Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 1, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

POSSIBILITIES FOR HERBICIDAL CONTROL OF MIXED WEED INFESTATION IN MAIZE (*Zea mays* L.)

Mariyan YANEV

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

Corresponding author email: mar1anski@abv.bg

Abstract

In 2018-2019, on the experimental field of the Agricultural University of Plovdiv, Bulgaria, a field experiment with maize hybrid P1114 was performed. The experiment included the following herbicide treatments: Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}), Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}), Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1}), Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}), Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) and Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}). The application was done in 4th - 6th true leaf of maize (BBCH 14-16). The dominant weeds on the field were Sorghum halepense (L.) Pers. developed from seeds and rhyzomes, Setaria viridis (L.) P. Beauv., Chenopodium album L., Amaranthus retroflexus L., Xanthium strumarium L., Abutilon theophrasti Medik., Datura stramonium L. and Solanum nigrum L. The nicosulfuron-containing herbicide in combination with other products showed good to excellent efficacy depending on the weed species. For all variants treated whit herbicides 1000 grain weight, hectolitre mass and the yield, were higher and with statistically proved differences in comparison to the untreated control.

Key words: *maize, weeds, herbicides, efficacy, yield.*

INTRODUCTION

Providing an abundance of food for the ever-growing population of Earth, of technical and medicinal raw materials, of fodder for farm animals, of building materials, etc. is an inalienable concern for humanity (Tonev et al., 2019). All branches of biological science work intensively and purposefully to solve a large number of problems and tasks (Georgiev et al., 2019; Nenova, 2019; Nenova et al., 2019; Petrova et al., 2019; Georgiev et al., 2017; Nenova, 2017; Shopova & Cholakov, 2015; Shopova & Cholakov, 2014; Tonev et al., 2010a; Tonev et al., 2009a).

Maize *(Zea mays* L.) is one of the most widely grown plants in the world and is a major food crop in many developing countries (Ram et al., 2017). It is grown for both grain and green fodder and silage for animals (Iken & Amusa, 2004). Its grain is a source of starch and cooking oils, and is used as a raw material for fermentation. Due to its productive potential and wider adaptability, maize is also known as the queen of cereals.

According to Aldrich et al. (1975) *Zea mays* L. has the greatest potential for carbohydrates per unit area per day.

Weed vegetation is a major limiting factor, providing serious competition to maize in terms of vegetation factors, leading to lower yields and quality of the production (Tonev et al., 2019; Saleem et al., 2015; Arnold et al., 2013). In addition, weeds deplete 30-40% of the applied nutrients from the soil. They hinder the efficiency of the use of fertilizers from cultivated plants, as a significant part of the fertilizer added to the soil is used by the weeds (Mundra et al., 2002).

Studies by a number of authors show that depending on the type and degree of weed infestation, as well as period of crop-weed competition and its intensity (Rai et al., 2018) the maize grain yield can be decreased from 24.0% to 96.7% (Dimitrova et al., 2018; Ehsas et al., 2016; Jagadish et al., 2016; Kakade et al., 2016; Yakadri et al., 2015; Mukherjee & Puspajit, 2013; Jat et al., 2012; Oerke & Dehne, 2004; Khan et al., 2003; Zhalnov & Raikov, 1996). According to Hall et al. (1992), maize is highly sensitive to weed competition in the early development stages.

In addition to weeds, the lack of nutrients, which is often caused by them, also has a negative effect on the formation of crop yields (Ivanov et al., 2019; Manolov & Neshev, 2017;

Neshev & Manolov, 2016; Kostadinova et al., 2015; Manolov et al., 2015; Neshev & Manolov, 2014; Neshev et al., 2014; Goranovska et al., 2014).

Depending on the latitudes and the presence of weed seeds in the soil, different weed associations develop in maize. In Bulgaria the weeds economically important in this crop are *Amaranthus retroflexus* L., *Datura stramonium* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Chenopodium album*, *Abutilon theophrasti* L., *Sinapis arvensis* L., *Echinochloa crus-gali* L., *Setaria glauca* L., *Sorghum halepense* L., *Convolvulus arvensis* L, *Cinodon dactilon* L. and *Cirsium arvense* L. (Mitkov et al., 2019; Hristova et al., 2012; Kalinova et al., 2012; Tonev et al., 2010b).

According to Vizantinopoulos and Katranis (1998) in Greece, in areas with intensive maize cultivation the weed species *Amaranthus* spp. dominates.

In Slovakia studies showed that the most common weeds in maize are *Chenopodium album* L., *Amaranthus* spp., *Echinichloa crus-galli* (L.) P. Beauv, *Datura stramonium* (L.), *Fallopia convolvulus* (L.) A. Lôve, *Persicaria* spp., *Cirsium arvense* (L.) Scop, *Elytrigia repens* (L.) P. Beauv, *Avena fatua* (L.) and *Abutilon theophrasti* Medik (Týr and Vereš, 2012). Smatana et al. (2015) reported that in maize the weeds *Atriplex* spp. and *Setaria viridis* (L.) P. Beauv. are widely distributed.

In India, the most aggressive weeds growing in the early stages of maize development are *Polygonum* (*P. pensylvanicum, P. persicaria, P. orientale*), *Stellaria media, Stellaria aquatica, Oldelandia diffusa, Oldenlandia umbellate, Physalis minima, Solanum nigrum*. In Belgaum district of Karnataka, India, the most distributed weeds are *Cynodon dactylon, Dinebra retroflexa, Echinochloa colonum, Eleusine indica, Cyperus rotundus, Parthenium hysterophorus, Commelina benghalensis, Portulaca oleracea, Cynotis cuculata, Phyllanthus niruri* and *Amaranthus viridis* (Soren et al., 2018; Mukherjee & Puspajit, 2013; Haji et al., 2012).

In maize fields in Mashhad, Iran the most often observed broadleaf weed species are *Amaranthus retroflexus* L., *Chenopodium album* L., *Portulaca oleracea* L. and *Solanum nigrum* L. (Baghestani et al., 2007).

One of the main weed control methods in maze is the usage of herbicides (Mitkov, 2020; Goranovska & Kalinova, 2018; Goranovska et al., 2017; Janak & James, 2016; Sevov et al., 2015; Umesha & Sridhara, 2015; Goranovska & Kalinova, 2014; Dimitrova et al., 2013b; Skrzypczak et al., 2011; Pannacci & Covarelli, 2009, Tonev et al., 2009b).

Against the annual grass and broadleaf weeds high efficacy for the application of Gardoprim plus gold 500 SK – 4.00 l ha^{-1} (99%), Lumax 538 SK – 4.00 l ha^{-1} (97%), Wing – 4.00 l ha^{-1} (97%) and Merlin flex – 0.42 l ha^{-1} (94.6%) was recorded (Dimitrova et al., 2013a).

The application of Merlin Duo in rates of 1.00 l ha^{-1} to 2.00 l ha^{-1} after sowing before germination of maize controls *Abuthilon theophrasti* L. and *Solanum nigrum* L. The highest efficacy against *Chenopodium album* L. after the application of Merlin Duo in the rates of 1.25, 1.5 and 2.00 l ha^{-1} was reported (Mitkov et al., 2018).

It was found that the application of foramsulfuron in dose of 20.3 g ai ha^{-1} showed 95% efficacy against *Amaranthus retroflexus* L., *Setaria viridis* (L.) Beauv., *Sinapis arvensis* L. and *Solanum nigrum* L. Against *Abutilon theophrasti* Medik., *Chenopodium album* L. and *Echinochloa crus-galli* (L.) Beauv. the same efficacy results are obtained, but for the rates of 20 до 50 g ai ha^{-1} of foramsulfuron (Pannacci, 2016).

For control of *Sorghum halepense* L., *Convolvulus arvensis* L., *Echinochloa crus-gali* L., *Chenopodium album* L., *Amaranthus retroflexus* L. and *Abutilon theophrasti* L. in maize it is recommended to apply Stomp 33 EK + Mistral 4 SK in rates of 3.00 l ha^{-1} + 1.30 l ha^{-1} (Kalinova et al., 2000). It is important to note that the use of pendimethalin has a lower risk of groundwater contamination compared to herbicides as alachlor (Brahushi et al., 2011).

Acording to Kierzek et al. (2012), the best control of mixed weed infestation in maize after the application of the mixture s-metolachlor + terbuthylazine + mesotrione, followed by foliar application of nicosulfuron with adjuvant Atpolan Bio 80 SL. In the maize fields Tonev et al. (2016) recorded high efficacy against broadleaf and grass weed species as *Sorghum halepense* L. *Convolvulus arvensis* L. and *Cirsium arvense* L. after application of the herbicide combination of Flurostar 200 EK + Nishin 4 OD in rates of 0.70 l ha^{-1} + 1.30 l ha^{-1}. If there is high infestation with *Chenopodium album* L. the combination of Mustang 306.25 SK and Nishin 4 OD in doses of 0.60 l ha^{-1} + 1.30 l ha^{-1} in tank mixture is recommendable.

For control of *Xanthium strumarium, Amaranthus retroflexus, Datura stramonium* and *Chenopodium album* in maize Damalas et al. (2018) established efficacy from 92 to 100% after the alone treatment of tembotrione at 100 g ai ha^{-1} and three mixtures of tembotrione with: rimsulfuron at 10 g ai ha^{-1}, nicosulfuron at 40 g ai ha^{-1} and foramsulfuron at 60 g ai ha^{-1}. After the application of foramsulfuron and nicosulfuron (sulfonylurea herbicides) applied in tank-mix with 2.4 D + MCPA the weeds *Amaranthus retroflexus* L. and *Chenopodium album* L. can be successfully controlled - from 78 to 100%, depending on the herbicide rates (Sarabi et al., 2018).

The aim of the current research is to study some possibilities for herbicidal control of mixed weed infestation in maize (Z*ea mays* L.).

MATERIALS AND METHODS

In the period of 2018 – 2019 a field plot trial with the maize hybrid P1114 (590 FAO) was conducted. The experiment was situated on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria.

The experiment included the following tretments: 1. Untreated control; 2. Callam (600 g/kg dicamba + 125 g/kg tritosulfuron) + Kelvin OD (40 g/l nicosulfuron) + Dash (adjuvant) in rates of 0.40 kg ha^{-1} + 1.00 l ha^{-1} + 1.00 l ha^{-1}; 3. Callam + Kelvin OD + Dash in rates of 0.50 kg ha^{-1} + 1.25 l ha^{-1} + 1.25 l ha^{-1}; 4. Callam + Kelvin OD + Dash in rates of 0.30 kg ha^{-1} + 1.25 l ha^{-1} + 0.625 l ha^{-1}; 5. Callam + Kelvin OD in rates of 0.30 kg ha^{-1} + 1.25 l ha^{-1}; 6. Cambio SL (320 g/l bentazone + 90 g/l dicamba) + Kelvin OD in rates of 2.00 l ha^{-1} + 1.25 l ha^{-1}; 7. Arat (500 g/kg dicamba + 250 g/kg tritosulfuron) + Kelvin OD in rates of 0.20 kg ha^{-1} + 1.25 l ha^{-1}. The trial was performed by the randomized block design in 4 replications with size pf the experimental plot 28 m^2. The herbicide application was done in 4^{th} – 6^{th} true leaf of maize (BBCH 14-16) via electrical backpack sprayer SOLO (model 417) with size of the working solution 250 l ha^{-1}.

During the two years of the research the maize was grown as monoculture. Also, the plants were grown under conditions of drip irrigation. On the trial field deep ploughing, two times disc harrowing and two times cultivation before sowing were done. On the whole experimental area basic combine fertilization with 250 kg ha^{-1} NPK (15:15:15) and spring dressing with 200 kg ha^{-1} NH_4NO_3 was performed. The sowing was performed in the optimal period. The sowing distance between the rows was 70 cm, with sowing density of 78 000 germinating seeds ha^{-1}. After sowing rolling was done.

The experimental area was naturally infested with *Sorghum halepense* (L.) Pers. developed from seeds and rhyzomes, *Setaria viridis* (L.) P. Beauv., *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Abutilon theophrasti* Medik., *Datura stramonium* L. and *Solanum nigrum* L.

The biological efficacy was reported on 14^{th}, 28^{th} and 56^{th} day after the herbicide application. The efficacy against the weeds was evaluated by the 10-score visual scale of EWRS. The efficacy results were compared with the untreated control.

The selectivity of the studied herbicides was evaluated on the 7^{th}, 14^{th}, 28th and 56^{th} day after the treatments by the 9-score visual scale of EWRS (at score 0 - there is no damage on the crop, and at score 9 there is complete death of the crop).

The following indicators are evaluated and analyzed: absolute seed mass of 1000 air-dry seeds (g), hectolitre seed mass (kg) and maize grain seed yield (t ha^{-1}).

The reported biometric indicators were processed with the software package SPSS 17 - module two-factor analysis of variance for Windows 8. The difference between the evaluated treatments was statistically analysed by ONE WAY ANOVA by using Duncan's multiple rage test. Statistical differences were considered proved at $p<0.05$.

RESULTS AND DISCUSSIONS

During both experimental years the weed infestation was presented by weeds belonging to two biological groups. The presenters of the late-spring weeds were *Setaria viridis* (L.) P.Beauv., *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Abutilon theophrasti* Medik., *Datura stramonium* L. and *Solanum nigrum* L. Presenter from the perennial group of weeds was *Sorghum halepense* (L.) Pers. developed from seeds and rhyzomes.

On the 14th day after application the highest herbicidal efficacy against *S. halepense* developed from seeds for the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 90.0% average for both year was found (Table 1). Similar to those efficacy for the treatment with Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) was reported - 86.7% in 2018 and 90.0% in 2019. For the other treatments, the efficacy against this weed varied from 83.4% - 87.5%.

The average results on the 28th day after treatments showed increasing values regarding the efficacy against *S. halepense* developed from seeds. For treatments 2, 3, 4 and 7 the efficacy was 100%.

On the 56th day after treatments, the reported efficacy reched 100% for all tretments. This can be explained by the sufficient time of action of the herbicides, especially nicosulfuron, on the weeds and their ability to show their maximum potential. Hernández-Labrador et. al. (2000) also reported that nicosulfuron at 30 g a.i. ha^{-1} showed excellent control of *Sorghum halepense*.

Table 1. Efficacy of the studied herbicides against *Sorghum halepense* (L.) Pers. developed from seeds, %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	86.7	100	100	90.0	100	100	88.4	100	100
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	90.0	100	100	90.0	100	100	90.0	100	100
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	85.0	100	100	83.3	100	100	84.2	100	100
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	81.7	100	100	85.0	98.3	100	83.4	99.2	100
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	83.3	100	100	85.0	98.3	100	84.2	99.2	100
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	88.3	100	100	86.7	100	100	87.5	100	100

Compared with the efficacy of the studied herbicides against *S. halepense* developed from seeds, the efficacy against *S. halepense* developed rhyzomes was lower.

Table 2. Efficacy of the studied herbicides against *Sorghum halepense* (L.) Pers. developed rhyzomes, %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	60.0	85.0	88.3	70.0	85.0	90.0	65.0	85.0	89.2
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	70.0	88.3	93.3	78.3	88.3	93.3	74.2	88.3	93.3
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	58.3	85.0	88.3	58.3	80.0	90.0	58.3	82.5	89.2
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	43.3	80.0	90.0	60.0	76.7	86.7	51.7	78.4	88.4
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	60.0	78.3	90.0	70.0	76.7	85.0	65.0	77.5	87.5
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	65.0	80.0	91.7	68.3	86.7	90.0	66.7	83.4	90.9

During the experimental period, an increase in the herbicidal effect from the 14th to the 56th day after application of the products was observed.

On the 14th day the highest efficacy reported in 2018 was 70.0% for the treatment wit Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}). In 2019 the efficacy of this treatment was similar - 78.3%.

On average the efficacy for the concrete treatment reached 88.3% on the 28th day.

The average results for the efficacy of the studied products on the 56th day were similar. The highest efficacy was found to be for the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}0 – 93.3%. The lowest herbicide efficacy for the treatment with Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) was recorded – 87.5% (Table 2). In experiments carried by Eleftherohorinos and Kotoula-Syka (1995), the authors observed satisfactory efficacy against *S. halepense* from rhizomes after application of nicosulfuron.

Regarding the control of *Setaria viridis* (L.) P. Beauv, the obtained results were close to those recorded for the control of *S. halepense* developed rhyzomes. In 2018, on the 14th day after application of Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) and Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) the efficacy against the weed was 83.3%. In 2019 the highest efficacy against *S. viridis* was for Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 86.7% (Table 3).

On the 28th day after treatments, average for the period, the highest herbicide efficacy for the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) was observed – 95.0%.

The results obtained on the 56th day did not show significant increase when compared to those recorded on the 28th day. The highest efficacy against *S. viridis* for Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) – 95.9% and Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 95.8% average for both years was found.

From the herbicides studied, the lowest efficacy against *S. viridis* was reported for the treatment with Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) – 90.9% (Table 3).

Dobbels and Kapusta (1993) reported that the application of nicosulfuron in maize showed 98-100% efficacy against *S. viridis*. Control of *S. viridis* was reduced when nicosulfuron at 24 g was applied as a tank-mix with atrazine alone or in combination with bentazone, bromoxynil or dicamba. Also, bentazone + atrazine in combination with nicosulfuron at 35 g reduced control of the weed.

Table 3. Efficacy of the studied herbicides against *Setaria viridis* (L.) P.Beauv., %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	83.3	91.7	93.3	85.0	93.3	95.0	84.2	92.5	94.2
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	76.7	93.3	93.3	86.7	96.7	98.3	81.7	95.0	95.8
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	75.0	91.7	93.3	78.3	86.7	95.0	76.7	89.2	94.2
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	70.0	90.0	91.7	75.0	85.0	90.0	72.5	87.5	90.9
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	73.3	90.0	91.7	81.7	93.3	95.0	77.5	91.7	93.4
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	83.3	95.0	96.7	85.0	93.3	95.0	84.2	94.2	95.9

The efficacy obtained after the treatments against the *Chenopodium album* L. is presented on table 4. In 2018, on the first reporting date, the efficacy of treatment 6 (Cambio SL - 2.00 l ha^{-1} + Kelvin OD 1.25 l ha$^{-1)}$ was the highest – 88.3%. In 2019 for treatment 3 and 2 the efficacy was – 91.7%. The average efficacy on the second reporting date was for the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) - 95.9%.

In 2018, on the third reporting date 100% efficacy after the treatments with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) and Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}). At the other treatments, the herbicide efficacy varied between 96.7% and

98.3%. In 2019, on the 56th day after application, the efficacy for all treatments achieved 100% control of the weed.

Mitkov et al. (2019) reported 100% control of *Ch. Album* after the application of Arigo WG (330 g ha^{-1}) + Trend 90 (1000 ml ha^{-1}) and Principal Plus WG (440 g ha^{-1}) + Trend 90 (1000 ml ha^{-1}). Sarabi et al. (2018) established that the combine application of foramsulfuron and nicosulfuron in tank mixture with 2.4-D + MCPA successfully controlled *Ch. Album*.

Table 4. Efficacy of the studied herbicides against *Chenopodium album L.*, %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	78.3	93.3	96.7	91.7	93.3	100	85.0	93.3	98.4
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	85.0	95.0	100	91.7	96.7	100	88.4	95.9	100
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	78.3	90.0	98.3	85.0	93.3	100	81.7	91.7	99.2
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	78.3	93.3	98.3	80.0	95.0	100	79.2	94.2	99.2
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	88.3	93.3	96.7	88.3	93.3	100	88.3	93.3	98.4
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	83.3	91.7	100	85.0	93.3	100	84.2	92.5	100

As well as *S. halepense* developed from seeds, during the trial, very easy to control with the evaluated herbicides were the weed species *Amaranthus retroflexus* L. and *Xanthium strumarium* L.

The highest herbicide efficacy against *A. retroflexus* on the 14th day for the application of Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) average for the years of the study was reported – 93.3%. On the 28th day the efficacy was increased and reached 100% on the last reporting date (Table 5). Dobbels and Kapusta (1993) also recorded 100% control of *A. retroflexus* after the alone application of nicosulfuron or in combinations with other herbicides.

Table 5. Efficacy of the studied herbicides against *Amaranthus retroflexus* L., %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	88.3	100	100	95.0	100	100	91.7	100	100
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	93.3	100	100	91.7	100	100	92.5	100	100
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	90.0	100	100	88.3	98.3	100	89.2	99.2	100
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	90.0	100	100	88.3	98.3	100	89.2	99.2	100
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	91.7	100	100	93.3	100	100	92.5	100	100
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	93.3	100	100	93.3	100	100	93.3	100	100

Regarding the control of the weed *Xanthium strumarium* L., the studied herbicide treatments showed approximately equal efficacy as those for the weed *A. retroflexus*.

The efficacy of all herbicide treatments varied within narrow extends, ranging from 83.3% to 91.7% on the 14th day after application in the first year and from 88.3% to 93.3% in the second year. The average results on the 28th day after application was 100% for the treatments with Callam (0.50 kg ha^{-1}) + Kelvin

OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) and Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}).

On the 56th day the efficacy reached 100% for all treatments (Table 6).

Table 6. Efficacy of the studied herbicides against *Xanthium strumarium L.*, %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	83.3	98.3	100	90.0	98,3	100	86.7	98.3	100
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	88.3	100	100	91.7	100	100	90.0	100	100
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	83.3	100	100	90.0	96,7	100	86.7	98.4	100
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	85.0	100	100	88.3	96,7	100	86.7	98.4	100
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	85.0	95.0	100	93.3	100	100	89.2	97.5	100
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	91.7	100	100	91.7	100	100	91.7	100	100

According to Dobbels and Kapusta (1993) the control of *Abutilon theophrasti* depends on the nicosulfuron content, on the other herbicide when applied as a tank mix and growing conditions. In the current study, the most efficient control of *Abutilon theophrasti* Medik., average for the period, on the 14th day after the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 74.2%, followed by Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) – 73.4% was acieved.

On the second reporting date, the efficacy was the highest for the variant treated with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 96.7%.

On the last reporting date the highest efficacy of 96.7% against *A. theophrasti* was found to be for treatment 3 (Table 7).

Table 7. Efficacy of the studied herbicides against *Abutilon theophrasti* Medik., %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	58.3	88.3	90.0	73.3	98.3	100	65.8	93.3	95.0
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	66.7	93.3	93.3	81.7	100	100	74.2	96.7	96.7
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	58.3	85.0	91.7	73.3	96.7	100	65.8	90.9	95.9
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	61.7	83.3	86.7	71.7	88.3	96,7	66.7	85.8	91.7
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	70.0	80.0	91.7	76.7	91.7	100	73.4	85.9	95.9
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	58.3	86.7	88.3	71.7	91.7	100	65.0	89.2	94.2

The application of nicosulfuron + dicamba + bentazon; nicosulfuron + dicamba + bentazon; nicosulfuron + tritosulfuron + dicamba; nicosulfuron + mesotrione; nicosulfuron + mesotrione + atrazine; etc. can have very good results for controlling *D. stramonium* (Torma et al., 2006). In the present research the efficacy of the studied herbicides against *Datura stramonium L.* is presented on table 8.

On the first reporting date in 2018, the highest results were for the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 58.3%, followed by Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) – 56.7%. In 2019 the highest efficacy was for Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) – 76.7% and Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 75.0%. On the second date the highest results were also for the treatments with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})– 96.7% and Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) – 93.4% average for the period.

On the 56th day, the highest efficacy for the following treatments was reported: Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) – 99.2%, Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1}) – 99.2% and Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) – 98.4%.

Table 8. Efficacy of the studied herbicides against *Datura stramonium* L., %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	56.7	90.0	96.7	76.7	96.7	100	66.7	93.4	98.4
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	58.3	95.0	98.3	75.0	98.3	100	66.7	96.7	99.2
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	55.0	88.3	98.3	71.7	90.0	100	63.4	89.2	99.2
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	51.7	85.0	91.7	63.3	90.0	100	57.5	87.5	95.9
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	50.0	83.3	93.3	61.7	96.7	100	55.9	90.0	96.7
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	38.3	88.3	96.7	35.0	81.7	100	36.7	85.0	98.4

The weed *S. nigrum* is one of the difficult-to-conrol weeds. In 2018, on the 14th day, the highest efficiency for the variant with Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) - 73.3% was reported. The lowest for Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) - 43.3%.

Table 9. Efficacy of the studied herbicides against *Solanum nigrum* L., %

Variants	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	-	-	-	-	-	-	-	-	-
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	63.3	75.0	90.0	75.0	100	100	69.2	87.5	95.0
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	63.3	66.7	78.3	71.7	76.7	83.3	67.5	71.7	80.8
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	60.0	66.7	85.0	71.7	80.0	86.7	65.9	73.4	85.9
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	58.3	75.0	83.3	66.7	85.0	91.7	62.5	80.0	87.5
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	73.3	78.3	91.7	85.0	96.7	100	79.2	87.5	95.9
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	43.3	55.0	83.3	51.7	68.3	90.0	47.5	61.7	86.7

In 2019, these results were repeated as the efficiency in treatment 6 was 85%, and in treatment 7 - 51.7%. On average for the two-year of the study period, the best control against *S. nigrum* on the 28th day after treatment in variants 6 and 2 was obtained - 87.5%. The lowest in this reporting date was the efficiency for variant 7 - 61.7%.

The average results for the biological efficacy of the herbicides on the 56th day after treatment showed that the best control against *S.nigrum* was for the treatment with Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) - 95.9 % and Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1}) - 95.0% (Table 9).

The visual observations of phytotoxicity in both experimental years showed that all studied herbicides in the respective doses showed excellent selectivity for the hybrid P1114.

The indicator absolute seed mass of 1000 air-dry seeds gives an idea of the size and nutritional status of the seeds. The obtained results showed that there is a statistically proven difference between the control and the treated variants. The best results were reported after the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}), where in 2018 the absolute seed mass was 330.06 g, and in 2019 - 328.97 g.

In the other variants treated with herbicides, on average for the two years, the values of the indicator vary from 311.45 g to 322.85 g. It is worth noting that there is no mathematically proven difference between the variants treated with herbicide.

By using Duncan's multiple range test with proved differences and the lowest values (at a level of significance gD = 5%) was the mass of 1000 seeds obtained from the untreated control. On average for the period it was 272.25 g (Table 10).

Table 10. Absolute seed mass of 1000 air-dry maize seeds, g

Variants	2018	2019	Average
1. Untreated control	269.71 b	274.79 b	272.25 b
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	318.73 a	326.96 a	322.85 a
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	330.06 a	328.97 a	329.52 a
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	306.33 a	322.80 a	314.57 a
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	305.90 a	317.00 a	311.45 a
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	315.49 a	325.58 a	320.54 a
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	310.89 a	323.19 a	317.04 a

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

Regarding the indicator hectolitre seed mass, the highest values on average for the period - 77.66 kg was obtained after the application of Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}).

The evaluated herbicide combinations did not show significant influence to this indicator. This fact is confirmed by the mathematically unproven differences between the herbicide-treated variants. The lowest was the hectoliter mass of the untreated control - 75.67 kg, proven with the other treatments at the level of significance gD = 5% (Table 11).

Table 11. Hectolitre seed mass (kg)

Variants	2018	2019	Average
1. Untreated control	76.33 b	76.01 b	75.67 b
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	76.95 a	77.78 a	77.37 a
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	77.25 a	78.06 a	77.66 a
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	76.83 a	77.56 a	77.20 a
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	76.57 a	77.39 a	76.98 a
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	76.93 a	77.75 a	77.34 a
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	76.91 a	77.68 a	77.30 a

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

The data for the maize seed yield of hybrid P1114 confirm that there is a positive correlation between the effect of herbicides against the available weeds and the mass of 1000 seeds, hectolitre mass and seed yield. The maize seed yield was the lowest for the untreated control where the weed density was severe and led to yield losses. For the untreated control the yield in 2018 was 6.99 t ha^{-1}, and in 2019 - 7.11 t ha^{-1}. The highest grain seed yield after the treatment with Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) was obtained. For the concrete treatment the yield in 2018 was 11.84 t ha^{-1}, and in 2019 - 12.48 t ha^{-1}. For the other treatments, average for the period, the maize seed yield varied from 11.88 to 12.02 t ha^{-1}. Only the difference between the untreated control and the variants with herbicide combinations was mathematically proven (Table 12).

Table 12. Maize grain seed yield (t ha^{-1})

Variants	2018	2019	Average
1. Untreated control	6.99 b	7.11 b	7.03 b
2. Callam (0.40 kg ha^{-1}) + Kelvin OD (1.00 l ha^{-1}) + Dash (1.00 l ha^{-1})	11.77 a	12.27 a	12.02 a
3. Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1})	11.84 a	12.48 a	12.14 a
4. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (0.625 l ha^{-1})	11.60 a	12.18 a	11.93 a
5. Callam (0.30 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	11.54 a	12.13 a	11.88 a
6. Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	11.74 a	12.24 a	11.99 a
7. Arat (0.20 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1})	11.68 a	12.20 a	11.95 a

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

CONCLUSIONS

On the 56th day after application the studied herbicide combinations showed 100% efficacy against *Sorghum halepense* (L.) Pers. developed from seeds, *Amaranthus retroflexus* L. and *Xanthium strumarium* L.

The most efficient control of *Sorghum halepense* (L.) Pers. developed rhyzomes, *Setaria viridis* (L.) P. Beauv., *Chenopodium album* L., *Abutilon theophrasti* Medik. and *Datura stramonium* L. after the application of Callam (0.50 kg ha^{-1}) + Kelvin OD (1.25 l ha^{-1}) + Dash (1.25 l ha^{-1}) was accomplished.

The highest efficacy against the weed *Solanum nigrum* L. was for the treatment of Cambio SL (2.00 l ha^{-1}) + Kelvin OD (1.25 l ha^{-1}).

Absolute seed mass of 1000 air-dry maize seeds, hectolitre seed mass and maize grain seed yield of hybrid P1114 were higher and with statistically proved differences for all variants treated with herbicides in comparison to the untreated control.

REFERENCES

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.

Baghestani, M., Zand, E., Soufizadeh, S., Eskandari, A., PourAzar, R., Veysi, M., Nassirzadeh, N. (2007). Efficacy evaluation of some dual purpose herbicides to control weeds in maize (*Zea mays* L.). *Crop Prot., 26*. 936–942.

Brahushi, F., Laze, P., Gjoka, F. (2011). Application of some herbicides in weed control of maize (*Zea mays* L.) and their environmental risk. *V International Scientific Symposium: Farm machinery and process management in sustainable agriculture, Lublin, Poland,* 15–18.

Damalas, Ch., Gitsopoulos, T., Koutroubas, S., Alexoudis, Ch., & Georgoulas, I. (2018). Weed control and selectivity in maize (*Zea mays* L.) with tembotrione mixtures. *International Journal of Pest Management, 64*(1), 11–18.

Dimitrova, M., Dimitrov, Ya., Palagacheva, N., Vitanova, M., Minev, N., Yordanova, N. (2018). Maize. *Videnov & Son*, Sofia (Book in Bulgarian).

Dimitrova, M., Dimova, D., Zhalnov, I., Zorovski, P., Zhelyazkov, I., Valcheva, E., Popova, R. (2013b). 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. (2013a). Efficiency and selectivity of new herbicides on fodder maize. *Agrolife Scientific Journal*, *2*(1), 47–50.

Dobbels, A., Kapusta, G. (1993). Postemergence weed control in corn (*Zea mays*) with nicosulfuron combinations. *Weed Technology*, 844–850.

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.

Eleftherohorinos, I., Kotoula-Syka, E. (1995). Influence of herbicide application rate and timings for post-emergence control of *Sorghum halepense* (L.) Pers. Maize. *Weed Research*., *35*(2), 99–103.

Georgiev, G., Encheva, V., Encheva, Y., Nenova, N., Valkova, D., Peevska, P., Georgiev, G. (2019). Breeding of Sunflower (Helianthus annuus L.) at Dobrudzha Agricultural Institute – General Toshevo. *Field Crop Studies*, *XII*(2), 5–16.

Georgiev, G., Nenova, N., Peevska, P., Georgiev, G. (2017). Investigation on the inheritance of the traits number of seeds per plant and 1000 kernel weight in sunflower hybrids. *Journal of Agricultural, Food and Environmental Sciences*, *72*(2), 78–82.

Goranovska, S., Kalinova, Sht. (2014). Biological efficacy of herbicide products at the maize hybrid Knezha 435. *Crop Sciences*, *LI*(2-3), 59–62.

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.

Goranovska, S., Kalinova, Sht., Valchinkova, P. (2014). Influence of herbicides and mineral nutrition on yield and photosynthestic pigments of maize hybrid Knezha 509. *Proceedings of Jubilee Scientific Conference 90 years Maize Research Institute „Breeding-genetic and technological innovations in cultivation of cultivated plants"*, 128–135.

Haji, I., Hunshal, C., Malligwad, L., Basavaraj, B., Chimmad, V. (2012). Effect of pre and post emergence herbicides on weed control in maize (*Zea mays* L.). *Karnataka Journal of Agricultural Sciences, Dharwad: University of Agricultural Sciences*, *25*(3), 392–394.

Hall, M., Swanton, C., Anderson, W. (1992). The critical period of weed control in grain corn (*Zea mays*). *Weed Science*, *40*. 441–447.

Hernández Labrador, M., Mejía Arreaza, J., Lazo A. (2000). Evaluation of nicosulfuron (4% SC) on maize (*Zea mays* L.) weed control. *Revista de la Facultad de Agronomía, Universidad Central de Venezuela*, *26*(1), 1–13.

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.

Iken, J., Amusa, N. (2004). Maize research and production in Nigeria. *African Journal of Biotechnology*, *3*. 302–307.

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.

Jagadish, S., Prashant, C. (2016). A review on weed management on maize (*Zea mays* L.). *Advances in Life Sciences*, *5*(9), 3448–3455.

Janak, T., & James, G. (2016). Weed Control in Corn (*Zea mays* L.) as Influenced by Preemergence Herbicides. *International Journal of Agronomy, 5*(10), 1–9.

Jat, R., Gopar, R., & Gupta, R. (2012). Conservation agricultural in maize-wheat cropping systems of eastern India: Weed dynamics and system productivity. *In: Extended summaries 3rd International Agronomy Congress, Vol. 3, November 26-30, 2012, New Delhi, India*.

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.

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.

Kostadinova, S., Kalinova, St., Hristoskov, A., Samodova, A. (2015). Efficiency of some foliar fertilizers in winter wheat. *Bulgarian Journal of Agriculture Science*, *21*(4), 742–746.

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. (2020). Biological efficacy and selectivity of herbicides for broadleaf weeds control in maize (Zea mays L.). *Scientific Papers, Series A. Agronomy*, *LXIII*(1), 422–427.

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.

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.

Mukherjee, P., Puspajit, D. (2013). Weed control practices in maize (*Zea mays* L.) under conventional and conservation tillage practices. The role of weed science in supporting food security by 2020. *Proceedings of the 24th Asian-Pacific Weed Science Society Conference, Bandung, Indonesia*, 302–311.

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.

Nenova, N, Valkova, D., Penchev, E. (2019). Analaysis of importatant indices in new Bulgarian hybrids Linzi and Deveda. *International Journal of Innovative Approaches in Agricultural Research*, *3*(3), 505–509.

Nenova, N. (2017). New Bulgarian sunflower hybrid "LINZI". *Field Crops Studies*, *XI*(1), 97–102.

Nenova, N. (2019). New perspective Bulgarian sunflower hybrid Deveda. *Field Crop Studies, XII*(1), 9–16.

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). Safequarding production–losses in major crops and the role of crop protection. *Crop Prot*., *23*. 275–285.

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.

Petrova, Z., Georgiev, G., Nenova, N. (2019). Effect of some herbicides on the productivity of sunflower hybrid Velko. *Field Crop Studies*, *XII*(2), 157–164.

Rai, A., Mahata, D., Lepcha, E., Nandi, K., Mukherjee, P. (2018). A Review on Management of Weeds in Maize (*Zea mays* L.). *Int. J. Curr. Microbiol. App. Sci.*, *7*(8), 2906–2922.

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.

Saleem, M., Tanveer, A., Abbas, T. (2015). Weed control in forage maize with preemergence herbicides. *Herbologia*, *15*(2), 69–77.

Sarabi, V., Ghanbari, A., Mohassel, M., Mahallati, M., Rastgoo, M. (2018). Broadleaf weed control in corn (Zea mays L.) with sulfonylurea herbicides tank-mixed with 2,4-D+MCPA. *Agronomy Journal 110*(2), 638–645.

Sevov, A., Dimitrova, M., Stoichev, D., Zorovski, P. (2015). Efficiancy and selectivity of some herbicides at sweetcorn. *Proceedings of the Sixth International Scientific Agricultural Symposium "Agrosym 2015"*, 1048–1052.

Shopova, N., Cholakov D. (2014). Effect of the age and planting area of tomato (*Solanum licopersicum* 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, L., 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.

Smatana, J., Macák, M., Týr, Š., Andrejčíková, M. (2015). Weed control in maize (*Zea mays* L.) on the interface of agro-climatic conditions of maize and sugar beet growing region. *Research Journal of Agricultural Science*, *47*(1), 211–218.

Soren, C., Chowdary, K., Sathish, G., Patra, B. (2018). Weed dynamics and yield of rabi maize (*Zea mays* L.) as influenced by weed management practices. *J. Exp. Bio. Agric. Sci.*, *6*(1), 150–158.

Tonev, T., Dimitrova, M., Kalinova, Sht., Zhalnov, I., Zhelyazkov, I., Vasilev, A., Tityanov, M., Mitkov, A., Yanev, M. (2019). *Herbology*, Publisher: Vidinov & son, Sofia (Textbook in Bulgarian).

Tonev, T., Mitkov, A., Dochev, Ch., Tityanov, M. (2009a). Possibilities of the SU technology for effective weed control in sunflower. *Plant Sciences*, *2*. 161–166.

Tonev, T., Mitkov, A., Tityanov, M. (2009b). Possibilities for effective chemical control of the weeds in sweat corn. *Proceedings of Third International Symposium „Ecological Approach in Production of Healthy and Safe Foods.* 229–236.

Tonev, T., Tityanov, M., Mitkov A. (2010a). Integrated weed control of the weeds in sunflower. *Scientific Works of the Agricultural University of Plovdiv, LV* (2), 127–132.

Tonev, T., Tityanov, M., Mitkov, A**.** (2010b). Integrated weed control during maize vegetation. Scientific works jubilee scientific conference with international participation. Traditions and challenges of agricultural education, science and business. *Agricultural University – Plovdiv, Scientific Works*, vol. LV, book 2.

Tonev, T., Tityanov, M., Mitkov, A., Yanev, M., Neshev, N. (2016). Control of highly blended weeding at maize (*Zea mays* L.). *Book of Proceedings, VII International Scientific Agriculture Symposium "Agrosym 2016", Jahorina, October 06th - 09th*; 1256-1262.

Torma, M., Kazinczi, G., Hódi, L. (2006). Postemergence herbicide treatments in maize against difficult to control weeds. *Hungary Journal of Plant Diseases and Protection*, *XX*. 781–786.

Týr, Š., Vereš, T. (2012). Top 10 of most dangerous weed species in maize stands in the Slovak republic in the years 2000-2010. *Research Journal of agricultural Science*, *44*(2), 104–107.

Umesha, C., Sridhara, S. (2015). Effect of pre and post emergent herbicides on growth, yield parameters and weed control efficiency in maize (Zea mays L.). *Trends in Biosciences*, *8*(10), 2468–2474.

Vizantinopoulos, S., Katranis, N. (1998). Weed management of Amaranthus spp. in corn (*Zea mays*). *Weed technology*, 145–150.

Yakadri, M., Rani, P., Prakash, T., Madhavi, M., Mahesh, M. (2015). Weed management in zero till-maize. *Indian Journal of Weed Science*, *47*(32), 240–245.

Zhalnov, I., Raikov, S. (1996). Influence of different infestation levels of *Sorghum halepense* L. on maize development. *Plant Science*, *XXXIII*(8), 64–66.