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WEED CONTROL IN SUNFLOWER BY SEPARATE AND COMBINED HERBICIDE APPLICATION

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Abstract

In 2019 and 2020 two field experiments with two sunflower hybrids (Diamantis CL and P64LP130 CLP) was conducted. The trial was stated on the experimental field of the Agricultural University of Plovdiv, Bulgaria. The efficacy and selectivity of the herbicide products Pulsar 40 (40 g/l imazamox), Pulsar Plus (25 g/l imazamox) and Viballa CE (3 g/l halauxifen-methyl), applied separately, in combinations as tank mixtures in 10 days interval and separately were evaluated. The dominating weeds on the field were Chenopodium album L., Amaranthus retroflexus L., Xanthium strumarium L., Abutilon theophrasti Medik., Datura stramonium L., Solanum nigrum L., Portulaca oleracea L., Setaria viridis L., Sinapis arvensis L., Sorghum halepense L. (Pers.), and Convolvulus arvensis L. The highest efficacy against Ch. album after the application of Viballa in both years of the study was recorded. For this product, the efficacy against D. stramonium, P. oleracea, and C. arvensis was the lowest. Both sunflower hybrids demonstrated the highest seed yield after the application of Pulsar 40 and Pulsar Plus separately followed by their tank mixture with Viballa in 10 days interval.

***Key words**: sunflower, weeds, herbicides, tank mixtures, efficacy.*

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the four most important annual crops in the world grown primarily for edible oil (De la Vega and Hall, 2002). It is successfully grown over a wide geographical area as it is adaptable to a wide range of environmental conditions (Beards and Geng, 1982). As oilseed crop, sunflowers play a major role in Europe. Sunflower oil is regarded as high quality oil for food use, and lately there is also an increasing demand for sunflower oil for industrial uses, mainly for the bio-diesel industry.

One of the factors limiting the development of cultivated plants is the annual ubiquity and development of weeds and nutrient availability in soil (Garapova, 2020; Yanev, 2015; Yanev et al., 2014a). Also, the absolute seed mass of 1000 seeds is crucial for the yields formation (Georgiev et al., 2014). It was found that in sunflower depending on the weed density, duration of the concurrence, weed spectrum and other factors, yield losses can be up to 81% (Carranza et al. 1995). Depending on weed density, time of competition duration, weed spectrum and other factors yield loss can be up to 81% (Carranza et al. 1995). Weed management is an important component for the successful crop production and in sunflower for particular (Yanev, 2020; Jursik et al., 2015; Saudy and El-Metwally, 2009; Awan et al., 2009; Shylaja and Sundari, 2008). Sunflowers are usually planted in low densities and grow slowly during the first weeks till row closure. Weeds that emerge and establish during this time are concurrent to the crop and suppress its normal growth and development. Generally, weed control options, especially for broadleaf weeds, in sunflower are limited (Breccia et al., 2011, Pfenning et al., 2008, Bruniard, 2001).

In the sunflower fields of Bulgaria a significant dynamics of the weed species and densities that form the weed associations has occurred. In the beginning of the monitoring the dominating weed species were *Xanthium strumarium* L., *Sinapis arvensis* L., and on separate fields *Cannabis ruderalis* Janisch. in high densities was prevailing. The reasons for the mass distribution of these weed species are the violated crop rotations, seeding of sunflowers in short period of time – in 1-2 years on the same field, insufficient quality of the soil tillage, the limited choice of herbicides for their control, etc. The implementation of the alternative cropping technologies like

Clearfield® and Express® Sun, their constant improvement, as herbicide content and selection process showed positive effect for decreasing the density and range of distribution of these three weeds in the sunflower fields. From the other hand it led to clearly expressed compensatory processes and mass distribution *Chenopodium album* L. and *Portulaca oleracea* L. to a lower extent. It is known that imazamox and tribenuron-methyl have limited efficacy against *Chenopodium album* and *Portulaca oleracea* (Tonev et al, 2020).

One of the most commonly used weed control method in cultivated plants is herbicide application. The choice of proper herbicide is one of the most important and responsible moments in the crop management. The proper herbicide must meet the following requirements - to be selective for the crop; to be highly effective against the existing weeds; its application rates should not lead to the accumulation of residues in plant production and in soil; should not deteriorate the quality of production ad should be harmless to soil microorganisms and the environment (Yanev and Kalinova, 2020; Goranovska and Yanev, 2016; Hristeva et al., 2015; Yanev, 2015; Semerdjieva et al., 2015; Hristeva et al., 2014; Yanev et al., 2014b). A number of authors have studied various herbicides for weed control in *Helianthus annuus* L. (Mohapatra et al., 2020; Jursík et al., 2020; Inoue et al., 2019; Jiří et al., 2017; Kostadinova et al., 2016; Sala et al., 2012).

The usage of tank mixtures of herbicides lead to increased efficacy against some dicotyledonous weeds as *Solanum nigrum* L., *Abutilon theophrasti* L. and *Amaranthus retroflexus* L. (Mitkov et al, 2018). The efficacy and selectivity of herbicides and tank-mixture combinations at different application terms in Clearfield and ExpressSun sunflowers were evaluated. The efficacy of tribenuron (TBM) was excellent and quite rapid on *Chenopodium album.* Its efficacy on other tested dicot weeds ranged around 90%, depending on weather conditions and growth stages of weeds (Jursík et al., 2017).

The Clearfield® technology in sunflower has been developed to allow the use of imidazolinone herbicides as a post-emergence weed control option (Balabanova and Vassilev, 2015). With the current Clearfield ImiSun system, amplified herbicide performance was penalized with unacceptable crop response. Other broadleaf herbicides for a combination with Imazamox in postemergence sunflower use are currently not available. This situation restricted an improvement of the herbicidal efficacy of the imazamox based Clearfield system. The development of a higher imidazolinone tolerance with the Clearfield Plus trait allows the use of a stronger adjuvant and a better formulation for imidazolinone herbicides and consequently a more flexible and reliable weed control in sunflower by maximizing the herbicidal efficacy per ai unit without any penalty on tolerance. The increased herbicide performance on difficult-to-control weeds and possible relaxed re-cropping restrictions through potential herbicide rate reduction with the new Clearfield Plus system provide sunflower growers a better tool to manage weeds and add to the value of the new Clearfield Plus sunflower production system (Pfenning et al, 2012). When Pulsar 40 was applied separately without DASH, its efficacy against Johnson grass, corn thistle, field bindweed, hemp agrimony, rough cocklebur, white goosefoot, purslane and broomrape was significantly reduced. Referring to its efficacy against the annual broad-leaved weed species redroot pigweed, charlock mustard, wild radish, cleavers, black nightshade, etc., it was 100% and no differences were observed between the rates of 0.80, 1.00 and 1.25 l ha^{-1}. The separate use of the herbicide at a rate of 1.25 l ha^{-1} showed the same efficacy against more stubborn weeds, as that of Pulsar 40 applied at the rate of 0.80 l ha^{-1} together with 0.80 l ha^{-1} of the adjuvant Dash (Mitkov et al., 2016). The highest efficacy against *S. halepense* from rhizomes was recorded for treatment 5 (Pulsar Plus - 2.40 l h^{-1}). *S. halepense* developed from seeds, *S. viridis*, *A. retroflexus*, *Xa. strumarium*, *S. nigrum* and *S. arvensis* were successfully controlled by application of Pulsar 40 or Pulsar Plus in the low examined rates. *Ch. album* and *A. theophrasti* can be controlled by Pulsar Plus at the lower rate - 1.20 l ha^{-1} (Neshev et al., 2020).

The aim of the study is to establish the possibilities for chemical control of several weeds during the sunflower growing season

(Clearfield and Clearfield Plus technologies), using vegetation herbicides, as well as their combinations and application systems.

MATERIALS AND METHODS

During the vegetation seasons of 2019 and 2020 two field trials with the sunflower hybrids Diamantis CL (Clearfield) and P64LP130 CLP (Clearfield Plus) were conducted. The experiments were stated on the Experimental field of the department of General agriculture and Herbology at the Agricultural University of Plovdiv, Bulgaria. The studies were performed by the randomized block design in 4 replications.

The trial with the Clearfield sunflower hybrid included the following variants: 1. Pulsar 40 (40 g/l imazmox) - 1.2 l ha^{-1}; 2. Viballa CE (3 g/l halauxifen-methyl) - 1.0 l ha^{-1}; 3. Pulsar 40 + Viballa CE - 0.6 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture); 4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later; 5. Pulsar 40 - 0.6 l ha^{-1}, followed by Pulsar 40 + Viballa CE – 0.6 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later; 6. Untreated control.

The trial with the Clearfield Plus sunflower hybrid included the following variants: 1. Pulsar Plus (25 g/l imazamox) - 1.6 l ha^{-1}; Viballa CE - 1.0 l ha^{-1}; 3. Pulsar Plus + Viballa CE - 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture); 4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later; 5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later; 6. Untreated control. The herbicide application was done in BBCH 14 – 16 with size of spraying solution 250 l ha^{-1}.

Predecessor of the sunflower hybrids was the winter wheat variety “Enola” during the two years of the study. On the whole experimental field combined fertilization with 250 kg ha^{-1} with N:P:K (15:15:15), followed by deep ploughing was done. Before sowing of the crop, disking on the depth of 15 cm and two harrowings on 8 cm of depth as well as spring dressing with 250 kg ha^{-1} NH_4NO_3 was also performed.

The efficacy of the studied herbicide rates against the weeds by the 10 score scale of EWRS (European Weed Research Society) on the 14th, 28th and 56th day after application was studied. The selectivity of the herbicide by the 9 score scale of EWRS was also evaluated Biological yield was determined by harvesting the entire plot and for the four replicates of each variant.

Preliminary investigation of the experimental fields for establishing the weed species was performed. On the experimental fields 12 weed species typical for the crop were identified. For both years of the study their average densities per 1 m^2 in the untreated plots were as follows: *Chenopodium album* L. - 39 specimens; *Amaranthus retroflexus* L. - 7 specimens; *Xanthium strumarium* L. - 10 specimens; *Abutilon theophrasti* Medic. - 21 specimens; *Datura stramonium* L. - 6 specimens, *Solanum nigrum* L. - 11 specimens; *Portulaca oleracea* L. - 9 specimens; *Setaria viridis* L. - 5 specimens; *Sinapis arvensis* L. - 5 specimens; *Sorghum halepense* Pers. Developed from seeds - 10 specimens; *Sorghum halepense* Pers. Developed from rhizomes - 17 specimens and *Convolvulus arvensis* L. - 5 specimens per m^2. The total weed number on average for the untreated controls was 145 specimens per m^2.

The results of the conducted research trials were processed with software package of SPSS 19 program - module one-factorial and two-factorial analysis of variance.

RESULTS AND DISCUSSIONS

On 12 tables is presented the efficacy of the studied herbicides and their combinations against the existing weeds on the experimental field.

On table 1 is the efficacy against the weed *Ch. album* average for both experimental years. On the 14th day after the last application of the herbicide Viballa CE, as well as its combination with Pulsar 40 and Pulsar Plus the efficacy varied from 80 to 90%.

Lower and unsatisfactory efficacy was recorded for the treatment with Pulsar 40 and Pulsar Plus - 40 - 45 %. On the 56th day after the herbicide treatment from 95 to 100% efficacy after the combined herbicide application and the alone treatment with Viballa CE was reported.

Against *Ch. album* the alone application of Pulsar 40 and Pulsar Plus the observed efficacy was not sufficient enough (variant 1 for both technologies.

Table 1. Efficacy of the evaluated herbicide products against *Ch. album* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	40	50	60
2. Viballa CE - 1.0 l ha^{-1}	90	95	100
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	90	95	100
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	95	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	45	55	65
2. Viballa CE - 1.0 l ha^{-1}	90	95	100
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	90	95	100
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	85	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	95	100
6. Untreated control	-	-	-

On table 2 is presented the effect of the tested herbicides against the weed *A. retroflexus* on average for the two years of the experiment. From the product Viballa CE the reported efficiency was the lowest - 35% on the 14th day after treatments. After the combined application of the examined herbicides 70 to 80% efficacy was against the weed recorded. On this reporting date, after the alone application of Pulsar 40 and Pulsar Plus excellent efficacy was recorded. On the last reporting date the efficacy for these treatments reached from 90 to 100%. On the 56th day after treatments the efficacy of Viballa CE was 45%.

Table 2. Efficacy of the evaluated herbicide products against *A. retroflexus* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	90	95	100
2. Viballa CE - 1.0 l ha^{-1}	35	40	45
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	70	80	90
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	75	85	90
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	80	90	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	90	95	100
2. Viballa CE - 1.0 l ha^{-1}	35	40	45
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	75	85	90
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	70	85	90
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	80	95	100
6. Untreated control	-	-	-

In the field crop rotation one of the most difficult-to-control weeds is *Xanthium strumarium L.* In the present study all studied herbicide products showed excellent efficacy against this noxious weed species. The obtained results are presented on table 3. For this weed, on the 14th day after the herbicide treatments the efficacy was low 65-80%. The efficacy increased on the second reporting date, on the 56th day it reached from 80 to - 95% among the treatments.

In a trial conducted by Neshev et al. (2020) the reported efficacy of the studied herbicides reached 100% for all treatments and the authors stated that the weed can be successfully controlled by Pulsar 40 or Pulsar Plus.

Table 3. Efficacy of the evaluated herbicide products against *Xa. strumarium* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	75	90	95
2. Viballa CE - 1.0 l ha^{-1}	65	80	85
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	65	85	90
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	65	80	85
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	75	90	95
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	80	90	95
2. Viballa CE - 1.0 l ha^{-1}	70	80	85
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	70	80	90
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	70	80	85
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	75	90	95
6. Untreated control	-	-	-

The annual broadleaf weed species *Abutilon theophrasti* Medic. proved to be easily controllable from all tested variants of the experiment during both years of the trial (Table 4). According to Neshev et al., (2020) this weed can be successfully controlled by application of Pulsar Plus even from the rate of 1.20 ha^{-1}. From the new herbicide Viballa CE and from the established in practice herbicides - Pulsar 40 and Pulsar Plus from 85 to 100% efficacy from the first to the last reporting dates was found.

Table 4. Efficacy of the evaluated herbicide products against *A. theophrasti* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	85	95	100
2. Viballa CE - 1.0 l ha^{-1}	85	95	100
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	90	95	100
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	100	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	90	95	100
2. Viballa CE - 1.0 l ha^{-1}	90	95	100
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	90	95	100
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	100	100
6. Untreated control	-	-	-

The efficacy against the weed *Datura stramonium L.* on the 14th day after the application of the herbicides, from Pulsar 40 and Pulsar Plus (var. 1 for both technologies) and in their combined application with Viballa CE (variant 5) relatively satisfactory efficacy in the range of 80 - 85% average for the two years of the experiment was found (Table 5). These efficiency results increased on the other two reporting dates, being 95% on the 56th day in all four variants.

For treatments 3 and 4 (for both technologies) from 80 to 85% efficacy against this weed was observed on the last evaluation date.

From the alone use of the herbicide Vibala CE zero effect on all three reporting dates was establishd.

Table 5. Efficacy of the evaluated herbicide products against *D. stramonium* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	85	90	95
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	70	80	85
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	65	75	80
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	80	90	95
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	85	90	95
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	70	80	85
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	65	75	80
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	80	90	95
6. Untreated control	-	-	-

On table 6 in presented the efficacy against *Solanum nigrum L.* average for both years of the research. This weed can be successfully controlled by the application of Pulsar 40 or Pulsar Plus (Neshev et al., 2020). The obtained efficacy of the herbicide product Viballa CE was 70 % on the 14th day after the treatments. On the second reporting date the efficacy increased, and on the 56th day it reached 85% for the herbicide Viballa CE.

The other treatments showed 95 – 100% efficacy on the last reporting date.

Table 6. Efficacy of the evaluated herbicide products against *D. stramonium* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	85	95	100
2. Viballa CE - 1.0 l ha^{-1}	70	80	85
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	80	90	95
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	85	95	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	85	95	100
2. Viballa CE - 1.0 l ha^{-1}	70	80	85
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	80	90	95
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	95
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	85	95	100
6. Untreated control	-	-	-

From all annual weeds existing on the experimental field, the species *Portulaca oleracea L.* was the most difficult-to-control. The obtained results are presented on table 7. Satisfactory efficacy after the herbicide application for any of the treatments was not recorded. The herbicide product Viball CE showed 0% efficacy when it was applied alone.

The control of the common purslane (*P. oleracea*) is mainly limited to the following measures: fertilization with manure free of seeds of the weed; qualitative and on time tillage of the stubborn; extra summer and autumn tillage after plowing if there is new infestation; on time and qualitative inter-row tillage operations, etc. (Tonev et al., 2019).

The common purslane can be controlled with the herbicides isoxaflutol, metribuzin, pendimethalin, tembotrione, etc. (Tonev et al., 2019).

Table 7. Efficacy of the evaluated herbicide products against *P. oleracea* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	15	25	30
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	10	20	25
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	10	20	25
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	20	25	30
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	25	35	40
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	15	20	25
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	15	25	30
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	25	35	40
6. Untreated control	-	-	-

From the data on table 8 it is clearly seen that after the alone application of Pulsar 40 and Pulsar Plus, as well as after their combined application excellent efficacy against the grass weed *S. viridis* on the 56th day was found. The herbicide product Viballa CE had no effect on this weed – it controls broadleaf weeds only. The efficacy against *S. viridis* was 0%.

In a study performed by Neshev et al. (2020) the obtained efficacy data showed that Green bristle grass (*S. viridis*) can be controlled by Pulsar 40 or Pulsar Plus.

Table 8. Efficacy of the evaluated herbicide products against *S. viridis* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	75	90	100
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	65	80	85
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	65	80	85
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	70	90	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	80	90	100
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	70	80	85
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	70	80	85
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	70	90	100
6. Untreated control	-	-	-

The efficacy data against *Sinapis arvensis* L. is shown on table 9.

Pulsar 40 and Pulsar Plus showed 100% efficacy against the weed *Sinapis arvensis* L. (Neshev et al., 2020).

For both trials, for the treatments where imazamox-containing herbicide products were applied (Pulsar 40 and Pulsar Plus), independently the combination and rate, the efficacy against this weed was 100% on the 56th day after treatments.

At variant 2 where Viballa CE was applied alone, the efficacy was 80% on the 56th day after the treatments. If there is infestation with *S. arvensis* on the field, the herbicide product have to be applied with parting herbicide for increasing the control of this widely spread weed species.

Table 9. Efficacy of the evaluated herbicide products against *S. arvensis* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	90	100	100
2. Viballa CE - 1.0 l ha^{-1}	60	70	80
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	75	90	100
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	75	90	100
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	100	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	95	100	100
2. Viballa CE - 1.0 l ha^{-1}	60	70	80
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	80	90	100
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	80	90	100
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	90	100	100
6. Untreated control	-	-	-

All treatments where imazamox-containing herbicide products were evaluated the efficacy against *Sorghum halepense Pers.* developed from seeds was excellent – 100% on the last reporting date.

The Viballa CE herbicide had no effect on the weed (0% efficacy) because of is broadleaf weed control spectrum (Table 10). In atrial conducted by Neshev et al. (2020) it was also found that the Johnson grass (*S. halepense*) can be successfully controlled by application of Pulsar 40 or Pulsar Plus. On the 56th day after application the efficacy against this weed was increased and reached 100% (Neshev et al., 2020).

Table 10. Efficacy of the evaluated herbicide products against *S. halepense (seeds)* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	100	100	100
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	85	95	100
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	85	95	100
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	95	100	100
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	100	100	100
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	90	95	100
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	90	95	100
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	95	100	100
6. Untreated control	-	-	-

As opposite to *S. helepense* developed from seeds, the weed developed from rhizomes was more difficult-to-control from Pulsar 40 or Pulsar Plus (Table 11). Neshev et al. (2020) also reported low efficacy against Johnson grass (*S. halepense*) developed from rhizomes. The authors recommended if there is high infestation of Johnson grass developed from rhizomes, a partner grass herbicide product to be applied. An appropriate herbicide product is Stratos Ultra/Focus Ultra (100 g/l cycloxydim) applied at rate of 2.00 ha^{-1}.

Table 11. Efficacy of the evaluated herbicide products against *S. halepense (rhizomes)* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	60	75	80
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	30	45	50
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	25	40	45
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	60	75	80
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	70	75	80
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	35	50	55
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	20	45	50
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	65	75	80
6. Untreated control	-	-	-

Against the weed *Convolvulus arvensis L.* very low efficacy was observed on the first reporting date. Later in time the efficacy reached 0% for all treatments (Table 12). The weed cannot be controlled by any of the evaluated herbicide products and combinations from the study.

Table 12. Efficacy of the evaluated herbicide products against *C. arvensis* average for 2019-2020 (%)

Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar 40 - 1.2 l ha^{-1}	15	0	0
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	5	0	0
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	5	0	0
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	15	0	0
6. Untreated control	-	-	-
Treatments	Days after treatment		
	14th	28th	56th
1. Pulsar Plus - 1.6 l ha^{-1}	20	0	0
2. Viballa CE - 1.0 l ha^{-1}	0	0	0
3. Pulsar Plus - 0.8 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	10	0	0
4. Pulsar Plus - 0.8 l ha^{-1} followed by Viballa CE - 1.0 l ha^{-1} 10 days later	10	0	0
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	20	0	0
6. Untreated control	-	-	-

There were no visible phytotoxic symptoms for any of the studied herbicide products and their combinations.

On table 13 are presented the results regarding the seed yields of the sunflower hybrid Diamantis CL on average for both experimental years. The differences in the obtained yield were determined by the herbicide selectivity and efficacy. The existing weed infestation leads to the lowest yields for the untreated control – (1.0026 t ha^{-1}).

According to the degree of mathematical proof, five separate groups are distinguished between the different variants (a, b, c, d, e). It is also seen that treatment 5 (Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later) is from group (e), farthest from the group of the untreated control (a). It had the highest seed yield - 3.9143 t ha^{-1}.

Due to the fact that the haloxyfen-methyl-containing herbicide Viballa CE applied alone is with a narrower spectrum of action and controls broadleaf weeds only, the yield is lower compared to the those of the other variants.

Table 13. Sunflower grain yield for the hybrid Diamantis CL average for 2019 and 2020

Treatments	Yields, t ha^{-1}
1. Pulsar 40 - 1.2 l ha^{-1}	3.5017* d
2. Viballa CE - 1.0 l ha^{-1}	2.4975* b
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	3.0819* c
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	3.0544* c
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	3.9143* e
6. Untreated control	1.0026 a

Legend: All values with a * sign have significant differences with the result of the untreated control. All values followed by different letters are with proved difference according to Duncan's test at $P < 0.05$

On table 14 are presented the results concerning the seed yields of the sunflower hybrid P64LP130 CLP on average for both years of the research.

The weed flora developing uncontrolled in the field is the reason for the lowest average seed yield obtained for the untreated control - 1.1113 t ha^{-1}.

For this hybrid, according to the degree of mathematical proof, also, five separate groups are distinguished between the different variants (a, b, c, d, e). Here the highest sunflower seed yield is also reported for treatment 5 (Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later) - 4.0110 t ha^{-1}.

Table 14. Sunflower grain yield for the hybrid P64LP130 CLP average for 2019 and 2020

Treatments	Yields, t ha^{-1}
1. Pulsar 40 - 1.2 l ha^{-1}	3.6223* d
2. Viballa CE - 1.0 l ha^{-1}	2.5991* b
3. Pulsar 40 - 0.6 l ha^{-1} + Viballa CE - 1.0 l ha^{-1} (in tank mixture)	3.1948* c
4. Pulsar 40 - 0.6 l ha^{-1}, followed by Viballa CE - 1.0 l ha^{-1} 10 days later	3.1759* c
5. Pulsar Plus - 0.8 l ha^{-1}, followed by Pulsar Plus + Viballa CE – 0.8 l ha^{-1} + 1.0 l ha^{-1} (in tank mixture) 10 days later	4.0110* e
6. Untreated control	1.1113 a

Legend: All values with a * sign have significant differences with the result of the untreated control. All values followed by different letters are with proved difference according to Duncan's test at $P < 0.05$

CONCLUSIONS

The herbicide product Viballa CE had excellent efficacy against the weeds *Chenopodium album* L. and *Abuthilon theophrasti* Medic.

The herbicide products Pulsar 40 and Pulsar Plus showed 100% efficacy against *Amaranthus* retroflexus L., *Abutilon theophrasti* Medic., *Solanum nigrum* L., *Setaria viridis* L., *Sinapis arvensis* L., and *Sorghum halepense* (L.) Pers from seeds.

The herbicide product Viballa CE overcomes the herbicide products Pulsar 40 and Pulsar Plus by its efficacy against *Chenopodium album* L.

The herbicide products Pulsar 40 and Pulsar Plus overcomes the herbicide product Viballa CE by their efficacy against *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Datura stramonium* L., *Solanum nigrum* L. and *Sinapis arvensis* L.

The herbicide combination of Viballa CE with Pulsar 40 and Viballa CE Pulsar Plus controlled the weeds from 80 to 100%, except the species *Portulaca oleracea* L., *Sorghum halepense* (L.) Pers. developed from rhizomes and *Convolvulus arvensis* L.

No visible signs of phytotoxicity for any of the evaluated herbicide products and their combinations were recorded.

Compared to the untreated control, mathematically proven differences for the indicator sunflower seed yield in favor of all variants treated with herbicides were reported.

For both technologies (Clearfield and Clearfield Plus) the highest yields for the herbicide combinations in treatment 5 for hybrid Diamantis CL (3.9143 t ha^{-1}) and for hybrid P64LP130CLP (4.0110 t ha^{-1}) were recorded.

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