STABILITY AND SELECTIVITY OF SOME HERBICIDES, HERBICIDE COMBINATIONS AND AN HERBICIDE TANK MIXTURE ON CHICKPEA (*CICER ARIETINUM* L.)

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Abstract. *The research was conducted during 2016 - 2018 on pellic vertisol soil type. Under investigation was chickpea cultivar Kabule (Cicer arietinum L.). Factor A included the years of investigation. Factor B included untreated control and 4 soil-applied herbicides – Dual gold 960 EC (S-metolachlor) - 1.5 l/ha, Stomp aqua (pendimethalin) - 3 l/ha, Merlin flex 480 SC (isoxaflutole) - 420 g/ha and Pelican 50 SC (diflufenikan) - 250 ml/ha. Factor C included untreated control, 3 foliar-applied herbicides – Pulsar 40 (imazamox) - 1.2 l/ha, Challenge 600 SC (aclonifen) - 4 l/ha and Shadow 3 EC (clethodim) - 1.6 l/ha and 1 herbicide tank mixture – Challenge 600 SC (aclonifen) - 4 l/ha + Shadow 3 EC (clethodim) - 1.6 l/ha. Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 6 - 8 real leaf stage of the chickpea. All of herbicides, herbicide combinations and herbicide tank-mixture were applied in a working solution of 200 l/ha. Mixing of foliar-applied herbicides was done in the tank on the sprayer. The highest yields of chickpea seeds are obtained by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Pelican and Merlin flex. High yields are obtained also by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Stomp aqua and Dual gold. Untreated control, herbicide combination Pelican + Pulsar and separated use antigraminaceous herbicide Shadow are the most unstable for seed yield. Combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Merlin flex and Pelican are technological the most valuable. They are followed by combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Stomp aqua and Dual gold. They combine high seed yield with high stability with relation to different years. Separated uses of soil-applied herbicides Pelican, Merlin flex, Stomp aqua and Dual gold, and their combined uses with antigraminaceous herbicide Shadow, and also herbicide combination Pelican + Pulsar have low estimates and do not be used. For complete control of all weeds and self-sown plants in chickpea crops, two herbicides should be combined - both soil-applied and foliar-applied.*

Key words: *chickpea, herbicides, herbicide combinations, seed yield, selectivity, stability*

INTRODUCTION

Chickpea is particularly sensitive to herbicides, and when grown, it is important to take into account their selectivity on chickpea plants and not just their biological efficacy. Weeds have acquired mechanisms to adapt to adverse conditions in its evolutionary. Therefore they are particularly harmful in drought due to their high ecological plasticity and adaptability compared to cultivated plants, and this makes them more competitive (SKROBAKOVA, E. 1998 AND 1999).

When creating a situation is increasingly more often droughts occurs serious problems to be solved (VELASQUEZ AND ALONSO, 1993; DELCHEV, 2018). One of these problems is the question of the efficacy and selectivity, or the behavior of soil-applied and foliar-applied herbicides under these conditions (JEFFERIES ET AL., 2015 AND 2016). It should be given a many factors that determine the effective implementation of these complex organic compounds. Herbicides will remain in future agriculture an effective tool for weed control as part of integrated fight against weeds in chickpea fields, which is why research is necessary to optimize their use (VAISSI AND SHIMI, 2003; SOLTERO-DÍAZ ET AL., 2010; RATNAM AND RAO, 2011).

The purpose of the investigation was to establish the selectivity and stability of some herbicides, herbicide combinations and an herbicide tank mixture on the chickpea by influence of different meteorological conditions.

MATERIALS AND METHODS

The research was conducted during 2016 - 2018 on pellic vertisol soil type. Under investigation was chickpea cultivar Kabule (*Cicer arietinum* L.). Three factors experiment was conducted under the block method, in 4 repetitions; the size of the crop plot was 15 m^2. Factor A included the years of investigation. Factor B included untreated control and 4 soil-applied herbicides – Dual gold 960 EC (S-metolachlor) - 1.5 l/ha, Stomp aqua (pendimethalin) - 3 l/ha, Merlin flex 480 SC (isoxaflutole) - 420 g/ha and Pelican 50 SC (diflufenikan) - 250 ml/ha. Factor C included untreated control, 3 foliar-applied herbicides – Pulsar 40 (imazamox) - 1.2 l/ha, Challenge 600 SC (aclonifen) - 4 l/ha and Shadow 3 EC (clethodim) - 1.6 l/ha and 1 herbicide tank mixture – Challenge 600 SC (aclonifen) - 4 l/ha + Shadow 3 EC (clethodim) - 1.6 l/ha. Active substances of herbicides and their doses are shown in Table 1.

Table 1

Investigated variants

№	Variants	Active substance	Doses
After sowing, before emergence			
1	Control	-	-
2	Dual gold 960 EC	S-metolachlor	1.2 l/ha
3	Stomp aqua	pendimethalin	3 l/ha
4	Merlin flex 480 SC	isoxaflutole	420 g/ha
5	Pelican 50 SC	diflufenikan	250 ml/ha
6 - 8 real leaf stage			
1	Control	-	-
2	Pulsar 40	imazamox	1.2 l/ha
3	Challenge 600 SC	aclonifen	4 l/ha
4	Shadow 3 EC	clethodim	1.6 l/ha
5	Challenge 600 SC + Shadow 3 EC	aclonifen + clethodim	4 l/ha + 1.6 l/ha
Herbicides Pulsar 40 was used in addition with adjuvant Dash HC – 1 l/ha.			

Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 6 - 8 real leaf stage of the chickpea. All of herbicides, herbicide combinations and herbicide tank-mixture were applied in a working solution of 200 l/ha. Mixing of foliar-applied herbicides was done in the tank on the sprayer. Due to of low adhesion of the herbicide Pulsar 40 was used in addition with adjuvant Dash HC – 1 l/ha.

The selectivity of herbicides 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, herbicide combinations and herbicide tank mixture 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 W_i of WRICKE (1962) and the stability criterion YS_i of KANG (1993).

RESULTS AND DISCUSSION

Data for the influence of investigated herbicides, herbicide combinations and the herbicide tank mixture on seed yield of chickpea (Table 2) show that the lower yield is obtained by alone use of antigraminaceous herbicide Shadow, especially during wet years. The increase in yield is unproven compared to untreated control, due to the low efficacy of Shadow over the annual and perennial broadleaved weeds that are dominant in the experiment.

Table 2

Influence of some herbicides, herbicide combinations and herbicide tank mixture on seed yield of chickpea (2016 - 2018)

Herbicides		2016		2017		2018	
Soil-applied	Foliar-applied	kg/ha	%	kg/ha	%	kg/ha	%
-	-	2077	100	1211	100	1760	100
	Pulsar	2278	109.7	1291	106.3	1880	106.8
	Challenge	2353	113.3	1345	111.1	1955	111.0
	Shadow	2125	102.3	1245	102.8	1822	103.5
	Challenge + Shadow	2397	115.4	1389	114.7	1989	113.0
Dual gold	-	2191	105.5	1284	106.0	1971	107.7
	Pulsar	2289	110.2	1321	109.1	1918	109.0
	Challenge	2399	115.5	1393	115.0	2049	116.4
	Shadow	2247	108.2	1326	109.5	1918	109.0
	Challenge + Shadow	2436	117.3	1405	116.0	2054	116.7
Stomp aqua	-	2216	106.7	1303	107.6	1917	108.9
	Pulsar	2303	110.9	1339	110.6	1989	111.1

	Challenge	2410	116.0	1399	115.5	2024	115.0
	Shadow	2264	109.0	1332	110.0	1941	110.3
	Challenge + Shadow	2453	118.1	1423	117.5	2059	117.0
Merlin flex	-	2233	107.5	1308	108.0	1932	109.8
	Pulsar	2337	112.5	1368	113.0	1969	111.9
	Challenge	2453	118.1	1425	117.7	2068	117.2
	Shadow	2264	109.0	1339	110.6	1955	111.1
	Challenge + Shadow	2517	121.2	1460	120.8	2094	119.0
Pelican	-	2250	108.3	1322	109.2	1955	111.1
	Pulsar	2195	105.7	1241	102.5	1833	104.2
	Challenge	2467	118.8	1441	119.0	1091	118.8
	Shadow	2274	109.5	1340	110.7	1964	111.6
	Challenge + Shadow	2513	121.0	1465	121.1	2107	119.7

LSD, kg/ha:

F.A	$p \le 5\% = 59$	$p \le 1\% = 81$	$p \le 0.1\% = 106$
F.B	$p \le 5\% = 87$	$p \le 1\% = 113$	$p \le 0.1\% = 141$
F.C	$p \le 5\% = 94$	$p \le 1\% = 115$	$p \le 0.1\% = 136$
AxB	$p \le 5\% = 127$	$p \le 1\% = 170$	$p \le 0.1\% = 221$
AxC	$p \le 5\% = 171$	$p \le 1\% = 228$	$p \le 0.1\% = 296$
BxC	$p \le 5\% = 189$	$p \le 1\% = 259$	$p \le 0.1\% = 333$
AxBxC	$p \le 5\% = 347$	$p \le 1\% = 461$	$p \le 0.1\% = 596$

The yield increase in relative to the control is also unproven by herbicide combination the Pelican + Pulsar. This is due to the strong phytotoxicity of this herbicide combination to chickpeas, despite its high efficacy against weeds.

Treatment with herbicide Pulsar showed higher yields over the untreated control during the three years. Chickpea is lagging poorly in its development, the maturing stage is delayed by 4-5 days, but however seed yields are not significantly reduced, as weeding is significantly lower than untreated control, because Pulsar destroys all available weeds and self-sown plants.

It is important to note that herbicide Pelican has an initial phytotoxic effect on chickpea, which is to inhibit plant growth during the first 20-30 days after treatment. Subsequently, chickpeas overcome this negative effect and at the vegetation end in this variant high seed yields have been obtained, which is proven mathematically. This is due to the good chemical control of herbicide Pelican against existing weeds.

The alone use of soil-applied herbicides Dual gold, Stomp aqua and Merlin flex increases less the see yields than the alone use of foliar-applied herbicide Challenge and the herbicide tank mixture Challenge + Shadow, because these herbicides cannot control the perennial weeds and part of the annual weeds.

The highest yields of chickpea seeds are obtained by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Pelican and Merlin flex – respectively 120.5 % and 120.2 % relative to the untreated control. High yields also are obtained also by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Stomp aqua and Dual gold – respectively 116.8 % and 117.5 %.

Combinations of soil-applied herbicides Dual gold, Stomp aqua, Merlin flex and Pelican with foliar-applied herbicides Challenge, Pulsar and Shadow always leads to higher yields compared to the alone use of the respective herbicides during the three years of the investigation.

Table 3

Analysis of variance for seed yield

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean squares	Fisher's criterion	Level of significance
Total	224	567895	100	-	-	-
Tract of land	2	35875	5.1	23456.7	8.5	**
Variants	74	452195	81.4	96228.7	33.3	***
Factor A – Years	2	172847	39.5	45678.9	24.2	***
Factor B – Soil-applied herbicides	4	27658	7.5	6432.1	1.1	***
Factor C – Foliar-applied herbicides	4	38398	9.2	7368.2	3.2	***
AxB	8	21365	3.3	2244.6	0.2	**
AxC	8	12989	3.8	2442.0	0.3	**
BxC	16	61258	14.4	8765.4	1.1	***
AxBxC	32	14123	3.7	2424.2	0.2	**
Pooled error	148	59095	13.5	4565.4	-	-

*p≤5% **p≤1% ***p≤0.1%

Analysis of variance for grain yield (Table 3) shows that the years have the highest influence on seed yield – 39.5 % on the variants. The reason is the large differences in the meteorological conditions during the three years of investigation. The strength of influence of soil-applied herbicides is 7.5 % and the strength of influence foliar-applied herbicides is 9.2 %. The influence of years, soil-applied herbicides and foliar-applied herbicides is very well proven at $p \leq 0.01$. There is an interaction between soil-applied herbicides and meteorological conditions of years (AxB) – 3.3 %, between foliar-applied herbicides and meteorological conditions of years (AxC) – 3.8 % and between soil-applied herbicides and foliar-apllied herbicides (BxC) – 14.4 %. Interactions between soil-applied herbicides and meteorological conditions of years (AxB) and between soil-applied herbicides and foliar-applied herbicides (BxC) are well proven at $p \leq 0.1$. Interaction between foliar-applied herbicides and meteorological conditions of years (AxC) is very well proven at $p \leq 0.01$. There is also interaction between three experiment factors (AxBxC) – 3.7 %. It is proven at $p \leq 0.1$.

Based on proven soil-applied herbicide x year interaction, foliar-applied herbicide x year interaction and soil-applied herbicide x foliar-applied herbicide, it was evaluated stability parameters for each herbicide combination between soil-applied herbicide and foliar-applied herbicide for seed yield of chickpea with relation to years (Table 4). It was calculated the stability variances σ_i^2 and S_i^2 of Shukla, the ecovalence W_i of Wricke and the stability criterion YS_i of Kang.

Stability variances (σ_i^2 and S_i^2) of Shukla, which 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 W_i 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 are untreated control, herbicide combination Pelican + Pulsar and alone use of herbicide Shadow without soil-applied herbicide. In these variants values of stability variance σ_i^2 and S_i^2 of Shukla and ecovalence W_i of Wricke are the highest and mathematically proven. In the untreated control and herbicide Shadow, instability is mainly due to the significant differences in seed yields in these variants over the years of experience, as the weather conditions are most affected. In the herbicidal combination Pelican + Pulsar the instability is due to the high phytotoxicity that this combination affects the chickpea plants. In untreated control there is instability from linear and nonlinear types - proven values σ_i^2 and S_i^2. In herbicide combination Pelican + Pulsar and alone use of herbicide Shadow without soil-applied herbicide there is instability from linear type - proven values σ_i^2. The values of S_i^2 are not proven. Other herbicides, herbicide combinations and herbicide tank mixture exhibit high stability because they interact poorly with the conditions of years.

To evaluate the complete efficacy of each tank mixture between soil-applied herbicide and foliar-applied herbicide should be considered as its effect on seed yield of chickpea and its stability - the reaction of wheat 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. The value of this criterion is experienced that using nonparametric methods and warranted statistical differences we get a summary assessment aligning variants in descending order according to their economic value.

Table 4

Stability parameters of some herbicides, herbicide combinations herbicide tank mixture for seed yield with relation to years

Herbicides		$\bar{x}$	σ_i^2	S_i^2	W_i	YS_i
Soil-applied	**Foliar-applied**					
-	-	1683	143.4*	251.8**	239.9	-2
	Pulsar	1816	71.7	61.6	40.4	7
	Challenge	1884	12.3	8.8	40.4	8
	Shadow	1731	103.1*	88.8	200.2	3
	Challenge + Shadow	1925	8.1	6.4	17.8	9
Dual gold	-	1815	-1.9	4.1	15.2	7
	Pulsar	1843	8.5	8.7	35.3	10+
	Challenge	1947	55.5	-6.7	110.0	17+
	Shadow	1830	82.3	66.5	141.6	5
	Challenge + Shadow	1965	44.4	38.8	143.1	20+
Stomp aqua	-	1812	-5.3	7.0	12.3	7
	Pulsar	1877	-7.4	5.1	19.1	11+
	Challenge	1944	46.0	51.5	82.7	18+
	Shadow	1846	96.1	72.2	194.7	5
	Challenge + Shadow	1978	62.6	95.9	123.4	21+
Merlin flex	-	1824	-4.4	5.5	10.8	8
	Pulsar	1891	-8.8	5.1	22.2	12+
	Challenge	1982	13.9	3.3	47.8	18+
	Shadow	1853	92.5	79.0	151.4	6
	Challenge + Shadow	2024	5.9	11.1	17.1	23+
Pelican	-	1842	37.3	19.1	45.6	8
	Pulsar	1756	127.7*	28.4	277.3	4
	Challenge	1957	11.5	-3.7	38.9	19+
	Shadow	1859	61.0	71.0	121.2	6
	Challenge + Shadow	2028	7.3	6.1	14.9	23+
Mean		1876				10.9
LSD (p=0.05)		118				

Generalized stability criterion YS_i of Kang, taking into accounts both the stability and value of yields gives negative assessments of untreated control, characterizing it as the most unstable and low yields. According to this criterion, technologically the most valuable appears combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Merlin flex and Pelican are technological the most valuable. They are followed by combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Stomp aqua and Dual gold. They combine high levels of seed yield and high stability of this index during the years. From the viewpoint of technology for chickpea growing, high ratings also have combinations of foliar-applied herbicide Challenge with the four soil-applied herbicides Pelican, Merlin flex, Stomp aqua and Dual gold, as well as combinations of foliar-applied herbicide Pulsar with the three soil-applied herbicides Merlin flex, Stomp aqua and Dual gold. They combine relatively good seed yields with high stability during the years of the investigation. Alone uses of the four soil-applied herbicides Pelican, Merlin flex, Stomp aqua and Dual gold and their combinations with antigraminaceous herbicide Shadow, as well herbicide combination Pelican + Shadow have low estimates and them to be avoided. In the combined use of Pelican with Pulsar is due to strong phytotoxicity to chickpeas. In other variants this is due to the absence of effective chemical control against part of weeds and self-sown plants.

CONCLUSIONS

The highest yields of chickpea seeds are obtained by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Pelican and Merlin flex.

High yields are obtained also by foliar treatment with herbicide tank-mixture Challenge + Shadow after soil-applied herbicides Stomp aqua and Dual gold.

Untreated control, herbicide combination Pelican + Pulsar and separated use antigraminaceous herbicide Shadow are the most unstable for seed yield.

Combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Merlin flex and Pelican are technological the most valuable. They are followed by combinations of herbicide tank-mixture Challenge + Shadow with soil-applied herbicides Stomp aqua and Dual gold. They combine high seed yield with high stability with relation to different years.

Separated uses of soil-applied herbicides Pelican, Merlin flex, Stomp aqua and Dual gold, and their combined uses with antigraminaceous herbicide Shadow, and also herbicide combination Pelican + Pulsar have low estimates and do not be used.

For complete control of all weeds and self-sown plants in chickpea crops, two herbicides should be combined - both soil-applied and foliar-applied.

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