



Аграрен университет – Пловдив, Научни трудове, т. LXVII, кн. 1, 2025 г.
Юбилейна научна конференция „80 години Аграрен университет –
Пловдив: Традиции срещат иновации“
Anniversary Scientific Conference
"80 Years Agricultural University – Plovdiv: Traditions Meet Innovations"
Agricultural University – Plovdiv, Scientific Works, vol. LXVII, book 1, 2025

[DOI: 10.22620/sciworks.2025.02.006](https://doi.org/10.22620/sciworks.2025.02.006)

STUDY ON SOIL HERBICIDES FOR WEED CONTROL IN TOMATOES (*SOLANUM LYCOPERSICUM* L.)

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Abstract

Tomatoes (*Solanum lycopersicum* L.) are one of the most widespread vegetable crops around the globe and in Bulgaria as well. Very often, effective weed control is a crucial element for sustainable crop production. In the period 2022 - 2023, a field experiment with tomatoes, variety "Prista" F₁ was carried out in the experimental field of the Agricultural University - Plovdiv, Bulgaria. The trial included the following variants: 1. Untreated control (without manual weeding and herbicides); 2. Economic control (manually weeded); 3. Benfluralin (1.500 kg ai ha⁻¹); 4. Metribuzin (0.276 kg ai ha⁻¹); 5. Clomazone (0.144 kg ai ha⁻¹). The herbicides were applied before transplanting the tomatoes (BBCH 00). After spraying, the benfluralin variant was incorporated into the soil. The highest herbicidal efficacy against *Portulaca oleracea* L., *Amaranthus retroflexus* L., and *Setaria viridis* (L.) P.Beauv., after the application of Benfluralin and Metribuzin was found. None of the herbicides studied controlled *Convolvulus arvensis* L. and *Sorghum halepense* (L.) Pers. developed from rhizomes. The highest yield of tomatoes was obtained at Economic control, followed by Benfluralin and Metribuzin.

Keywords: tomatoes, herbicides, weeds, efficacy, yield

INTRODUCTION

The tomato (*Solanum lycopersicum* L.) is one of the leading vegetable crops both globally and in Bulgaria (Meza et al., 2013; MZH, 2025). This crop is characterized by high nutritional value, as its fruits contain significant amounts of macro- and microelements, antioxidants, and vitamins A and C, which play an essential role in maintaining human health (Adalid et al., 2004; Luthria et al., 2006; Borguini and Da Silva Torres, 2009; Nour et al., 2013).

In Bulgaria, tomato production is structured in three directions – early, mid-early, and late production. Weeds are among the most significant factors limiting the growth and development of tomato plants. They compete with the crop for essential growth factors such as water, nutrients, light, and space (Tonev et al., 2019). In

addition, weeds can cause indirect damage through their ability to serve as hosts for various diseases, pests, and parasitic nematodes (Amare et al., 2015).

Studies show that certain weed species can have allelopathic effects on cultivated plants. For example, the tubers of *Cyperus spp.* have an inhibitory effect on the development of the root system in tomatoes and cucumbers (Alsaadawi and Salih, 2009). Competition between weeds and cultivated plants results in a decrease in both yield and fruit quality in *S. lycopersicum L.*

The degree of impact of weeds on tomatoes depends to a large extent on the duration of competition between them. Studies show that prolonged weed infestation can reduce tomato yields by up to 70% (Govindra et al., 1986; Nurse et al., 2006; Bakht and Khan, 2014; Qasem, 2019). According to Adigun (2002), extremely high weed infestation can cause yield losses of up to 95%.

A number of agrotechnical measures can be used to control weeds in tomatoes, including manual weeding, solarization, mulching, etc. (Kumar et al., 2003; Mauromicale et al., 2005; Moreno et al., 2011; Campiglia et al., 2015; Agarwal et al., 2022; Hu et al., 2023). Despite the spread of these practices, the main method of weed control in tomato crops remains the use of herbicides.

Robinson et al. (2004) indicate that an effective weed control strategy involves soil treatment with s-metolachlor in combination with metribuzin, followed by foliar application of thifensulfuron-methyl. According to Ulises (1994), high efficacy against weeds in tomatoes can be achieved by using pendimethalin in combination with metribuzin, as well as trifluralin mixed with metribuzin. Another study shows that the combination of Stomp (pendimethalin), Ronstar (oxadiazon), and Sencor (metribuzin) provides reliable control of weeds in *S. lycopersicum L.* (Siviero and Marasi, 2002). According to Mohseni-Moghadam & Doohan (2017), the application of fomesafen at a dose of 840 g ha⁻¹ also provides reliable control of annual grass species, chickweed, and redroot pigweed.

Cyperus esculentus L. and *Cyperus rotundus L.* are considered to be among the most resistant and difficult to control weed species in tomatoes. According to data from Dayton et al. (2017), effective control of *C. esculentus L.* in polyethylene-mulched tomatoes is achieved by applying metam-sodium and s-metolachlor. Bayat et al. (2021) indicate that successful control of *C. rotundus L.* is observed after soil treatment with metribuzin or s-metolachlor, combined with foliar application of halosulfuron in tomatoes mulched with polyethylene.

The spectrum of action of different herbicides against weeds is very specific. Therefore, their application does not always guarantee complete efficacy against all types of weeds in tomatoes. Experiments have shown that a single treatment with clomazone at doses of 120 to 840 g ha⁻¹ does not result in complete control of *Abutilon theophrasti*, *Chenopodium album*, and *Solanum ptycanthum* (Nurse et al., 2006). McGiffen and Masiunas (1991) report that pyridate has no significant effect on *Abutilon theophrasti*, while metribuzin has been shown to be effective against this species but does not achieve good results with *Solanum ptycanthum*. The aim of this study is to investigate soil herbicides for weed control in tomatoes (*Solanum lycopersicum L.*).

MATERIAL AND METHODS

In the period 2022-2023, a field experiment with tomatoes of the Prista F₁ variety was conducted at the experimental field of the Department of Horticulture at the Agricultural University of Plovdiv, Bulgaria. Prista F₁ is a Bulgarian indeterminate tomato hybrid characterized by medium early maturity, resistance to blight, and high yield potential (Geosemselect, 2025). The trial included the following variants: 1. Untreated control (without manual weeding and herbicides); 2. Economic control (manually weeded); 3. Benfluralin (1.500 kg ai ha⁻¹); 4. Metribuzin (0.276 kg ai ha⁻¹); 5. Clomazone (0.144 kg ai ha⁻¹).

The test was conducted using a randomized block design in three replicates. The size of the experimental plot was 9.6 m², on which 30 plants were grown. The application of the studied herbicides was carried out one day before planting (BBCH 00). The treatment was carried out with a Solo backpack electric sprayer (model 417) with a working solution for soil herbicides of 300 l ha⁻¹. After spraying, the Benfluralin variant was incorporated into the soil.

Styrofoam containers containing 77 cells were used for sowing the seeds. The seeds were sown between June 4 and 7. After one month, the plants were transplanted when they were in the fourth to sixth true leaf stage in the high bed-furrow according to a 100 + 60/40 cm pattern.

The experimental area was naturally infested with *Portulaca oleracea* L., *Amaranthus retroflexus* L., *Solanum nigrum* L., *Setaria viridis* (L.) P.Beauv., *Sorghum halepense* (L.) Pers. developed by rhizomes, and *Convolvulus arvensis* L. Biological efficacy was reported on the 14th, 28th, and 56th days after treatment (DAT) with soil herbicides. Efficacy against weeds was assessed on a 10-point visual scale of EWRS. The selectivity of the herbicides studied was assessed on the 7th, 14th, 21st, and 28th day after treatment on the 9-point visual scale of the EWRS (where 1 means no damage to the crop and 9 means complete destruction of the crop).

At the end of the growing season, the yield of each treatment was recorded. The results obtained were processed using the SPSS 19 software package. The difference between the evaluated treatments was statistically analyzed using One Way Anova with Duncan's multiple range test. Statistical differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSIONS

During the two experimental years, six weed species belonging to three biological groups were recorded in the field of the Department of Horticulture. The group with the most representatives is that of late spring weeds - *Portulaca oleracea* L., *Amaranthus retroflexus* L., *Setaria viridis* (L.) P.Beauv., and *Solanum nigrum* L. Rhizomatous weeds are represented by *Sorghum halepense* (L.) Pers. developed by rhizomes, and root suckers by *Convolvulus arvensis*.

Of all the weeds present in the experiment, *Portulaca oleracea* L. has the highest density, followed by *Amaranthus retroflexus* L.

In the Economic control, weeds are mechanically removed in a timely manner. As a result, 100% weed control has been achieved.

In the control of *Portulaca oleracea* L. on the 14th day after herbicide application, the highest average efficacy for the period – 100% – was reported only after the application of Benfluralin (1.500 kg ai ha⁻¹). With Metribuzin (0.276 kg ai ha⁻¹)

1) and Clomazone (0.144 kg ai ha⁻¹), control was 90%. At 28th DAT, excellent weed control was maintained in variant 3, while in variants 4 and 5 it decreased to 85%. On the third reporting date – 56th DAT, the effect of herbicides against weeds was lowest compared to the first reporting date. However, only after the application of Benfluralin was almost perfect efficacy reported – an average of 95% against the dominant weed purslane in the experiment. The other two herbicides showed almost identical control against *P. oleracea* L., with Clomazone at 77.5% and Metribuzin at 70% (Table 1). According to Mohseni-Moghadam and Doohan (2017), higher efficacy against common purslane can be achieved after applying clomazone in combination with S-metolachlor – over 94%.

Table 1. Efficacy (%) of studied herbicides against *Portulaca oleracea* L., day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	100	100	100	100	100	90.0	100	100	95.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	95.0	90.0	70.0	85.0	80.0	70.0	90.0	85.0	70.0
5. Clomazone (0.144 kg ai ha ⁻¹).	95.0	90.0	80.0	85.0	80.0	75.0	90.0	85.0	77.5

When controlling *Amaranthus retroflexus* L. with herbicides, the best results were reported for Benfluralin. In 2022, at 14th DAT, 100% control against *A. retroflexus* L. was reported for variants 3 and 4. In 2023, at the first assessment, Benfluralin again had the highest efficacy – 95%, followed by Metribuzin – 90%. With Clomazone at 14th DAT in both years, control against *A. retroflexus* L. was the lowest – 85%. At 28th DAT, Benfluralin again showed the highest efficacy against weeds, with 100% in 2022 and 90% in 2023. The application of Metribuzin provides 95% control of common tumbleweed in 2022 and 85% control in 2023. On the same reporting date, the lowest herbicidal efficacy against *A. retroflexus* L. was recorded for Clomazone – an average of 77.5%. At 58th DAT, very good weed control – 90% on average for the period – was reported after the application of Benfluralin (1.500 kg ai ha⁻¹). A similar effect was also reported for Metribuzin (0.276 kg ai ha⁻¹) – 85%. Of the three herbicides studied, Clomazone (0.144 kg ai ha⁻¹) provided the lowest efficacy against *A. retroflexus* L. – 67.5% (Table 2).

At 14th DAT, the highest herbicidal efficacy against *Solanum nigrum* L. – 100% was reported for Clomazone. The control with Metribuzin was also almost excellent – 95% on average. The lowest herbicidal efficacy on the first date, on average for the period, was recorded after the application of Benfluralin – 90%. On the 28th DAT, control ranged from 85% for Benfluralin to 95% for Clomazone. On the third reporting date, the highest efficacy against *S. nigrum* L. was again recorded after the application of Clomazone – 85%, and the lowest was with Benfluralin – 70% (Table 3).

Table 2. Efficacy (%) of studied herbicides against *Amaranthus retroflexus* L., day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	100	100	95.0	95.0	90.0	85.0	97.5	95.0	90.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	100	95.0	90.0	90.0	85.0	80.0	95.0	90.0	85.0
5. Clomazone (0.144 kg ai ha ⁻¹).	85.0	80.0	70.0	85.0	75.0	65.0	85.0	77.5	67.5

Table 3. Efficacy (%) of studied herbicides against *Solanum nigrum* L., day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	95.0	90.0	70.0	85.0	80.0	70.0	90.0	85.0	70.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	100	95.0	80.0	90.0	85.0	75.0	95.0	90.0	77.5
5. Clomazone (0.144 kg ai ha ⁻¹).	100	100	90.0	100	90.0	80.0	100	95.0	85.0

The annual grass weeds in the experiment were represented only by *Setaria viridis* (L.) P.Beauv.. On 14th DAT, full weed control was recorded on average for the period with Benfluralin and Clomazone. Very good efficacy was also reported with Metribuzin – 92.5% on average. At 28th DAT, 100% control was maintained only with Benfluralin, while a decrease was recorded with the other herbicides, with 90% in variant 5 and 87.5% in variant 4. The high control of *S. viridis* (L.) P.Beauv. reported after the application of Benfluralin in the previous two reports was maintained on the third reporting date. At 56th DAT, an average of 90% very good efficacy against weeds was reported for variant 3. After the application of Clomazone, 75% efficacy against weed was reported. The use of Metribuzin provided unsatisfactory control against *S. viridis* (L.) P.Beauv. at 56th DAT – 65% (Table 4).

The results related to the control of *Sorghum halepense* (L.) Pers. developed by rhizomes and *Convolvulus arvensis* show zero efficacy after application of the three herbicides studied (Tables 5 and 6).

Visual observations of the selectivity of the herbicides studied show that under the conditions of the experiment on the 7th, 14th, 21st, and 28th day after treatment, none of the studied herbicides showed signs of phytotoxicity on tomatoes of the Prista F₁ variety. As a result, all three herbicides were rated 1 - no damage to the crop (Table 7).

Table 4. Efficacy (%) of studied herbicides against *Setaria viridis* (L.) P. Beauv., day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	100	100	95.0	100	100	85.0	100	100	90.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	95.0	90.0	70.0	90.0	85.0	60.0	92.5	87.5	65.0
5. Clomazone (0.144 kg ai ha ⁻¹).	100	90.0	70.0	100	90.0	80.0	100	90	75.0

Table 5. Efficacy (%) of studied herbicides against *Sorghum halepense* (L.) Pers. developed by rhizomes, day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Clomazone (0.144 kg ai ha ⁻¹).	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 6. Efficacy (%) of studied herbicides against *Convolvulus arvensis*, day after treatment (DAT)

Variants/Years	2022			2023			Average		
	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT	14 th DAT	28 th DAT	56 th DAT
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Economic control	100	100	100	100	100	100	100	100	100
3. Benfluralin (1.500 kg ai ha ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Metribuzin (0.276 kg ai ha ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5. Clomazone (0.144 kg ai ha ⁻¹).	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7. Selectivity of the studied herbicides in tomatoes, variety “Prista” F₁ according to the 9-score visual scale of EWRS

Variants/ Years	2022				2023				Average			
	7 th DAT	14 th DAT	21 th DAT	28 th DAT	7 th DAT	14 th DAT	21 th DAT	28 th DAT	7 th DAT	14 th DAT	21 th DAT	28 th DAT
1.	1	1	1	1	1	1	1	1	1	1	1	1
2.	1	1	1	1	1	1	1	1	1	1	1	1
3.	1	1	1	1	1	1	1	1	1	1	1	1
4.	1	1	1	1	1	1	1	1	1	1	1	1
5.	1	1	1	1	1	1	1	1	1	1	1	1

During the experiment, the effect of the tested herbicides on tomato yield was studied. The results showed that the highest yield was recorded in Economic control, where weeds were manually weeded. In 2022, the tomato yield in option 2 was 64.552 t ha⁻¹, and in 2023 it was 62.117 t ha⁻¹. The highest yield obtained with this option can be explained by the provision of optimal conditions for the growth and development of tomato plants. In the context of this statement, Ahmed and Kandeel (1991) found that in garlic, weed control by hand hoeing leads to the highest crop yield.

Of the herbicides studied, the highest average yield was recorded after the application of Benfluralin (1.500 kg ai ha⁻¹) – 56.009 t ha⁻¹. This result corresponds to the reported high efficacy of the herbicide against the two dominant weeds in the experiment – *Portulaca oleracea* L. and *Amaranthus retroflexus* L. (Tables 1 and 2). A similar yield was obtained after the application of Metribuzin (0.276 kg ai ha⁻¹) – an average of 53.370 t ha⁻¹. Other studies also show that the application of metribuzin leads to an increase in tomato yield (Sinha and Lagoke, 1984; Singh and Tripathi, 1988; Nath and Sharma, 2000; Sinha et al., 2000).

According to Duncan's test, there is no mathematically proven difference between variants 3 and 4 in the first and second years of the experiment. A statistically proven difference was found between Benfluralin (1.500 kg ai ha⁻¹) and Clomazone (0.144 kg ai ha⁻¹). The use of Clomazone in 2022 resulted in a yield of 49.981 t ha⁻¹, and in 2023 - 47.647 t ha⁻¹. Despite the lower yield in variant 5 compared to variant 3, it is fair to note that all herbicide treatments in the experiment led to a proven higher yield than that in the Untreated control. The increase in yield as a result of herbicide use has also been reported in other studies (Trojak-Goluch and Solarska, 2010; Anyszka et al., 2011).

Table 8. Tomato yield (t ha⁻¹)

Variants/Years	2022	2023	Average
1. Untreated control	26.371 d	23.829 d	25.100
2. Economic control	64.552 a	62.117 a	63.335
3. Benfluralin (1.500 kg ai ha ⁻¹)	57.878 b	54.140 b	56.009
4. Metribuzin (0.276 kg ai ha ⁻¹)	53.737 bc	53.002 bc	53.370
5. Clomazone (0.144 kg ai ha ⁻¹)	49.981 c	47.647 c	48.814

Values with different letters are significantly different according to Duncan's test ($p < 0.05$).

Of all the variants, the lowest yield was recorded in Untreated control, where no weed control was applied. In 2022, the yield from variant 1 was 26.371 t ha⁻¹, and in 2023 it was 23.829 t ha⁻¹. These results confirm the negative impact of weeds on crop growth and development.

CONCLUSIONS

Under the conditions of the 56th DAT experiment, the highest herbicidal efficacy against the dominant weeds in the experiment - *Portulaca oleracea* L., *Amaranthus retroflexus* L., as well as against *Setaria viridis* (L.) P.Beauv. was reported after the use of Benfluralin (1.500 kg ai ha⁻¹), respectively 95%, 90% and 90%. The best control against *Solanum nigrum* L. was established after the application of Clomazone (0.144 kg ai ha⁻¹) – 85%. The soil herbicides studied do not control *Sorghum halepense* (L.) Pers. developed by rhizomes and *Convolvulus arvensis*. The tested herbicides in the respective doses are selective to tomatoes, variety "Prista" F₁. The highest tomato yield was recorded with Economic control – an average of 63.335 t ha⁻¹, followed by Benfluralin (1.500 kg ai ha⁻¹) – average 56.009 t ha⁻¹ and Metribuzin (0.276 kg ai ha⁻¹) – average 53.370 t ha⁻¹.

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