

EFFICACY AND SELECTIVITY OF HERBICIDES TESTED ALONE AND IN COMBINATION WITH BIOSTIMULANTS IN MAIZE

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Abstract

In 2024 and 2025, a field experiment was conducted with corn, hybrid Adnano (FAO 480). The experiment was conducted in the village of Brest, Gulyantsi municipality, Bulgaria. No-Till technology is applied on the experimental area. The experiment was based on a wheat predecessor. Direct sowing of corn was carried out. The experiment was set up according to a randomized block design. In the phenophase 4-6 leaf (BBCH 14-16) of the crop, treatment was carried out with the herbicides Capreno SC (345 g/l tembotrione + 68 g/l thiencarbazone-methyl + 134 g/l isoxadifen-ethyl) and Mistral Plus OD (220 g/l dicamba + 50 g/l nicosulfuron). Each of the products was applied alone and in a tank mixture with the biostimulants Lebosol Aminosol (115 g/l N - 9.4 %; 15 g/l K₂O - 1.1 %; 0.25 % S; 1.28 % Na; 66.3 % organic substance) and Lebosol Zinc 700 SC (700 g/l Zn - 40 %). The weeds in the experimental field were represented by: *Conyza canadensis* L., *Chenopodium album* L., *Polygonum convolvulus* L., *Abutilon theophrasti* Medic., *Convolvulus arvensis* L. and *Sorghum halepense* (L.) Pers.

Key words: maize; weeds; herbicides; biostimulants.

INTRODUCTION

One of the main problems accompanying the implementation of agricultural production is the fight against weeds. Weeds appear everywhere every year and cause enormous damage to cultivated plants, reducing yields and lowering the quality of the resulting products. (Tonev et al, 2019; Kostadinova et al., 2016; Kalinova and Yanev, 2015; Yanev, 2015; Yanev et al., 2014a; Yanev et al., 2014b). Studies by a number of authors show that depending on the type and degree of weed infestation, corn yield can decrease from 24% to 96.7% (Mukherjee, P. K. and Puspajit Debnath, 2013; Oerke and Dehne, 2004; Khan et al., 2003; Zhalnov and Raykov, 1996). A wide range of broadleaf weeds infest corn fields, including *Amaranthus* spp., *Chenopodium album* L., *Abutilon theophrasti* Medik., *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L., etc. За да се избегне негативното влияние на плевелите е необходимо да бъдат контролирани. Pannacci found that application of foramsulfuron at a dose of 20.3 g ai/ha provided 95% efficacy against *Amaranthus retroflexus* L., *Setaria viridis* (L.) Beauv.), *Sinapis arvensis* L. и *Solanum nigrum* L. Against *Abutilon theophrasti* Medik., *Chenopodium album* L. and *Echinochloa crus-*

galli (L.) Beauv. the same percentage of herbicide efficacy was reported, but at doses of 20 to 50 g ai/ha (Pannacci, 2016). For the control of *Sorghum halepense* L., *Convolvulus arvensis* L., *Echinochloa crus-galli* L., *Chenopodium album* L., *Amaranthus retroflexus* L. and *Abutilon theophrasti* L. in corn, the combination of Stomp 33 EC + Mistral 4 SC is recommended at doses of 300 ml/da + 130 ml/da, respectively (Kalinova et al., 2000). Against *Xanthium strumarium*, *Amaranthus retroflexus*, *Datura stramonium* and *Chenopodium album* in maize Damalas et al., 2018 found efficacy of 92-100% after the use of tembotrione alone. Today, high-yield agriculture is heavily dependent on herbicides, as they constitute a vital and integral component of weed control practices. One herbicide-based approach to controlling herbicide-resistant weeds could involve the use of newly registered dual-active herbicides with a novel mechanism of action. (Goranovska and Yanev, 2016; Janak et al., 2016; Koprivlenski et al., 2015; Sevov et al., 2015; Noor Muhammd et al., 2012; Skrzypczak et al., 2011; Pannacci and Covarelli, 2009; Tonev, 1986).

The role of biostimulants applied in a tank mix with chemical weed control agents is also important to study (Alijani et al., 2023). A focus on published studies on the timing of

biostimulant application in field crops confirms that this period is very often close to the herbicide application period and a single spray is sufficient (Li et al., 2022). This may be explained by the need to support the crop at a specific growth stage, due to research on a more effective application period, or possibly due to the convenience of making this application close (sequential) or even together (tank mix) with the main cropping practice for chemical weed control (Neshev et al., 2021; Ronga et al., 2019). For example, Soltani et al. (2015) reported excellent efficacy of combined application of herbicides and biostimulants on *Abutilon theophrasti* Medik., *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Chenopodium album* L. and *Setaria viridis* L. and other annual weeds in field trials with maize. The application of biostimulants and herbicides in agricultural practices is a new and very complex objective (Araújo et al., 2023). In general, the combination of biostimulants and herbicides from the research results so far has shown different effects on crops, some of which were positive and others negative or insignificant (Panfili et al., 2019). The huge number of different applications of these combined substances can be considered a difficulty or a challenging opportunity for researchers to explore which of these combinations can be used in agriculture (Sangiorgio et al., 2020; Zarzecka et al., 2020). New biostimulant products are introduced every day, while the availability of herbicides is constantly changing (Borowik et al., 2017). It is up to researchers to find the most appropriate combination and application method to promote crop growth, quality and quantitative characteristics and increase herbicide efficacy, while mitigating their adverse effects on non-target plants, either protecting the crop or helping it overcome damage. (Katsenios et al., 2023).

The aim of the study is to establish the efficacy and selectivity of foliar herbicides applied alone and in combination with biostimulants in corn grown using No-Till technology.

MATERIALS AND METHODS

In 2024 and 2025, a field experiment with corn, hybrid "Adnano" (FAO 480) was conducted in the village of Brest, Gulyantsi municipality,

Bulgaria. The experiment was set up according to a randomized block design in 4 replications with a total plot size of 100 m² for the four replications. Before treatment with herbicides and biostimulants, the species weeding and the density of weeds in the experimental field were recorded. Five dicotyledonous and one monocotyledonous weed were observed in the reporting field. The average density of weeds from the two experimental years per 1 m² is as follows: *Conyza canadensis* L. - 13.25 pieces; *Chenopodium album* L. - 9.5 pieces; *Polygonum convolvulus* L. - 4.25 pieces; *Abutilon theophrasti* Medic. - 4.5 pieces; *Convolvulus arvensis* L. - 4.25 pieces; *Sorghum halepense* (L.) Pers. from rhizomes - 18.5 pieces. The study included the following variants: 1. Untreated control; 2. Capreno SC (345 g/l tembotrione + 68 g/l thienencarbazone-methyl + 134 g/l isoxadifen-ethyl (safener)) - 0.29 l ha⁻¹ + Mero (adjuvant) - 2.00 l ha⁻¹; 3. Mistral Plus OD (220 g/l dicamba + 50 g/l nicosulfuron) - 1.20 l ha⁻¹; 4. Capreno SC - 0.29 l ha⁻¹ + Mero - 2.00 l ha⁻¹ + Lebosol Amimosol (115 g/l N - 9.4 %; 15 g/l K₂O - 1.1 %; 0.25 % S; 1.28 % Na; 66.3 % organic substance) - 2.00 l ha⁻¹; 5. Capreno SC - 0.29 l ha⁻¹ + Mero - 2.00 l ha⁻¹ + Lebosol Zinc 700 SC (700 g/l Zn - 40 %) - 1.00 l ha⁻¹; 6. Mistral Plus OD - 1.20 l ha⁻¹ + Lebosol Amimosol - 2.00 l ha⁻¹; 7. Mistral Plus OD - 1.20 l ha⁻¹ + Lebosol Zinc 700 SC - 1.00 l ha⁻¹. At the time of spraying, the corn had reached the phenophase 4-6 leaves (BBCH 14-16). The treatment with the tested products was carried out with a SOLO backpack battery sprayer, nozzle type: fan-shaped, upwind FLAT FAN, with a working solution consumption of 200 l ha⁻¹. The experimental area is part of a production field, on which the No-Till technology has been applied for eight years. The experiment in both experimental years was established after a wheat predecessor. After harvesting its grain, the field was covered (mulched) with wheat straw. In the post-harvest period, a treatment with a total herbicide (glyphosate) was carried out. Before sowing the corn, a basic nitrogen fertilization was carried out with 60 kg ha⁻¹ active substance nitrogen. Fertilization was carried out with a self-propelled sprayer with special equipment for applying liquid fertilizer UAN 32% at a fertilizer rate of 150 l ha⁻¹. Direct sowing was

carried out under appropriate agrotechnical conditions with a row spacing of 70 cm and a seeding rate of 55,000 germinating seeds per hectare, at a depth of 4.5-5 cm, with a spring row seeder for precise and accurate sowing of seeds "VADERSTAD TEMPO L". All units of the technology for growing corn in no-tillage conditions were observed. Weed control was assessed on days 14, 28 and 56 after application of herbicides and biostimulants. The 10-point EWRS (European Weed Research Society) scale was used. The 9-point EWRS visual scale was used to determine the selectivity of herbicides. The Duncan's multiple range test was used for statistical analyses of the obtained maize yields. Level of significance was at $p < 0.05$.

RESULTS AND DISCUSSIONS

Table 1 shows the dynamics of the efficacy of herbicides applied alone and in a tank mixture with the tested biostimulants on *Conyza canadensis* during the reporting period.

Table 1. Biological efficacy of the tested herbicides (in % on the EWRS visual scale) against *C. canadensis*

Treatments	Doses (l ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	80	70	20
3. Mistral Plus OD	1.2	85	85	70
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	75	75	40
5. Capreno SC+Mero+ Lebosol Zinc	0.29+2 + 1	80	75	45
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	85	75	75
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	80	75	75

At variant 2 (Capreno SC + Mero), as well as in variants 9 and 10, where the same herbicide was applied in combination respectively with Lebosol Aminosol and Lebosol Zinc we report 75-80% efficacy on the 14th day after treatment. On the 28th day, the efficacy decreases by 5 to 10% or remains the same in the same variants of the experiment. On the 56th day after spraying, we observe a very low efficacy of 20% with the single application of Capreno SC + Mero and low after its application with the biostimulants (40-45%). On the first evaluation date, the herbicide Mistral Plus OD controls the weed

relatively well, regardless of whether it is applied alone or in a tank mixture with the tested biostimulants. On the second evaluation date, the same efficacy is maintained only after the use of the herbicide alone. Unsatisfactory efficacy was reported after the application of Mistral Plus OD (70%) and after treatment with the same herbicide, but in combination with the biostimulants Lebosol Aminosol and Lebosol Zinc (75%) on the last evaluation date against *Conyza canadensis*.

Table 2. Biological efficacy of the tested herbicides (in % on the EWRS visual scale) against *Ch. album*

Treatments	Doses (l ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	90	98	98
3. Mistral Plus OD	1.2	90	95	98
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	90	95	98
5. Capreno SC+Mero+ Lebosol Zinc	0.29+2 + 1	90	95	98
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	70	85	90
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	75	85	90

Table 2 shows the dynamics of herbicide efficacy against *Ch. album* reported on the 14th, 28th and 56th day after treatment. At the first evaluation date, we report a high herbicidal effect from the second to the fifth variant inclusive. It is noteworthy that the herbicide Mistral Plus OD, applied alone, has a higher herbicidal efficacy compared to its use in a tank mixture with the biostimulants Lebosol Aminosol (70%) and Lebosol Zinc (75%). This trend persists, but to a lesser extent, until the last evaluation date. On the 28th day after treatment, the highest efficacy (98%) is reported with the single application of Capreno SC + Mero. In the variants treated with the herbicide Mistral Plus OD in combination with the biostimulants, we report a satisfactory efficacy of 85%. Only from Capreno SC + Mero we obtain the same efficacy reported on the 56th day against weeds compared to its combined use with the tested biostimulants. However, at the same evaluation date, we report high efficacy from all treated variants of the experiment, which is from 90 to 98%. Against *P. convolvulus*, fourteen days after treatment the highest efficacy of 90% was

reported for Capreno SC + Mero, Mistral Plus OD and Capreno SC + Mero + Lebosol Zinc (Table 3). The lowest herbicidal effect of 80% was reported for Mistral Plus OD + Lebosol Zinc. On the 28th day after spraying, we report an increase in efficacy in all treated variants by 5 to 10%. The highest efficacy of 95% was reported with Capreno SC + Mero, as well as from the combination of this herbicide with Lebosol Zinc, Mistral Plus OD applied alone and in a tank mixture with Lebosol Aminosol. A slightly lower herbicidal effect was observed with the application of Capreno SC + Mero + Lebosol Aminosol and Mistral Plus OD + Lebosol Zinc (90%). On the 56th day after treatment, practically all applied products have a very high effect of 95 to 98%.

Table 3. Biological efficacy of the tested herbicides (in % on the EWRS visual scale) against *P. convolvulus*

Treatments	Doses (1 ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	90	95	98
3. Mistral Plus OD	1.2	90	95	98
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	85	90	95
5. Capreno SC+Mero+ Lebosol Zinc	0.29+2 + 1	90	95	98
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	85	95	98
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	80	90	98

Table 4 shows the effect of the tested herbicides, as well as their application with biostimulants against *A. theophrasti*. A high percentage of efficacy is reported already on the 14th day after the application of the products. On the 28th day after the treatment, the percentages of efficacy increase slightly in the variants where the herbicide Capreno SC was applied. After the application of Mistral Plus OD, the herbicidal effect is maintained. In the last reading, the efficacy is again increased only in variants 2, 4 and 5. The herbicide Capreno SC, regardless of whether it is applied alone or in a tank mixture with the tested biostimulants, controls 100% of weed. The herbicide Mistral Plus OD, applied alone, again retains its efficacy of 95%. When used in combination with the biostimulants Lebosol Aminosol and Lebosol Zinc, the effect decreases slightly and reaches 90%.

Table 4. Biological efficacy of the tested herbicides (in % on the EWRS visual scale) against *A. theophrasti*

Treatments	Doses (1 ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	95	98	100
3. Mistral Plus OD	1.2	95	95	95
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	95	98	100
5. Capreno SC+Mero+ Lebosol Zinc	0.29+2 + 1	95	98	100
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	95	95	90
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	95	95	90

Against *C. arvensis*, the results of the herbicides and biostimulants used are reflected in Table 5. On the 14th day, the highest biological efficacy of 85% was reported from the application of Mistral Plus OD. A lower percentage of efficacy was noted from the herbicide applied in a tank mixture with the tested biostimulants. Even lower efficacy was reported in variant 2 treated with Capreno SC + Mero (70%). It is noteworthy that when applying the same herbicide tested in combination with Lebosol Aminosol and Lebosol Zinc, respectively, the effect is increased and reaches 80%. With the exception of variants 3, 6 and 7, in the rest of the experiment, we report a decrease in the herbicidal effect, reported on the next assessment date. On the 28th day after treatment with the products, we report a relatively good herbicidal effect only from the independent application of Mistral Plus OD (85%). This trend is also maintained on the last reporting date regarding weed control.

Table 5. Biological efficacy of the tested herbicides (in % on the EWRS visual scale) against *C. arvensis*

Treatments	Doses (1 ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	70	65	65
3. Mistral Plus OD	1.2	85	85	85
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	80	75	75
5. Capreno SC+Mero+ Lebosol Zinc	0.29+2 + 1	80	75	75
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	75	75	75
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	75	75	70

Table 6. Biological efficacy of the tested herbicides
(in % on the EWRS visual scale)
against *S. halepense* from rhizomes

Treatments	Doses (l ha ⁻¹)	Days after application		
		14	28	56
1. Untreated control	-	-	-	-
2. Capreno SC+Mero	0.29+2	50	25	20
3. Mistral Plus OD	1.2	65	80	85
4. Capreno SC+Mero+ Lebosol Aminosol	0.29+2 + 2	50	25	20
5. Capreno SC+Mero + Lebosol Zinc	0.29+2 + 1	50	25	20
6. Mistral Plus OD + Lebosol Aminosol	1.20 + 2	70	80	90
7. Mistral Plus OD + Lebosol Zinc	1.20 + 1	70	80	90

Table 6 shows that *S. halepense* from rhizomes is not controlled by Capreno SC + Mero, regardless of whether the herbicide is applied alone or in a tank mixture with the biostimulants Lebosol Aminosol and Lebosol Zinc. Only on the 14th day after treatment is there a suppression of weed development, which is very quickly overcome and at the next evaluation date we have an extremely low herbicidal effect from variants 2, 4 and 5. In contrast, after the application of Mistral Plus OD and the biostimulants used, we have an efficacy of 65-70% from the first reading. This herbicidal effect increases and on the 28th day after the application of the same products reaches 80%. We also report an increase in the percentage of efficacy on the 56th day after the application of the herbicide, and in the variants where it is applied together with Lebosol Aminosol and Lebosol Zinc we have the highest 90% control. During the experiment, for both experimental years, no visual symptoms of phytotoxicity were detected in any of the variants treated with herbicides and in their combined use with foliar fertilizers on the 7th, 14th and 28th days after application of the products, which means complete selectivity - no symptoms of damage to the cultivated plants.

Table 7 presents the results of the yields obtained on average for each variant of the experiment. The natural background of weeding with highly competitive weed species on average for the period leads to a low average yield from the untreated control (4.06 t ha⁻¹). By the degree of statistical evidence on average for the period, 3 separate groups of variants are

distinguished here (a, b, c). It is also noticeable here that the variants treated with the herbicide Mistral Plus OD, applied both alone with the Mero adjuvant and in a tank mixture with the tested biostimulants, are from group "c", the most distant from the untreated control group, that is, with the highest yields. Lower yields are reported from the variants in which the herbicide Capreno SC is tested, but nevertheless they also differ significantly from the yield from the untreated control.

Table 7. Corn grain seed yield, t ha⁻¹

Treatments	Doses (l ha ⁻¹)	Yields
1. Untreated control	-	4.06a
2. Capreno SC + Mero	0.29+2	7.68*b
3. Mistral Plus OD	1.2	8.52*c
4. Capreno SC+Mero + Lebosol Aminosol	0.29+2 + 2	7.78*b
5. Capreno SC+Mero + Lebosol Zinc	0.29+2 + 1	7.82*b
6. Mistral Plus OD + Lebosol Aminosol	1.20+ 2	8.66*c
7. Mistral Plus OD + Lebosol Zinc	1.20+ 1	8.65*c

Legend: All variants with * are significantly different from the untreated control. Values followed by different letters (a, b and c) are significantly different according to Duncan's test at $p < 0.05$.

CONCLUSIONS

The herbicides Capreno SC and Mistral Plus OD are very effective in *Ch. album*, *P. convolvulus* and *A. theophrasti*.

Against *A. theophrasti* the highest herbicidal effect is obtained from Capreno SC, applied both alone and in combination with Lebosol Aminosol and Lebosol Zinc.

Mistral Plus OD is superior to Capreno SC in its activity against the weeds *C. canadensis* and *S. halepense* from rhizomes. The herbicide Capreno SC cannot control *C. canadensis* and *S. halepense* from rhizomes.

Mistral Plus OD applied alone controls *C. arvensis* better than its combined use with Lebosol Aminosol and Lebosol Zinc, and with Capreno SC an inverse relationship is observed. Throughout the entire vegetation period of the corn, hybrid Adnano, no visible signs of phytotoxicity were recorded in any of the trial variants.

Compared to the untreated control, mathematically proven differences in corn grain yield were recorded in favor of all treated variants.

The highest average yield was obtained from the variant treated with Mistral Plus OD, applied in a tank mixture with Lebosol Aminosol (8.66 t ha⁻¹).

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