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COMPETITIVE RELATIONSHIPS BETWEEN WEEDS AND *Sorghum bicolor* L. GROWN BY IGROWTH® TECHNOLOGY

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Abstract

In 2023-2024 in the experimental field of the Agricultural University-Plovdiv, weed associations in different BBCH stages of Sorghum bicolor L. were established. The crop was grown by igrowth® technology under non-irrigated conditions. The highest weed density from the late-spring group were Amaranthus retroflexus L., Chenopodium album L., Solanum nigrum L., Setaria viridis L., Portulaca oleracea L., and from perennial group - Sorghum halepense L. and Convolvulus arvensis L. In the control plot, during BBCH 14-15 stage of S. bicolor, the heights of the species Chenopodium album L. and Amaranthus retroflexus L. exceed the crop by 7.3 cm and 1.55 cm in 2023, but in 2024 the trend was the opposite. In BBCH 50, in both years, the two species were taller by 13.2 cm to 14.7 cm compare to S. bicolor. Sorghum halepense L. dominated with its height in both growing stages for the study period. The herbicide Pulsar 40 (imazamox), applied at rates of 1.20, 2.40 and 4.80 L ha-1, controlled the weeds up to BBCH 50 of the crop by 15% to 100%, depending on the species density

Key words: *Sorghum bicolor L., imazamox, igrowth® technology, weeds.*

INTRODUCTION

Sorghum is the fifth most important cereal crop grown in the world and a staple food in several regions of the Third World, mainly in Sub-Saharan Africa and India, where more than 300 million people rely on sorghum grain as a staple food (Rooney, 2004; Laidlaw and Godwin, 2008), and in the world, it has more than 60 million hectares of cultivated area, with the largest producers being the USA, India, China, Mexico, etc. Weeding is the main limiting factor for the intensive cultivation of sorghum for grain (Adu Tutu and Drennan, 1991; Rapparini, 1994; Rapparini et al., 1996; Limon-Ortega et al., 1998; Saayman, 2002). Weed control is a prerequisite for obtaining high and quality grain and green mass yields of sorghum. Due to this fact, in recent years it has become an increasingly widely studied crop in Bulgaria (Kikindonov et al., 2009; Enchev S. and G. Kikindonov, 2015; Enchev S., 2013).

In the early phases of its development, this crop is highly sensitive to weeding and yields significantly decrease if weeds are not destroyed in a timely manner (Limon-Ortega et al., 1998; Saayman, 2002).

In this regard, the aim of the present scientific work is to see the impact of the herbicide Pulsar 40 on the development and health status of the sorghum crop under the conditions of the igrowth® technology in the region of Central-South Bulgaria.

MATERIALS AND METHODS

The study was conducted at the Educational, Experimental and Implementation Base of the Agricultural University-Plovdiv at the Department of Agriculture and Herbology in 2023 and 2024. The experimental field of the Agricultural University - Plovdiv is located on alluvial-meadow soils, formed from sandy-clay and sandy-gravelly deposits of Quaternary origin. They are part of the second, higher terrace of the Maritsa River and are mainly made up of sandy and gravelly alluvial deposits, which in certain places also contain clay impurities. The thickness of the alluvial layer exceeds 54 meters. The width of this terrace varies between 300 meters and 4-5 kilometers, and it is of important importance for agriculture in the region (R. Popova et al., 2012.). The study was conducted with sorghum, a hybrid Sentinel, which was selected as suitable for cultivation using igrowth® technology (resistant to all imazamox-based herbicides). Pulsar 40 was used, which is a vegetative systemic herbicide from the imidazolinone group. It has a broad-spectrum effect against annual and perennial cereal and broadleaf weeds. It contains 40 g/l of the active ingredient imazamox. The recommended application rate is 1.2 L/ha. The active ingredient is taken up by the green parts of sensitive weeds, transported along the xylem and phloem to all growth points and inhibits the enzyme acetolactate synthetase (ALS). As a result, the weeds stop their growth, necrotize and die.

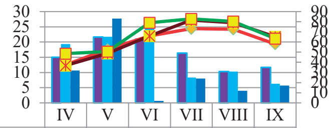
A two-factor field experiment was set up using the fractional plot method with a plot size of 20 m^2, in four replications. The experiment variants are as follows: A_1-Control (untreated), A_2-Pulsar 40 at a dose of 1.20 L/ha (imazamox 40 g/l), A_3-Pulsar 40 at a dose of 2.40 L/ha (imazamox 40 g/l), A_4-Pulsar 40 at a dose of 4.80 (imazamox 40 g/l).

The density of weeds and the height of the crop plant and individual weed species were recorded in stages BBCH 14-15 and BBCH 50.

Spraying with the herbicide Pulsar was carried out on 16.06.2023 and 13.06.2024 in BBCH 14-15 of the crop. The herbicide was applied with a backpack sprayer with a working solution of 20 l/da.

RESULTS AND DISCUSSIONS

The climatic conditions in the experimental years 2023 and 2024 pose a significant challenge for the crop, which is grown under non-irrigated conditions (Figure 1). In both years, the crop was sown at the appropriate time for it under favorable soil conditions. In 2023, at the beginning of the growing season, sorghum developed normally. From May to the end of the growing season, however, average monthly temperatures significantly exceeded normal values. Particularly high temperatures were recorded in the months of July, August and September, with temperatures reaching 40.9°C in July. These critical climatic conditions during the year have a significant impact on the growth and development of the crop, which have a negative impact on the overall development and productivity of the crop. In May 2024, the region is characterized by normal rainfall amounts of 83 l/m^2. Precipitation for the period June-August is only 38 mm, while in the first experimental year (2023) 135 mm fell for these 3 months. This extremely severe drought has had a negative impact on crop growth and development. However, weeds, which are not as dependent on rainfall, are developing in high density and competing with sorghum in phenological development and elements of growth and yield. Average monthly maximum temperatures for the period May-August 2024 are also at record highs, which further stress the crop plants.



	IV	V	VI	VII	VIII	IX
precip (mm/m2) aver. 1981-2010	45	65	63	49	31	35
precip. (mm/m2) 2023	58	65,1	79	25	31	19
precip. (mm/m2) 2024	32	83	2	24	12	17
t° C aver. 1981-2010	12,5	17,6	22	24,4	24,2	19,3
t° C 2023	12,3	16,3	22	27,2	26,3	21,7
t° C 2024	16,2	16,9	26,3	27,6	26,8	21,1

Figure 1. Agrometeorological conditions in the vegetation year 2023 and 2024

The selectivity of the herbicide Pulsar 40 (imazamox 40 g/L) applied at different doses to the sorghum crop, hybrid Sentinel IG, was monitored on the 7th, 14th and 21st day after the treatment of the crop, and the impact of the herbicide on the development and health status of the crop was recorded. The visual scale of the European Weed Research Society (EWRS) was applied, where at a score of 1 there was no damage to the crop, and at a score of 9 the crop was completely destroyed. (Table 1).

Table 1. Selectivity of studied herbicide towards *Sorghum bicolor* L., hybrid Sentinel IG, 2023

Variants	Selectivity, % by EWRS		
	7^{-th} day	14^{-th} day	21^{-st} day
A_1. Control (untreated)	1	1	1
A_2. Pulsar 40 1.2 L/ha (imazamox 40 g/L)	1	1	1
A_3. Pulsar 40 2.4 L/ha (imazamox 40 g/L)	2	1	1
A_4. Pulsar 40 4.8 L/ha (imazamox 40 g/L)	3	2	1

In the first experimental year, plants from all variants treated with herbicides reached the mass sweep phase (BBCH 50) on about the

40th day after spraying, with the exception of variants A_4, where the plants had a delayed growth and reached the 10th leaf phase. The growth lag and the non-simultaneous phenological development of some of the plants in the plots can be explained by a complex interaction between herbicide phytotoxicity and climatic conditions during the growing season (lack of precipitation and high temperatures). The applied herbicide Pulsar 40 at a dose of 2.4 L/ha (A_3) causes a milder and temporary phytotoxic effect, with a score of 2 on the 7th day after treatment. The crop recovers after the 14th day of herbicide application (score 1). No visible phytotoxic effects are detected in the A_2 variants after application of the product.

In 2024, on the 7th day after treating the crop with the herbicide Pulsar 40 at doses of 1.2 L/ha, 2. and 4.8 L/ha, no visible phytotoxic effect on the plants was observed and a score of 1 was recorded. At the next observation on the 14th day, slower growth was observed in variants A_4 compared to the other variants. By the end of the growing season, the plants treated with the herbicide Pulsar 40 remained the lowest in variants A_4. Weed height and density are shown in Table 2, at BBCH 14-15 of the crop. Extremely heavy weed infestation was reported by various annual and perennial species that were established in the trial area before spraying in 2023 and 2024

Table 2. Weed density and height before spraying with herbicide in the trial plots, hybrid Sentinel IG, BBCH 14-15 of the crop, year 2023 and 2024

Weeds	Weed density, pcs/m^2		Weed height, cm		Crop height, cm	
	2023	2024	2023	2024	2023	2024
Amaranthus retroflexus L.	157	6	26.2	15.5	24.7	25.6
Chenopodium album L.	152	72	32	13.2		
Xanthium strumarium L.	1	5	14.7	17.5		
Solanum nigrum L.	28	10	12.7	9.5		
Portulaca oleracea L.	117	17	5	10.5		
Setaria viridis L.	82	42	12	11.2		
Sinapis arvensis L.	2	6	16.5	13.5		
Anthemis arvensis L.	8	4	13.5	4.7		
Tribulus terrestris L.	3	4	7.2	9		
Datura stramonium L.	1	4	13.2	10.5		
Lolium perenne L.	2	7	24.2	14.2		
Echinochloa crus-galli L.	2	9	4	5.7		
Amaranthus blitoides L.	9	21	11.2	12.2		
Abutilon theophrasti L.	1	4	13.2	15.7		
Sorgum halepense L.	1	5	29.5	33.7		
Convolvulus arvensis L.	3	5	14.7	11.7		

The representatives present in the experiment for the two experimental years are described, with the most numerous species being the late spring weeds group – 6 species. These are: *Amaranthus retroflexus* L., *Amaranthus blitoides* L., *Chenopodium album* L., *Solanum nigrum* L., *Portulaca oleracea* L. and *Setaria viridis* L. With one representative each are the groups of early spring weeds - *Sinapis arvensis* L.; winter-spring weeds – *Anthemis arvensis* L., and from perennial group weeds - *Convolvulus arvensis* L. and *Sorghum halepense* L.

It is noteworthy that in 2023, before spraying sorghum (BBCH 14-15), the density of individual species was very different from the second experimental year. The highest density of species was *Amaranthus retroflexus* L., which was 157 pcs./m^2; for *Chenopodium album* L. the density was 152 pcs./m^2, *Setaria viridis* L. - 82 pcs./m^2, and the density of*Portulaca oleracea* L. e 117 pcs./m^2. The remaining weeds were at a significantly lower density, ranging from 9 pcs./m^2 for *Sorghum halepense* L. and up to 28 pcs./m^2 for *Solanum nigrum* L.

High weed density has the most negative impact on crop development. As a result of competition between weeds and sorghum, plants in the untreated control have delayed growth and set panicles significantly later than the treated variants.

In the second experimental year before spraying the sorghum, the density of individual species was significantly lower than the previous year, which was due to the rotation of the fields and the different stocking of the soil with weed seeds and organs for vegetative reproduction. The highest density is again maintained in the species *Chenopodium album* L., *Setaria viridis* L., *Portulaca oleracea* L. and *Amaranthus blitoides* L. In *Chenopodium album* L. the density is 72 pcs /m^2, in *Setaria viridis* L. - 42 pcs./m^2, and in *Portulaca oleracea* L. - 17 pcs./m^2. The density of *Solanum nigrum* L. is 10 pcs./m^2, and in *Amaranthus blitoides* L. is 21 pcs./m^2. The rest of the weeds are significantly lower, 5 pcs./m^2 за *Sorghum halepense* L. And in this experimental year, the tendency for the negative impact of high weed density on the phenological development of the crop in the control remained.

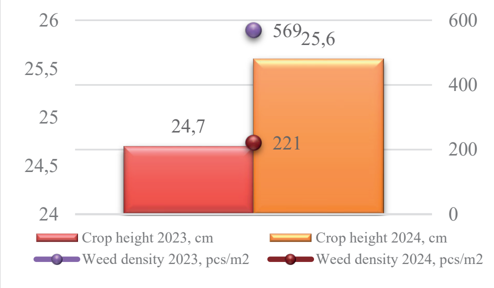


Figure 2. Crop height and total weed density before spraying with herbicide in the trial plots, BBCH 14-15 of the crop, year 2023 and 2024

The total weed density before treatment in 2023 was 569 pcs./m^2, while the height of the crop plant was 24.7 cm. In 2024, the total weed density was 221 pcs./m^2 and the height of the crop was 25.6 cm (Figure 2).

The results of the study show visible differences in the efficacy of the applied herbicide on different types of weeds, which provides important information for their control in agricultural crops. Table 3 presents data on the efficacy of the herbicide applied at different doses against individual weed species. Weeds were scored using the EWRS visual efficacy scale, and the results were compared with the untreated control. In 2023, the applied Pulsar 40 exerts practically complete control (100%) regardless of the doses applied to *Solanum nigrum* L., *Xanthium strumarium* L., *Sinapis arvensis* L., *Anthemis arvensis* L., *Tribulus terrestris* L., *Datura stramonium* L., *Lolium perenne* L., *Echinochloa crus-galli* L. и *Abutilon theophrasti* L. It has high efficacy against *Amaranthus retroflexus* L., which reaches 90% at herbicide doses of 1.2 L/ha and 2.4 L/ha, respectively 10 and 9 pcs./m^2, and at the highest dose the control reaches 100%. The efficacy against *Setaria viridis* L. at a dose of 1.2 L/ha educes the number of weeds om m^2 by half compared to the control, and with an increase to 2.4 and 4.8 L/ha pcs./m^2 reaches 17 pcs./m^2. Against *Chenopodium album* L., the herbicide at a dose of 4.8 L/ha (4 times higher than the registered one) achieves efficacy that reduces the number on m^2 by half, while at lower doses (1.2 L/ha and 2.4 L/ha) the control over the weed species is weaker. Against *Portulaca oleracea* L. of 140 pcs./m^2 in the control variant, the effect of the herbicide varies from 24 pcs./m^2 at the lowest dose of 1.2 L/ha to 16 pcs./m^2 at the highest dose 4.8 L/ha. The application of Pulsar 40 at a dose of 1.2 L/ha at *Amaranthus blitoides* L. has limited control-14 pcs./m^2, and with an increase in the herbicide dose to 4.8 L/ha it reaches 2 pcs./m^2. In *Convolvulus arvensis* L. the efficacy of the herbicide at a dose of 1.2 L/ha reduces the number to 10 pcs./m^2 compared to the control, where we have 14 pcs./m^2. Again with increasing the dose to 2.8 L/ha and 4.8 L/ha, the control is from 9 pcs./m^2 to 5 pcs./m^2. The perennial weed *Sorghum halepense* L., developed from rhizomes, is not controlled by Pulsar 40 at the registered dose of 1.2 L/ha. After its application, its control decreases in number reaching 1 pcs./m^2, but its height is significantly higher compared to the other species, reaching the height of the crop.

In 2024 г. the applied Pulsar 40 provided complete control (100%) against the species *Setaria viridis* L., *Sinapis arvensis* L., *Anthemis arvensis* L., *Tribulus terrestris* L., *Lolium perenne* L. and *Echinochloa crus-galli* L. (Table 4). At the highest dose (4.8 L/ha) it showed high efficacy against *Amaranthus retroflexus* L., reducing to 1 pcs./m^2 from 19 бр./m^2 in the control variant. In *Amaranthus blitoides* L. the efficacy was equally high at all doses of the herbicide, reducing from 33 pcs./m^2 in the untreated control to 2 pcs./m^2 in all treated variants. Against *Chenopodium album* L this year at a dose of 4.8 L/ha Pulsar 40 achieved greater efficacy, reaching 22 pcs./m^2, and at lower doses (1.2 L/ha и 2.4 L/ha) it also showed good control over the weed species – 30 and 26 pcs./m^2. Against *Portulaca oleracea* L. he effect varied from 19 pcs./m^2 at the lowest dose to 14 pcs./m^2 at the highest dose. The density of *Xanthium strumarium* L., is reduced from 7 pcs./m^2 in the control variant to 2 pcs./m^2 regardless of the herbicide dose. Pulsar 40 is also highly effective against *Solanum nigrum* L., which reaches up to 2 pcs./m^2 at all doses of the herbicide. In *Datura stramonium* L. at a herbicide dose of 1.2 L/ha and 2.4 L/ha the number is reduced to 3 pcs./m^2, and at 4.8 L/ha it reaches to 2 pcs./m^2.

Table 3. Weed height and density in BBCH 50 of the crop, 2023

	Control		Pulsar 40 1.2 L/ha		Pulsar 40 2.4 L/ha		Pulsar 40 4.8 L/ha	
Weeds	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2
Amaranthus retroflexus L.	61.7	188	35	10	34.7	9	0	0
Chenopodium album L.	60.2	178	43.2	151	36.2	120	34.2	90
Xanthium strumarium L.	59.7	4	0	0	0	0	0	0
Solanum nigrum L.	17.2	34	0	0	0	0	0	0
Portulaca oleracea L.	25	140	24	43	22.5	18	22.2	16
Setaria viridis L.	36	98	31.2	40	30.5	18	24.2	17
Sinapis arvensis L.	30.5	2	0	0	0	0	0	0
Anthemis arvensis L.	26.2	10	0	0	0	0	0	0
Tribulus terrestris L.	16.7	4	0	0	0	0	0	0
Datura stramonium L.	35	3	0	0	0	0	0	0
Lolium perenne L.	26.7	2	0	0	0	0	0	0
Echinochloa crus-galli L.	21.7	5	0	0	0	0	0	0
Amaranthus blitoides L.	24.2	14	21.2	11	21.2	5	20.7	2
Abutilon theophrasti L.	33.7	3	0	0	0	0	0	0
Sorgum halepense L.	85.7	6	63.7	1	61.7	1	61	1
Convolvulus arvensis L.	36.2	14	32.2	10	31.7	9	24.5	5

Table 4. Weed height and density in BBCH 50 of the crop, 2024

	Control		Pulsar 40 1.2 L/ha		Pulsar 40 2.4 L/ha		Pulsar 40 4.8 L/ha	
Weeds	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2	Weed height, cm	Weed density, pcs./m^2
Amaranthus retroflexus L.	36.2	19	30.7	3	28.7	3	27.5	1
Chenopodium album L.	47.5	86	25	30	21.2	26	19.5	22
Xanthium strumarium L.	47.7	7	31	2	26.2	2	25	2
Solanum nigrum L.	13	14	13.2	1	12.7	1	10.7	1
Portulaca oleracea L.	18.7	32	16.5	19	15	15	12.2	14
Setaria viridis L.	27.2	50	0	0	0	0	0	0
Sinapis arvensis L.	26	11	0	0	0	0	0	0
Anthemis arvensis L.	16	6	0	0	0	0	0	0
Tribulus terrestris L.	14	9	0	0	0	0	0	0
Datura stramonium L.	65	12	57.5	3	43.7	3	42.5	2
Lolium perenne L.	24.2	9	0	0	0	0	0	0
Echinochloa crus-galli L.	19.2	15	0	0	0	0	0	0
Amaranthus blitoides L.	24.7	33	21.2	2	21	2	20.7	2
Abutilon theophrasti L.	49	8	48.2	4	42.2	2	37.2	1
Sorgum halepense L.	65	17	57.5	4	43.7	3	42.5	3
Convolvulus arvensis L.	31.2	11	29.7	4	29.2	4	29.5	4

With the highest dose of the herbicide (4.8 L/ha) in the species *Abutilon theophrasti* L. the efficacy reaches 1 бр./m^2, while at a dose of 1.2 L/ha and 2.4 L/ha is 4 pcs./m^2 and 2 pcs./m^2. In *Convolvulus arvensis* L. the efficacy of the herbicide is the same regardless of the dose, reaching 4 бр./m^2. The perennial weed *Sorghum halepense* L., developed from rhizomes, is not controlled by Pulsar 40, and after its application, the effect is 3 pcs./m^2 at a dose of 4.8 L/ha.

The height of the crop at BBCH 50 stage was recorded during the two experimental years. Data show that the plants are the lowest in the untreated control. In the variants with the application of the herbicide Pulsar 40, the plants are the lowest at the highest dose of the herbicide (4.8 L/ha) reaching 56.7 cm in 2023 and 53.5 cm in 2024. In both years, the plants remained tallest at the lowest herbicide dose (1.2 L/ha), 61 cm and 58.8 cm, respectively.

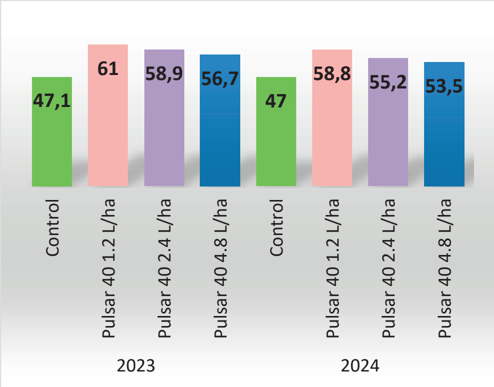


Figure 3. Crop height in BBCH 50 phase during the two experimental years, cm

CONCLUSIONS

From the research conducted at the experimental field of the Department of Agriculture and Herbology, the following important conclusions can be drawn:

With increasing dose of herbicide Pulsar 40, weed control increases, but the phytotoxic effect on sorghum increases. In the first year, a visible phytotoxic effect is observed, which is expressed in chlorosis and delayed plant growth. In the second experimental year, no visible phytotoxic effect is observed, but the plants remain shorter.

During both experimental years, the applied Pulsar 40 in all doses provided complete control (100%) against the species *Sinapis arvensis* L., *Anthemis arvensis* L., *Tribulus terrestris* L., *Lolium perenne* L. and *Echinochloa crus-galli* L.

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