Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

BIOLOGICAL EFFICACY OF HERBICIDES AND HERBICIDE COMBINATIONS APPLIED TO CORN

Maya DIMITROVA[1], Chavdar DOCHEV[2], Veselin PETKOV[2], Ivan DRAJEV[2], Doycho DOYCHEV[2], Svetlin IVANOV[3]

[1]Agricultural University of Plovdiv, Faculty of Agronomy, 12 Mendeleev Blvd., Plovdiv, Bulgaria
[2]Corteva Agriscience, 4 Mladost Street, Park Sofia 1A, Sofia, Bulgaria
[3]Trakia University, Student Campus, Stara Zagora, Bulgaria

Corresponding author email: mayadimitrova30@yahoo.com

Abstract

In the period 2018-2019, the biological efficacy of new herbicides and herbicide combinations for maize was studied in the experimental field of Agricultural University, Plovdiv. The experiment was performed using the block method with DuPont Pioneer hybrid P0216 and included preparations applied in phase 5-6 leaf of the crop. In both experimental years, annual late-spring dicotyledonous species predominate - Amaranthus retroflexus L.,Chenopodium album L., Solanum nigrum L., Xantium strumarium L., Datura stramonium L., Abutilon theophrasti Medic., Portulaca oleracea L. From the perennial weeds 2 species are common - Sorghum halepense (L.) Pers and Convolvulus arvensis L. The best control of weeding was observed when using the combination of Victus OD - 1250 ml/ha + Cabadex Extra - 300 ml/ha. These results correlate both with the yields obtained from the crop and the physical characteristics of the grain.

Key words*: weeds, efficacy, herbicides, Zea mays L, yield.*

INTRODUCTION

Corn (*Zea mays* L.) is one of the most important food and feed crops in the world. Over the last few years, there has been a steady tendency to an increase of the planted areas in Bulgaria, expanding from 328 000 ha in 2010 to 550000 ha in 2019 (Agricultural Reports 2010-2019, website of the Ministry of Agriculture and Food in the Republic of Bulgaria).

The main harmful factor for obtaining a high and quality yield from the crops are the weeds. (Tonev et al., 2019; Dimitrova et al., 2018; Zhelyazkov I., 2007). Agricultural practice has shown that the grain yield could decline between 70 and 90% in highly weeding maize fields (Mahana et al., 2014; Troyer, 2009). It has been proven that weeds not only reduce the yield but also adversely affect the quality of the grain, which makes combating them effective and economically viable (Koprivlenski et al., 2015; Dimitrova, et al., 2013a; Dimitrova, et al., 2013b; Haall et al., 1992).

The aim of the present study was to follow out the biological efficacy of new herbicides and herbicide combinations in maize and the effect of herbicides on physical characteristics of the grain.

MATERIALS AND METHODS

In 2018 and 2019 in the Training-and-Experimental Fields of the Agricultural University in Plovdiv, precise field trials were carried out with maize hybrids P0216. The plants were grown at planting densities 70000 plants per hectare. The experiments were set by the split-plot design method with a perpendicular location of the factors. Drip irrigation was provided in the experimental field during the trial years.

The soil in the experimental field of the Agricultural University - Plovdiv has been determined as alluvium, which based on the international classification of FAO belongs to the category of Mollic Fluvisols. It is characterized by average sandy-clay mechanical composition, not high humus content of 1.01-1.32%, a weak alkaline reaction of the soil (pH 7.6-7.9) (Popova et al., 2012).

Variants of the trial:

1. Untreated control - (K_1);

2. Industrial control – untreated area with 1-2 hoeing (K_2);
3. Victus OD - 1250 ml/ha + Derby Super - 330 g/ha;
4. Victus OD - 1250 ml/ha + Starane Gold - 1200 ml/ha;
5. Victus OD - 1250 ml/ha + Kabadex Extra - 300 ml/ha;
6. Arigo WG - 330 g/ha + 0.1% Trend;
7. Principal Plus - 440 g/ha + 0.1% Trend;
8. Elumis OD - 1600 ml/ha.

Plant Material

Seeds of the maize hybrid for forage production of Pioneer Company were used.

According to the length of their vegetation period the hybrid P 0216 **-** according to FAO 480. Stay green type with open leaves wrapping the cob. It is recommended for the production of biogas. It can also be used for silage. It has an excellent yield potential.
(*www.pioneer.com*)

Agro-technical practices

The experimental field was fertilized with a nitrogen fertilizer at the rate of 240 kg/ha NH_4NO_3, applied at the stage of 5^{th}-6^{th} leaf of the crop. During the vegetation, treatment was carried out at the 4^{th}-6^{th} leaf stage of the crop with different herbicides.

Selectivity of the herbicide preparations to the crop was reported following *EWRS* (*European Weed Research Society*) scale: from score 1 - no damage to the crop plants, to score 9 - the crop is completely destroyed.

Foliar herbicides were applied by a back-sack sprayer with spray solution 300 l/ha.

The agro-technical measures were carried out according to the generally accepted technology for maize growing (soil cultivation, fertilization, sowing, rolling).

Data analysis

The data were processed statistically by method ANOVA to determine the significance of the differences between the tested variants.

RESULTS AND DISCUSSIONS

In both experimental years, the growing season was warm, with temperatures around and above average over a long period of time (Figures 1 and 2). In terms of temperature, the year 2018 was warmer compared to the second year of the experiment. There is a substantial difference in the average monthly temperatures in years during the initial period of the growth of the crop in April and May, in 2018 the temperatures were higher than those registered in 2019. Regarding the rest of the vegetation period, the values of this indicator in the different months are quite similar and exceed the average values for the period of many years (Figure 1).

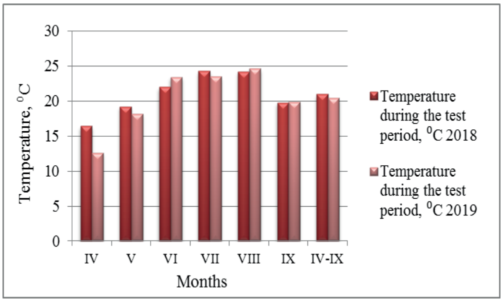

Figure1.Temperature during the test period, °C

Despite the large quantity of the rainfall in May and June 2018 (112.3 and 118.9 mm, respectively), it is extremely unevenly distributed, which necessitated conducting the first irrigation of the crop with a norm of 40 m^3. The year 2019 was characterized by the high values of the rainfall, which during the vegetation period of the crop exceeded the threefold average values for the period of many years (Figure 2).

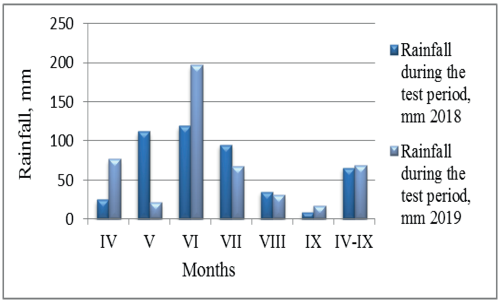

Figure 2. Rainfall during the test period, mm

In the period 2018-2019, the experimental areas were heavily infested by weeds from the group of the annual late-spring species. Major representatives of that group were: *Solanum nigrum* L., *Xantium strumarium L., Chenopodium album* L., *Amaranthus retroflexus* L., *Portulaca oleraceae* L., *Datura stramonium* L., *Setaria* spp., *Echinochloa crus-*

galli L.The perennial weed species found were: *Sorghum halepense* Scop. and *Convolvulus arvensis* L. Those weed species are typical for the maize crop in the region (Mitkov et al., 2018; Dimitrova et al., 2013; Zhelyazkov, 2007).

The obtained results on the efficacy of the tested herbicides during the years of the experiment are shown in Tables 1 and 2.

On the 20th day of the first year of the experiment, after applying the respective treatment (05.06.2018), the number of the weeds in the untreated control sample reached 108.0 weeds/m^2, of which 84.3 weeds are annual and 23.7 weeds are perennial (*Sorghum halepense* Scop. and *Convolvulus arvensis* L.). The highest was the density of *Solanum nigrum* L. - 39.6 weeds/m^2, *Xantium strumarium* L. - 14.2 weeds/m^2, *Chenopodium album* L. - 8.4 weeds/m^2, *Amaranthus retroflexus* L. and *Setaria* spp. - 6.4 weeds/m^2.

Table 1. Weed density on the 20th days after treatment, 2018

Variants	Weed density on the 20th days after treatment (05.06.2018), number/m^2											
	Annual									Perennial		
	Amaranthus retroflexus	Solanum nigrum	Datura stramonium	Setaria spp.	Abutilon theophrasti	Xantium strumarium	Chenopodium album	Portulaca oleracea	Total annual	Sorghum halepense	Convolvulus arvensis	Total perennial
1. Untreated control	6.4	39.6	2,7	6.5	2.9	14.2	8.4	3.6	84.3	18.3	5.4	23.7
2. Industrial control – untreated area with 1-2 hoeing (K_2)	1.2	11.3	0.7	1.2	0.6	2.8	1.7	1.5	21.0	4.1	1.8	5.9
3. Victus OD – 1250 ml/ha + Derby Super – 330 g/ha	0.2	0.4	0.2	0.2	0.6	0.8	0	0.4	2.8	0.5	0.8	1.3
4. Victus OD – 1250 ml/ha + Starane Gold – 1200 ml/ha	0.1	0.3	0.2	0.2	0.2	0.5	0.4	0.3	2.2	0.5	0	0.5
5. Victus OD – 1250 ml/ha + Kabadex Extra–300 ml/ha	0.1	0.3	0	0	0	0.2	0	0.4	1.0	0.4	0.2	0.6
6. Arigo WG – 330 g/ha + 0,1% Trend	0	0.4	0	0.1	0	0.9	0	2.3	3.7	0.7	1.8	2.5
7. Principal Plus – 440 g/ha + 0,1% Trend	0	2.5	0.2	0	0	0.8	0	0.4	3.9	0.2	0.4	0.6
8. Elumis OD – 1600 ml/ha	0.1	0.4	0	0.6	0.8	1.1	0	1.7	4.7	0.2	4.0	4.2

The data on Table 1 show the high efficacy of the applied herbicides and combinations, which compared to the overall weed coverage ranges from 98.5% (var. 5. Victus OD - 1250 ml/ha + Kabadex Extra - 300 ml/ha) to 91.7% (var. 8 Elumis OD - 1600 ml/ha). The weaker effect of the combination in variant 8 is primarily due to the weaker control of the type *Xantium strumarium* L. - 89% compared to the untreated control sample and *Convolvulus arvensis* L. - 74%. Table 1 shows the effect of the preparations on the separate weed types. These are foliar herbicides and this allows us to apply the herbicides having the highest level of efficacy in a differentiated manner, after we have determined the type composition to be found among the crops. On the 40th day after spraying (25.06.2018), the number of the weeds in the untreated control sample reached 139.6 weeds/m^2, as the density of the annual types is 108.0 weeds/m^2.

The farm control sample was dug only once, which led to a reduction of almost 2.5 times in the level of weed coverage.

The governing laws that we found during the first reporting on the efficacy of the applied herbicides and combinations were preserved. Considering the overall level of weed coverage, it is the highest in variant 5 (Victus OD - 1250 ml/ha + Kabadex Extra - 300 ml/ha - 97.2% and variant 4 (Victus OD - 1250 ml/ha + Starane Gold - 1200 ml/ha) - 95%.

The large quantity of the rainfall in June and July 2018, 118.9 and 94.7 mm, respectively, which exceeded the norm during this period 2.7 times, was the reason for the secondary weed coverage, which emerged after the 40th day of the treatment using herbicides.

During the second year of the experiment, there is lower density of the weeds compared to the first year but the type composition is the same as in the year 2018.

On the 20th day after treatment (06.06.2019), the number of the weeds in the untreated control sample reached 104.2 weeds/m^2, of which 80.7 weeds are annual and 23.5 weeds are perennial (*Sorghum halepense* Scop. and *Convolvulus arvensis* L.).

The highest was the density of the European black nightshade *Solanum nigrum* L. - 45.0 weeds/m^2, *Xantium strumarium* L. - 15.3, *Chenopodium album* L. and *Setaria* spp., 5.6-5.3 weeds/m^2 (table 2).

The data show the high efficacy of the applied herbicides and combinations like the previous year of the experiment.

Considering the overall weed coverage, it ranges from 97.7% in variant 5 to 92% in variant 8 (Elumis OD), which is due to its weaker effect on *Xantium strumarium* L.

On the 40th day after spraying (26.06.2019), the number of the weeds in the untreated control sample reached 128.7 weeds/m^2 and the density of the annual types was 95.9 weeds/m^2.

The farm control sample was dug only once, which led to a decrease of the level of weed coverage by almost 2.6 times. The governing laws established during the first reporting on the efficacy of the applied herbicides and combinations are preserved.

The quantity of the rainfall in June and July 2019, 196.7 and 67.5 mm, respectively, as well as the high summer temperatures, are the reason for the substantial secondary weed coverage which emerged after the 40th day of the treatment using herbicides.

Table 2. Weed density on the 20th days after treatment, 2019

Variants	Weed density on the 20th days after treatment (06.06.2019), number/m^2											
	Annual								Total annual	Perennial		Total perennial
	Amaranthus retroflexus	Solanum nigrum	Datura stramonium	Setaria viridis	Abutilon theophrasti	Xantium strumarium	Chenopodium album	Portulaca oleracea		Sorghum halepense	Convolvulus arvensis	
1. Untreated control	4.0	45.0	1.4	5.3	1.9	15.3	5.6	2.2	80.7	19.3	4.2	23.5
2. Industrial control – untreated area with 1-2 hoeing (K$_2$)	0.9	10.1	0.4	0.8	0.4	6.1	2.2	0.9	21.8	7.8	1.4	9.2
3. Victus OD – 1250 ml/ha + Derby Super – 330 g/ha	0.1	0.8	0	0.3	0.1	1.4	0	0.1	2.8	0.8	1.0	1.8
4. Victus OD – 1250 ml/ha + Starane Gold– 1200 ml/ha	0.1	0.5	0.1	0	0	1.5	0.1	0.1	2.4	0.9	0.6	1.5
5. Victus OD – 1250 ml/ha + Kabadex Extra– 300 ml/ha	0	0.4	0	0	0	0.5	0	0.1	1.0	0.9	0.5	1.4
6. Arigo WG – 330 g/ha + 0,1% Trend	0	0.5	0	0.2	0	0.9	0	0.6	2.2	1.0	1.4	2.4
7. Principal Plus – 440 g/ha + 0,1% Trend	0.1	3.0	0.1	0.2	0.3	1.0	0	0.2	4.9	0.3	0.5	0.9
8. Elumis OD – 1600 ml/ha	0.1	0.8	0.1	0.6	0.7	1.5	0.1	1.0	4.9	0.4	3.5	3.9

Tables 3, 4 and 5 show the results from the conducted dispersion analysis of the obtained data on the yield and the physical characteristics of the grain - hectoliter weight and the weight of 1000 grains, under the influence of the studied herbicides applied on maize hybrid P0216. The grain yield of maize plants is presented in Table 3, on average for the two years of the study. The yield was harvested at 12% grain moisture content.

An assessment was made of the proven differences of the data during the two years of the experiment regarding the untreated control sample. The results related to the three studied signs show that the highest values were registered in variant 5 (Victus OD - 1250 ml/ha + Kabadex extra - 300 ml/ha) and variant 4

(Victus OD - 1250 ml/ha + Starane Gold - 1200 ml/ha. The gradation of the variants with reference to the 3 signs is relatively identical. The differences have been proven to be significant with levels of significance $P_{1\%}$ and $P_{0.1\%}$.

Regarding the yield, even in the farm control sample a higher value was registered (though on the lowest level $P_{5\%}$). With reference to the hectoliter weight and weight of 1000 grains, the values of the farm control sample are at the same level as those of the untreated control sample.

Table 3. Grain yield of corn (kg/ha)

Variants	$\bar{X}$ kg/ha	(D)	Significance
5	15459.0	8692.0	+++
4	14908.0	8141.0	+++
3	14720.0	7953.0	+++
6	14511.0	7744.0	+++
7	14482.5	7715.5	+++
8	14179.0	7412.0	+++
2	8228.5	1461.5	+
1 K_1	6767.0		

Table 4. Hectoliter weight (kg/hl)

Variants	$\bar{X}$ (kg/hl)	(D)	Significance
5	77.20	3.80	+++
4	76.95	3.55	+++
7	76.60	3.20	+++
6	76.40	3.00	+++
3	76.40	3.00	+++
8	76.15	2.75	+++
2	73.90	0.50	Ns
1 K_1	73.40		

Table 5. Weight of 1000 grains (g)

Variants	$\bar{X}$ (g)	(D)	Significance
5	355.40	101.50	++
4	353.45	99.55	++
3	352.60	98.70	++
6	352.50	98.60	++
7	352.50	98.60	++
8	352.00	98.10	++
2	272.84	18.94	ns
1 K_1	253.90		

CONCLUSIONS

In the period 2018-2019, the experimental areas were heavily infested by weeds from the group of the annual late-spring species. Major representatives of that group were: *Solanum nigrum* L., *Xantium strumarium* L., *Chenopodium album* L., *Amaranthus retroflexus* L., *Portulaca oleraceae* L., *Datura stramonium* L., *Setaria* spp., *Echinochloa crus-galli* L. The perennial weed species found are: *Sorghum halepense* Scop. and *Convolvulus arvensis* L.

The highest density was registered among the types *Solanum nigrum* L., *Xantium strumarium* L., *Chenopodium album* L, *Setaria* spp. and *Sorghum halepense* Scop.

The large quantity of the rainfall in June and July, which exceed 2-3 times the norm for this period, is the main reason for the emergence and the high density of the secondary weed coverage among the crops.

During the two years of the experiment, on the 20^{th} and the 40^{th} days after spraying, the highest density of overall weed coverage was registered in var. 5 - 97% (Victus OD - 1250 ml/ha + Kabadex extra – 300 ml/ha) and var. 4 - 95% (Victus OD - 1250 ml/ha + Starane Gold - 1200 ml/ha).

The yield in all variants treated with herbicides exceed the zero control sample (6767 kg/ha) 2.1 up to 2.3 times. Their average values for the period range from 14179.0 kg/ha (var. 8) to 15459.0 kg/ha (var. 5).

The physical indicators of the grain also manifest higher values compared to the untreated control sample. The weight of 1000 grains is 34-40% larger. The hectoliter weight ranges from 76.15 to 77.2 kg/hl, exceeding the control sample by 3.7% to 5.2%.

ACKNOWLEDGEMENTS

This study was funded by the Project of Corteva, Bulgaria in the period 2018-2019.

REFERENCES

Dimitrova M., Dimitrov Y., Palagacheva N., Vitanova M., Minev N., Yordanova, N. (2018). Maize – weeds, diseases and pests. Fertilization. *Videnov & son*, Sofia (Book in Bulgarian).

Dimitrova, M., Dimova, D., Zhalnov, Iv., Zovorski, P., Zhelyazkov, I., Valcheva, E., Popova, R. (2013a). The influence of new herbicides on the growth and the some structural elements of the yield of fodder maize. *Scientific Papers*. *Series A. Agronomy, LVI*, 226–230.

Dimitrova, M., Zhalnov I., Zhelyazkov, I., Stoychev, D. (2013b). Efficiency and selectivity of new herbicides on fodder maize. *Agrolife Scientific Journal*, *2*(1), 47–50.

Haall,. M.R. et al., 1992. The critical period of weed control in grain corn (*Zea mays* L.). *Weed Sciense, 40*, 441–447.

Koprivlenski, V., Dimitrova, M., Zhalnov (2015). Economic evaluation of new herbicides for weed control in maize grain. *Bulgarian Journal of Agricultural Science*, *21*(2), 315–319.

List of authorized plant protection products for sale and use, registered fertilizers, soil improvers and nutrient media. Ministry of Agriculture and Food (2018-2019). *Videnov & son*, Sofia.

Mahana, B., Seglar, B., Owens, F., Dennis, S., Newell, R. (2014). Silage Zone Manual. *Du Pont Pioneer. Johnston, IA* In: Johnston, I. A. (Ed.).

Mitkov, A., Yanev, M., Neshev, N., Tonev, T. (2018). Biological efficacy of some soil herbicides at maize (*Zea mays* L.). *Scientific Papers. Series A. Agronomy*, *LXI*(1), 340–346.

Popova, R., Zhalnov, I., Valcheva,E., Zorovski,P., Dimitrova,M. (2012). Estimates of environmental conditions of soils in Plovdiv Region in applying the new herbicides for Weed control in major field crops. *JCEA., 13*(3), 595–600.

Tonev, T., Dimitrova, M., Kalinova, Sht., Zhalnov, I., Zhelyazkov, I., Vasilev, A., Tityanov, M., Mitkov, A., Yanev, M. (2019). Herbology. *Vidinov & son*. ISBN: 978-954-8319- 75-1 (Text book in Bulgarian).

Troyer, A. (2009). Development of hibrid corn and the seed corn industry. in: Bennetzen J. L. and S. Hake, (Eds.), *Maize Handbook: Genetics and Genomics, Vol. II.* (87-95).Springer, New York.

Zhelyazkov, I. (2007). Integration of new and classical methods against heavy weed infestation in some field crops. *PhD Thesis*, Plovdiv, Bulgaria.

*** www.pioneer.com