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WEED ASSOCIATION DYNAMICS IN THE SUNFLOWER FIELDS

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Abstract

The data analyses from the research showed that 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 ExpressSun®, 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 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.

***Key words**: weed associations, dynamics, Clearfield® and ExpressSun®, sunflower.*

INTRODUCTION

It is considered, that the sunflower is the fourth oilseed crop in the world (Nisar et al., 2011). It is established, that the percentage of seed oil and protein is 40-55% and 23% respectively (Jadaan et al., 1999). The seeds also content linoleic acid, oleic acid and linoleic acid (Nasralla et al., 2014). In Bulgaria sunflower is main oilseed crop and in 2018 the total harvested area was 788 656 ha with average seed yield of 2,443 t/ha (www.mzh.government.bg). In order to achieve high yields, in addition to optimizing the main vegetation factors, it is necessary to effectively control weeds.

Under intensive agriculture, a key element of weed control is their systematic reporting and in the agricultural areas. A number of authors have examined weed infestation in sunflower fields. The most important weed species in Slovakia are *Agropyron repens* (L.) P. Beauv., *Iva xanthiifolia* Nutt., *Echinochloa crus-galli* (L.) Beauv, *Chenopodium album* L., *Chenopodium hybridum* L., *Abutilon theophrasti* Medik., *Datura stramonium* L., *Convolvulus arvensis* L., *Panicum miliaceum* L., *Cirsium arvense* (L.) Scop., *Fallopia convolvulus* (L.) Á. Löve, *Amaranthus* spp., *Persicaria* spp. and *Polygonum* spp. (Týr and Vavrík, 2015).

In Hungary, the most distributed weed species are *Ambrosia artemisiifolia* L., *Chenopodium album* L., *Convolvulus arvensis* L., *Xanthium italicum* Moretti, *Echinochloa crus-galli* (L.) Beauv, *Panicum miliaceum* L., and *Setaria pumila* (Poir.) Roem. & Schult. (Pinke et al., 2013; Pinke and Karácsony, 2010).

In Dagestan, Russia the most important role in suppressing the normal development of sunflower *Convolvulus arvensis* L., *Sonchus arvensis* L., *Cynodon dactylon* (L.) Pers., *Equisetum arvense* L., *Phragmites vulgaris* (Lam.) Crép., *Chenopodium album* L., *Setaria viridis* (L.) P. Beauv., *Echinochloa crus-galli* (L.) Beauv, *Xanthium strumarium* L., *Amaranthus retroflexus* L. and *Capsella bursa-pastoris* (L.) Medik. (Kurbanov et al., 2018).

In Bulgaria, the most distributed weed species in the sunflower fields are *Amaranthus* spp., *Sinapis arvensis* L., *Chenopodium album* L., *Setaria* spp., *Echinochloa crus-galli* (L.) Beauv, *Sorghum halepense* (L.) Pers., *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L. etc. (Manilov and Zhalnov, 2015; Tonev et al., 2010). In the region of Plovdiv and Stara Zagora (Bulgaria) the most common species are *Amaranthus blitoides* S. Wats., *Amaranthus albus* and *Convolvulus arvensis* L. (Moskova et al., 2016). Not only in sunflower, but also in other trench crops the main weeds are the annual late-spring weeds (Sevov et al., 2014; Dimitrova and Laleva, 2003; Tonev, 2002; Tonev and Valeva, 1989).

Another important biotic factor limiting sunflower production is the root parasite broomrape. *Orobanche cumana* Wallr. is a obligate parasite without chlorophyll, as a result of which it cannot do photosynthesis. The broomrape supplies its nutrients and water entirely from the host. It is widespread in all sunflower-growing countries in Central-Eastern and Eastern Europe as well as in Western Asia. The sunflower broomrape populations are classified in races that as more and more aggressive new more virulent races occur (Encheva, 2018; Masliiov et al., 2018; Fernandez-Aparicio, 2016; Amri et al., 2012).

Crucial to successful weed control is the early plowing after harvesting of the predecessor and the additional summer and autumn tillage operations. From the spring pre-sowing tillage applications, the most important is the first early cultivation with harrowing, which is carried out in order to destroy any soil bark formed and reduce weed infestation. The second harrowing is recommended to be prformed after the formation of the first pair of true leaves (Tonev et al., 2019).

Incorporating sunflower into science-based crop rotations, which alternate mainly with winter cerials, facilitates the control of the noxious weeds (Tonev et al., 2007).

The crop is most sensitive to weed infestation in the early development stages. Golipour et al. (2009) established that in the presence of weeds in the sunflower fields, the critical period for performing weed control measures is from 1 to 9.5 weeks after crop germination. The control of the weeds in this crop is performed mainly by herbicides (Prashant et al., 2017).

There are several sunflower cropping systems that determine the choice of the used herbicides. Good to excellent control (81-100%) against the broadleaf weeds in sunflower is performed by oxyfluorfen application (Osman et al., 2014). Jursík et al. (2011) found that 88 to 95% efficacy against *Chenopodium album* after application of oxyfluorfen. For grass and broadleaf weed control Pannacci et al. (2007) recommend the application of s-metolachlor+aclonifen and s-metolachlor+oxyfluorfen. Tonev et al. (2010) recorded that *pendimethalin* controls the annual weeds, as the grass weed control was more pronounced. The authors also found that *oxyfluorfen* has excellent broadleaf weed control and limited grass weed control.

The herbicide products Stomp Aqua, Gardoprim Plus Gold, Wing-P and Pledge 50 WP performed much better control of the main annual monocotyledonous and dicotyledonous weeds, accept *Xanthium strumarium* L. The application of the herbicide combinations Wing-P at 400 cm^3/da+Stratos Ultra in rate of 200 cm^3/da and Stomp Aqua at 350 cm^3/da+Stratos Ultra at rate of 200 cm^3/da ensured 84.4 to 88.0% efficacy against the mixed weed infestation in sunflower (Manilov and Zhalnov, 2015). When growing conventional sunflower hybrids, the selective herbicides have no efficacy against *Xanthium strumarium* L. and *Cirsium arvense* (L.) Scop. In the recent years, these two weeds multiplied in high density. An alternative for control of these noxious weeds is the ExpressSun® technology at sunflower (*Helianthus annuus* L.) (Mangiapan et al., 2012; Tonev et al., 2009). At this technology the main herbicide is tribenuron-methyl - Express 50 SG. It should be applied at sunflower hybrids bred to be resistant to the active substance. At this technology main and difficult-to-control broadleaf weeds are controlled. Manilov and Zhalnov (2018) reported that the herbicide combinations of Express 50 SG at 40 g ha^{-1} + Stratos Ultra in a rate of 2.0 l ha^{-1} and Express 50 SG at 40 g ha^{-1} + Fusilade Forte at rate of 1.3 l ha^{-1} ensured 87.2 and 83.3% efficacy.

In the recent years the interest to the herbicide tolerant sunflower hybrids is increased. Other widely spread alternative for broadleaf and grass weeds as well as broomrape control is the Clearfield® technology. At this technology the sunflower hybrids are bred to be resistant to herbicides from the group of imidazolinones (Pfenning1 et al., 2008; Istilart, 2005).

Manilov and Zhalnov (2016) observed that the treatment of the sunflower hybrid EC Candimis CL Plus with Pulsar 40 without Dash, significantly reduces the efficiency against *Sorghum helepense* L., *Cirsium arvense* L. and

Chenopodium album L. However, the efficacy against against *Amaranthus* spp., *Sinapis arvensis* L., *Raphanus raphanistrum* L., *Solanum nigrum* L. is 100%. The pre-emergence herbicides, used immediately after sowing show very good control against some annual weeds in the early development stages of crop.

At hybrid ES Candimis CL Plus Mitkov et al. (2015) also found that the application of Pulsar 40 without Dash significantly reduces the efficacy against *S. halepense*, *C. arvense*, *C. arvensis*, *C. ruderalis*, *Xa. strumarium*, *Ch. album* and Or. cumana. The efficacy against *A. retroflexus*, *S. arvensis*, *R. raphanistrum* is 100%.

The aim of the research is to study the weed association dynamics in sunflower fields for the ecological conditions of Bulgaria.

MATERIALS AND METHODS

Table 1. Description of the investigated areas with sunflower in the period 2001-2019

Year/Municipalities	Settlements	Hybrid	Investigated Area, da	Total area, da
2001/Shumen	Village of Marash	Albena	320	800
2001/Shumen	Village of Salmanovo	Albena	320	800
2002/Novi Pazar	Village of Voivoda	Albena	200	650
2003/Brezovo	Village of Streltsi	LG 54.78	360	540
2003/Kaloyanovo	Village of Suhozem	LG 54.78	90	310
2004/Parvomay	Village of Poroina	Talento	130	700
2005/Tsar Kaloyan	Village of Ezerche	PR63E82	150	400
2006/Radnevo	Town of Radnevo	San Luka	200	800
2006/Yambol	Village of Ovchi Kladenets	Almansor	120	360
2007/Ruen	Village of Lyulyakovo	Albena	400	700
2007/G. Toshevo	Village of Petleshkovo	San Luka	200	500
2008/G. Oryahovitsa	Town of D. Oryahovitsa	Armada CL	450	1000
2008/Popovo	Village of Popovo	PR 63 E 82	300	800
2009/Vidin	Village of Dimovo	Armada CL	300	1000
2009/Pazardzhik	Village of Dragor	Sumiko	500	1500
2010/Radnevo	Village of Beli Bryag	Meldimi	100	1050
2010/Nova Zagora	Village of Pet Mogili	Armada CL	100	460
2010/Opan	Village of Pastren	PR63E82	100	1050
2011/Plovdiv	City of Plovdiv	PR63E82	60	200
2011/Rodopi	Village of Krumovo	Rimisol CL	200	600
2012/Haskovo	Village of Dinevo	PR63E82	140	400
2012/Tundzha	Village of Roza	Rimisol CL	400	1200
2012/Tundzha	Village of Miladinovtsi	Armada CL	200	500
2013/Tundzha	Village of Tenevo	P64LE25	300	800
2013/Tundzha	Village of Dryanovo	Neoma	140	400
2014/Harmanli	Village of Ivanovo	P64LE25	20	65
2014/Harmanli	Village of Leshnikovo	P64LE25	140	440
2015/Dryanovo	Village of Gostilitsa	P64LE25	90	310
2015/Sadovo	Town of Sadovo	P64LE25	130	1000
2016/G. Toshevo	Village of Samoilovo	P63LE113	80	190
2016/ G. Toshevo	Village of Malina	P63LE113	130	700
2017/Svishtov	Village of Tsarevets	P64LC108	50	400
2017/Svishtov	Village of Sovata	P64LC108	100	150
2017/Svishtov	Village of Hadzhidimitrovo	P64LC108	200	550
2018/Burgas	Village of Vetren	Bacardi	160	520
2018/Aytos	Town of Aytos	Neostar	150	500
2019/Pavlikeni	Village of Slomer	Bacardi	200	600
2019/Pavlikeni	Village of Duskot	Neostar	120	290
2019/Svishtov	Village of Kozlovets	P64LE25	100	300
Total - 27	Total - 39		7 450 da 31.65%	23 535 da 100%

The study was performed during the period of 2001-2019 in 10 districts, 27 municipalities and the lands of 39 settlements in the Republic of Bulgaria. The criteria for choosing the pigeonholed areas were to be typical for the sunflower production and with optimal soil-climatic conditions. The weed infestation monitoring of the fields on which conventional sunflower hybrids are grown is in period of 20 years and the weed infestation monitoring of the areas with Clearfield® and ExpressSun® sunflowers is in period of 10 years.

The weed mapping was performed by "Methodology for reporting and mapping of the weed infestation in main field crops" (Dimitrova et al., 2004).

The efficacy of imazamox and tribenuron-methyl was reported by the 10-score visual scale of EWRS.

The data from table 1 shows that, the committed study of sunflower weed infestation in an area of 23 535 da. The mapping and determination of the species composition of weed associations covers an area of 7450 da, to 31.65% of the total area and the study of the dynamics of weed associations in sunflower is representative.

RESULTS AND DISCUSSIONS

The weed species in the areas with sunflower in the different regions of Bulgaria is very diverse. The data is presented on Table 2. 21 species of weeds from 6 biological groups have been identified. The predominant species are late-spring weeds - 65% of the total weed infestation-, which is explained by the fact that their mass development and reproduction coincides with the sunflower growing season. The weed species Fat hen (*Chenopodium album* L.), Mat amaranth (*Amaranthus blitoides* L.), Common amaranth (*Amaranthus retroflexus* L.), Common purslane (*Portulaca oleracea* L.), Black nightshade (*Solanum nigrum* L.), Rough cocklebur (*Xanthium strumarium* L.), Green foxtail (*Setaria viridis* (L.) P.B.), etc., are widespread. In separate regions in Bugaria the Wild hemp *(Cannabis ruderalis Janisch.),* and Barnyard millet (*Echinochloa crus-galli* (L.) Beauv) are also observed. From the early-spring weeds Wild mustard (*Sinapis arvensis* L.) is widely distributed. The most widely found weeds from the winter-spring group is Wild radish (*Raphanus raphanistrum* L.) which is found to be in low densities in comparison to the perennial weeds like Johnson grass developed from seeds and rhizomes (*Sorghum halepense* (L.) Pers.) and Creeping thistle (*Cirsium arvense* (L.) Scop.). Field horsetail (*Equisetum arvense* L.), Bermuda grass (*Cynodon dactylon* (L.) Pers.) and Field bindweed (*Convolvulus arvensis* L.) are more common in northern Bulgaria. With respect to diversity, perennial

Table 2. Weed species in sunflower fields not treated with herbicides in the period 2001- 2019

	Grass weeds	Broadleaf weeds
I. Annual		
A/Winter-spring		Wild radish – *Raphanus raphanistrum L.*
B/ Early spring		Wild mustard – *Sinapis arvensis L.*
C/ Late spring	Barnyard millet - Echinochloa crus-galli (L.) Beauv	Common amarants – *Amaranthus retroflexus L.*
	Hairy crabgrass – Digitaria sanquinalis (L.) Scop.	Fat hen – *Chenopodium album L.*
	Green foxtail – Setaria viridis L.	Common purslane – *Portulaca oleracea L.*
	Yellow foxtail - Setaria glauca L.	Rough cocklebur – *Xanthium strumarium L.*
		Velvetleaf – *Abutilon teophrasti Medic*
		Black nightshade – *Solanum nigrum L.*
		Mat amaranth – *Amaranthus blitoides L.*
		Jimson weed – *Datura stramonium L.*
		Wild hemp – *Cannabis ruderalis L.*
II. Perennial		
A/ Rhizome	Johnson grass – *Sorgum halepense (L.) Pers.*	
	Field horsetail – *Equisetum arvense L.*	
	Bermuda grass – *Cynodon dactylon (L.) Pers.*	
B/ Root-sprouted		Creeping thistle – *Cirsium arvense (L.) Scop.*
		Field bindweed – *Convolvulus arvensis L.*
III. Parasite		Broomrape – *Orobanche cumana Wallr.*

weeds take second place of the total weed infestation of sunflower in Bulgaria - 25%.

Data from twenty-year mapping about the root parasite Broomrape (*Orobanche Cumana* Wallr.) do not lead to an accurate algorithm for its distribution. An exception is observed in the Haskovo and Harmanli regions. There, because of impaired crop rotation and sunflower growing on the same area in 2-3 years period the Broomrape infection is increased.

During the period 2016-2019 in eight regions in the country, a race appurtenance of the Broomrape was performed. Race H predominates and was followed by race E. in one of the regions race D was found (Table 3).

Table 3. The sunflower broomrape races (*Or. cumana* Wallr.)

Origin Location	Year	Race
Kardam	2016	H
Dobroudja Agricultural Institute, General Toshevo, Bulgaria (DAI) (Infectious disease)	2016	H
Dobroudja Agricultural Institute, General Toshevo, Bulgaria (DAI) (Experimental field)	2017	E
Kardam	2018	H
Tyulenovo	2018	H
Dyakovo	2017	H
Selanovtsi	2017	D
Svishtov	2019	E
Radnevo	2016	E
Radnevo broomrape on *Artemisia maritima* L .	2017	E

The data regarding the efficacy of the Clearfield® technology showed that average for the period of investigation the following weed species in high density were reported: from the dicotyledonous late spring weeds Fat hen, Rough cocklebur, Velvetleaf, Common amaranth, Black nightshade and Common purslane.

From the dicotyledonous early spring weeds only Wild mustard was found. Observed species from the monocotyledonous group were the late spring weeds Green foxtail and Barnyard millet.

The most widely spread perennial weed species were found to be Johnson grass and Creeping thistle.

The root parasite Broomrape is also observed in very high densities but only in some regions of the country.

From the abovementioned weeds after the herbicide application at the Clearfield® system the following species are successfully controlled: Wild mustard, Common amaranth, Black nightshade, Rough cocklebur and Barnyard millet (Figure1).

When the rhizome weed Johnson grass is in high density could not be efficiently controlled and a partner herbicide product should be applied. Such herbicides are като cycloxidim, fluazifop-P-butyl, fluazifop-P-ethyl, etc. The efficacy of imazamox against Creeping thistle is relatively good - 85% on average. At this technology the main problems are the weeds Fat hen and Common purslqne. The reason is that in years with less precipitation in the spring, no soil herbicides are used that have excellent efficacy against these two weeds and they multiply in great density. In the presence of Fat hen and Common Purslane, as well as Wild hemp, the efficacy of imazamox is even lower, especially when administered without the adjuvant Dash.

Against the Broomrape in the sunflower fields the Clearfield® technology relies entirely on the mode of action of the herbicide products containing imazamox. The efficacy of the herbicide imazamox is high enough and reaches 90%.

In some regions of Bulgaria on the 56th day after the herbicide application secondary parasitaion in low density can be observed.

In many scientific studies it has been proven that the broomrape that remains in the field after treatment with imazamox containing herbicide products forms sterile seeds, which is also economically important.

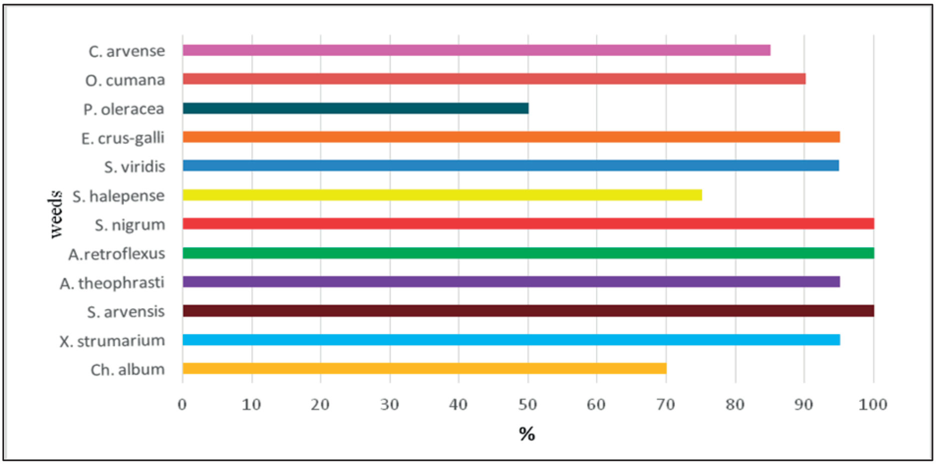

Figure1. Efficacy of imazamox against the weeds average for the period of the study

For the ExpressSun® technology (Figure 2), the tribenuron-methyl efficacy is slightly higher against some of the major dicotyledonous weeds that are controlled by using imazamox in the Clearfield® system. Despite this fact, in the ExpressSun® technology again difficult-to-control weeds are Fat hen and Common purslane. If these two weeds as well as Wild hemp are present on the sunflower fields it is obligatory the active substance tribenuron-methyl with the adjuvant Trend 90 in concentration 0.1% to be applied. This measure is necessary for increasing the efficacy against these noxious weeds. Tribenuron-methyl cannot control the dicotyledonous weeds. That is why if there are grass weeds on the field it is mandatory graminicides as cycloxidim, cletodim, fluazifop-P-butyl, fluazifop-P-ethyl, propaquizafop, etc. to be applied as partner herbicides. To avoid the risks of phytotoxicity under the different meteorological conditions each year, it is better to apply them separately rather than in tank mixture with herbicides containing tribenuron-methyl.

At the ExpressSun® technology the control of the broomrape relies entirely on the genetic resistance of some homozygous hybrids to the "G" race. The active ingredient tribenuron-methyl cannot control the root parasite in any extent.

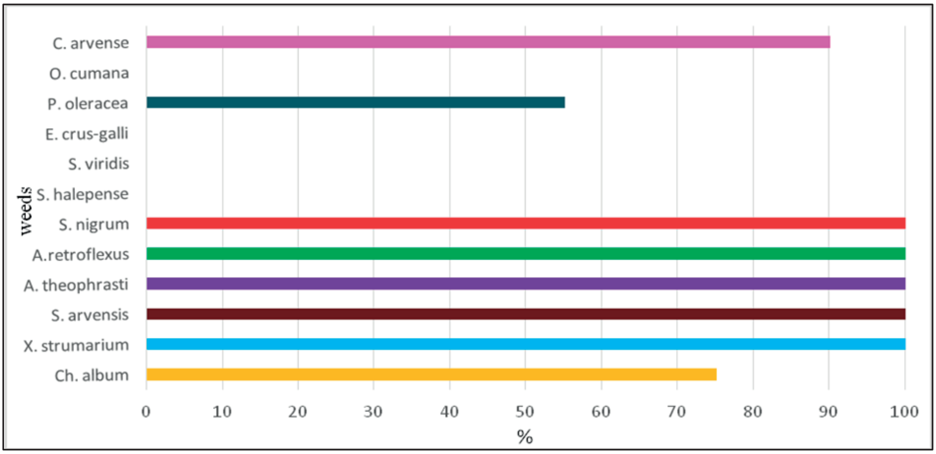

Figure 2. Efficacy of tribenuron-methyl against the weeds average for the period of the study

In conclusion, it can be said that in the last 10-15 years the Clearfield® and ExpressSun® technologies took 85 to 90% of the fields seeded with sunflower plants in Bulgaria. The share of conventional sunflower hybrids during the investigation period significantly reduces from 100% in the period of 2001-2005 to 7-10% during the las several years. The control of the weeds at conventional sunflower production in the period of our study is performed by a great number of soil herbicides as acetochlor, oxyfluorfen, s-metolachlor, flumioxazin, diflofenican, pendimethalin, dimethenamid, etc. For grass weeds control cycloxidim, cletodim, fluazifop-P-butyl, propaquizafop, etc. during the vegetation can be applied.

CONCLUSIONS

The data from the research showed that in the sunflower fields of Bulgaria a significant dynamics of the weed species and densities has occurred. In the beginning of the monitoring period the dominating weed species were Rough cocklebur (*Xanthium strumarium* L.), Wild mustard (*Sinapis arvensis* L.), and on separate fields the Wild hemp (*Cannabis ruderalis* Janisch.).

The implementation of the Clearfield® and ExpressSun® technologies showed positive effect for decreasing the density and range of distribution the weeds in the sunflower fields.

The growing share of the Clearfield® and ExpressSun® technologies - from 80 to 85% of the total sunflower production in Bulgaria, compared to the conventional technology - 7 – 10% had led to compensatory processes and distribution of Fat-hen (*Chenopodium album* L.) and Common purslane (*Portulaca oleracea* L.).

It is also known that imazamox and tribenuron-methyl have limited efficacy against *Ch. album* and *P. oleracea*. This is also contributed by the frequent application of both herbicides without adjuvants - Dash and Trend 90, respectively.

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