THE CYCLOHEXANEDIONES EFFECT ON THE *SORGHUM HALEPENSE* CONTROL IN THE SUNFLOWER AGROECOSYSTEM

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Abstract. *Helianthus annuus (Asteraceae) is one of the most important oil plants grown in North America, Asia, and Europe for over 100 years (Serim T.A. et. al, 2018). Sunflower occupies significant area in the Romanian culture, being on the second position in the crops group, after maize (Berca, 2004). The sunflower achenes yield is strongly influenced by the pressure of the weeds, which can cause losses up to 80%. One of the weed species present in the sunflower agroecosystem is Sorghum halepense which can reduce the yield with 30-70%. The longevity and vitality of the seeds, the allelopathic potential and the resistance to herbicides favor the infestation with Sorghum halepense. For this reason, the control of this species is very important for the successful growth of this crop. This study aimed the Sorghum halepense population control from the sunflower culture by applying different doses of three herbicides from the cyclohexanediones group. The sunflower hybrid used in the experiment was ES JANIS CLP. The randomized blocks method was used for experimental plot, with 7 variants in four repetitions. The substances used in the control of Sorghum halepense were: cycloxydim 200 g/ ha, cycloxydim 400 g/ha, clethodim 180 g/ha, clethodim 240 g/ha, fluazifop - p-butyl 150 g/ha, fluazifop - p-butyl 195 g/ha. After the treatments it was made evaluations regarding: the herbicides efficiency to reduce the Sorghum halepense plants; the phytotoxicity and vigor of sunflower plants, and at the end of the vegetation period the achenes yield was determined. The first observations in the experimental field highlighted the presence and dominance of the species Sorghum halepense (49.66 plants/m^2). The Sorghum halepense population from the sunflower agroecosystem has been eradicated from 86.0 to 99.5% by applying herbicides from the cyclohexanediones group. Clethodim (240 g/ha) was the most efficient herbicide, controlling 99.5% of Sorgum halepense plants present in experimental plot. Similar results were also obtained in the variants treated with cycloxydim 400 g/ha. Fluazifop – p- butyl occupied the third place, after clethodim and cycloxydim, offering an important and efficient control in 86 – 90.5% range.*

Keywords:*Sorghum halepense, sunflower, cyclohexanediones,control*

INTRODUCTION

Helianthus annuus (*Asteraceae*) is one of the most important oil plants grown in North America, Asia, and Europe for over 100 years. Around 85% of the world sunflower yield comes from ten countries (China, Russia, Ukraine, Argentina, etc). Romania, Bulgaria, France, Turkey, Hungary and Spain belong to the second group of the main world producers (SERIM et. al, 2018).

Sunflower occupies significant area in the Romanian culture, being on the second position in the crops group, after maize (ȘTEF R., 2017). According to INS data, quoted by Agerpres, Romania was situated in 2016 on the first place in Europe regarding the cultivated sunflower surface. The same institution shows that in 2015 Romania occupied first place in the European Union both on the sunflower production and cultivated surfaces, with a yield totaling 1.75 million tones for one million hectares.

Sunflower is mainly cultivated for food industry (the obtained oil has a good quality) (DE LA VEGA and HALL 2002, MANGIN et al., 2017) but also for animal feeding (KAYA et al., 2012), being used also for its ornamental, medicinal properties and bio-diesel production in some countries as Pakistan, USA and Serbia (BURNETT, 2017; ĐURIŠIĆ-MLADENOVIĆ et al., 2018).

The sunflower culture has become, in recent years, more and more attractive for the Romanian farmers, both through the stability offered by the constant prices at the harvest time, and by the increased tolerance in drought case. At the same time, it should not be forgotten that this crop also comes with a series of risks caused by the short rotation also with sunflower (2-3 years) or with another oilseed plant, or by the climatic conditions without predictability.

The sunflower achenes yield is influenced both by abiotic and biotic factors. The biological factors that limit the sunflower yield are weeds that exert an increased pressure manifested by competition for space, light, nutrients and water (SEDGHI et al., 2008). Significant production losses are caused by some dicotyledonous weeds (*Sinapis arvensis* L., *Convolvulus arvensis* L., *Xanthium strumarium* L.); but also by monocotyledons such as *Digitaria sanguinalis* (L.) Scop., *Sorghum halepense* (L.) Pers. (ÇORUH and ZENGIN, 2009; OLSON et al., 2011; BAŞARAN et al., 2017).

The studies conducted by ELEZOVIC et. (2012) shows that sunflower is extremely sensitive during the first three weeks of growing period, having a low competitive capacity. During this period, weeds can compete very strongly and can reduce significantly the sunflower yield up to 80% (DAUGOVISH et al. 2003, SIMIC et al. 2011). For this reason, weeds control in the sunflower case is important for the successfully growing of this crop.

Sorghum halepense is also part of the group of weeds that reduce the sunflower yield, this plant being one of the most endangered species in the agroecosystem, the damage caused to this crop being in the range of 30-70% (ŞTEF R., 2017). The first information about the *Sorghum halepense* species dates from 1780, when it was introduced in the U.S.A. This species has been used throughout the 1900s as a forage crop, which has greatly contributed to its distribution. In 1997 the *Sorghum halepense* species was reported as a weed problem from latitude 55°N to latitude 45°S, infesting about 30 crops in 53 countries (HOLM et al. 1997). This species has been frequently reported in cotton, corn, sunflower, soybean, sugar beet, potato and vegetable crops on several continents (GUNES et al. 2008).

Sorghum halepense is an invasive species that threatens local and global biodiversity, agriculture and public health. In 2015 an American study on the risk of the presence of the *Sorghum halepense* species (https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/wra/sorghum-halepense.pdf) found that from 300 of the evaluated species, for *Sorghum halepense* was obtained the highest risk score regarding the adaptability/ spread potential. The easy way to adapt of this plant, even in the colder regions, has allowed it to be widely distributed, and the global warming will encourage further expansion (FOLLAK and ESSL, 2013). The species spread is also ensured by the high multiplication capacity, both by seeds and rhizomes (CHIRIȚĂ R. et. al., 2004). This species can produce up to 28,000 seeds (HOROWITZ 1973), around 1.1 kg of seeds in a single growing season (BENNETT 1973), with a viability in soil of 12.5 years (EGLEY and CHANDLER 1983). In addition, the extensive and deep rhizomes use nutrients and soil water, which are otherwise unavailable for crops. For agroecosystems it reduces yield (MCWHORTER, 1989) and increases the production costs (MCWHORTER and ANDERSON, 1981).

The *Sorgum halepense* species is considered one of the most competitive weeds in the agroecosystems. It is recognized also for the allelopathic substances production (ŞTEF R., 2015). Although the control methods for the *Sorghum halepense* presence have been continuously improved over the last 20 years, researchers continue to test new efficient control strategies (ANDÚJAR et al, 2013a, JOHNSON and NORSWORTHY, 2014), including for herbicide-resistant populations (JOHNSON et al., 2014).

The sunflower did not benefit for a long time by a complete technology, because of the non-combating by chemical methods of the "resistant" annual dicotyledonous species (*Xanthium*, *Datura*, *Abutilon*) and perennials (*Cirsium*, *Sonchus*, *Convolvulus*), not being registered a systemic herbicide that destroys these species. The most important stage in the field of dicotyledonous weeds control in the sunflower culture was recorded after 2000, when after many international researches have been created herbicide-tolerant varieties (HT). Obtaining these varieties allowed a better weed management, increasing the herbicide efficiency and selectivity for sunflower growing. Conventional sunflower varieties are very sensitive to many herbicides (PANNACCI et al. 2007; JURSÍK et al. 2013).

After 2000 it was implemented Clearfield and ExpressSun technologies (TAN et al. 2005). Both HT technologies have been adopted very quickly and nowadays are used worldwide (JOCIC et al. 2011).

Clearfield sunflower varieties are tolerant of herbicides imidazolinone (imazapyr, imazapic, imazethapyr, imazamox, imazamethabenz and imazaquin). The first Clearfield hybrids were commercially used in the United States, Argentina and Turkey in 2003 (TAN et al. 2005). Herbicides based on imidazolinone control well the most annual monocotyledonous weeds (FRANCISCHINI et al. 2012). It also controls many dicotyledons, including weed parasites such as *Orobanche* spp. (PFENNING et al., 2008).

ExpressSun sunflower varieties are tolerant to tribenuron sulphonylurea and were developed later than the *Clearfield* system. Tribenuron controls many dicotyledonous weeds, including *Cirsium arvense* (ZOLLINGER, 2004), but on some weeds such as *Ambrosia artemisiifolia*, *Galium aparine* the effect is smaller comparatively to imidazolinones (TUEMMLER and SCHROEDER, 2013).

Both technologies must be optimized for specific growth conditions.

The synthesis of new products as well as the interest shown by the farmers by increasing the sunflower cultivated areas determined us to continue the studies on the chemical control of the species *Sorghum halepense*.

MATERIAL AND METHODS

The research regarding the influence of the active substances from the cyclohexanedione group on the population of *Sorghum halepense*, from the sunflower agroecosystem, was carried out in the western part of Romania, in Jebel belonging to the Timiș County.

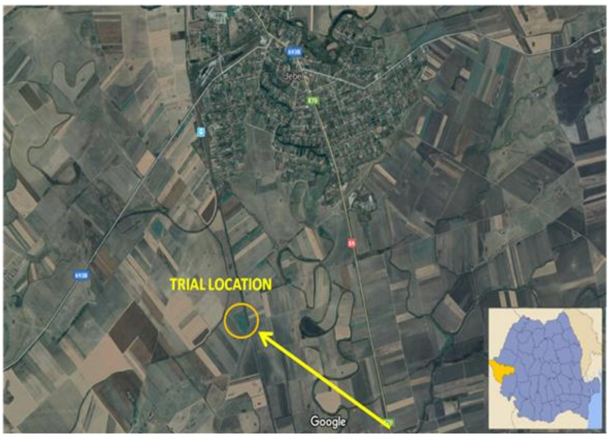


Figure 1 - The geographical location of the experimental field

The experimental was conducted using the randomized blocks method with 7 plots in four repetitions. The plot was L/W - 10 m/ 3.0 m.

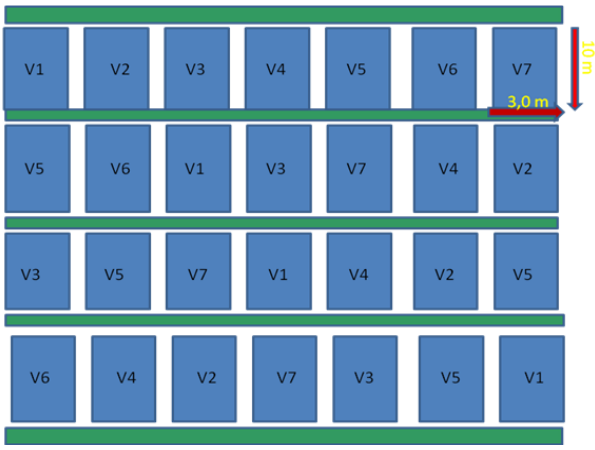


Figure 2 - Description of the experimental field (herbicide/sunflower)

The sunflower hybrid used in the experiment was *ES JANIS CLP*. This linoleic hybrid has the newest production system - Clearfield® Plus, genetic resistance at *Orobanche* - A-G breeds, a small waist and minimal harvesting losses because of its height. It was sown on 28.03.2019.

Treatments regarding the reduction of the population of *Sorghum halepense* were applied post-emergently, in the BBCH phenophase 12-14. On the day of the herbicides application (11.05.2019) it was also determined the density of the species *Sorghum halepense* in the experimental variants.

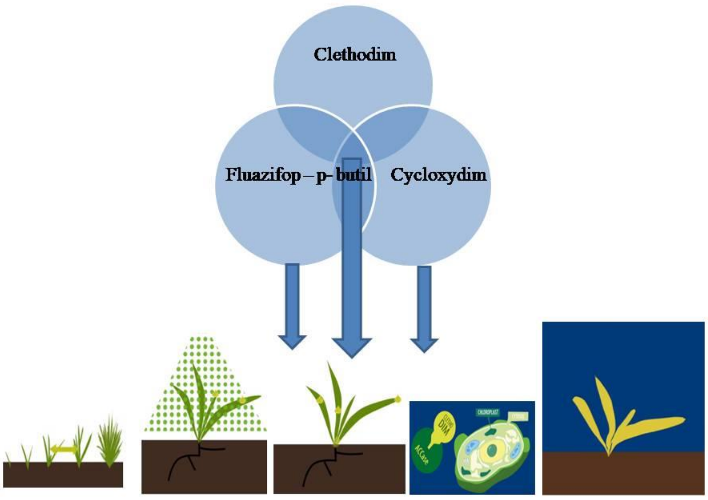
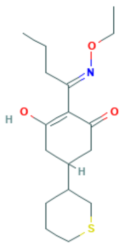
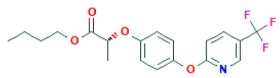
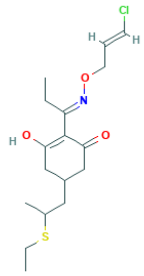


Figure 3 – Scheme of application of the substances used in the control of the *Sorghum halepense* (According to Arista LifeScience presentation)

The substances used to control the *Sorghum halepense* were: cycloxydim 200 g/ha, cycloxydim 400 g/ha, clethodim 180 g/ha, clethodim 240 g/ha, fluazifop - p-butyl 150 g/ha, fluazifop - p-butyl 195 g/ha. After the treatments it was made the following evaluations: their efficiency to reduce the *Sorghum halepense* species; phytotoxicity and vigour of sunflower plants, and at the end of the vegetation period the production of achenes was determined.

Cycloxydim Fluazifop – p- butyl Clethodim

Figure 4 - Chemical structure of substances used in the control of the *Sorghum halepense* species from sunflower culture (https://pubchem.ncbi.nlm.nih.gov)

Soil description: sand: 26.9%; silt: 29.9%; clay: 43.2%; OM:10%; pH:6.04; texture: C clay %; soil name: clay.

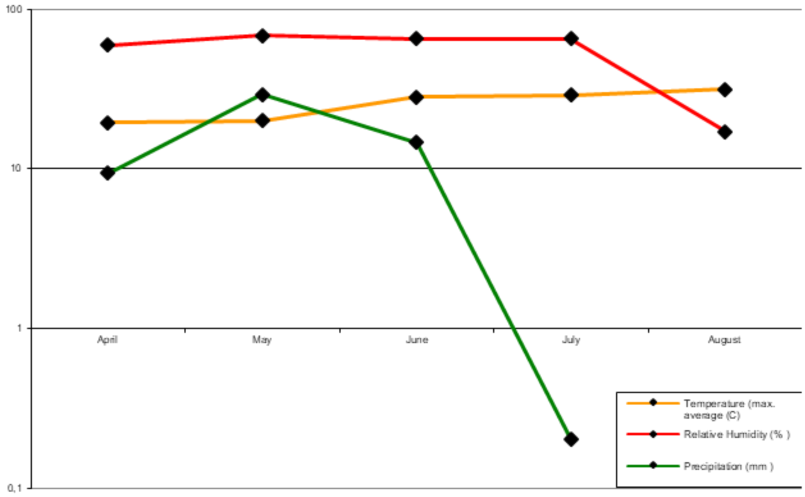


Figure 5 - The climatic conditions of the study regarding the effect of cyclohexanediones in *Sorghum halepense* reducing from sunflower culture

RESULTS AND DISCUSSIONS

The first observations regarding the composition of the weed flora was made in 11.05.2019. The untreated control variant presented an infestation degree around 93 plants/ m^2, the weed spectrum being represented by *Sorghum halepense* (53.60%), *Xanthium italicum* (28.77%), *Chenopodium album* (11.15%) and *Sinapis nigra* (from previous sunflower culture) (6.48%).

The dominant species in the sunflower culture was represented by *Sorghum halepense* (49.66 plants/m^2).

The rainfall was unevenly distributed during the vegetation season (Figure 5), but it did not have an important significance on the herbicides efficiency to reduce the *Sorghum halepense* population.

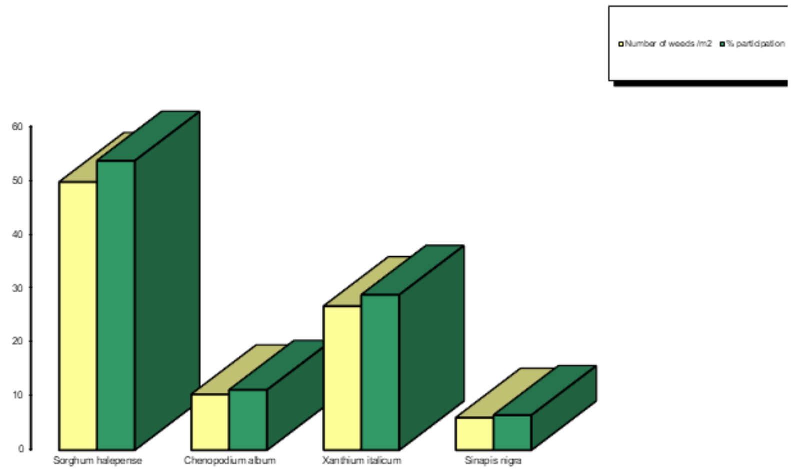


Figure 6 – Infestation degree and weed spectrum for untreated control variant of sunflower culture, in 2019

Table 1

The decrease in the percent of *Sorghum halepense* population by cyclohexanediones post-emergent application

Variant	Active substance	Dose l/ha	a.s. g/ha	Control *Sorghum halepense* (%)
V1 – control	-	-	-	-
V2 – Stratos Ultra (SL)	Cycloxydim	4.0	400	98.50***
V3 - Stratos Ultra (SL)	Cycloxydim	2.0	200	90.25***
V4 – Centurion Plus	Clethodim	1.5	180	89.25***
V5 - Centurion Plus	Clethodim	2.0	240	99.50***
V6 – Fusilade Forte (EC)	Fluazifop – p- butyl	1.0	150	86.0***
V7 - Fusilade Forte (EC)	Fluazifop – p- butyl	1.3	195	90.50**

DL5% = 1,71; DL1% = 2,39; DL0.1% = 3,38

The application of herbicides from the cyclohexanediones group (which inhibits the acetyl CoA carboxylase - ACCase) decreased the *Sorghum halepense* population from the sunflower agroecosystem in percentages between 86.0 - 99.5%.

Clethodim herbicide was the most efficient at 240 g/ha dose, controlling 99.5% of the *Sorghum halepense* number of plants present in the experimental plot. The results of this experiment are similar to those of previous researches, which concluded that clethodim applied at different doses is an efficient option to reduce the *Sorghum halepense* population (BRIDGES 1989; JORDAN et al. 1996; ROSALES-ROBLES et al. 1999; JOHNSON and DENNIS BRENT, 2013).

In the plots treated with cycloxydim 400 g/ha, after 30 days of application, it was determined a very significant reduction of the *Sorghum halepense* population (98.5%).

Applying lower doses of clethodim (180 g/ha) and cycloxydim (200 g/ha) determined a significantly lower suppression than the higher doses.

Fluazifop-p-butyl occupied the third place, after clethodim and cycloxydim, providing a consistent and efficient control of 86 and 90.5% (Table 1).

The results of BRIDGES and CHANDLER (1987) regarding the *Sorghum halepense* control obtained values in 83-95% range. Also the studies of BANKS and BUNDUSCH (1989) and BREWSTER and SPINNEY (1989) reported a *Sorghum halepense* control of 90% by fluazifop-p-butyl application.

The results of this experiment were also similar to those observed by SHAW et al. (1990), who obtained a *Sorghum halepense* control of 83-90%.

Table 2

The influence of cyclohexanediones on the selectivity and vigour of sunflower plants

Active substance	a.s. g/ha	Vigour of sunflower plants	Selectivity
Control	-	85	-
Cycloxydim	400	90	1.0
Cycloxydim	200	92	1.0
Clethodim	180	90	1.0
Clethodim	240	95	1.0
Fluazifop – p- butyl	150	90	1.0
Fluazifop – p- butyl	195	95	2.0

After 14 days since the treatments were applied, it was made observations regarding the vigour of the sunflower plants (table 2). The vigour of the plants showed values between 85% (the untreated variant) and 95% (the variants treated with fluazifop - p-butyl 195 g/ha and Clethodim 240 g/ha).

It was made observations regarding the selectivity of the Es Janis CLP hybrid because of the herbicides application against the grasses. In the variant treated with fluazifop - p - butyl 198 g/ha the sunflower plants presented weak yellowing symptoms, this being evaluated with note 2 according to EWRS. After 30 days since the application of the treatments, the symptoms of chlorosis were no longer present, and the negative effects on the sunflower yield were not registered (table 2).

The sunflower yield obtained in the experimental variants had values between 1.25 - 3.50 t/ha. In the climatic conditions of the year 2019, the reduction of the sunflower yield because of the weed competition was 1.60 - 2.25 t/ha.

In the six treated experimental variants were obtained very significant increasing of sunflower yields comparatively with the untreated control variant yield.

It was obtained a relative increase of sunflower yield (279.93%) comparatively to the control variant yield by applying 240 g/ha the active substance of clethodim. Relative increases were recorded in all the variants treated with substances of the cyclohexanediones group comparatively to the untreated control variant.

Table 3

The herbicides of cyclohexanediones impact on sunflower yield

Active substance	Dose l/ha	a.s. g/ha	Yield (t/ha)	Relative yield (%)	Difference in yield (t/ha)
Control	-	-	1.25	100.00	0.00
Cycloxydim	4.0	400	3.350^{***}	267.93	-2.100
Cycloxydim	2.0	200	2.990^{**}	239.16	-1.740
Clethodim	1.5	180	3.125^{***}	249.96	-1.875
Clethodim	2.0	240	3.500^{***}	279.93	-2.250
Fluazifop – p- butil	1.0	150	2.855^{**}	227.94	-1.600
Fluazifop – p- butil	1.3	195	2.950^{***}	235.94	-1.700

DL5% = 0.89; DL1% = 1.24; DL0.1% = 1.75

Experimental variants aspects

CONCLUSIONS

The *Sorghum halepense* population from the sunflower agroecosystem has been eradicated from 86.0 to 99.5% by applying herbicides from the cyclohexanediones group. The best results for the *Sorghum halepense* suppression were obtained in the variants where clethodim 240 g/ha (a.s.) was applied.

Cyclohexanediones did not affect plant development and were selective with the Es Janis CLP hybrid.

The sunflower achenes yield was correlated with the degree of combating.

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