

APPLICATION OF IMAZAMOX FOR WEED CONTROL IN SORGHUM (*Sorghum bicolor* (L.) Moench)

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Abstract

In 2023 and 2024, a field trial with sorghum, hybrid Sentinel IG in the experimental field of the Agricultural University - Plovdiv, Bulgaria, was conducted. The experience variants include: 1. Untreated control; 2. Pulsar 40 - 1.20 L ha⁻¹ (BBCH 14-16); 3. Pulsar 40 + Tonivit in rates of 1.20 L ha⁻¹ + 1.00 L ha⁻¹ (BBCH 14-16); 4. Pulsar 40 - 1.20 L ha⁻¹ (BBCH 14-16) + Apetayzer - 0.50 L ha⁻¹ (BBCH 17-19); 5. Pulsar 40 + Tonivit in rates of 1.20 L ha⁻¹ + 1.00 L ha⁻¹ (BBCH 14-16) + Apetayzer - 0.50 L ha⁻¹ (BBCH 17-19); 6. Pulsar 40 - 4.80 L ha⁻¹ (BBCH 14-16). The application of Pulsar 40 (4.80 L ha⁻¹) provides one hundred percent control against *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Sinapis arvensis* L., and *Setaria viridis* L. On the 7th day after application of Pulsar 40 (4.80 L ha⁻¹) it causes phytotoxicity with a score of 3 - slight chlorosis on the leaves, and by the 21st day the crop recovers. The highest yield was recorded after application of Pulsar 40 + Tonivit + Apetayzer (variant 5).

Key words: sorghum, herbicides, weeds, efficacy, yield.

INTRODUCTION

Ensuring sustainable resources for the food sector remains key challenges facing modern society. Crops play a crucial role as a primary source of raw materials. As a result, scientific interest has increased, along with the number of studies focusing on the development and implementation of innovative technological solutions for efficient and sustainable agricultural production (Ahmad et al., 2025; Dulaimy et al., 2025; Mitkov 2025; Thuleau et al., 2025; Tourneur et al., 2025; Panayotov et al., 2024; Panchev & Shopova, 2024; Shevchenko et al., 2024; Kolentsova et al., 2023; Shopova, 2023; Fernández-Aparicio et al., 2022; Ivanov et al., 2021; Kalinova et al., 2021; Tonev et al., 2021; Komitov et al., 2020; Mitkov, 2020; Dimtrova et al., 2019; Ivanov et al., 2019; Goranovska et al., 2017; Shopova & Cholakov, 2015; Uzunova et al., 2015; Dimitrova et al., 2014; López-Bellido et al., 2014; Mitkov et al., 2014; Shopova & Cholakov, 2014; Kalinova et al., 2012; Tonev et al., 2010; Mitkov et al., 2009).

Climate change observed in recent years has further limited the range of crops suitable for cultivation. The trend toward rising temperatures, combined with reduced and unevenly distributed precipitation, highlights

the need to cultivate crops that are better adapted to changing environmental conditions. One of the potential crops capable of thriving under such conditions is sorghum (*Sorghum bicolor* L. Moench) (Fontanet-Manzanegue et al., 2025; Abreha et al., 2022). For example, Hadebe et al. (2017) report that sorghum is well-suited for cultivation in the dry and semi-arid agroecological zones of Sub-Saharan Africa. This suitability is largely due to its root system, which consists of numerous root hairs that facilitate water uptake from the soil, and the waxy layer on its leaves, which reduces water loss (El Bassam, 2010).

Among cereal crops worldwide, sorghum ranks fifth in importance after wheat, rice, maize, and oats (Khalil, 2008; Pacheco, 1998). The high nutritional value of its grains - rich in proteins and dietary fiber, and gluten-free-supports their use as a substitute for wheat flour in baking and confectionery products (Impa et al., 2019; Xiong et al., 2019; McCann et al., 2015). Additionally, sorghum can serve as a raw material for bioethanol production (Mathur et al., 2017; Makuh et al., 2013), and its ability to produce large amounts of biomass makes it valuable as animal feed (Ghani et al., 2015).

Weeds are one of the main factors limiting the growth and development of *Sorghum bicolor* L. Moench (Geier et al., 2009). They compete with

sweet sorghum for essential resources such as water, light, and nutrients (Grabovskiy et al., 2018). In addition, weeds may serve as intermediate hosts for various diseases and pests and may also interfere with the harvesting of the crop (Ottman & Olsen, 2009; Capinera, 2005; Zimdahl, 1999). According to Dille et al. (2020), competition from weeds can reduce sorghum yield by more than 60%. Bagavathiannan et al. (2018) report that grassy weeds are more difficult to control in sorghum compared with broadleaf weeds. Magani (2008) found that weed infestation in sorghum fields resulted in a significant yield reduction of 40-60%, while Stahlman and Wicks (2000) reported yield losses of 30-50%, along with a deterioration in crop quality. More detailed studies have shown that infestation of sorghum with *Parthenium hysterophorus* can reduce yield by up to 81% in Pakistan (Bajwa et al., 2020) and up to 97% in Ethiopia (Tamado et al., 2002).

Effective weed management requires accurate identification of the weed species. In Ludhiana, sorghum fields are heavily weed-infested, with species such as *Trianthema portulacastrum*, *Digera arvensis*, *Commelina benghalensis*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Cyperus rotundus*, *Eclipta alba*, and *Digitaria sanguinalis* predominating (Kaur et al., 2024). In the Kafr El-Sheikh Governorate, Egypt, the most common weeds are *Corchorus olitorius*, *Xanthium strumarium*, *Amaranthus album*, *Portulaca oleracea*, *Ammania aegyptiaca*, *Echinochloa colona*, and *Dinebra retroflexa* (Khaffagy et al., 2014). Sweet sorghum fields in the Kyiv region, Ukraine, were reported to be infested with *Chenopodium album* L., *Setaria viridis* L., *Setaria glauca* L., *Amaranthus retroflexus* L., *Echinochloa crus-galli* L., *Convolvulus arvensis* L., *Capsella bursa-pastoris* L., *Polygonum convolvulus* L., *Cirsium arvense* L., and *Elytrigia repens* L. (Grabovskiy et al., 2018). In Italy, perennial weeds such as *Sorghum halepense* and *Convolvulus* spp. occur at high densities in sorghum fields (Rapparini, 2000).

Various methods can be employed for weed control. Traditional hand weeding is effective but labor- and time-intensive, making it less economically viable under conditions of high labor costs (Vijayakumar et al., 2014). Mechanized weed control offers a more efficient

alternative, requiring less labor and time (Chivinge, 1990). In modern agriculture, chemical control through herbicides is the primary approach. Soil-applied pyroxasulfone (0.1275 kg a.i./ha) has been recommended for controlling broadleaf and grassy weeds in sorghum, with only minimal early-stage phytotoxicity that is overcome in later growth stages (Kaur et al., 2024).

Bajwa et al. (2023) report that pendimethalin followed by bromoxynil effectively controls *Parthenium* weeds. Dimitrova (2005) found that pre-emergence application of isoxaflutole (94 g/ha) followed by 2,4-D + dicamba at the 4-5 leaf stage, combined with a single inter-row cultivation, provides optimal weed control. Post-emergence applications of 2,4-D, sometimes combined with soil-applied atrazine, have also been recommended for controlling broadleaf weeds and sedges (Krishnamurthy et al., 2021; Dan et al., 2010; Kumar et al., 2008; Stahlman & Wicks, 2000).

For environmental reasons, post-emergence herbicides are preferred, even though their action may be shorter than soil-applied herbicides (Takano et al., 2016). Flumioxazin (50 g ha⁻¹) has been identified as a potential herbicide for broadleaf weeds in sweet sorghum, although it may cause a low degree of phytotoxicity (Galon et al., 2016). Although sorghum exhibits mixed weed infestations, grassy weeds remain particularly challenging, and chemical options for their control during vegetative growth are limited (Dille et al., 2020; Bagavathiannan et al., 2018). As a result, sorghum cultivars with enhanced herbicide tolerance, including igrowth™ (resistant to imazamox), Inzen™ (resistant to nicosulfuron), and DoubleTeam™ (resistant to quizalofop), have been developed (Norsworthy et al., 2020).

This study aims to investigate the application of imazamox for weed control in sorghum (*Sorghum bicolor* (L.) Moench).

MATERIALS AND METHODS

In 2023 and 2024, a field trial with sorghum, hybrid Sentinel IG, was conducted in the experimental field of the Agricultural University - Plovdiv, Bulgaria. The experiment was laid out using the long-plot method with four

replications, with a plot size of 50 m² (Dimova & Marinkov, 1999). The experimental treatments included: 1. Untreated control - without tillage or herbicides; 2. Pulsar 40 - 1.20 L ha⁻¹ (BBCH 14-16); 3. Pulsar 40 + Tonivit at rates of 1.20 L ha⁻¹ + 1.00 L ha⁻¹ (BBCH 14-16); 4. Pulsar 40 - 1.20 L ha⁻¹ (BBCH 14-16) + Apetayzer - 0.50 L ha⁻¹ (BBCH 17-19); 5. Pulsar 40 + Tonivit at rates of 1.20 L ha⁻¹ + 1.00 L ha⁻¹ (BBCH 14-16) + Apetayzer - 0.50 L ha⁻¹ (BBCH 17-19); 6. Pulsar 40 - 4.80 L ha⁻¹ (BBCH 14-16). The application of the products was carried out using a SOLO backpack electric sprayer (model 417), with a working solution volume of 200 L ha⁻¹.

Pulsar® 40 is a post-emergence systemic herbicide containing 40 g L⁻¹ imazamox. The active ingredient belongs to the imidazolinone group of herbicides and inhibits the enzyme acetolactate synthase, which is essential for the synthesis of branched-chain amino acids in plants. It is effective against both annual and perennial grassy and broadleaf weeds (BASF, 2022).

The biostimulant Tonivit contains an extract of the brown algae *Ascophyllum nodosum* and provides 13% water-soluble phosphorus pentoxide (P₂O₅) and 5% potassium oxide (K₂O). It also includes biologically active compounds such as amino acids, vitamins, and oligosaccharides, which enhance physiological processes and nutrient uptake in plants (UPL, 2023a).

Apetayzer is a biostimulant based on *Ascophyllum nodosum* filtrate, supplemented with water-soluble manganese and zinc. It incorporates a proprietary technology designed to activate nutrient-related physiological processes in plants (UPL, 2023b).

The preceding crop was wheat. Following its harvest in autumn, deep plowing to a depth of 30-35 cm and two diskings were performed. Pre-sowing fertilization was carried out with a combined NPK fertilizer (15:15:15) at 200 kg ha⁻¹. At the 7-8 leaf stage of *S. bicolor* L. Moench, top-dressing was applied using 200 kg ha⁻¹ NH₄NO₃. Sowing of the Sentinel IG hybrid was performed on 12 May 2023 (first year) and 8 May 2024 (second year), at a seeding rate of 6,500 plants ha⁻¹. The crop was grown under rainfed conditions.

During both years, the experimental fields were naturally infested with *Amaranthus retroflexus* L., *Chenopodium album* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Portulaca oleracea* L., *Sinapis arvensis* L., *Setaria viridis* L., *Anthemis arvensis* L., and *Sorghum halepense* (L.) Pers. developed from rhizomes. The biological efficacy of Pulsar® 40 and the biostimulants was assessed at 7, 14, and 28 days after treatment (DAT) using the EWRS visual assessment scale. The selectivity of imazamox, applied alone or in combination with biostimulants, was evaluated at 7, 14, 21, and 28 DAT according to the EWRS scale (score 1 - no crop injury, score 9 - complete crop destruction). In addition to biological efficacy and selectivity, grain yield (t ha⁻¹) was recorded. Statistical analysis was performed using Duncan's multiple range test with SPSS 19 software (Duncan, 1955), and differences were considered significant at $p < 0.05$.

RESULTS AND DISCUSSIONS

The meteorological conditions during the study period were variable between the two experimental years. The first year, 2023, was characterized by higher mean monthly temperatures and lower overall precipitation compared to the long-term averages (Tables 1 and 2). In May and June, precipitation exceeded the multi-year mean by 31.3 mm/m² and 47 mm/m², respectively, creating favorable soil moisture conditions for seed germination and normal crop development. However, during July, August, and September, total rainfall was only 57 mm/m², which was 104 mm/m² lower than the multi-year average. Mean monthly temperatures from May until the end of the crop's growing season were above the norm, with a cumulative temperature sum 13.7 °C higher than the long-term average. July, August, and September were particularly hot, with maximum temperatures exceeding 38 °C in July. In contrast, meteorological conditions in the second experimental year, 2024, were less favorable for rainfed sorghum cultivation. Although May rainfall provided adequate soil moisture for germination, it exceeded the long-term average by 51 mm/m². From June to September, a prolonged drought occurred, restricting normal crop growth. Total

precipitation during this period was 141.8 mm/m² lower than the multi-year average (Table 1). Concurrently, mean monthly temperatures throughout the growing season were substantially above the norm, with a cumulative temperature sum from May to September 16.4

°C higher than the long-term average (Table 2). Similar to 2023, temperatures in July exceeded 38 °C. The adverse meteorological conditions during 2024 had a negative impact on grain yield.

Table 1. Precipitation amount during the study period, mm/m²

Month	2023	Average for the period 1916-1970	Deviation	2024	Average for the period 1916-1970	Deviation
May	63.3	32	+31.3	83	32	+51
June	83	36	+47	2	36	-34
July	26.5	42	-15.5	24.2	42	-17.8
August	10.5	54	-43.5	12	54	-42
September	20	65	-45	17	65	-48
Total	202.8	229	-26.2	138.2	229	-90.8

Table 2. Average monthly temperature for the study period, °C

Month	2023	Average for the period 1916-1970	Deviation	2024	Average for the period 1916-1970	Deviation
May	18.9	17.2	+1.7	16.9	17.2	-0.3
June	22.8	20.9	+1.9	26.3	20.9	+5.4
July	26.1	23.2	+2.9	27.6	23.2	+4.4
August	26.4	22.7	+3.7	26.8	22.7	+4.1
September	21.8	18.3	+3.5	21.1	18.3	+2.8
Total	116	102.3	+13.7	118.7	102.3	+16.4

The results indicate that the biological efficacy of the tested products increased progressively from 7 to 28 DAT. On the seventh DAT, control of *Amaranthus retroflexus* L. – the most

abundant weed species in the experiment – was 90% across all herbicide-treated plots, reaching 100% control by 28 DAT (Table 3).

Table 3. Efficacy (%) of the studied products against *Amaranthus retroflexus* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	85	90	100	95	100	100	90	95	100
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	95	100	100	85	90	100	90	95	100
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	90	100	100	90	90	100	90	95	100
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	95	100	100	85	90	100	90	95	100
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	95	100	100	85	90	100	90	95	100

Imazamox applied alone or in combination with biostimulants exhibited lower efficacy against *Chenopodium album* L. compared to *A. retroflexus* L. On the first assessment date, all plots treated with Pulsar 40 at 1.20 L ha⁻¹, either alone or in combination with Tonivit and Apetayzer, showed 65% control. Quadrupling the registered dose of Pulsar 40 significantly increased efficacy to 85%. By 14 DAT, efficacy reached 70% in variants 2, 3, 4 and 5 and 90% in the high-dose treatment. At 28 DAT, the highest control (95%) was achieved with Pulsar

40 at 4.80 L ha⁻¹, while variants 2, 3, 4 and 5 showed satisfactory control at 75% (Table 4). For the late-spring weed *Xanthium strumarium* L., the highest efficacy on the seventh DAT was recorded in the high-dose Pulsar 40 variant (4.80 L ha⁻¹) - 85%, while other treatments achieved 75%. By 14 DAT, efficacy increased, reaching 90% in the high-dose treatment, and by 28 DAT, complete control (100%) was observed. Variants 2, 3, 4 and 5 also showed very good control, reaching 95% efficacy (Table 5).

Table 4. Efficacy (%) of the studied products against *Chenopodium album* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	70	75	80	60	65	70	65	70	75
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	70	75	80	60	65	70	65	70	75
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	65	65	70	65	75	80	65	70	75
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	70	75	80	60	65	70	65	70	75
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	90	95	100	80	85	90	85	90	95

Table 5. Efficacy (%) of the studied products against *Xanthium strumarium* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	70	80	90	80	90	100	75	85	95
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	75	80	95	75	90	95	75	85	95
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	70	85	90	80	85	100	75	85	95
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	70	80	95	80	90	95	75	85	95
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	90	90	100	80	90	100	85	90	100

Table 6. Efficacy (%) of the studied products against *Solanum nigrum* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	80	80	95	80	90	95	80	85	95
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	75	80	90	85	90	100	80	85	95
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	85	90	100	75	80	90	80	85	95
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	80	85	90	80	85	100	80	85	95
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	80	85	100	90	95	100	85	90	100

The results regarding the control of *Solanum nigrum* L. were similar to those observed for *Xa. strumarium* L. On the first assessment date, the highest efficacy - 85% was achieved with Pulsar 40 at 4.80 L ha⁻¹ (variant 6). In the remaining treatments with Pulsar 40, applied either alone or in combination with biostimulants, control was 80%. On the 14 DAT, efficacy in the treated plots ranged from 85 to 90%, while by the 28 DAT it reached 100% for variant 6 and 95% for variants 2, 3, 4, and 5 (Table 6).

The tested herbicides and biostimulants showed limited control of *Portulaca oleracea* L. On the 7 DAT, in all treatments containing Pulsar 40 at

1.20 L ha⁻¹, efficacy against the weed was 25%. In the treatment with Pulsar 40 at 4.80 L ha⁻¹, control was slightly higher (40%) but still unsatisfactory. On the 14 DAT, only a minimal increase in control was observed. In variants 2, 3, 4, and 5, efficacy was merely 30%, whereas in variant 6 it reached 50%. By the 28 DAT, even after some improvement in control of *P. oleracea* L., efficacy in variants 2, 3, 4, and 5 remained unsatisfactory (35%). Control of this weed remained limited (55%) even after applying a fourfold higher than the registered dose of Pulsar 40 at 4.80 L ha⁻¹ (Table 7).

Table 7. Efficacy (%) of the studied products against *Portulaca oleracea* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	20	25	30	30	35	40	25	30	35
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	20	30	30	30	30	40	25	30	35
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	25	25	35	25	35	35	25	30	35
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	25	35	40	25	25	30	25	30	35
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	35	45	50	45	55	60	40	50	55

Table 8. Efficacy (%) of the studied products against *Sorghum halepense* (L.) Pers. developed from rhizomes, day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	15	20	25	25	30	35	20	25	30
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	20	25	25	20	25	35	20	25	30
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	15	20	25	25	30	35	20	25	30
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	15	20	25	25	30	35	20	25	30
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	70	75	80	80	85	90	75	80	85

Table 9. Efficacy (%) of the studied products against *Sinapis arvensis* L., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	75	80	90	75	90	100	75	85	95
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	70	80	90	80	90	100	75	85	95
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	70	85	90	80	85	100	75	85	95
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	75	85	95	75	85	95	75	85	95
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	85	90	100	95	100	100	90	95	100

Similar to the control of *P. oleracea* L., the application of Pulsar 40 at the registered dose of 1.20 L ha⁻¹, either alone or in combination with Tonivit and Apetayzer, failed to effectively suppress *Sorghum halepense* (L.) Pers. developed from rhizomes. The highest efficacy in these treatments was recorded on the 28 DAT after treatment, reaching only 30%. Application of Pulsar 40 at 4.80 L ha⁻¹ provided substantially better control, achieving 85% efficacy against the weed by the 28 DAT (Table 8).

Sinapis arvensis L. was identified as one of the weed species most sensitive to the herbicides used in the study. By the 7 DAT, application of

Pulsar 40 at 4.80 L ha⁻¹ achieved 90% efficacy, which increased to 100% by the 28 DAT. In variants with lower imazamox rates, control of *S. arvensis* L. was 75% on the 7 DAT, reaching 95% by the 28 DAT (Table 9).

Under the conditions of the experiment, control of *Setaria viridis* (L.) P. Beauv. ranged from very good to excellent, depending on the applied imazamox rate. On the 7 DAT, average efficacy across variants 2, 3, 4, and 5 was 75%, while variant 6 reached 85%. By the 28 DAT, 100% control was achieved with Pulsar 40 at 4.80 L ha⁻¹. In the remaining variants involving imazamox, efficacy reached 90% (Table 10).

Table 10. Efficacy (%) of the studied products against *Setaria viridis* (L.) P.Beauv., day after treatment (DAT)

Variants	2023			2024			Average		
	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT	7 DAT	14 DAT	28 DAT
1. Untreated control	0	0	0	0	0	0	0	0	0
2. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16	80	85	95	70	75	85	75	80	90
3. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16	75	80	85	75	80	95	75	80	90
4. Pulsar 40 (1.20 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	70	75	85	80	85	95	75	80	90
5. Pulsar 40 (1.20 L ha ⁻¹) + Tonivit (1.00 L ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 L ha ⁻¹) BBCH 17-19	75	80	85	75	80	95	75	80	90
6. Pulsar 40 (4.80 L ha ⁻¹) BBCH 14-16	80	85	100	90	95	100	85	90	100

Regarding the selectivity of the tested products towards *sorghum*, hybrid Sentinel IG, the following key results were obtained. Under the experimental conditions, the application of Pulsar 40 at 4.80 L ha⁻¹ caused phytotoxic effects on the sorghum hybrid. On the 7 DAT, a phytotoxicity score of 3 on the EWRS scale was recorded, manifested as slight leaf chlorosis. By the second assessment at 14 DAT, the crop began to recover, but phytotoxicity was still observed with a score of 2. On the 21 DAT, the crop overcame the herbicide stress, reaching a score of 1 on the EWRS scale. In the other treatments with Pulsar 40 at 1.20 L ha⁻¹ (variants 2, 3, 4, and 5), no visual signs of phytotoxicity were observed, with a consistent score of 1 on the EWRS scale.

In addition to the biological efficacy and selectivity of the tested products, the grain yield of sorghum, hybrid Sentinel IG, was also determined during the experiment. After statistical analysis of the data, the lowest yield was observed in the Untreated control (0.65 t ha⁻¹), where weeds were not controlled. It is noteworthy that yields across all variants in 2024 were lower compared to 2023 (Table 11). This decrease is attributable to the less favorable climatic conditions in 2024, despite the drought tolerance of sorghum (Tables 2 and 3).

The highest grain yield was obtained following the combined application of Pulsar 40 (1.20 L ha⁻¹) + Tonivit (1.00 L ha⁻¹) at the 4-6 leaf stage and Apetayzer (0.50 L ha⁻¹) at the 7-9 leaf stage (variant 5). In this variant, yield reached 2.23 t ha⁻¹ in 2023 and 1.75 t ha⁻¹ in 2024. Similar average yields were observed in variants 3, 4, and 2, with 1.96 t ha⁻¹, 1.92 t ha⁻¹, and 1.90 t ha⁻¹, respectively. It is important to note that no statistically significant differences were found among these four variants across the two

experimental years (Table 11). The yield increase resulting from effective weed control through herbicide application has also been confirmed by Solaimalai & Muthusankaranarayanan (2000).

Table 11. Sorghum grain seed yield (t ha⁻¹)

Variants	2023	2024	Average
1. Untreated control	0.71 c	0.59 c	0.65
2. Pulsar 40 (1.20 l ha ⁻¹) BBCH 14-16	2.13 a	1.67 a	1.90
3. Pulsar 40 (1.20 l ha ⁻¹) + Tonivit (1.00 l ha ⁻¹) BBCH 14-16	2.19 a	1.72 a	1.96
4. Pulsar 40 (1.20 l ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 l ha ⁻¹) BBCH 17-19	2.15 a	1.69 a	1.92
5. Pulsar 40 (1.20 l ha ⁻¹) + Tonivit (1.00 l ha ⁻¹) BBCH 14-16 + Apetayzer (0.50 l ha ⁻¹) BBCH 17-19	2.23 a	1.75 a	1.99
6. Pulsar 40 (4.80 l ha ⁻¹) BBCH 14-16	1.95 b	1.53 b	1.74

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

Although Pulsar 40 at 4.80 L ha⁻¹ provided the highest weed control, the grain yield obtained with this treatment over the two years was significantly lower than that recorded for treatments with Pulsar 40 at 1.20 L ha⁻¹, either applied alone or in combination with Tonivit and Apetayzer. This reduction is likely attributable to phytotoxic effects on the crop caused by the fourfold increase in the imazamox dose, compounded by adverse meteorological conditions.

CONCLUSIONS

The application of Pulsar 40 at a rate of 4.80 L ha⁻¹ (BBCH 14-16) provides one hundred percent control against *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Sinapis arvensis* L., and *Setaria viridis* L. The highest efficacy against *Chenopodium*

album L. - 95%, *Sorghum halepense* (L.) Pers. developed from rhizomes - 85%, and *Portulaca oleracea* L. - 55% was also recorded with Pulsar 40 at a rate of 4.80 L ha⁻¹.

Under the experimental conditions, Pulsar 40 at a rate of 4.80 L ha⁻¹ caused phytotoxicity on sorghum, hybrid Sentinel IG, at 7 DAT, with a score of 3 on the EWRS scale, expressed as slight leaf chlorosis. By 21 DAT, the crop had overcome the herbicide stress, reaching a score of 1 on the EWRS scale.

The highest yield was recorded following the combined application of Pulsar 40 (1.20 L ha⁻¹) + Tonivit (1.00 L ha⁻¹) + Apetayzer (0.50 L ha⁻¹) - 1.99 t ha⁻¹, followed by Pulsar 40 (1.20 L ha⁻¹) + Tonivit (1.00 L ha⁻¹) - 1.96 t ha⁻¹, Pulsar 40 (1.20 L ha⁻¹) + Apetayzer (0.50 L ha⁻¹) - 1.92 t ha⁻¹, and Pulsar 40 (1.20 L ha⁻¹) - 1.90 t ha⁻¹. No statistically significant differences were observed among these treatments.

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