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STABILITY OF VEGETATION-APPLIED HERBICIDES AND THEIR MIXTURES WITH COMPLEX FOLIAR FERTILIZER LACTOFOL B AT OIL-BEARING SUNFLOWER BY INFLUENCE OF DIFFERENT METEOROLOGICAL CONDITIONS

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Abstract

During the period 2010 - 2012, on the experimental field of the Field Crops Institute - Chirpan was carried out a field experiment with oil-bearing sunflower (Helianthus annuus L.). It was investigated 18 variants from the three technologies for oil-bearing sunflower growing - conventional (hybrid Arena), ClearField (hybrid Alego) and ExpressSun (hybrid P64LE20). Treatment of complex foliar fertilizer Lactofol B with herbicides Stomp, Raft, Wing and Modown as tank mixtures after soil-applied herbicide Pelican increases the selectivity of these herbicides. The effect of foliar fertilizer Lactofol B is the poorest by combination with herbicides Goal and Pledge. From the viewpoint of conventional technology for growing of oil-bearing sunflower, high rating have tank mixtures of herbicides Wing, Raft, Stomp and Modown with complex foliar fertilizer Lactofol B, followed by tank mixtures of Goal and Pledge with Lactofol B. Technologically the most valuable are herbicide tank mixtures Express + Stratos ultra and Pulsar + Stomp by respectively ExpressSun and ClearField technologies. Herbicides Goal, Stomp, Raft, Wing, Pledge and Modown by self-use without foliar fertilizer Lactofol B is more appropriate to be used as soil-applied herbicides.

Key words: *oil-bearing sunflower, weeds, herbicides, grain yield, stability*

1. INTRODUCTION

A large part of oil-bearing sunflower in the world is grown by ClearField and ExpressSun technologies. There are significant areas in Bulgaria where sunflower still is grown by conventional technology. There are many unsolved problems in this technology about controlling of weeds such *Xanthium strumarium* L., *Cirsium arvense* Scop., *Convolvulus arvensis* L., *Orobanche cumana* Wall., which necessitated the introduction of new ExpressSun and ClearField technologies for growing of oil-bearing sunflower (Valchev et al., 1995, 1995a, 1995b; Simić et al., 2012; Brighenti et al., 2012). Herbicides have influence on both the weeds and on the culture plants. Phytotoxicity on crop plants is explained by the specific reaction of cultivars, based on inherited genetic basis of the cultivar, of different rate of degradation of the herbicide in different cultivars and as well as the growing conditions (Zand et al., 2009).

Foliar fertilizers ensure better physiological development of the plants and increase grain yield (Pavlova et al., 1992; Panayotova, 2005, 2007, 2007a; Panayotova and Vulkova, 2006; Panayotova et al., 2012, 2012a, 2013).

The aim of this study was to investigate the selectivity and stability of group herbicides by conventional technology and their mixtures with complex foliar fertilizer Lactofol B on oil-bearing sunflower under different weather conditions.

2. MATERIALS AND METHODS

During the period 2010 - 2012, on the experimental field of the Field Crops Institute - Chirpan was carried out a field experiment with oil-bearing sunflower (*Helianthus annuus* L.). Experiment was carried out by the block method, in four replications, the size of experiment plot 15 m^2, on the leached vertisol soil type, after predecessor durum wheat. It was investigated 18 variants. Active substances and doses of investigated herbicides are shown at Table 1. Vegetation-applied herbicides by conventional technology was treated after soil-applied herbicide Pelican in dose 250 ml/ha. Pelican applied after sowing before emergence of sunflower against primary weeding by annual graminaceous and broadleaved weeds.

The efficacy and selectivity of the herbicide combinations by the conventional technology are compared to those of the herbicides in the new ClearField and ExpressSun technologies. Because of the low adhesion of the herbicide Pulsar it was used in addition with adjuvant Dash – 500 ml/ha (to be more effective against *Sorghum*

helepense L. and *Cirsium arvense* Scop.) Because of the low adhesion of herbicide express it was used in addition with adjuvant Trend - 0.1 %. All of variants are treated with working solution of 200 l/ha.

Table 1. Investigated variants

№	Variants	Active substance	Doses
Conventional technology – hybrid Brio			
1	Check – weeded	-	-
2	Goal 2 E	oxifluorfen	800 ml/ha
3	Stomp new 330 EK	pendimethalin	4 l/ha
4	Raft 400 SC	oxidiargil	800 ml/ha
5	Wing P	pendimethalin + dimethenamid	4 l/ha
6	Pledge 50 WP	flumioxazin	80 g/ha
7	Modown 4 F	bifenox	1.5 l/ha
8	Lactofol B	*	8 l/ha
9	Goal 2 E+ Lactofol B	oxifluorfen *	800 ml/ha + 8 l/ha
10	Stomp new 330 EK + Lactofol B	pendimethalin *	4 l/ha + 8 l/ha
11	Raft 400 SC + Lactofol B	oxidiargil *	800 ml/ha + 8 l/ha
12	Wing P + Lactofol B	pendimethalin + dimethenamid *	4 l/ha + 8 l/ha
13	Pledge 50 WP + Lactofol B	flumioxazin *	80 g/ha + 8 l/ha
14	Modown 4 F + Lactofol B	bifenox *	1.5 l/ha + 8 l/ha
Clearfield technology – hybrid Neoma			
15	Check – weeded	-	-
16	Pulsar 40 + Stomp new 330 EK	imazamox pendimethalin	1.2 l/ha + 2.3 l/ha
ExpressSun technology – hybrid P64LE19			
17	Check – weeded	-	-
18	Express 50 SX + Stratos ultra	tribenuron-methyl cycloxydim	40 g/ha + 2 l/ha

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All of variants of conventional technology are on herbicide Pelican 50 SC (diflufenikan) - 250 ml/ha, which treated after sowing before emergence of the sunflower.
* Lactofol B - nitrogen in amide, ammonium and nitrate forms, easily absorbable phosphorus and potassium, trace elements, amino acids, physiologically active substances, complexing agent - lactic acid

Variants from conventional technology was carried out with hybrid Brio, variants from ClearField technology was carried out with hybrid Neoma (imitolerant hybrid of hybrid Brio) and variants of ExpressSun technology was carried out with hybrid P64LE19 (tribenuron-methyl tolerant hybrid).

The selectivity of herbicides and herbicide tank mixtures has been established through their influence on seed yield. 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 for seed yield with relation to years was estimated using the stability variances σ_i^2 and S_i^2 of Shukla (1972), the ecovalence Wi of Wricke (1962) and the stability criterion YS_i of Kang (1993).

3. RESULTS AND DISCUSSION

Seed yields are a result from the additive effect of the efficacy and selectivity of investigated herbicides. The highest seed yields were obtained in 2010, when weather conditions were most favorable for the growth and development of oil-bearing sunflower (Table 2). Yields were highly limited in 2011, by unfavorable weather conditions as a result of big drought during the summer months. Significant rainfall fell in May 2012 and created favorable conditions for the development of the sunflower, but the high temperatures during the summer, accompanied by absence of rainfall reduced the part of seed yields.

The highest seed yields by the conventional technology are obtained by tank mixtures of herbicides Raft, Wing, Stomp and Modown with foliar fertilizer Lactofol B - from 18.2 % to 20.2 % over the weeded check. Combinations of Goal and Pledge with Lactofol B have less increase in seed yield respectively 16.9 % and 15.3 %. Seed yields of the conventional hybrid Brio are lower in comparison to the yields of imitolerant hybrid Neoma and tribenuron- methyl tolerant hybrid P64LE19. The main reason for this is the bigger phytotoxicity in the tank mixtures used in the conventional technology with their good efficacy against weeds. The lowest yield increases are obtained by self-use of herbicides Goal, Stomp, Raft, Wing Pledge and Modown without the addition of foliar fertilizer Lactofol B - from 11.4 % to 17.0 %. The main reason for this is the higher phytotoxicity of herbicides in their self-use.

A comparison of herbicides by conventional technology is showed that yields are highest by tank mixtures of Raft and Wing with Lactofol B. They are the result, by one hand of the good efficacy of these herbicides against graminaceous and broadleaved weeds and by the other hand - of the increased selectivity of Raft and Wing as a result of the addition to them of complex foliar fertilizer Lactofol B.

The highest seed yield are obtained by using ClearField technology - treatment of hybrid Neoma with herbicide combination Pulsar + Stomp - 30.9 % above the weeded check. Immediately after it are the yields by the ExpressSun technology - treatment of hybrid P64LE19 with combination Express + Stratos ultra - 28.6 % over the untreated check. These yields are result from the higher herbicidal efficacy and selectivity of these two herbicidal tank mixtures.

Analysis of variance for seed yield (Table 3) shows that the influence of investigated variants is 76.4 % of the total variability of the data. They are proven at $p \leq 0.1$ %. Years and herbicides have almost the same effect on seed yield. Influence of the years on seed yield is 83.0 % by this of the variants. It is determined by the unequal response of variants to changing in environmental conditions. The power of influence of herbicides and herbicide combinations is 32.6 %. The influences of the years and herbicides are well proven at $p \leq 0.1$ %. There is an interaction of herbicides with the meteorological conditions of year (A x B) – 4.1 %. It is proven at $p \leq 5$ %.

Based on proven year x herbicide interaction, it was evaluated stability parameters for each variant for seed yield of oil-bearing sunflower with relation to years (Table 4). It was calculated the stability variances σ_i^2 and S_i^2 of Shukla, the ecovalence Wi of Wricke and the stability criterion YS_i of Kang.

Stability variances (σ_i^2 and S_i^2) of Shukla, who recorded respectively linear and nonlinear interactions, unidirectional 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 σ_i^2 and S_i^2 are considered 0. At high values of either of the two parameters - σ_i^2 and S_i^2, the variant are regarded as unstable. At the ecovalence Wi of Wricke, the higher are the values of the index, the more unstable is the variant.

On this basis, using the first three parameters of stability, it is found that the most unstable is the variant with self-use of foliar fertilizes Lactofol B without vegetation-applied herbicide, following by untreated, weeded checks of the three technologies – conventional, ClearField and ExpressSun. In Lactofol B values of stability variances σ_i^2 and S_i^2 of Shukla and ecovalence Wi of Wricke are the highest and mathematically proven. These results indicate that foliar fertilization of the sunflower with Lactofol B should not be done by the presence of weeds. It stimulates the growth of weeds, which further depress sunflower after end of herbicide effect of soil-applied herbicide Pelican.

Table 2. Influence of some vegetation-applied herbicides and their tank-mixtures with complex foliar fertilizer Lactofol B on seed yield of sunflower (2010 - 2012)

Factor A / Factor B		2010		2011		2012		Mean (Factor B)	
		kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Conventional technology – hybrid Brio									
Check – weeded		2211	100	1870	100	1958	100	2013	100
Pelican 50 SC - ASBE	Goal 2 E	2631	119.0	2192	117.2	2246	114.7	2356	117.0
	Stomp new 330 EK	2481	112.2	2072	110.8	2175	111.1	2243	111.4
	Raft 400 SC	2596	117.4	2169	116.0	2252	115.0	2338	116.1
	Wing P	2532	114.5	2106	112.6	2222	113.5	2287	113.6
	Pledge 50 WP	2571	116.3	2147	114.8	2232	114.0	2317	115.1
	Modown 4 F	2501	113.1	2107	112.7	2158	110.2	2255	112.0
	Lactofol B	2401	108.6	1973	105.5	2075	106.0	2150	106.8
	Goal 2 E+ Lactofol B	2631	119.0	2188	117.0	2252	115.0	2354	116.9
	Stomp new 330 EK + Lactofol B	2611	118.1	2231	119.3	2305	117.7	2382	118.3
	Raft 400 SC + Lactofol B	2689	121.6	2237	119.6	2334	119.2	2420	120.2
	Wing P + Lactofol B	2689	121.6	2252	120.4	2320	118.5	2420	120.2
	Pledge 50 WP + Lactofol B	2582	116.8	2152	115.1	2226	113.7	2320	115.3
	Modown 4 F + Lactofol B	2647	119.7	2201	117.7	2289	116.9	2379	118.2
Clearfield technology – hybrid Neoma									

Check – weeded	2200	100	1881	100	2003	100	2028	100
Pulsar 40 + Stomp new 330 EK	3000	136.4	2380	126.5	2525	126.0	2635	130.9
ExpressSun technology – hybrid P64LE19								
Check – weeded	2222	100	1831	100	2022	100	2025	100
Express 50 SX + Stratos ultra	3002	135.1	2307	126.0	2503	123.8	2604	128.6
Mean (Factor A)	2567	-	2128	-	2224	-	-	

LSD, kg/ha:

F. A p≤5%=128 p≤1%=137 p≤0.1%=148

F. B p≤5%=168 p≤1%=190 p≤0.1%=216

A x B p≤5%=218 p≤1%=256 p≤0.1%=302

To evaluate the complete efficacy of each variant should be considered as its effect on seed yield of oil-bearing sunflower and its stability - the reaction of sunflower to this variant during the years. Valuable information about the value of technologic value of the variant give the stability criterion YS_i of Kang for simultaneous assessment of yield and stability, based on the reliability of the differences in yield and variance of interaction with the environment. Synthesis stability criterion YS_i of Kang, taking into accounts both the stability and value of yields gives a negative assessment only of untreated, weeded checks of the three technologies for oil-bearing sunflower growing, characterizing them as the most unstable and low yields.

Table 3. Analysis of variance for seed yield

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean square
Total	161	138094	100	-
Tract of land	2	27053	19.6	13526.5***
Variants	53	105396	76.4	1988.6***
Factor A - Years	2	57504	39.7	28752.0***
Factor B – Herbicides	17	45083	32.6	2651.9***
A x B	34	2809	4.1	82.6*
Pooled error	106	5645	4.0	53.3

*p≤5% **p≤1% ***p≤0.1%

According to this criterion, the most valuable technology appears ClearField and ExpressSun technologies, respectively herbicide tank mixtures Pulsar + Stomp and Express + Stratos ultra. These tank mixtures combine high levels of seed yield and high stability of this index during the years.

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From the viewpoint of conventional technology for oil-bearing sunflower growing, high rating also have tank mixtures of herbicides Wing, Raft, Stomp and Modown with complex foliar fertilizer Lactofol B, followed by that of Goal and Pledge with Lactofol B. Despite the high efficacy of herbicides against weeds, these variants have lower rating in competition of variants Pulsar + Stomp and Express + Stratos ultra because of high phytotoxicity of these six herbicides. Variants with self-use of Goal, Raft and Pledge gets lower ratings due to their higher phytotoxicity.

Herbicides Stomp, Wing and Modown without foliar fertilizer Lactofol B get low ratings. They are ineffective against broadleaved weeds *Xanthium strumarium* L., *Cirsium arvense* Scop. and *Convolvulus arvensis* L. although their high selectivity.

The results for the technological value of herbicides Goal, Stomp, Raft, Wing, Pledge and Modown show that it is more appropriate to be used as soil-applied herbicides. Vegetation use of these herbicides, on basis soil use of herbicide Pelican after sowing before emergence period is only recommended when sowed conventional sunflower hybrid, but later become secondary weeding by annual and perennial broadleaved weeds. Vegetation treatment with these herbicides should be done in extreme cases only. When such treatment is necessary, it must be combined with foliar fertilizer Laktofol B. Treatment of this complex foliar fertilizer at a dose of 8 l/ha as tank mixtures with herbicide Stomp, Raft, Wing and Modown (but without Goal and Pledge), helps to reduce phytotoxicity and its faster overcome by the sunflower plants.

4. CONCLUSIONS

Treatment of complex foliar fertilizer Lactofol B with herbicides Stomp, Raft, Wing and Modown as tank mixtures after soil-applied herbicide Pelican increases the selectivity of these herbicides.

The effect of foliar fertilizer Lactofol B is the poorest by combination with herbicides Goal and Pledge.

From the viewpoint of conventional technology for growing of oil-bearing sunflower, high rating have tank mixtures of herbicides Wing, Raft, Stomp and Modown with complex foliar fertilizer Lactofol B, followed by tank mixtures of Goal and Pledge with Lactofol B.

Table 4. Stability parameters for the herbicides for seed yield with relation to years

Variants		$\bar{x}$	σ_i^2	S_i^2	W_i	YS_i
Conventional technology – hybrid Brio						
Check – weeded		2013	194.6*	20.0	377.4	-3
Pelican 50 SC - ASBE	Goal 2 E	2356	15.6	35.8	36.9	13+
	Stomp new 330 EK	2243	7.8	2.1	23.1	3
	Raft 400 SC	2338	-3.1	1.4	3.7	11+
	Wing P	2287	4.2	9.0	16.6	6
	Pledge 50 WP	2317	-3.2	-0.5	3.6	9+
	Modown 4 F	2255	17.5	23.3	40.3	5
	Lactofol B	2150	182.7*	188.3**	1044.4	1
	Goal 2 E+ Lactofol B	2354	16.7	35.5	38.9	12+

	Stomp new 330 EK + Lactofol B	2382	24.7	-6.6	53.2	16+
	Raft 400 SC + Lactofol B	2420	-3.4	-1.7	3.2	18+
	Wing P + Lactofol B	2420	3.0	13.6	14.6	19+
	Pledge 50 WP + Lactofol B	2320	-0.7	7.0	7.9	10+
	Modown 4 F + Lactofol B	2379	-3.3	9.0	3.4	15+
Clearfield technology – hybrid Neoma						
Check – weeded		2028	199.4*	53.9	363.7	-4
Pulsar 40 + Stomp new 330 EK		2635	89.7	52.2	101.9	23+
ExpressSun technology – hybrid P64LE19						
Check – weeded		2025	173.6*	25.1	317.8	-5
Express 50 SX + Stratos ultra		2604	87.1	38.0	99.5	22+

Technologically the most valuable are herbicide tank mixtures Express + Stratos ultra and Pulsar + Stomp by respectively ExpressSun and ClearField technologies.

Herbicides Goal, Stomp, Raft, Wing, Pledge and Modown by self-use without foliar fertilizer Lactofol B is more appropriate to be used as soil-applied herbicides.

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