P + Amalgerol and Bazagran + Amalgerol. They combine high values and high stability with regard to fat content in cotton seeds in different years.The alone use of herbicide Linuron and its combination with Amalgerol have low assessment and they should be avoided.

4. Conclusions

It has been found that investigated herbicides and their combinations with growth regulator and foliar fertilizer do not have a phytotoxic effect on the fat content of the cotton seed cultivar Helius.

These herbicides and tank mixtures reduce the fat content in the seeds of cultivar Darmy.The decrease is greatest in the Linuron 45 SC herbicide and its combination with Amalgerol.

For the first time, it has been established that, from the point of view of the technology for cotton growing of cultivar Helius, technologically the most valuable are all herbicides and their combinations with growth regulator and foliar fertilizer.

Technologically the most valuable in cotton cultivar Darmy are tank mixtures of herbicides Wing-P and Bazagran 480 SL with growth regulator Amalgerol. They combine high values and high stability of fat content in cotton seed during different years.

The alone use of herbicide Linuron 45 CK and its combination with Amalgerol receives negative assessments and should be avoided.

The most economically effective are tank mixtures of herbicides Wing-P and Bazagran 480 SL with growth regulator Amalgerol.

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