

EFFICACY OF HERBICIDES AND HERBICIDE COMBINATIONS AT MAIZE (*Zea mays* L.)

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Abstract

The research was conducted during 2012 - 2014. Under investigation was cycloxydim tolerant maize hybrid Ultrafox duo (*Zea mays* L.). Factor A included no treated check and 3 soil-applied herbicides - Adengo 465 SC, Wing P and Lumax 538 SC. Factor B included no treated check and 5 foliar-applied herbicides - Stellar 210 SL, Principal plus, Ventum WG, Monsun active and Laudis OD. In addition to these variants by conventional technology for maize growing, in the experience is included one variant by Duo system technology. It includes soil-applied herbicide Merlin flex 480 SC and tank mixture of antigraminaceous herbicide Focus ultra + antibroadleaved herbicide Kalam. Combinations between soil-applied herbicides Adengo, Wing and Lumax and vegetation-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis by conventional technology, have very high efficacy against annual graminaceous weeds and against *Sorghum halepense* Pers. from seeds and rhizomes, medium efficacy against *Agropyrum repens* L. and not efficacy against *Cynodon dactylon* Pers. Herbicide combination between soil-applied herbicide Merlin flex and tank herbicide mixture Focus ultra + Kalam by Duo system technology have very high efficacy against perennial weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L. Herbicide Wing is inefficacy against of ClearField and ExpressSun sunflower self-sown plants in maize crops. Herbicide combination of soil-applied herbicide Merlin flex with tank mixture Focus ultra + Kalam by Duo system technology lead to obtaining of high grain yield. High yields of maize grain also are obtained by herbicide combinations Lumax + Principal plus, Lumax + Laudis and Wing + Principal plus. Alone application of herbicides leads to lower yields due to must to combine soil-applied with foliar-applied herbicides for full control of weeds in maize crops.

Key words: grain maize, herbicides, herbicide combinations, efficacy, selectivity, grain yield.

INTRODUCTION

Weeds are one of the main limiting factors for maize production (Vancetovic et al., 2010; Dragičević et al., 2012). The main species weeding maize crops are the group of late spring weeds. When growing cool-resisting maize hybrids weed infestation is changed and serious competitors and also early spring weeds that are typical for sunflower fields (Sinzar et al., 1998; Michel, 2001; Delchev, 2018). From an economic and ecological view point, the combination of the chemical and mechanical controls of weeds is very positive. Limiting soil tillage on mechanical weed control reduces the risk of soil erosion, especially in hilly areas and decreasing herbicide treatments reduces the risk of contamination of soil and water (Dawoud et al., 2006; Moteva & Stoyanova, 2008; Pajić et al., 2009; Stoyanova & Gospodinov, 2009; Korpanov et al., 2010).

The use of herbicides in the early stages of maize development is essential for high yield production (Kees & Lutz, 1991). In conventional technology for grain maize growing there are unsolved problems of control of some perennial graminaceous weeds such as *Cynodon dactylon* Pers. and *Agropyron repens* L., which necessitated the introduction of the new Duo system technology for maize growing (Jovovic et al., 1999; Asadi et al., 2009).

The purpose of this investigation was to establish the efficacy and selectivity of some herbicides and herbicide combinations on the grain maize by influence of different meteorological conditions.

MATERIALS AND METHODS

The research was conducted during 2012-2014 with the cycloxydim tolerant maize hybrid Ultrafox duo (*Zea mays* L.). It was carried out a two factors field experiment as a block method in 4 repetitions, on a 20 m² harvesting area, on

pellic vertisol soil type, after durum wheat predecessor. Factor A included no treated check and 3 soil-applied herbicides - Adengo 465 SC, Wing P and Lumax. Factor B included no treated check and 5 foliar-applied herbicides - Stellar 210 SL, Principal plus, Ventum WG (foramsulfuron + iodosulfuron) - 150 g/ha, Monsun active and Laudis OD. In addition to these variants by conventional technology for

maize growing, in the experience is included one variant by Duo system technology. It includes soil-applied herbicide Merlin flex 480 SC and tank mixture of antigraminaceous herbicide Focus ultra + anti-broadleaved herbicide Kalam. The active substances and doses of the investigated herbicides are given in Table 1.

Table 1. Investigated variants

№	Variants	Active substance	Doses
Conventional technology			
After sowing, before emergence			
1	Check	-	-
2	Adengo 465 SC	isoxaflutol + tiencarbazon	440 ml/ha
3	Wing P	pendimethalin + dimethenamid	4 l/ha
4	Lumax 538 SC	S-metolachlor + terbuthylazine + mesotrione	4 l/ha
5 - 7 leaf stage			
1	Check	-	-
2	Stellar 210 SL	topramezon + dicamba	1 l/ha
3	Principal plus	nicosulfuron + rimsulfuron + dicamba	380 g/ha
4	Ventum WG	foramsulfuron + iodosulfuron	150 g/ha
5	Monsun active OD	foramsulfuron + tiencarbazon	1.5 l/ha
6	Laudis OD	Tembotrione	2 l/ha
Duo system technology			
After sowing, before emergence			
1	Merlin flex 480 SC	Isoxaflutole	420 g/ha
5 - 7 leaf stage			
2	Focus ultra + Kalam	cycloxydim tritosulfuron + dicamba	2 l/ha 300 g/ha

Herbicides Stellar 210 SL and Kalam they were used in addition with adjuvant Dash HC - 1 l/ha, herbicide Principal plus - with adjuvant Trend - 0.2% and herbicide Ventum WG - with adjuvant Mero 80 EC - 2 l/ha.

Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 5-7 leaf stage of the maize. All of herbicides and herbicide combinations were applied in a working solution of 200 l/ha. Due to of low adhesion of the herbicides Stellar 210 SL and Kalam they were used in addition with adjuvant Dash HC - 1 l/ha, herbicide Principal

plus - with adjuvant Trend - 0.2% and herbicide Ventum WG - with adjuvant Mero 80 EC - 2 l/ha.

It was investigated efficacy and selectivity of herbicides and their tank mixtures. It was established their influence on grain yield. Efficacy of herbicides against weeds and self-sown plants of sunflower was appointed according to 100% scale of EWRS (European

Weed Research Society). Selectivity of herbicides to maize plants was followed according to the 9-rate scale of EWRS (rating 1 - without damages, rating 9 - crop is completely destroyed). The mathematical processing is done with analysis of variance method.

RESULTS AND DISCUSSIONS

Dominant weeds that determine secondary weed infestation in the experiment field are late spring annual broadleaved species *Xanthium strumarium* L., *Amaranthus retroflexus* L., *Amaranthus albus* L., *Chenopodium album* L., *Solanum nigrum* L., *Datura stramonium* L., *Polygonum aviculare* L., *Abutilon theophrasti* Medic., *Portulaca oleracea* L., in a small amount *Amaranthus blifoides* W., *Polygonum aviculare* L., *Hibiscum trionum* L., *Tribulus terrestris* L. Early spring annual broadleaved species are mainly *Sinapis arvensis* L. and *Falopia convolvulus* Leve.

Annual graminaceous weeds are represented by *Echinochloa crus-galli* L., *Panicum sanguinale* L., *Setaria viridis* Beauv., *Setaria glauca* Beauv. As single plants is established *Echinochloa coarctata* Vas. and *Setaria verticillata* Beauv.

Perennial species in experiment are broadleaved weeds, *Cirsium arvense* Scop. and *Convolvulus arvensis* L., and graminaceous weeds, *Sorghum halepense* Pers., *Cynodon dactylon* Pers. and less frequently *Agropyrum repens* L.

Self-sown plants of sunflower (*Helianthus annuus* L.) are from sunflower was grown two years ago as predecessor. In the previous year, before the maize was grown durum wheat (*Triticum durum* Desf.).

Soil-applied herbicides Adengo, Wing and Lumax applied during the period after sowing before germination are inefficacy against perennial broadleaved weeds, *Cirsium arvense* Scop. and *Convolvulus arvensis* L. (Table 2). These herbicides have very high efficacy against late spring annual broadleaved weeds - *Amaranthus retroflexus* L., *Amaranthus albus* L., *Chenopodium album* L., *Solanum nigrum* L., *Datura stramonium* L., *Abutilon theophrasti* Medic., *Portulaca oleracea* L., *Polygonum*

aviculare L., *Hibiscum trionum* L. et al. Adengo and Wing are inefficacy against *Xanthium strumarium* L. only and Lumax control this weed of 80%. Wing is less effective against *Sinapis arvensis* L. and *Chenopodium album* L. - controls them, respective of 90% and 93%.

Foliar-applied herbicides Principal plus and Laudis, applied during 4-8 leaf of maize have very high efficacy against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L. Herbicides Ventum and Monsun active control of 100% *Cirsium arvense* Scop. but their efficacy against *Convolvulus arvensis* L. is weaker - 95%. It may be explained by the later emergence of *Convolvulus arvensis* L. in which a part of its later germinated shoots remain unsprayed with herbicide solution. Herbicide Stellar have weaker efficacy against perennial broadleaved weeds - 95% against *Cirsium arvense* Scop. and 90% against *Convolvulus arvensis* L.

Foliar-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis and their combinations control successfully all annual broadleaved weeds.

Self-sown plants of ClearField and ExpressSun sunflower are controlled successfully by soil-applied herbicides Adengo and Lumax and foliar-applied herbicides Stellar, Ventum, Monsun active and Laudis. Foliar-applied herbicide Principal plus has weaker efficacy against these self-sown plant - control them of 97%, but this percent is sufficient for their efficacy control. Soil-applied herbicide Wing is inefficacy against these self-sown plants.

The initial effect of herbicide Monsun active against self-sown plants of ClearField and ExpressSun sunflower is weaker. They die slower compared with other herbicides and herbicide combinations. Part sunflower self-sown plants not die immediately after treatment with this herbicide. Usually these are those volunteer who are in rows between the maize plants. They absorb less herbicide solution because they are partially covered by leaves of maize. These self-sown plants in all cases are highly depressed in their development. They remain under the maize plants, some of them later died, while other

Table 2. Efficacy of some herbicides and herbicide combinations against broadleaved weeds and self-sown plants at maize according to the 100% visual scale of EWRS (mean 2012-2014)

Herbicides		Weeds							
Soil-applied	Foliar-applied	<i>Cirsium arvense</i>	<i>Convolvulus arvensis</i>	<i>Xanthium strumarium</i>	<i>Amaranthus retroflexus</i>	<i>Chenopodium album</i>	<i>Solanum nigrum</i>	<i>Sinapis arvensis</i>	<i>Helianthus annuus</i> *
Conventional technology									
	-	0	0	0	0	0	0	0	0
	Stellar – 1 l/ha	95	90	100	100	100	100	100	100
	Principal plus – 380 g/ha	100	100	100	100	100	100	100	97
	Ventum – 150 g/ha	100	95	100	100	100	100	100	100
	Monsun active – 1.5 l/ha	100	95	100	100	100	100	100	100
	Laudis – 2 l/ha	100	100	100	100	100	100	100	100
	-	0	0	0	100	100	100	100	100
	Stellar – 1 l/ha	95	90	100	100	100	100	100	100
	Principal plus – 380 g/ha	100	100	100	100	100	100	100	100
Adengo – 440 ml/ha	Ventum – 150 g/ha	100	95	100	100	100	100	100	100
	Monsun active – 1.5 l/ha	100	95	100	100	100	100	100	100
	Laudis – 2 l/ha	100	100	100	100	100	100	100	100
	-	0	0	0	100	93	100	90	0
	Stellar – 1 l/ha	95	90	100	100	100	100	100	100
Wing – 4 l/ha	Principal plus – 380 g/ha	100	100	100	100	100	100	100	100
	Ventum – 150 g/ha	100	95	100	100	100	100	100	100
	Monsun active – 1.5 l/ha	100	95	100	100	100	100	100	100
	Laudis – 2 l/ha	100	100	100	100	100	100	100	100
	-	0	0	80	100	100	100	100	100
	Stellar – 1 l/ha	95	90	100	100	100	100	100	100
Lumax – 4 l/ha	Principal plus – 380 g/ha	100	100	100	100	100	100	100	100
	Ventum – 150 g/ha	100	95	100	100	100	100	100	100
	Monsun active – 1.5 l/ha	100	95	100	100	100	100	100	100
	Laudis – 2 l/ha	100	100	100	100	100	100	100	100
Duo system technology									
Merlin flex – 420 g/ha	Focus ultra – 2 l/ha + Kalam – 300 g/ha	100	100	100	100	100	100	100	100

* - self-sown plants of ClearField and ExpressSun sunflower

ones remained alive, but poorly developed and practically no influenced on the value of maize grain yield

Herbicide combination by Duo system technology between soil-applied herbicide

Merlin flex applied during after sowing before emergence, and tank herbicide mixture Focus ultra + Kalam applied during 5-7 leaf stage, control successfully of 100% all annual and perennial broadleaved weeds in fields of

cycloxydim tolerant maize. This combination has very high efficacy against self-sown plants of ClearField and ExpressSun sunflower. Soil-applied herbicides Adengo, Wing and Lumax have very high efficacy against all

existing in the trial annual graminaceous weeds - *Echinochloa crus-galli* L., *Panicum sanguinale* L., *Setaria viridis* Beauv., *Setaria glauca* Beauv. (Table 3).

Table 3. Efficacy of some herbicides and herbicide combinations against graminaceous weeds at maize according to the 100% visual scale of EWRS and selectivity according to the 9-rate scale of EWRS (mean 2012-2014)

Herbicides		Weeds							
Soil-applied	Foliar-applied	<i>Sorghum halepense</i>	<i>Cynodon dactylon</i>	<i>Agropirum repens</i>	<i>Echinochloa crus-galli</i>	<i>Setaria viridis</i>	<i>Setaria glauca</i>	<i>Digitaria sanguinale</i>	Selectivity
Conventional technology									
	-	0	0	0	0	0	0	0	1
	Stellar – 1 l/ha	100*	0	0	100	100	100	100	1
	Principal plus – 380 g/ha	100	0	85	100	100	100	100	1
	Ventum – 150 g/ha	100	0	85	90	98	100	90	1
	Monsun active – 1.5 l/ha	100	0	75	95	98	100	95	1
	Laudis – 2 l/ha	82	0	70	100	100	100	100	1
	-	100*	0	0	100	100	100	100	1
	Stellar – 1 l/ha	100*	0	0	100	100	100	100	1
	Principal plus – 380 g/ha	100	0	85	100	100	100	100	1
	Ventum – 150 g/ha	100	0	85	100	100	100	100	1
	Monsun active – 1.5 l/ha	100	0	75	100	100	100	100	1
	Laudis – 2 l/ha	82	0	70	100	100	100	100	1
	-	96*	0	0	100	100	100	100	1
	Stellar – 1 l/ha	100*	0	0	100	100	100	100	1
	Principal plus – 380 g/ha	100	0	85	100	100	100	100	1
	Ventum – 150 g/ha	100	0	85	100	100	100	100	1
	Monsun active – 1.5 l/ha	100	0	75	100	100	100	100	1
	Laudis – 2 l/ha	82	0	70	100	100	100	100	1
	-	80*	0	0	100	100	100	100	1
	Stellar – 1 l/ha	100*	0	0	100	100	100	100	1
	Principal plus – 380 g/ha	100	0	85	100	100	100	100	1
	Ventum – 150 g/ha	100	0	85	100	100	100	100	1
	Monsun active – 1.5 l/ha	100	0	75	100	100	100	100	1
	Laudis – 2 l/ha	82	0	70	100	100	100	100	1
Duo system technology									
	Merlin flex – 420 g/ha	Focus ultra – 2 l/ha + Kalam – 300 g/ha	100	100	100	100	100	100	1

* - against *Sorghum halepense* Pers. from seeds only

These three herbicides are inefficacy against perennial graminaceous weeds - *Sorghum halepense* Pers., *Cynodon dactylon* Pers. and *Agropyrum repens* L. Adengo and Wing control only *Sorghum halepense* Pers. by seeds, respective of 100% and 96%. Lumax has weaker efficacy against this weed - 80%.

Foliar-applied herbicides Ventum and Monsun active have weaker efficacy against annual graminaceous weeds - *Echinochloa crus-galli* L. and *Panicum sanguinale* L. Ventum controls these two weeds of 90% and Monsun active - 95%. Herbicides Stellar, Principal plus and Laudis have very high efficacy against the annual graminaceous weeds. Herbicide Stellar controls only *Sorghum halepense* Pers. by seeds, but does not control perennial graminaceous weeds.

Combinations of foliar-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis with soil-applied herbicides Adengo, Wing and Lumax control successfully all annual graminaceous weeds.

Herbicide combinations of Principal plus, Ventum and Monsun active with soil-applied herbicides Adengo, Wing and Lumax have very high efficacy against *Sorghum halepense* Pers. by seeds and rhizomes, middle efficacy against *Agropyrum repens* L. and inefficacy *Cynodon dactylon* Pers. Combinations of Laudis with Adengo, Wing and Lumax are weaker efficacy also against *Sorghum halepense* Pers. by rhizomes. Combinations of Stellar with the three soil-applied herbicides control only *Sorghum halepense* Pers. by seeds, but do not control *Sorghum halepense* Pers. by rhizomes; *Cynodon dactylon* Pers. and *Agropyrum repens* L.

Herbicide combination of soil-applied herbicide Merlin flex with tank herbicide mixture Focus ultra + Kalam by Duo system technology has 100% efficacy against *Sorghum halepense* Pers. by seeds and rhizomes, as well as against all annual graminaceous weeds - *Echinochloa crus-galli* L., *Panicum sanguinale* L., *Setaria viridis* Beauv., *Setaria glauca* Beauv. This combination has also very high efficacy against perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens*

L. This is due to the participation of herbicide Focus ultra in this combination.

Perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L. practically cannot be controlled at the conventional technology. Duo system technology is the only way to chemical control of *Cynodon dactylon* Pers. and *Agropyrum repens* L. in maize crops.

Soil-applied herbicides Adengo, Wing and Lumax, foliar-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis by conventional technology, as well as their combinations have very high selectivity for maize - rating 1 by scale of EWRS (Table 3).

Herbicide combination of soil-applied herbicide Merlin flex with tank herbicide mixture Focus ultra + Kalam has also very high selectivity for cycloxydim tolerant maize (CTM) which are grown by Duo system technology - rating 1 by scale of EWRS.

Data about the influence of the investigated herbicides and herbicide combinations on maize grain yields (Table 4) show that the lowest yield was obtained by the untreated check. The alone use of soil-applied herbicides Adengo, Wing and Lumax increases grain yield average for the period from 114.5% to 116.2%. Alone use of vegetation-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis increased grain yield from 116.1% to 118.2%.

The herbicide combinations between soil-applied herbicides Adengo, Wing and Lumax by the one hand and vegetation-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis by the other hand, lead to a bigger increase in yield compared with alone use of these herbicides during the three years the investigation. Herbicide combinations provide full control of all annual and perennial weeds in maize crops except *Cynodon dactylon* Pers. and *Agropyron repens* L. The highest grain yield by conventional technology is obtained by the herbicide combination Lumax + Principal plus - 125.7% over the no treated check, followed by Lumax + Laudis - 124.9% and Wing + Principal plus - 124.6%.

Table 4. Influence of some herbicide combinations on maize grain yield (2012-2014)

Herbicides		2012		2013		2014		Mean	
Soil-applied	Vegetation-applied	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Conventional technology									
	-	3510	100	4688	100	5555	100	4584	100
	Stellar – 1 l/ha	4037	115.0	5429	115.8	6499	117.0	5322	116.1
	Principal plus – 380 g/ha	4114	117.2	5532	118.0	6605	118.9	5417	118.2
	Ventum – 150 g/ha	4103	116.9	5485	117.0	6583	118.5	5390	117.6
	Monsun active – 1.5 l/ha	4082	116.3	5466	116.6	6555	118.0	5368	117.1
	Laudis – 2 l/ha	4068	115.9	5466	116.6	6583	118.5	5372	117.2
	-	4012	114.3	5335	113.8	6499	117.0	5282	115.4
	Stellar – 1 l/ha	4233	120.6	5626	120.0	6788	122.2	5549	121.1
	Principal plus – 380 g/ha	4342	123.7	5757	122.8	6960	125.3	5686	124.0
Adengo – 440 ml/ha	Ventum – 150 g/ha	4258	121.3	5644	120.4	6855	123.4	5586	121.9
	Monsun active – 1.5 l/ha	4282	122.0	5682	121.2	6888	124.0	5617	122.5
	Laudis – 2 l/ha	4310	122.8	5719	122.0	6927	124.7	5652	123.3
	-	3994	113.8	5307	113.2	6444	116.0	5248	114.5
	Stellar – 1 l/ha	4247	121.0	5644	120.4	6760	121.7	5550	121.1
	Principal plus – 380 g/ha	4370	124.5	5785	123.4	6977	125.6	5711	124.6
Wing – 4 l/ha	Ventum – 150 g/ha	4324	123.2	5766	123.0	6888	124.0	5659	123.5
	Monsun active – 1.5 l/ha	4293	122.3	5696	121.5	6833	123.0	5607	122.3
	Laudis – 2 l/ha	4352	124.0	5719	122.0	6922	124.6	5664	123.6
	-	4037	115.0	5419	115.6	6527	117.5	5328	116.2
	Stellar – 1 l/ha	4324	123.2	5715	121.9	6855	123.4	5631	122.8
	Principal plus – 380 g/ha	4419	125.9	5827	124.3	7038	126.7	5761	125.7
Lumax – 4 l/ha	Ventum – 150 g/ha	4370	124.5	5766	123.0	6949	125.1	5695	124.2
	Monsun active – 1.5 l/ha	4352	124.0	5752	122.7	6899	124.2	5668	123.6
	Laudis – 2 l/ha	4388	125.0	5785	123.4	7000	126.0	5724	124.9
Duo system technology									
Merlin flex – 420 g/ha	Focus ultra – 2 l/ha + Kalam – 300 g/ha	4461	127.1	5893	125.7	4461	127.1	5822	127.0
	LSD 5 %	221	6.2	236	5.0	240	4.3		
	LSD 1 %	260	7.4	271	5.8	289	5.2		
	LSD 0.1 %	286	8.1	305	6.5	333	6.0		

Combination of soil-applied herbicide Merlin flex with tank herbicide mixture Focus ultra + Kalam by Duo system technology, increases the most grain yield - 127.0% compared to not treated check. This is due to the complete control of all broadleaved and graminaceous weeds, including *Cynodon dactylon* Pers. and *Agropyron repens* L.

CONCLUSIONS

Combinations between soil-applied herbicides Adengo, Wing and Lumax and vegetation-applied herbicides Stellar, Principal plus, Ventum, Monsun active and Laudis by conventional technology, have very high efficacy against annual graminaceous weeds and against *Sorghum helepense* Pers. from

seeds and rhizomes, medium efficacy against *Agropyrum repens* L. and not efficacy against *Cynodon dactylon* Pers.

Herbicide combination between soil-applied herbicide Merlin flex and tank herbicide mixture Focus ultra + Kalam by Duo system technology have very high efficacy against perennial weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L.

Herbicide Wing is inefficacy against of ClearField and ExpressSun sunflower self-sown plants in maize crops.

Herbicide combination of soil-applied herbicide Merlin flex with tank mixture Focus ultra + Kalam by Duo system technology lead to obtaining of high grain yield.

High yields of maize grain also are obtained by herbicide combinations Lumax + Principal plus, Lumax + Laudis and Wing + Principal plus.

Alone application of herbicides leads to lower yields due to must to combine soil-applied with foliar-applied herbicides for full control of weeds in maize crops.

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