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PRODUCTIVITY OF DUO SYSTEM AND CONVENTIONAL GRAIN MAIZE (*Zea mays* L.) BY INFLUENCE OF SOME HERBICIDES AND HERBICIDE TANK MIXTURES

Grozi DELCHEV

Trakia University, Faculty of Agriculture, Department of Plant Production, Stara Zagora, Bulgaria

Corresponding author email: delchevgd@abv.bg

Abstract

The research was conducted during 2018-2020 on pellic vertisol soil type. Under investigation was cycloxydim-tolerant grain maize hybrid Trilogi duo (Zea mays L.), FAO 350. A total of 22 variants were investigated. They included untreated control, 7 soil-applied herbicides by conventional technology: Sulcotrack (sulcotrione + terbuthylazine), Successor TX (petoxamide + terbuthylazine), Acris (dimethenamid-P + terbuthylazine), Deflexo mix (S-metolachlor + terbuthylazine), Click duo (terbuthylazine + pendimethalin), Bismarck KS (clomazone + pendimethalin), Pledge 50 VP (flumioxazine); 6 foliar-applied herbicides by conventional technology: Sovereign OD (nicosulfuron + sulcotrione), Mistral plus (dicamba + nicosulfuron), Spandis (prosulfuron + dicamba + nicosulfuron), Arigo WG (mesotrione + nicosulfuron + rimsulfuron), Collage 64 OD (thiphensulfuron-methyl + nicosulfuron), Capreno SC (tembotrione + thiencarbazone-methyl); 8 herbicide tank mixtures by Duo system technology: Starane gold + Focus ultra (fluroxypyr + florasulam + cycloxydim), Kabadex extra + Focus ultra (mesotrione + florasulam + cycloxydim), Callisto plus + Focus ultra (mesotrione + dicamba + cycloxydim), Magneto top 464 SL + Focus ultra (2.4-D + dicamba + cycloxydim), Peak 75 WG + Focus ultra (prosulfuron + cycloxydim), Permit + Focus ultra (halosulfuron-methyl + cycloxydim), Bentador + Focus ultra (bentazone + cycloxydim), Onyx + Focus ultra (pyridate + cycloxydim). The highest grain yields are obtained by use of herbicide tank mixtures by technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra. High grain yields are also obtained by use of foliar herbicides by conventional technology Spandis, Arigo and Mistral plus. The use of soil-applied herbicides Sulcotrack, Successor, Acris, Deflexo mix, Click duo, Bismarck and Pledge in maize crops leads to lower grain yields due to their inefficacy against perennial graminaceous and broadleaved weeds and against the annual broadleaved weed Xanthium strumarium L. Increase in grain yield is due to the greatest degree of increase in indexes grains number per cob, grain weight per cob and 1000 grains weight.

Key words*: grain maize, herbicides, herbicide tank mixtures, seed yield, structural elements.*

INTRODUCTION

In order to obtain high maize yields, it is important not only to have favourable climatic conditions, but also to apply appropriate cultivation technology. Starting with tillage, going through fertilization and seeds and reaching plant protection, these are all important elements of the overall production process.

Soil-applied and foliar-applied herbicides are used to control weeds, the choice of which must take into account the characteristics of each field, weed species, agro-climatic conditions. A number of authors in their research have established the positive influence of the correct weed control on the yield of maize grain (Soukup et al., 2004; Dragičević et al., 2012; Delchev, 2020).

The use of herbicides in the early stages of maize development is essential to achieve high yields (Simic et al., 2012). Soil-applied herbicides ensure clean and well-garnished sowing in the earliest stages of maize development, because most of the germinating weeds are destroyed (Malidza et al., 2009; Matić et al., 2011).

Soil-applied herbicides act for about 40-50 days, and then secondary weed infestation begins, which requires vegetative spraying (Asadi et al., 2009; Delchev, 2018, 2021). Foliar-applied herbicides are weakly dependent on soil moisture as opposed to soil-applied herbicides. This has its advantages - safe action and selection of the most suitable product for the weeds that have appeared (Kopmanis and Gaile, 2008; Vancetovic et al., 2010)

The purpose of this study was to establish the changes in the grain yield and structural elements of yield by influence of some herbicides and herbicide tank mixtures in Duo system and conventional grain maize under different meteorological conditions.

MATERIALS AND METHODS

The research was conducted during 2018 - 2020 on pellic vertisol soil type. Under investigation was cycloxydim-tolerant grain maize hybrid Trilogi duo (*Zea mays* L.), FAO 350. It was carried out a field experiment as a block method in 4 repetitions, on a 20 m^2 harvesting area, after durum wheat predecessor. A total of 22 variants were investigated. They included untreated control, 7 soil-applied herbicides by conventional technology: Sulcotrack, Successor TX, Acris, Deflexo mix, Click duo, Bismarck KS, Pledge 50 VP; 6 foliar-applied herbicides by conventional technology: Sovereign OD, Mistral plus, Spandis, Arigo WG, Collage 64 OD, Capreno SC; 8 herbicide tank mixtures by Duo system technology: Starane gold + Focus ultra, Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top 464 SL + Focus ultra, Peak 75 WG + Focus ultra, Permit + Focus ultra, Bentador + Focus ultra, Onyx + Focus ultra. Active substances of herbicides, their doses and treatment periods are shown in Table 1. Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 5-7 maize leaf stage. All of herbicides and herbicide tank mixtures were applied in a working solution of 300 l/ha. Due to of low adhesion herbicide Spandis was used in addition with adjuvant Dash HC - 1 l/ha, herbicide Arigo WG - with adjuvant Trend 90-0.1%, herbicide Capreno SC - with adjuvant Mero 80 EC - 2 l/ha, herbicide Kabadex extra - with adjuvant Dasoil 26-2N - 500 ml/ha and herbicide Peak 75 WG - with adjuvant Atplus - 0.2 %.

At grain maize maturity all plots were evaluated for grain yield and yield components - cob length, grain number per cob, the grain weight per cob and 1000 grain weight, to evaluate the influence of the herbicides and herbicide tank mixtures on maize grain yield and yield components. It was investigated and changes who made of the tested factors in the plant height.

The statistical analysis of the data was done according to the analyses of variance method (Shanin, 1977; Barov, 1982; Lidanski, 1988).

RESULTS AND DISCUSSIONS

The weed flora present during the 3-year experiment was quite varied.

The dominant weeds that determine weed infestation in maize crops are mainly late spring annual broadleaved species - *Amaranthus retroflexus* L., *Amaranthus albus L.*, *Xanthium strumarium* L., *Chenopodium album* L., *Solanum nigrum* L., *Polygonum aviculare* L., *Portulaca oleracea* L., *Datura stramonium* L., *Abutilon teophrasti* Medic., a lesser amount *Amaranthus blifoides* W., *Tribulus terrestris* L., *Hibiscum trionum* L. Early spring annual broadleaved weeds are mainly *Falopia convolvulus* Leve and *Sinapis arvensis* L.

Annual graminaceous weeds are represented by *Panicum sanguinale* L., *Echinochloa crus-galli* L., *Setaria viridis* Beauv., *Setaria glauca* Beauv. In a lesser amount are *Setaria verticilata* Beauv. and *Echinochloa coarctata* Vas.

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 often *Agropyrum repens* L.

Sunflower self-sown plants (*Helianthus annuus* L.) are from Clearfield and ExpressSun sunflower hybrids grown two years ago as predecessor. In the previous year, durum wheat (*Triticum durum* Desf.) was grown as predecessor before maize.

The data on the influence of herbicides and herbicide tank mixtures included in the experiment on the grain yield of cycloxide-tolerant maize by Duo system technology (Table 2) show that there is a positive correlation between their biological efficacy against weeds and grain yields.

The lowest grain yields are obtained by the untreated control, as a result of the strong weed infestation with broadleaved and graminaceous weeds and self-sown plants of Clearfield and ExpressSun sunflower (*Helianthus annuus* L.).

Table 1. Investigated variants

№	Variants	Active substance	Doses	Treatment period
1	Control – untreated	-	-	-
		Conventional technology		
		Soil-applied herbicides		
2	Sulcotrack	sulcotrione + terbuthylazine	2.6 l/ha	ASBE
3	Successor TX	petoxamide + terbuthylazine	4 l/ha	ASBE
4	Acris	dimethenamid-P + terbuthylazine	3 l/ha	ASBE
5	Deflexo mix	S-metolachlor + terbuthylazine	3.5 l/ha	ASBE
6	Click duo	terbuthylazine + pendimethalin	4 l/ha	ASBE
7	Bismarck KS	clomazone + pendimethalin	2 l/ha	ASBE
8	Pledge 50 VP	flumioxazine	80 g/ha	ASBE
		Foliar-applied herbicides		
9	Sovereign OD	nicosulfuron + sulcotrione	2 l/ha	5-7 leaf
10	Mistral plus	dicamba + nicosulfuron	1.2 l/ha	5-7 leaf
11	Spandis	prosulfuron + dicamba + nicosulfuron	500 g/ha	5-7 leaf
12	Arigo WG	mesotrione + nicosulfuron + rimsulfuron	330 g/ha	5-7 leaf
13	Collage 64 OD	thiphensulfuron-methyl + nicosulfuron	1 l/ha	5-7 leaf
14	Capreno SC	tembotrione + thiencarbazone-methyl + isoxadifen-ethyl (antidote)	290 ml/ha	5-7 leaf
		Duo system technology		
		Herbicide tank mixtures		
15	Starane gold +	fluroxypyr + florasulam	1.2 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
16	Kabadex extra +	mesotrione + florasulam	300 ml/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
17	Callisto plus +	mesotrione + dicamba	2 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
18	Magneto top 464 SL +	2.4-D + dicamba	1 l/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
19	Peak 75 WG +	prosulfuron	15 g/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
20	Permit +	halosulfuron-methyl	50 g/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
21	Bentador +	bentazone	2 kg/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf
22	Onyx +	pyridate	500 ml/ha	5-7 leaf
	Focus ultra	cycloxydim	2 l/ha	5-7 leaf

Herbicide Spandis was used in addition with adjuvant Dash HC – 1 l/ha, herbicide Arigo WG – with adjuvant Trend 90 – 0.1 %, herbicide Capreno SC – with adjuvant Mero 80 EC – 2 l/ha, herbicide Kabadex extra – with adjuvant Dasoil 26-2N – 500 ml/ha and herbicide Peak 75 WG – with adjuvant Atplus – 0.2 %.
ASBE – after sowing, before emergence

The highest grain yields are obtained when using the herbicide tank mixtures by the technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra,

Table 2. Influence of some herbicides and herbicide tank mixtures on maize grain yield (2018-2020)

Variants	2018		2019		2020		Mean	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Control – untreated	6060	100	5680	100	6666	100	6135	100
			Conventional technology					
			Soil-applied herbicides					
Sulcotrack	6951	114.7	6435	113.3	7533	113.0	6973	113.7
Successor	6914	114.1	6515	114.7	7406	111.1	6945	113.2
Acris	6921	114.2	6532	115.0	7526	112.9	6993	114.0
Deflexo mix	7024	115.9	6475	114.0	7566	113.5	7022	114.5
Click duo	6987	115.3	6452	113.6	7533	113.0	6991	113.9
Bismarck	6902	113.9	6452	113.6	7499	112.5	6951	113.3
Pledge	6866	113.3	6407	112.8	7466	112.0	6913	112.7

Foliar-applied herbicides								
Sovereign	7193	118.7	6759	119.0	8000	120.1	7317	119.3
Mistral plus	7375	121.7	6873	121.0	8086	121.3	7445	121.3
Spandis	7411	122.3	6901	121.5	8133	122.0	7482	122.0
Arigo	7393	122.0	6873	121.0	8146	122.2	7471	121.8
Collage	7314	120.7	6873	121.0	7873	118.1	7353	119.9
Capreno	7260	119.8	6771	119.2	8066	121.0	7366	120.1
Duo system technology								
Herbicide tank mixtures								
Starane gold + Focus ultra	7502	123.8	7009	123.4	8246	123.7	7586	123.6
Kabadex extra + Focus ultra	7569	124.9	7123	125.4	8333	125.0	7675	125.1
Callisto plus + Focus ultra	7587	125.2	7100	125.0	8326	124.9	7671	125.0
Magneto top + Focus ultra	7533	124.3	7072	124.5	8259	123.9	7621	124.2
Peak + Focus ultra	7096	117.1	6680	117.6	7666	115.0	7147	116.5
Permit + Focus ultra	7575	125.0	7134	125.6	7559	113.4	7423	121.0
Bentador + Focus ultra	7108	117.3	6612	116.4	7893	118.4	7204	117.4
Onyx + Focus ultra	7084	116.9	6549	115.3	7646	114.7	7093	115.6
LSD 5 %	370	6.1	256	4.5	340	5.1		
LSD 1 %	442	7.3	307	5.4	393	5.9		
LSD 0.1 %	485	8.0	352	6.2	440	6.6		

Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra. The differences between these variants are small and have not been mathematically proven. These herbicide tank mixtures have very high herbicide efficacy against all annual and perennial broadleaved and graminaceous weeds and against sunflower self-sown plants.

High grain yields are also obtained by use of foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus. They are lower than those for herbicide tank mixtures by Duo system technology. The reason for this is that these herbicides cannot control perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L. Grain yields by foliar-applied herbicides Capreno, Collage and Sovereign are lower. These herbicides, in addition to not being able to control perennial graminaceous weeds *Cynodon dactylon* Pers. and *Agropyrum repens* L., are less efficacy against perennial graminaceous weed *Sorghum halepense* Pers., as well as against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L.

Grain yields by herbicide tank mixtures Bentador + Focus ultra, Peak + Focus ultra and Onyx + Focus ultra are even lower. The reason for this is that these herbicide tank mixtures are poorly efficacy against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L.

Low grain yields are obtained by use of soil-applied herbicides Sulcotrek, Successor, Akris, Deflexo mix, Click duo, Bismarck and Pledge.

Table 3. Influence of some herbicides and herbicide tank mixtures on structural elements of the yield (mean 2018-2020)

Variants	Cob length, cm	Grains per cob, number	Grain weight per cob, g	1000 grains weight, g	Plant height, cm
Control – untreated	18.5	607.4	124.72	211.3	218.8
Conventional technology					
Soil-applied herbicides					
Sulcotrack	18.1	624.1	144.36	226.2	246.0
Successor	18.1	624.2	140.54	225.6	243.5
Acris	18.7	629.0	145.32	228.7	250.2
Deflexo mix	18.5	649.2	146.54	234.0	250.5
Click duo	17.9	625.1	144.57	226.4	246.8
Bismarck	18.1	624.8	142.62	226.4	255.0
Pledge	18.1	629.8	138.00	230.0	250.1
Foliar-applied herbicides					
Sovereign	18.9	626.8	148.00	223.3	243.7
Mistral plus	19.3	650.2	148.12	232.3	250.5
Spandis	19.5	623.7	148.72	237.2	249.9

Arigo	19.3	642.3	148.54	234.0	250.0
Collage	18.1	623.7	144.22	226.0	246.5
Capreno	19.1	636.7	148.14	229.4	249.9
Duo system technology					
Herbicide tank mixtures					
Starane gold + Focus ultra	19.4	624.8	148.67	237.6	250.7
Kabadex extra + Focus ultra	19.7	646.3	149.29	237.3	250.8
Callisto plus + Focus ultra	19.6	638.7	148.79	236.4	250.6
Magneto top + Focus ultra	19.5	643.3	148.71	233.8	250.4
Peak + Focus ultra	18.2	629.8	144.00	230.0	246.2
Permit + Focus ultra	19.5	649.2	148.18	233.3	250.6
Bentador + Focus ultra	18.8	623.9	147.80	237.3	249.8
Onyx + Focus ultra	18.1	626.9	143.70	225.9	245.6
LSD 5%	1.1	8.7	11.1	13.5	7.9
LSD 1%	2.2	12.1	17.4	19.0	11.3
LSD 0.1%	5.2	16.3	23.6	25.5	15.3

These herbicides are inefficacy against perennial graminaceous weeds *Sorghum halepense* Pers., *Cynodon dactylon* Pers. and *Agropyrum repens* L., against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolisulus arvensis* L., as well as against the annual broadleaved weed *Xanthium strumarium* L. Only herbicide Successor has a low efficacy of 10 % against *Cirsium arvense* Scop. and 15 % against *Convolvulus arvensis* L., but on the other hand this herbicide shows low phytotoxicity against maize plants. However, grain yields by use of the seven soil-applied herbicides are higher than with weed infested, untreated control.

To explain changes in grain yields obtained by Duo system and conventional technologies were investigated some of the structural elements that determine it (Table 3). Differences in the efficacy and selectivity of the studied herbicides and herbicide tank mixtures lead to changes in the values of the indicators cob length, grain number per cob, the grain weight per cob and 1000 grain weight. The differences are mathematically proven. The greatest increase in the grain number per cob, the grain weight per cob and 1000 grain weight compared to untreated control is obtained by herbicide tank mixtures by Duo system technology Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra, followed by foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus.

It was established an increase in the cob length in the variants of both grain maize cultivation technologies - Duo system and conventional. The increase in this index is less, but also has been proven mathematically. The cob length has a lesser influence on the yield value. More importantly for grain maize, the cobs are to have many grains, with well-fed and well ripened grains.

Studied herbicide combinations and combined herbicides have an influence on plant height. It is lowest in the untreated control. This is due to competition between existing in the control weeds and maize plants. Eliminate the negative effect of weeds leads to an increase in plant height in all variants of both technologies for maize cultivation. The highest values of the indicator plant height are at herbicide tank mixtures by Duo system technology Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra, Starane gold + Focus ultra and Permit + Focus ultra, followed by the foliar-applied herbicides by conventional technology Spandis, Arigo and Mistral plus. At soil-applied herbicide Successor and foliar-applied herbicide Sovereign plant heights are lower. As this reduction in height is accompanied by an increase in grain yield as a result of the high herbicide efficacy, these herbicides by conventional technology have a retardant effect rather than a phytotoxic effect. This is a further positive effect of their use, as it reduces the risk of pulling down or breaking of the plants in a storm and downfall of the yield.

CONCLUSIONS

The highest grain yields are obtained by use of herbicide tank mixtures by technology Duo system Kabadex extra + Focus ultra, Callisto plus + Focus ultra, Magneto top + Focus ultra,

Starane gold + Focus ultra and Permit + Focus ultra.

High grain yields are also obtained by use of foliar herbicides by conventional technology Spandis, Arigo and Mistral plus.

The use of soil-applied herbicides Sulcotrack, Successor, Acris, Deflexo mix, Click duo, Bismarck and Pledge in maize crops leads to lower grain yields due to their inefficacy against perennial graminaceous and broadleaved weeds and against the annual broadleaved weed *Xanthium strumarium* L.

Increase in grain yield is due to the greatest degree of increase in indexes grains number per cob, grain weight per cob and 1000 grains weight.

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