EFFICACY AGAINST BROOMRAPE AND SELECTIVITY OF IMAZAMOX-CONTAINING HERBICIDES AT SUNFLOWER

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Abstract

During the period of 2016-2017 a field trial for evaluating the efficacy of imazamox-containing herbicide products for control of sunflower broomrape (*Orobanche cumana* Wallr.) was conducted. The experiment was carried out in the experimental base of the department of "Agriculture and Herbology" of the Agricultural University of Plovdiv, Bulgaria. The selectivity of the herbicides to the sunflower plants was also evaluated. The grown sunflower hybrid was „Lucia CLP". Variants of the trial were: 1. Untreated control; 2. Pulsar® 40 - 1200 ml ha^{-1}; 3. Pulsar® 40 - 2400 ml ha^{-1}; 4. Pulsar® 40 - 1200 ml ha^{-1}; 5. Pulsar® 40 - 2400 ml ha^{-1}; 6. Pulsar® Plus - 2000 ml ha^{-1}; 7. Pulsar® Plus - 4000 ml ha^{-1}; 8. Pulsar® Plus - 2000 ml ha^{-1}; 9 Pulsar® Plus - 4000 ml ha^{-1}. At variants 2, 3, 6 and 7 the herbicides were applied in phenophase 4th – 6th true leaf of the sunflower (BBCH 14-16), and at variants 4, 5, 8 and 9 – in phenophase 8th – 10th true leaf (BBCH 18-19). The highest efficacy against the broomrape was reported for the treatments of variants 4 and 9. For the control the highest broomrape density was reported – 13.65 specimens per 1 sunflower plant average for the period. It was observed that Pulsar® Plus is more selective to the sunflower hybrid in the study in comparison to Pulsar® 40. After the treatment with Pulsar® Plus at rate of 2000 ml ha^{-1} in phenophase 8th – 10th true leaf the highest sunflower seed yield was recorded. It was proven that the seed yield from the plants treated with doubled herbicide rates was lower from the plants treated with the registered rates. The untreated control had the lowest yield. A similar tendency for the indicators 1000 seeds weight and hectoliter seed mass was observed.

Keywords: *broomrape, sunflower, imazamox, efficacy, selectivity*

INTRODUCTION

The most distributed weeds in the Bulgarian sunflower fields are the weed species *Amaranthus retroflehus* L., *Sinapis arvensis* L., *Chenopodium album* L., *Xanthium strumarium* L., *Setaria* spp., *Echinochloa crus-galli* L., *Sorghum halepense* L., *Cirsium arvense* L., *Convolvulus arvensis* L. and the root holoparasite *Orobanche cumana* Wallr. (Neshev at al., 2017). *O. cumana* L. is distributed all over Bulgaria (Stoyanov et al, 1967). The broomrape is one of the main factors limiting the sunflower production (Tsvetkova et al., 1998). This parasitic plant is naturally distributed from central Asia to south-eastern Europe, where it parasitizes wild Asteraceae species. It is also an important parasitic weed of sunflower crops (Stoyanov et al, 1967; Pineda-Martos et al., 2014). The control of the sunflower broomrape is mainly driven by the creation of sustainable and tolerant varieties, as well as the cultivation of resistant to the herbicide imazamox varieties. It is considered that the integration of different methods and tools implies best parasitic control options (Tonev et al., 2018). Shindrova (2006) reported that the highest sunflower broomrape infestation has in south-eastern Bulgaria. In the different areas there is up to 80% infestation and a parasite density of 50-60 specimens per sunflower plant. In the south-eastern and north-eastern regions of the country, the degree of infestation is up to 50% and the parasite density from 15 to 20 specimens per plant. The measurements for decreasing the degree of broomrape infestation include preventive measures, improvement of the phytosanitary conditions of the crops and control (Kleifeld, 1998). As a result of growing broomrape resistant-sunflower varieties, "the old" parasite races disappear and in their place ”new” more virulent ones appear (Alonso, 1996; Pacureanu-Joita et al., 1998). In a study conducted by Domínguez et al. (2014) an excellent broomrape control after the treatment of the plants imazamox is recorded. Making hybrids resistant to imazamox and tribenuron-methyl enabled an efficient control of the main broadleaf and grassy weeds, including parasitic species from genus Orobanche (Malidza et al., 2003; Fernandez-Martinez et al., 2009).

The aim of the study is to establish the efficacy against the broomrape and the selectivity of imazamox-containing herbicides in Clearfield® Plus sunflower hybrid.

MATERIAL AND METHODS

The experiment was situated in the experimental field of the base for training and implementation of the Agricultural University of Plovdiv, Bulgaria. The trial was conducted by the randomized block design in 4 replications. The size of the experimental plot was 28 m². The grown sunflower hybrid was „Lucia CLP” which is susceptible to parasitation of *O. cumana*. Variants of the trial were: 1. Untreated control; 2. Pulsar® 40 - 1200 ml ha^{-1}; 3. Pulsar® 40 - 2400 ml ha^{-1}; 4. Pulsar® 40 - 1200 ml ha^{-1}; 5. Pulsar® 40 - 2400 ml ha^{-1}; 6. Pulsar® Plus - 2000 ml ha^{-1}; 7. Pulsar® Plus - 4000 ml ha^{-1}; 8. Pulsar® Plus - 2000 ml ha^{-1}; 9 Pulsar® Plus - 4000 ml ha^{-1}. Pulsar® 40 is containing 40.0 g/l *Imazamox* and Pulsar® Plus is containing 25 g/l *Imazamox*. At variants 2, 3, 6 and 7 the herbicides were applied in phenophase 4^{th} – 6^{th} true leaf of the sunflower (BBCH 14-16), and at variants 4, 5, 8 and 9 – in phenophase 8^{th} – 10^{th} true leaf (BBCH 18-19). The sowing is performed in the optimal time for the region. A predecessor of the sunflower was winter wheat – for both experimental years. On the trial field deep ploughing, two times disc harrowing and two times cultivation before sowing were done. 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 number of the parasites per one sunflower plant was counted at the end of the vegetation. Per every repetition of each variant 2 sunflower rows were taken out from each plot and the number of parasites was recorded. The selectivity by the 9 score scale of EWRS was evaluated on the 7^{th} and the 14^{th} day after the herbicide application (at score 0 there are not damages on the crop, and at score 9 the crop is completely destroyed). The hectoliter seed mass was measured by weighing two parallel samples of 100 dm^3 air dry seeds. The hectoliter mass is calculated, as the arithmetic means of the established mass of the two samples (in grams) multiply by 100 and the resulting is divided into 1000 to obtain the mass in kilograms (Tonev et al., 2018). The absolute seed mass of 1000 clean, air-dry seeds, expressed in grams was also measured (Tonev et al., 2018). Statistical analysis of collected data was performed by using Duncan’s multiple range test by the software SPSS 19. Statistical differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

The highest number of the parasite per one sunflower plant was recorded for the control (Table 1). In the first year of the experiment, the number of *O. cumana* was 9.29 specimens/sunflower. In the second experimental year, the parasite's number increased and reached 18.00 specimens per sunflower plant from the control. This increase is possibly due to the growing of the sunflower on the same field for a second year. Our data corresponded with results obtained by Tsyliuryk et al. (2018) who found that the parasitism naturally increased with the reduction of the time interval of sunflower return in crop rotation. Average for the period, the number of the parasites was 13,64 specimens per sunflower. The difference of the obtained results for the control was considered significant according to Duncan's multiple range test ($p<0.05$) in comparison to the variants with applied herbicides (Table 1).

Table 1. Number of *O. cumana* per sunflower plant

Treatments	2016	2017	Average
1	9,29 a	18,00 a	13,64 a
2	2,94 b	5,68 b	4,31 b
3	1,69 c	3,13 c	2,41 c
4	0,05 f	0,08 f	0,07 f
5	0,21 e	0,60 e	0,41 e
6	0,80 d	1,14 d	0,97 d
7	0,66 d	0,83 d	0,75 d
8	0,26 e	0,48 e	0,37 e
9	0,04 f	0,07 f	0,06 f

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

After the treatment with Pulsar® 40 at the rate of 1200 ml ha^{-1} (variant 2) in phenophase 4^{th} – 6^{th} leaf of sunflower (BBCH 14-16) the lowest efficacy was reported - 4.31 parasites/sunflower average for the period. The efficacy of the doubled rate of 2400 ml ha^{-1} was higher - 2.41 specimens average for the period. For treatments 4 and 9 the application of Pulsar® 40 (at rate of 1200 ml ha^{-1}) and Pulsar® Plus (at rate of 4000 ml ha^{-1}) the number of the parasites at the end of the sunflower vegetation was 0,07 and 0,06 specimens respectively average for the period of the study (Table 1). The efficacy of the treatments at the other variants (5, 6, 7 and 8) was satisfactory.

The visual evaluation of the herbicide phytotoxicity is presented in table 2. The highest herbicide toxicity was observed for variants 3 and 5 (score 3). It was determined as moderate phytotoxicity. This was due to the treatment of the doubled rate of Pulsar® 40. The content of the active substance in the herbicide product is higher and it was more aggressive to the sunflower hybrid that is bred to be grown by the Clearfield Plus technology. Sulfonylureas (tribenuron-methyl) and imidazolinones (imazamox) are herbicides inhibiting the ALS enzyme (Acetolactate synthase), which is involved in the biosynthesis of the vital amino acids valine, leucine and isoleucine. The visual phytotoxic symptoms at the sensitive plants or non-target crops are growth retardation, the leaves lost its turgor, the plants lose their vitality, etc. (Fedke and Duke, 2005).

Table 2. Visual phytotoxicity at the sunflower (by the visual scale of EWRS)

Variants	2016	2017	Average
1	-	-	-
2	2	2	2
3	3	3	3
4	2	2	2
5	3	3	3
6	1	1	1
7	2	2	2
8	1	1	1
9	2	2	2

Balabanova and Vassilev (2015) concluded that the treatment with the herbicide imazamox causes an inhibition of growth and photosynthetic performance in IMI-R Clearfield sunflower hybrids. The inhibition is less pronounced in the plants treated with the recommendable dose (120 ml/da Pulsar 40) and significantly higher in the plants treated with the exceeded imazamox dose.
The phytotoxicity was lower for treatments 2 and 4 (score 2) and it was determined as weak. After the treatments for variants 6 and 8 the phytotoxic symptoms were classified as very weak (score 1). This was probably due to treatment with Pulsar® Plus in the registered rates. At variants 7 and 9 the phytotoxicity was score 2 (weak).

The absolute seed mass of 1000 seeds is a very important indicator. The results are presented in table 3. The seeds with bigger values of the indicator have a higher price. According to a lot of authors this indicator has crucial for the formation of the yields (Georgiev et al., 2014). Hladni et al. (2008) found that seed yield was most positively correlated with thousand seed weight. At high levels of broomrape infestation, the mass of 1000 seeds was the lowest (Gisca et al., 2017). That statement corresponds with the results from our experiment.

The lowest absolute seed mass of 1000 clean, air-dry seeds was recorded for the control (61,23 g) where the infestation was the highest.

Table 3. Absolute seed mass of 1000 seeds, g.

Variants	2016	2017	Average
1	62,09 e	60,38 d	61,23 d
2	64,19 c	63,48 b	63,84 b
3	62,65 de	61,26 cd	61,96 d
4	67,35 a	64,98 a	66,17 a
5	62,46 de	61,33 cd	61,89 d
6	67,43 a	64,98 a	66,21 a
7	62,79 d	60,69 cd	61,74 d
8	66,46 b	65,14 a	65,80 a
9	63,83 c	61,80 c	62,82 c

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

It should be noted that the values for this indicator are lower in the second year of the experiment in all variants. The highest 1000 seeds mass was reported for treatment 6 (Pulsar® Plus - 2000 ml ha^{-1} in BBCH 18-19) - 66,21 g average for the period. The difference of the obtained results for treatment 6 was with proved differences according to Duncan's multiple range test ($p<0.05$) average for the period in comparison to the rest of the variants. Only the results of treatment 4 where with insignificant differences compared to treatments 6. At the variants with doubled rates of the evaluated herbicides, a decrease of the values of the indicator was observed. This could be a result of the herbicide stress caused by the higher imazamox rate.

High hectoliter mass is thus preferred by the industry (Abraham Nel, 2001). The lowest hectoliter mass of the sunflower seeds was the lowest for the control - 26,19 kg, (Table 4) average for the period. Gisca et al. (2017) reported a decrease of the values of this indicator at the variants with a higher level of infestation at the variants with higher *O. cumana* infestation. The magnitude of the hectoliter mass is determined by the grain size, the presence of impurities, etc. (Tonev et al., 2018).

Table 4. Hectoliter seed mass, kg.

Variants	2016	2017	Average
1	26,33 d	26,04 e	26,19 e

2	32,63 b	32,13 b	32,38 b
3	30,45 c	29,72 cd	30,08 c
4	33,15 ab	31,95 bc	32,55 b
5	29,38 cd	27,08 de	28,23 d
6	32,24 b	31,76 bc	32,00 b
7	31,22 bc	30,06 c	30,64 c
8	34,24 a	33,20 a	33,72 a
9	30,41 c	29,43 d	29,92 cd

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

The highest hectoliter mass of the sunflower seeds was recorded for variant 8 - 33,72 kg. The difference of the obtained results for treatment 8 was with proved differences according to Duncan's multiple range test ($p<0.05$) average for the period in comparison to the other treatments. As well as for the 1000 seeds mass the values of this indicator were lower at all variants for the second year of the study.

Also for this indicator a tendency of decrease in the values after the application of double herbicide rates independently the phenophase of the sunflower was recorded. This could also be a result of the herbicide stress.

In infested fields, *Orobanche* causes severe yield and quality losses (Duca and Glijin, 2013). Depending on the aggressiveness of the broomrape and the climatic conditions, the yield losses vary within 5-90 % (Gisca et al., 2017). The lowest yields were recorded for the control variant - 208,35 kg da^{-1} average for the period. Pulsar Plus is superior Pulsar in regard to the control of *O. cumana* control, as well as in regard to the yield (Pfenning et al., 2016). In our study the same tendency was found.

Table 5. Sunflower seed yield, kg ha^{-1}

Variants	2016	2017	Average
1	223,33 i	193,37 i	208,35 i
2	367,73 e	345,07 e	356,40 e
3	245,03 h	225,83 h	235,43 h
4	372,60 d	353,23 d	362,92 d
5	297,61 g	269,28 g	283,44 g
6	435,18 a	404,17 a	419,68 a
7	385,20 c	368,44 c	376,82 c
8	425,44 b	431,49 b	428,46 b
9	325,19 f	315,76 f	320,48 f

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

The highest sunflower seed yield was recorded after the treatment with Pulsar® Plus - 2000 ml ha^{-1} in BBCH 18-19 (variant 8) - 428,46 kg da^{-1} average for the period. The difference of the obtained results for the sunflower seed yield at treatment 8 were with proved differences according to Duncan's multiple range test ($p<0.05$) average for the period in comparison to the other treatments. The variants treated with doubled imazamox rates had lower yields in comparison with those treated with registered doses. This was probably due to the obtained herbicide stress from the high rates of the herbicides. Despite this fact the yield from the stressed sunflower plants was higher than those of the control highly infested with broomrape. This in turn shows how harmful it can the sunflower broomrape can be.

CONCLUSIONS

The highest number of the parasite per one sunflower plant was recorded for the control. In the second experimental year the parasite's number increased and reached 18.00 specimens per sunflower plant.

The highest herbicide toxicity was observed for treatments 3 (Pulsar® 40 - 2400 ml ha^{-1} in BBCH 14-16) and 5 (Pulsar® 40 - 2400 ml ha^{-1} in BBCH 18-19).

The lowest 1000 seed mass, as well as hectoliter mass, was recorded for the control where the infestation was the highest.

The lowest sunflower seed yield was recorded for the control variant - 208,35 kg da^{-1} average for the period. It was found that the variants treated with doubled imazamox rates had lower yields in comparison with those treated with registered doses, but the yield from the stressed sunflower plants was higher than those of the control.

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