

EVALUATION OF FOLIAR HERBICIDES FOR WEED CONTROL IN MAIZE (*Zea mays* L.).

Mariyan YANEV

Agricultural University of Plovdiv, 12 Mendelev Blvd, Plovdiv, Bulgaria

Corresponding author email: marlanski@abv.bg

Abstract

In 2022 and 2023 a field experiment with the maize hybrid P 9610 was conducted. The trial was performed on the experimental field of the Agricultural University - Plovdiv, Bulgaria. The variants of the experiment were: 1. Untreated control; 2. Economic control; 3. Aminopielik 600 SL (1.20 l ha⁻¹); 4. Arigo WG (0.33 kg ha⁻¹); 5. Callam (0.40 kg ha⁻¹); 6. Starane Gold (1.20 l ha⁻¹). The herbicides were applied in the crop growth stage 3rd-5th leaf (BBCH 13-15). The weed infestation was represented by *Chenopodium album* L.; *Amaranthus retroflexus* L.; *Xanthium strumarium* L.; *Abutilon theophrasti* Medik., and *Solanum nigrum* L. The highest weed control against *Ch. album*, *A. retroflexus*, and *A. theophrasti* after the application of Callam was recorded, and against *X. strumarium* and *S. nigrum* after the application of Starane Gold. For the Economic control as well as for the variants treated with herbicides, the parameters ear diameter, ear length, number of seeds per ear cob, absolute seed mass, hectoliter seed mass and grain yield were higher and mathematically proven compared to the untreated control's results for these parameters.

Key words: maize, weeds, herbicides, efficacy, biometry.

INTRODUCTION

Providing sufficient raw materials to feed the growing population is one of the main challenges facing humanity. Agricultural crops are a major source of food products. Therefore, a large number of scientific studies are aimed at the successful and optimized production of agricultural crops (Panayotov et al., 2024; Mitkov, 2023; Rankova et al., 2023; Shopova, 2023; Dimtrova et al., 2019; Shopova & Cholakov, 2015; Dimitrova et al., 2014a; Dimitrova et al., 2014b; Shopova & Cholakov, 2014; Tityanov et al., 2010; Mitkov et al., 2009; Tityanov et al., 2009a).

Maize (*Zea mays* L.) is one of the most important cereal crops in the world (Ram et al., 2017). It is a vital source of carbohydrates and is used as animal feed, fuel, and raw materials for various industries, which determines its wide distribution area (Veeral & Abirami, 2021). In addition, maize has high adaptability and productive potential (Aldrich et al., 1975).

Weeds are one of the main factors hindering the maize cultivation. They compete with the crop for water, light, nutrients, and space, which leads to a decrease in yield and quality of the produced product (Tonev et al., 2019; Saleem et al., 2015; Arnold et al., 2013; Mundra et al.,

2002). In addition, weeds can serve as hosts for the development of some parasitic plants, insects, and disease agents (Monteiro & Santos, 2022; Tonev et al., 2019).

The extent of yield reduction in maize depends on both the type and density of weeds and the duration of the competitive relationship between the crop and the weeds. Kumar et al. (2023a) found that prolonged weed development reduced the yield of *Z. mays* L. by up to 65.6%. Mukhtar et al. (2007) reported that if weeds are not destroyed, maize yield can decrease by 58% to 79%, which is accompanied by a 65% reduction in maize plant height. Other researchers also confirm the reduction in yield of *Z. mays* L. as a result of competition with weeds (Sharma & Rayamajhi, 2022; Gharde et al., 2018; Ehsas et al., 2016; Jagadish & Prashant, 2016; Kakade et al., 2016; Jat et al., 2012; Oerke & Dehne, 2004; Khan et al., 2003; Zhelnov & Raikov, 1996).

Sharma & Rayamajhi (2022) reported that the critical period for weed control in maize is between 4 and 7 weeks after sowing. Successful weed control during this period leads to the elimination of the harmful effect of weeds on crop yield. Fuadi & Wicaksono (2018) also reported that the first 30 days of maize growth are critical for weed control. The authors found

that if weeds are not controlled during this period, the yield of *Z. mays* L. can be reduced by 20% to 50%.

In both cultivated plants and corn, yield reduction, in addition to weed development, can also be caused by nutrient deficiency (Ivanov et al., 2021; Ivanov et al., 2019; Manolov & Neshev, 2017; Neshev & Manolov, 2016; Manolov et al., 2015; Neshev & Manolov, 2014; Neshev et al., 2014). Depending on the geographical latitude, agro-ecological conditions and crop cultivation technology, weeds of different species composition and density are widespread in maize fields. In Bulgaria, the following weeds are most often found with *Zea mays* L.: *Amaranthus retroflexus* L., *Datura stramonium* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Chenopodium album*, *Abutilon theophrasti* L., *Sinapis arvensis* L., *Echinochloa crus-galli* L., *Setaria glauca* L., *Sorghum halepense* L., *Convolvulus arvensis* L., *Cinodon dactylon* L. and *Cirsium arvense* L. (Yanev, 2023; Mitkov et al., 2019; Hristova et al., 2012; Kalinova et al., 2012; Mitkov et al., 2009).

Weed control in agricultural crops (Mitkov, 2024; Mitkov, 2021; Uzunova et al., 2015; Tityanov, et al., 2009b) including maize, is most often carried out through herbicide application (Bada et al., 2022; Mitkov, 2022; Goranovska & Kalinova, 2018; Goranovska et al., 2017; Sevov et al., 2015; Pannacci & Covarelli, 2009; Tonev et al., 2009b).

Dimitrova et al. (2013a) found that successful control of grass and broadleaf weeds could be achieved after soil application of Gardoprim plus gold 500 SK at a rate of 4.00 l ha⁻¹, Lumax 538 SK at a rate of 4.00 l ha⁻¹ and Wing at a rate of 4.00 l ha⁻¹. Mitkov et al. (2018) recommended the application of Merlin Duo at rates of 1.00 l ha⁻¹ to 2.00 l ha⁻¹ after sowing before maize emergence for the control of *Abutilon theophrasti* L. and *Solanum nigrum* L.

Very good efficacy against *Amaranthus retroflexus* L., *Setaria viridis* (L.) Beauv., *Sinapis arvensis* L. and *Solanum nigrum* L. was achieved after treatment with foramsulfuron at a rate of 20.3 g ai ha⁻¹. At a higher dose of 20 to 50 g ai ha⁻¹, the herbicide also provides very good control against *Abutilon theophrasti*

Medik., *Chenopodium album* L. and *Echinochloa crus-galli* (L.) Beauv. (Pannacci, 2016).

Kalinova et al. (2000) reported that a system application of Stomp 33 EK (3.00 l ha⁻¹) and Mistral 4 SK (1.30 l ha⁻¹) in maize controlled *Sorghum halepense* L., *Convolvulus arvensis* L., *Echinochloa crus-galli* L., *Chenopodium album* L., *Amaranthus retroflexus* L. and *Abutilon theophrasti* L.

In the presence of mixed infestations of cereal and broadleaf weeds, Kierzek et al. (2012) recommend soil application of a tank mix of s-metolachlor + terbuthylazine + mesotrione and vegetative use of nicosulfuron with the adjuvant Atpolan Bio 80 SL.

A large number of scientists have established the biological efficacy of atrazine in combination with other herbicides for weed control in maize (Acharya et al., 2022; Bottcher et al., 2022; Burhanuddin Wiqar et al., 2022; Choudhary et al., 2022; Jha et al., 2022; Khanna et al., 2022; Pinsupa et al., 2022; Wasnik et al., 2022). Soil application of atrazine followed by vegetative treatment with tembotrione has been found to successfully control weeds in maize (Arunkumar et al., 2019). Bada et al. (2022) also reported effective weed control using a system involving soil application of atrazine followed by foliar treatment with tembotrione or topramezone. Kurniadie et al. (2023) recommended the use of a herbicide mixture of atrazine 265 g/l and nicosulfuron 35 g/l at doses of 1.0 l/ha to 3 l/ha for successful control of *Bidens pilosa*, *Ageratum conyzoides*, *Synedrella nodiflora*, *Richardia brasiliensis*, *Eleusine indica* and *Digitaria ciliaris*.

According to Damalas et al. (2018), when weeding maize with *Xanthium strumarium*, *Amaranthus retroflexus*, *Datura stramonium* and *Chenopodium album* very good control can be achieved after applying tembotrione at 100 g ai ha⁻¹ and tembotrione at 100 g ai ha⁻¹ in combination with rimsulfuron at 10 g ai ha⁻¹, nicosulfuron at 40 g ai ha⁻¹ and foramsulfuron at 60 g ai ha⁻¹.

The aim of the present study was to evaluate foliar herbicides for weed control in maize (*Zea mays* L.).

MATERIALS AND METHODS

In 2022 and 2023, a field experiment with maize, hybrid P 9610, was conducted in the experimental field of the Department of Agriculture and Herbiology at the Agricultural University - Plovdiv. The experiment was conducted using the randomized block method (Dimova & Marinkov, 1999) in 4 replications, with a plot size of 20 m².

The experiment variants include: 1. Untreated control - without digging and herbicides; 2. Economic control - earthed-up, without herbicides; 3. Aminopielik 600 SL (2.4 D amine salt 600 g/l) at a rate of 1.20 l ha⁻¹; 4. Arigo WG (Nicosulfuron 120 g/kg + Mesotrione 360 g/kg + Rimsulfuron 30 g/kg) at a rate of 0.33 kg ha⁻¹; 5. Callam (Dicamba 600 g/kg + Tritosulfuron 125 g/kg) at a rate of 0.40 kg ha⁻¹; 6. Starane Gold (Florasulam 1 g/l + Fluroxypyr 100 g/l) at a rate of 1.20 l ha⁻¹. The herbicides were applied in the phenophase 3rd-5th leaf of the crop with a backpack electric sprayer SOLO (model 417), with a working solution consumption of 210 l ha⁻¹.

The corn was grown after a corn predecessor (monoculture) under non-irrigated conditions. The experimental area was fertilized with 250 kg ha⁻¹ combined N:P:K (15:15:15) fertilizer, after which the soil was deeply plowed. Before sowing the crop, a 15 cm disking was performed followed by two cultivations at a depth of 8 cm. The corn was sown at the optimal time for the region, with a density of 65,000 plants per hectare. Spring fertilization with 25 kg/da NH₄NO₃ was also carried out.

During the two years of the study, weeding in the field was represented by the following weed species: *Chenopodium album* L.; *Amaranthus retroflexus* L.; *Xanthium strumarium* L.; *Abutilon theophrasti* Medik. and *Solanum nigrum* L. The efficacy of the herbicides was assessed using the 10-point visual scale of EWRS on the 14th, 28th and 56th days after treatment. The selectivity of the herbicides was assessed on the 7th, 14th and 28th days after application. For this purpose, the 9-point scale of EWRS was used, where at a score of 1 - there is no damage to the crop, and at a score of 9 there is complete death of the crop (Zhelyazkov et al. 2017).

The following corn parameters were recorded and analyzed - ear diameter (cm), ear length (cm), number of seeds per ear cob, absolute seed mass (g), hectoliter seed mass (kg) and grain yield (t ha⁻¹). Duncan's method was used for statistical data processing with the SPSS 19 program (Duncan, 1955). Differences were considered significant at p<0.05.

RESULTS AND DISCUSSIONS

The results of the studies show that, with the exception of sow thistle, the biological efficacy of the applied herbicides increased from the 14th to the 56th day for the remaining weeds present in the experiment (Tables 1 to 6). On average, for the period of the 14th day after application of the studied herbicides, the highest efficacy against *Chenopodium album* L. was recorded for Aminopielik 600 SL at a rate of 1.20 l ha⁻¹ - 60%, followed by Callam at a dose of 0.40 kg ha⁻¹ - 57.5%. The weakest control against the weed was recorded for Starane Gold (1.20 l ha⁻¹) - 25%. On the 28th day, the highest efficacy was recorded after treatment with Callam - 75%. Again, the control after the application of Starane Gold was unsatisfactory - 35%. During the last reporting date, very good efficacy against *Ch. album* was recorded for Callam - 90%. The application of Aminopielik 600 SL and Arigo WG provided good control against the weed - 80%. After the application of 2, 4-D sodium salt 80% WP at a dose of 1,250 g ha⁻¹ in maize Kumar et al. (2023b) found almost the same efficacy - 77.3% in the control of *Chenopodium album* (L.), *Physalis minima* Roem. & Schult, *Melilotus indicus* (L.) and *Cichorium intybus*. Of all the herbicides studied in the experiment, the lowest efficacy against *Ch. album* L. was reported for Starane Gold - 45% (Table 1).

Of the weeds present in the experiment, *Amaranthus retroflexus* L. is the most sensitive to the applied herbicides. On the first reporting date, the highest control was after the application of Aminopielik 600 SL - 70%, followed by Arigo WG and Callam - 65%. On the second reporting, an increase in efficacy was observed after the application of the herbicides, with the highest being in the variant with Arigo WG - 85%.

On the 56th day, very good control against *Am. retroflexus* L. - 95% was observed with Arigo WG and Callam. The other two herbicides also

successfully controlled the weed, with the efficacy for Aminopielik 600 SL being 90%, and for Starane Gold - 87.5% (Table 2).

Table 1. Efficacy (%) of the studied herbicides against *Chenopodium album* L., day after treatment (DAT)

Variants	2022			2023			Average		
	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Economic control	100	100	100	100	100	100	100	100	100
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	55.0	70.0	75.0	65.0	70.0	85.0	60.0	70.0	80.0
4. Arigo WG (0.33 kg ha ⁻¹)	45.0	65.0	75.0	55.0	75.0	85.0	50.0	70.0	80.0
5. Callam (0.40 kg ha ⁻¹)	55.0	70.0	90.0	60.0	80.0	90.0	57.5	75.0	90.0
6. Starane Gold (1.20 l ha ⁻¹)	30.0	40.0	50.0	20.0	30.0	40.0	25.0	35.0	45.0

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

Variants	2022			2023			Average		
	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Economic control	100	100	100	100	100	100	100	100	100
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	70.0	75.0	85.0	70.0	85.0	95.0	70.0	80.0	90.0
4. Arigo WG (0.33 kg ha ⁻¹)	60.0	80.0	90.0	70.0	90.0	100	65.0	85.0	95.0
5. Callam (0.40 kg ha ⁻¹)	60.0	75.0	90.0	70.0	85.0	100	65.0	80.0	95.0
6. Starane Gold (1.20 l ha ⁻¹)	60.0	75.0	85.0	60.0	85.0	90.0	60.0	80.0	87.5

Table 3. Efficacy (%) of the studied herbicides against *Xanthium strumarium* L., day after treatment (DAT)

Variants	2022			2023			Average		
	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Economic control	100	100	100	100	100	100	100	100	100
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	55.0	45.0	35.0	65.0	55.0	45.0	60.0	50.0	40.0
4. Arigo WG (0.33 kg ha ⁻¹)	65.0	55.0	35.0	70.0	65.0	45.0	67.5	60.0	40.0
5. Callam (0.40 kg ha ⁻¹)	50.0	65.0	75.0	60.0	70.0	85.0	55.0	75.0	80.0
6. Starane Gold (1.20 l ha ⁻¹)	45.0	65.0	80.0	55.0	75.0	90.0	50.0	70.0	85.0

Table 4. Efficacy (%) of the studied herbicides against *Abutilon theophrasti* Medik. L., day after treatment (DAT)

Variants	2022			2023			Average		
	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Economic control	100	100	100	100	100	100	100	100	100
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	80.0	90.0	95.0	70.0	80.0	95.0	75.0	85.0	95.0
4. Arigo WG (0.33 kg ha ⁻¹)	50.0	75.0	80.0	55.0	85.0	90.0	52.5	80.0	85.0
5. Callam (0.40 kg ha ⁻¹)	50.0	70.0	95.0	60.0	80.0	95.0	55.0	75.0	95.0
6. Starane Gold (1.20 l ha ⁻¹)	40.0	55.0	80.0	40.0	65.0	80.0	40.0	60.0	80.0

Table 5. Efficacy (%) of the studied herbicides against *Solanum nigrum* L., day after treatment (DAT)

Variants	2022			2023			Average		
	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT	14 DAT	28 DAT	56 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Economic control	100	100	100	100	100	100	100	100	100
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	50.0	70.0	80.0	60.0	75.0	80.0	55.0	75.0	80.0
4. Arigo WG (0.33 kg ha ⁻¹)	60.0	75.0	90.0	65.0	80.0	90.0	62.5	77.5	90.0
5. Callam (0.40 kg ha ⁻¹)	45.0	65.0	70.0	55.0	70.0	80.0	50.0	67.5	75.0
6. Starane Gold (1.20 l ha ⁻¹)	60.0	75.0	85.0	65.0	85.0	95.0	62.5	80.0	90.0

One of the difficult weeds to control in the experiment was *Xanthium strumarium* L. It was found that when using Arigo WG and

Aminopielik 600 SL, the highest efficacy was on the 14th day, 67.5% and 60%, respectively. During the remaining two reports, the control

with these two preparations decreased, with the lowest being on the 56th day - 40% for Arigo WG and Aminopielik 600 SL. The opposite was observed with the remaining two herbicides. The highest efficacy after the application of Starane Gold and Callam was reported on the 56th day after treatment. Of the herbicides studied, the best control against *X. strumarium* was provided by Starane Gold, where on the third reporting date the average for the period was 85% (Table 3).

The highest efficacy against *Abutilon theophrasti* Medik. on the 14th day was registered after the application of Aminopielik 600 SL - 75%. In the other herbicide variants, the control was significantly lower, ranging from 40% to 55%. On the 28th day, an increase in efficacy was reported, with Aminopielik 600 SL reaching 85% and Arigo WG reaching 80%. On the 56th day, the best control against *A. theophrasti* Medik. - 95% was reported after the use of Aminopielik 600 SL and Callam. Of all the herbicides studied, the weakest control was in the variant with Starane Gold - 80%. (Table 4).

The results related to the biological efficacy of the applied herbicides against *Solanum nigrum* L. show that on the 14th day the best control was with Arigo WG and Starane Gold - 62.5%. The application of Aminopielik 600 SL and Callam provided 55% and 50% efficacy against the weed, respectively. On the 28th day the best control against *S. nigrum* L. was reported with Starane Gold - 80%. Similar efficacy was also found in the variants with Arigo WG and Aminopielik 600 SL, 77.5% and 75%, respectively. Of all the herbicides studied on the 56th day, on average for the period, the best control against the weed was registered after the use of Starane Gold - 90% and Arigo WG - 90%. On the last reporting date, Aminopielik 600 SL provided 80%, and Callam - 75% efficacy against *S. nigrum* L. (Table 5).

In addition to assessing the control of the applied herbicides against the available weeds during the two experimental years, the selectivity of the products towards maize, hybrid P 9610, was also monitored. Under the conditions of the experiment, on the 7th, 14th and 28th day after the application of the herbicides, no visible symptoms of phytotoxicity were detected - score 1 on the EWRS scale.

During the experiment, the productivity of the maize hybrid P 9610 was monitored, both in the variants treated with herbicides, and in the Untreated and Economic controls. It was found that the largest cob diameter in both years was recorded in the Economic control and Callam (0.40 kg ha⁻¹), on average 3.71 cm and 3.64 cm. It is correct to note that there is no statistically proven difference between these two variants. It has been proven that there is no difference between Starane Gold (1.20 l ha⁻¹), Arigo WG (0.33 kg ha⁻¹) and Aminopielik 600 SL (1.20 l ha⁻¹) in terms of the studied indicator. The lowest ear diameter of all variants was found in the untreated control, as in 2022 it was 2.37 cm, and in 2023 it was 2.21 cm. The results were mathematically proven according to Duncan's multiple range test ($p < 0.05$) (Table 6).

Table 6. Ear diameter, cm

Variants	2022	2023	Average
1. Untreated control	2.37 c	2.21 c	2.29
2. Economic control	3.75 a	3.67 a	3.71
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	3.23 b	3.20 b	3.22
4. Arigo WG (0.33 kg ha ⁻¹)	3.32 b	3.19 b	3.26
5. Callam (0.40 kg ha ⁻¹)	3.66 a	3.61 a	3.64
6. Starane Gold (1.20 l ha ⁻¹)	3.35 b	3.23 b	3.29

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

Under the conditions of the experiment, the longest ears were recorded in the Economic control and Callam (0.40 kg ha⁻¹). In 2022, in the Economic control, the ear length was 14.90 cm, and in 2023 it was 14.35 cm. Close to these values were recorded after the application of Callam as well, where in 2022 the ear length was 14.55 cm, and in 2023 it was 14.10 cm. No mathematically proven difference was found between variants 2 and 5. The results of the Duncan test showed that in 2022 there was no proven difference between Callam (14.55 cm), Starane Gold (13.65 cm) and Arigo WG (13.65 cm), but there was a significant difference between Aminopielik 600 SL (13.25 cm) and Callam (14.55 cm). In 2023, it was found that the ear length in the Economic control and Callam was proven to be higher than the variants with Arigo WG (12.75 cm) and Aminopielik 600 SL (12.25 cm). Again, the shortest cob length was in the Untreated control plants – an average of 10.58 cm where we do not use herbicides and hoeing (Table 7).

Table 7. Ear lenght, cm

Variants	2022	2023	Average
1. Untreated control	10.85 d	10.30 d	10.58
2. Economic control	14.90 a	14.35 a	14.63
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	13.25 c	12.25 c	12.75
4. Arigo WG (0.33 kg ha ⁻¹)	13.65 bc	12.75 c	13.20
5. Callam (0.40 kg ha ⁻¹)	14.55 ab	14.10 ab	14.33
6. Starane Gold (1.20 l ha ⁻¹)	13.65 bc	13.00 bc	13.33

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

Regarding the indicator number of seeds per mazie ear, the lowest values were proven in the untreated control, where in 2022 they were 215.00, and in 2023 they were 207.70.

It has been statistically proven that the highest number of seeds in the Economic control and Callam was recorded.

In variants 2 and 5, the number of seeds in 2022 was 359.75 and 357.20, respectively, and in 2023 it was 341.40 and 338.75. No mathematically proven difference was fund between the Economic control and Callam (Table 8).

Table 8. Number of seeds per msize ear

Variants	2022	2023	Average
1. Untreated control	215.00 c	207.70 d	211.35
2. Economic control	359.75 a	341.40 a	350.58
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	322.15 b	303.50 c	312.83
4. Arigo WG (0.33 kg ha ⁻¹)	336.35 ab	320.20 bc	328.28
5. Callam (0.40 kg ha ⁻¹)	357.20 a	338.75 ab	347.98
6. Starane Gold (1.20 l ha ⁻¹)	330.50 b	319.20 bc	324.85

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

The results related to the absolute seeds mass showed that it is proven to be the highest in the Economic control and Callam - an average of 265.68 g and 261.48 g. There was no mathematically proven difference between these two variants.

The highest values of the indicator in variants 2 and 5 correspond to the highest results in terms of weed control. Other authors also found higher values of the absolute mass of seeds after successful weed control (Bastegan et al., 2022; Fang et al., 2022).

The lowest absolute seed mass in both years was found in the Untreated control - an average of 183.55 g. It is correct to note that proven higher values of this indicator than in the untreated control were recorded after the application of Arigo WG, Starane Gold and Aminopielik 600 SL (Table 9).

Table 9. Absolute seed mass, g

Variants	2022	2023	Average
1. Untreated control	189.00 c	178.10 c	183.55
2. Economic control	271.20 a	260.15 a	265.68
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	226.60 b	216.60 b	221.60
4. Arigo WG (0.33 kg ha ⁻¹)	243.35 b	226.90 b	235.13
5. Callam (0.40 kg ha ⁻¹)	266.10 a	256.85 a	261.48
6. Starane Gold (1.20 l ha ⁻¹)	232.25 b	220.75 b	226.50

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

The highest values for the hectoliter seed mass were variants 2 and 5. In the Economic control in 2022, the hectoliter mass was 75.25 kg, and in 2023 it was 71.15 kg. Almost the same values of the indicator were recorded after the application of Callam, where in 2022 it was 75.00 kg, and in 2023 it was 69.50 kg. There was no proven difference between these two variants according to Duncan's multiple range. For Starane Gold, Arigo WG and Aminopielik 600 SL, during the two years of study, the values of the indicator varied from 64.15 kg to 60.40 kg, and there is no mathematically proven difference between them. Of all the variants in the trial, the lowest hectoliter mass in the Untreated control was recorded, where in 2022 it was 56.35 kg, and in 2023 - 53.15 kg (Table 10).

Table 10. Hectoliter seed mass, kg

Variants	2022	2023	Average
1. Untreated control	56.35 c	53.15 c	54.75
2. Economic control	75.25 a	71.15 a	73.20
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	62.60 b	60.40 b	61.50
4. Arigo WG (0.33 kg ha ⁻¹)	63.15 b	62.90 b	63.03
5. Callam (0.40 kg ha ⁻¹)	75.00 a	69.50 a	72.25
6. Starane Gold (1.20 l ha ⁻¹)	64.15 b	63.60 b	63.88

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

Under the conditions of the study, the lowest proven maize grain yield, hybrid P 9610, was recorded in the Untreated control, where no measures were no weed management was done. The yield for the Untreated control in 2022 was 3.17 t ha⁻¹, and in 2023 it was 2.94 t ha⁻¹ (Table 11). Many scientists have proven that the high weed infestation leads to yield decrease, the extent of which depends on the type and density of the weeds (Manilov & Manhart, 2024; Mitkov, 2024; Choudhary et al., 2022; Mitkov, 2022; Wiqar et al., 2022; Mitkov 2020; Tursun et al., 2016; Skrzypczak et al., 2011; Tonev et al., 2010; Tonev et al., 2009a; Walia et al., 2005).

From all studied variants of the experiment, the highest maize yield in the Economic control and after the application of Callam was recorded. As a result of weed control in 2022, the yield in the Economic control was 6.47 t ha⁻¹, and in 2023 it was 6.25 t ha⁻¹. Other authors also reported that when weeds are controlled by hoeing, better conditions are created for the growth and development of corn (Kumar et al., 2017; Sarma et al., 2010). In second place in terms of yield was the variant with Callam, with 6.41 t ha⁻¹ in 2022 and 6.19 t ha⁻¹ in 2023. There was no proven difference between the two variants according to Duncan's multiple range test ($p < 0.05$). It is worth noting that the herbicide treatments with Arigo WG, Starane Gold, and Aminopielik 600 SL also proved to increase the maize yields when compared to that obtained from the Untreated control. The obtained results confirm the positive correlation between the efficacy of herbicides against weeds and the yields.

Tabele 11. Maize grain seed yield (t ha⁻¹)

Variants	2022	2023	Average
1. Untreated control	3.17 c	2.94 c	3.06
2. Economic control	6.47 a	6.25 a	6.36
3. Aminopielik 600 SL (1.20 l ha ⁻¹)	6.02 b	5.80 b	5.91
4. Arigo WG (0.33 kg ha ⁻¹)	6.14 b	5.89 b	6.02
5. Callam (0.40 kg ha ⁻¹)	6.41 a	6.19 a	6.30
6. Starane Gold (1.20 l ha ⁻¹)	6.05 b	5.86 b	5.96

Variants with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$).

CONCLUSIONS

During the experimental period, the highest herbicidal efficacy against *Chenopodium album* L., *Amaranthus retroflexus* L. and *Abutilon theophrasti* Medik. L. was found on the 56th day after the application of Callam at a rate of 0.40 kg ha⁻¹, 90%, 95% and 95%, respectively. Of the herbicides studied treatment with Starane Gold at a dose of 1.20 l ha⁻¹ provided the best control against *Xanthium strumarium* L. and *Solanum nigrum* L., with 85% and 90%, respectively, on the 56th day after the treatment.

Under the conditions of the experiment, after the application of the studied herbicides, no visible symptoms of phytotoxicity were detected for the maize hybrid P 9610 grown in the study.

Ear diameter, ear length, number of seeds per ear, absolute seed mass, hectoliter seed mass and

grain yield were proven to be highest for the Economic control and after the use of Callam.

ACKNOWLEDGEMENTS

The research was financially supported by Project 17-12 at the Center of Research, Technology Transfer and Protection of Intellectual Property Rights at the Agricultural University of Plovdiv, Bulgaria.

REFERENCES

Acharya, R., Karki, T. B., Adhikari, B. (2022). Effect of various weed management practices on weed dynamics and crop yields under maize-wheat cropping system of western hills. *Agronomy Journal of Nepal*, 6(1), 153–161. <https://doi.org/https://www.nepjol.info/index.php/AJN/article/view/47965>

Aldrich, S., Scott, W., Leng, E. (1975). Modern Crop Production, 2nd Edn., A & L Publication, IL, USA.

Arnold, R., O'Neill, M., Smeal, D., Lombard, K., West, M. (2013). Pest Control in Crops Grown in Northwestern New Mexico. *Annual Data Report 100-2012*, 1-16.

Arunkumar, Negalur, R. B., Halepyati, A. S., Yadahalli, G. S., Nagaraj, M. N. (2019). Effect of post emergent herbicides on weed management in maize (*Zea mays* L.). *Journal of Farm Sciences*, 32(3), 264–269.

Bada, M. R., Elankavi, S., Baradhan, G., Muthuselvam, K. (2022). Evaluation of weed management practices on weed dynamics and yield of maize (*Zea mays* L.). *Crop Research (Hisar)*, 57(5/6), 330–334. <https://doi.org/10.31830/2454-1761.2022.CR-879>

Bastegan, F., Kazemeini, S. A., Ghadiri, H. (2022). Effect of sulfonylurea herbicides on weeds control, growth and yield of sweet corn (*Zea mays* L. var. *saccharata*). *Journal of Iranian Plant Protection Research*, 36(3), 385–398.

Bottcher, A. A., Albrecht, A. J. P., Albrecht, L. P., Silva, A. F. M., Freitas, J. De., Souza, T. (2022). Terbutylazine herbicide: an alternative to atrazine for weed control in glyphosate-tolerant maize. *Journal of Environmental Science and Health. Part B, Pesticides, Food Contaminants, and Agricultural Wastes*, 57(8), 609–616.

Burhanuddin Wiqar, Jat, S. L., Parihar, C. M., Mandal, B. N., Ahmadzai, K. M. (2022). Efficiency of post-emergence herbicides for enhancing growth and yield of hybrid maize (*Zea mays*) in Kandahar, Afghanistan. *Indian Journal of Agronomy*, 67(2), 208–211. <https://doi.org/https://indianjournals.com/ijor.aspx?target=ijor:ija&volume=67&issue=2&article=018>

Choudhary, D., Chhokar, R. S., Gill, S. C., Samota, S. R., Kumar, N., Yadav, G. L. (2022). Effect of tillage and herbicides on weeds and yield of maize (*Zea mays* L.). *Journal of Cereal Research*, 14(2), 204–210. <http://doi.org/10.25174/2582-2675/2022/121970>

- Dimitrova, M., Dimova, D., Zhalnov, I., Stoychev, D., Zovorski, P., Georgieva, T., Mitkov, A., Idirizova, E. (2014b). Influence of some herbicides on the growth and development of winter oilseed rape. *Balkan agricultural congress, 8-11 september, Edirne, Turkey. Turkish Journal of Agricultural and Natural Science*, 1058–1062.
- Dimitrova, M., Dimova, D., Zhalnov, I., Zovorski, P., Georgieva, T., Mitkov, A., Idirizova, E. (2014a). The influence of some herbicides on the structural elements of the yield of winter oilseed rape. *Turkish Journal of Agricultural and Natural Sciences*, 1, 1054–1057.
- Dimitrova, M., Minev, N., Yordanova, N., Valcheva, V., Yanev, M. (2019). Effect of planting density of different maize hybrids on crop growth and yield. *Scientific Papers. Series A. Agronomy*, LXII(2), 73–76.
- Dimitrova, M., Zhalnov, I., Zhelyazkov, I., Stoychev, D. (2013). Efficiency and selectivity of new herbicides on fodder maize. *Agrolife Scientific Journal*, 2(1), 47–50.
- Dimova, D. & Marinov, E. (1999). *Trial design ant biometrics*. Academic publisher of VSI, Plovdiv (Book in Bulgarian).
- Ehsas, J., Desai, L., Ahir, N., Joshi, J. (2016). Effect of integrated weed management on growth, yield, and yield attributes and weed parameters on summer maize (*Zea mays* L.) under South Gujarat condition. *International Journal of Science, Environment and Technology*, 5(4), 2050–2056.
- Fang, H., Niu, M., Xue, X., Ji, C. (2022). Effects of mechanical-chemical synergistic weeding on weed control in maize field. *Trans. CSAE*, 38(6), 44–51.
- Fuadi, R. & Wicaksono, K. (2018). Applications of herbicide atrazine mesotrione on weeds and results of sweet corn (*Zea mays* L. *saccharata*) bonanza variety. *Jurnal Produksi Tanaman* 6, 767–74.
- Gharde, Y., Singh, P.K., Dubey, R.P., Gupta, P.K. (2018). Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection*, 107, 12–18.
- Goranovska, S., & Kalinova, Sht. (2018). Influence of the systems of herbicides on the weed populations and grain yield of maize grown in the conditions of South-East Bulgaria. *Proceedings of the Scientific and Technical Conference with International Participation „Ecology and Health”*, 99–103.
- Goranovska, S., Kalinova, Sht., Tahsin, N. (2017). Effectiveness of systems of herbicides in maize cultivated at agroecological conditions of Northwest Bulgaria. *Journal of Mountain Agriculture on the Balkans*, 20(1), 201–211.
- Hristova, S., Nankov, M., Georgiva, I., Tonev, T., Kalinova, Sht. (2012). Influence of Wild mustard (*Sinapis arvensis* L.) on the growth and productivity of maize hybrid KH-613. *Proceedings of the 9th Scientific and Technical Conference with International Participation „Ecology and Health”*, 277–282.
- Ivanov, K., Tonev, T., Nguen, N., Peltecov, A., Mitkov, A. (2019). Impact of foliar fertilization with nanosized zinc hydroxy nitrate on maize yield and quality. *International Conference on Agricultural Infrastructure and Environmental*. July 20-21. *Emirates Journal of Food and Agriculture*, 31(8), 597–604.
- Ivanov, K., Vassilev, A., Mitkov, A., Nguen, N., Tonev, T. (2021). Application of Zn-containing foliar fertilisers for recovery of the grain productivity potential of Zn-deficient maize plants. *Italian Journal of Agronomy*, <https://doi.org/10.4081/ija.2021.1759>.
- Jagadish, S., & Prashant, C. (2016). A review on weed management on maize (*Zea mays* L.). *Advances in Life Sciences*, 5(9), 3448–3455.
- Jat, R., Gopar, R., Gupta, R. (2012). Conservation agricultural in maize-wheat cropping systems of eastern India: productivity. Weed dynamics and system *In: Extended summaries 3rd International Agronomy Congress, Vol. 3, November 26-30, 2012, New Delhi, India*.
- Jha, S. K., Agrawal, R. K., Roy, A. K. (2022). Management of weeds in fodder maize by tank-mix application of pre and post emergence herbicides. *Range Management and Agroforestry*, 43(1), 116–123. <https://doi.org/https://www.indianjournals.com/ijor.aspx?target=ijor:rma&volume=43&issue=1&article=016>
- Kakade, S., Deshmukh, J., Bhale, V., Solanke, M., Shingrup, P. (2016). Efficacy of pre and post emergence herbicides in Maize. *Extended Summaries*, 1: 442–443.
- Kalinova, Sht., Hristova, S., Glogova, L. (2012). Influence of infestation with Johnson grass (*Sorghum halepense* brot.) on yield and its structural elements in corn hybrid Kn-613. *Science and Technologies*, II(6), 141–144.
- Kalinova, Sht., Zhalnov, I., Yanchev, I. (2000). Influence of the combined action of Stomp 33 EK and Mistral 4 SK on the weeds in maize. *Journal of Mountain Agriculture on the Balkans*, 3(6), 705–712.
- Khan, M., Marwat, K., Khan, N. (2003). Efficacy of different herbicides on the yield and yield components of maize. *Asian J. Plant Sci.*, 2(3), 300–304.
- Khanna, N., Bhullar, M. S., Jaidka, M., Kaur, T. (2022). Maize weed control and yield using different applications of tembotrione. *International Journal of Pest Management*, 1–9. <https://doi.org/10.1080/09670874.2022.2050833>
- Kierzek, R., Paradowski, A., Kaczmarek, S. (2012). Chemical methods of weed control in maize (*Zea mays* L.) in variable weather conditions. *Acta Scientiarum Polonorum – Agricultura*, 11(4), 35–52.
- Kumar B., Prasad S., Mandal D., and Kumar R. (2017) Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of rabi maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*, 6(4), 1431–1440.
- Kumar, P., Sangwan, M., Poonia, T. M., Punia, R. (2023a). Bio-efficacy of sequential application of herbicides on weeds and productivity of maize (*Zea mays*). *Current Advances in Agricultural Sciences*, 15(2), 140–144.
- Kumar, S., Sanodiya, P., Jha, A. K., Sahu, M. P., Verma, B. (2023b). Effect of 2, 4-D sodium salt on weeds,

- growth and yields in rabi maize (*Zea mays* L.). *Indian Journal of Agronomy*, 68(4), 426–429.
- Kurniadie, D., Widayat, D., Hidayati, R. F. (2023). The effectiveness of atrazine 265 g/L and nicosulfuron 35 g/L for weed control in hybrid maize plants (*Zea mays* L.). *Research on Crops*, 24(4), 678–683.
- Manilov, T., & Manhart, S. (2024). Biological efficacy of post emergence herbicides applied to corn. *Journal of Mountain Agriculture on the Balkans*, 27(3), 193–211.
- Manolov, I., & Neshev, N. (2017). Growth and yields of potato varieties depend on potassium fertilizer rate and source. *Proceedings of 52nd Croatian and 12th International Symposium on Agriculture, Dubrovnik, Croatia in February*, 356–360.
- Manolov, I., Neshev, N., Chalova, V., Yordanova, N. (2015). Influence of potassium fertilizer source on potato yield and quality. *Proceedings. 50th Croatian and 10th International Symposium on Agriculture, Opatija, Croatia*, 363–367.
- Mitkov, A. (2014). Biological efficacy of some leaf herbicides against economically important weeds in field experiments with wheat. *Agricultural University-Plovdiv, Scientific Works, LVIII*, 105–114.
- Mitkov, A. (2020). Biological efficacy and selectivity of herbicides for broadleaf weeds control in maize (*Zea mays* L.). *Scientific papers, Series A. Agronomy, Vol. LXIII*(1), 422–427.
- Mitkov, A. (2021). Weed control in sunflower by separate and combined herbicide application. *Scientific Papers. Series A. Agronomy, Vol. LXIV*(1), 461–472.
- Mitkov, A. (2022). Evaluation of some soil herbicides and their combinations in maize. *Scientific Papers. Series A. Agronomy, Vol. LXV* (1), 434–439.
- Mitkov, A. (2023). Opportunities for chemical control of some weeds in wheat. *Scientific Papers. Series A. Agronomy, Vol. LXVI* (1), 441–448.
- Mitkov, A. (2024). A comparative study of some soil herbicides for annual weeds control in maize. *Scientific Papers. Series A. Agronomy, Vol. LXVII*(1), 562–568.
- Mitkov, A., Tonev, T., Tityanov, M. (2009). Spreading of the major weeds and different agroecological regions of South Bulgaria. *Plant Science*, 46, 148–153.
- 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), 340–345.
- Mitkov, A., Yanev, M., Neshev, N., Tityanov, M., Tonev, T. (2019). Herbicide control of the weeds in maize (*Zea mays* L.). *Scientific Papers. Series A. Agronomy, LXII*(1), 368–373.
- Monteiro, A., & Santos, S. (2022). Sustainable approach to weed management: The role of precision weed management. *Agronomy*, 12, 1–14.
- Mukhtar, A. M., Eltahir, S. A., Siraj, O. M., Hamada, A. A. (2007). Effect of weeds on growth and yield of maize (*Zea mays* L.) in Northern State, Sudan. *Sudan Journal of Agricultural Research (Sudan)*, 8, 1–7.
- Mundra, S., Vyas, A., Mailwal, P. (2002). Effect of weed and nutrient management on nutrient uptake by maize and weeds. *Indian J. Agron.*, 43(3), 378–383.
- Neshev, N., & Manolov, I. (2014). Influence of potassium fertilizer source on vegetative parameters of potatoes. *Scientific Works of Agricultural Academy*, 3(2), 213–218.
- Neshev, N., & Manolov, I. (2016). Effect of fertilization on soil fertility and nutrient use efficiency at potatoes. *Geophysical Research Abstracts*, 18, EGU, 139. EGU General Assembly.
- Neshev, N., Manolov, I., Chalova, V., Yordanova, N. (2014). Effect of nitrogen fertilization on yield and quality parameters of Potatoes. *Journal of Mountain Agriculture on the Balkans*, 17(3), 615–627.
- Oerke, E., & Dehne, H. (2004). Safeguarding production—losses in major crops and the role of crop protection. *Crop Prot.*, 23, 275–285.
- Panayotov, N., Panchev, V. & Shopova, N. (2024). Assessment of the storability of tomatillo (*Physalis Ixocarpa* Brod.) seeds. *Journal of Mountain Agriculture on the Balkans*, 27(2), 296 – 317.
- Pannacci, E. (2016). Optimization of foramsulfuron doses for post-emergence weed control in maize (*Zea mays* L.). *Spanish Journal of Agricultural Research*, 14(3), 1–9.
- Pannacci, E., & Covarelli, G. (2009). Efficacy of mesotrione used at reduced doses for post-emergence weed control in maize (*Zea mays* L.). *Crop Protection*, 28(1), 57–61.
- Pinsupa, J., Ekkathin, P., Mahawong, T., Thanuthong, E., Chindakul, A., Chanbut, P. (2022). Efficiency of pre- and post-emergence herbicide tank mixtures on weed control in maize (*Zea mays* L.). *Kaen Kaset = Khon Kaen Agriculture Journal*, 50(1), 435–442. https://doi.org/https://ag2.kku.ac.th/kaj/PDF.cfm?file name=29-Agr01_P-Final.pdf&id=4733&keeptrack=4
- Ram, P., Sreenivas, G., Leela Rani, P. (2017) Impact of sustainable weed management practices on growth, phenology and yield of rabi grain maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences*, 6, 701–710.
- Rankova, Z., Moskova, Ts., Neshev, N., Yanev, M., Dimitrov, G. (2023). Effect of different approaches to soil surface maintenance on weed infestation and growth performance of young apricot plantations. *Journal of Mountain Agriculture on the Balkans*, 26 (3), 238–250.
- Saleem, M., Tanveer, A., Abbas, T. (2015). Weed control in forage maize with preemergence herbicides. *Herbologia*, 15(2), 69–77.
- Sarma C. K., & Gautam, R. C., (2010) Weed growth, production and nutrient uptake in maize (*Zea mays*) as influenced by tillage, seed rate and weed control method, *Indian Journal of Agronomy*, 55(4), 299–303.
- Sevov, A., Dimitrova, M., Stoichev, D., Zorovski, P. (2015). Efficiency and selectivity of some herbicides at sweetcorn. *Proceedings of the Sixth International Scientific Agricultural Symposium “Agrosym 2015”*, 1048–1052.
- Sharma, N., & Rayamajhi, M. (2022). Different aspects of weed management in maize (*Zea mays* L.): A brief review. *Advances in Agriculture*, 1, 7960175
- Shopova, N. (2023). Planting time effect on the growth and yield of tomato (*Solanum lycopersicum* L.). *Scientific Papers. Series B. Horticulture*, 67(2), 391–396.

- Shopova, N., & Cholakov, D. (2014). Effect of the age and planting area of tomato (*Solanum lycopersicum* L.) seedlings for late field production on the physiological behavior of plants. *Bulgarian Journal of Agricultural Science*, 20(1), 173–177.
- Shopova, N., & Cholakov, D. (2015). Economic efficiency of late tomato field production with seedlings grown in containers of different substrate composition. *Agricultural University – Plovdiv, Scientific Works*, 59(4), 131–136.
- Skrzypczak, G., Sobiech, Ł., Waniorek, W. (2011). Evaluation of the efficacy of mesotrione plus nicosulfuron with additives as tank mixtures used for weed control in maize (*Zea mays* L.). *Journal of Plant Protection Research*, 51(3), 300–305. DOI: 10.2478/v10045-011-0049-1
- Tityanov, M., Tonev, T., Mitkov, A. (2009a). New opportunities for efficient chemical control of weeds in wheat. *Plant Science*, XLVI, 154–160.
- Tityanov, M., Tonev, T., Mitkov, A. (2009b). News in chemical weed control in rape. *Proceedings of the third International Symposium "Ecological Approaches in Manufacturing Safe Food"*, 237–245.
- Tityanov, M., Tonev, T., Mitkov, A. (2010). Chemical control of Field brome (*Bromus arvensis* L.) in wheat fields. In *Scientific works jubilee scientific conference with international participation. Traditions and challenges of agricultural education, science and business. Agricultural University-Plovdiv, Scientific Works*, LV(2), 139–142.
- Tonev T., Tityanov, M., Mitkov A. (2010). Integrated weed control during maize vegetation. In *Scientific works jubilee scientific conference with international participation. Traditions and challenges of agricultural education, science and business. Agricultural University-Plovdiv, Scientific Works*, LV(2), 133–138.
- Tonev, T., Dimitrova, M., Kalinova, Sht., Zhelnov, I., Zhelyazkov, I., Vasilev, A., Tityanov, M., Mitkov, A., Yanev, M. (2019). *Herbology*, Publisher: Vidinov & son, Sofia (Textbook in Bulgarian).
- Tonev, T., Mitkov, A., Tityanov, M. (2009b). Possibilities for effective chemical control of the weeds in sweet corn. *Proceedings of Third International Symposium „Ecological Approach in Production of Healthy and Safe Foods*. 229-236.
- Tonev, T., Mitkov, A., Tityanov M. (2009a). Possibilities for effective chemical control of the weeds in sweet corn. *Proceedings of Third International Symposium "Ecological Approach in Production of Healthy and Safe Foods"*. 229–236.
- Tursun, N., Datta, A., Sakinmaz, M. S., Kantarci, Z., Knezevic, S. Z., Chauhan, B. S. (2016). The critical period for weed control in three corn (*Zea mays* L.) types. *Crop Protection*, 90, 59–65.
- Uzunova, K., Mitkov, A., Tonev, T. (2015). A choice of statistical evaluation criterion for data from an agricultural experiment with cv Enola wheat. *Agricultural sciences*, VII(18), 99–103.
- Veeral, D. K., & Abirami, G. (2021). Effects of liquid organic manures on growth, yield and grain quality of sweet corn (*Zea mays* convar. *sacharata* var. *rugosa*). *Crop Res.*, 56, 295–300.
- Walia, US, Brar, LS., Singh, B. (2005). Recommendations for weed control in field crops. *Research Bulletin, Department of Agronomy, Agrometerology and Forestry, PAU Ludhiana*. pp. 5.
- Wasnik, V. K., Ghosh, P. K., Halli, H. M., Gupta, G. (2022). Effect of tillage and weed control measures on the yield and economic efficiency of maize under rainfed conditions of semi-arid region. *Indian Journal of Weed Science*, 54(1), 51–57. <https://doi.org/https://indianjournals.com/ijor.aspx?target=ijor:ijws&volume=54&issue=1&article=009>
- Wiqar, B., Jat, S. L., Parihar, C. M., Mandal, B. N., Ahmadzai, K. M. (2022). Efficiency of post emergence herbicides for enhancing growth and yield of hybrid maize (*Zea mays*) in Kandahar, Afghanistan. *Indian Journal of Agronomy*, 67(2), 208–211.
- Yanev, M. (2023). Application of herbicides for weed control before germination and in the early vegetation in maize. *Scientific Papers. Series A. Agronomy*, 66(1), 631–642.
- Zhelnov, I., & Raikov, S. (1996). Influence of different infestation levels of *Sorghum halepense* L. on maize development. *Plant Science*, XXXIII(8), 64–66.
- Zhelyazkov, I., Mitkov, A., Stoychev, D., (2017). *A Guidebook for Exercises on Herbology*. Academic publisher of the Agricultural University of Plovdiv, Bulgaria. 188 Pages (In Bulgarian).