THE SENSITIVITY OF THE *GALIUM APARINE* L. SPECIES TO SULFONYLUREA HERBICIDES

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Abstract. *Galium aparine L. from Rubiaceae family, is believed to has originated in Eurasia. Galium aparine it is a weed problem producing direct damages, on wheat production, through the consumption of nutrients, water, etc., but also indirect by the fact that it lodges the cereal plants, makes it difficult to harvest by winding on cereal heder, it is a plant host for nematodes, insects and pathogens. Studies conducted by different researchers have shown that the species Galium contents alkaloids, saponins, etc. which have negative effects on growth and germination of wheat plants as well as on animal health (causes poisoning). Research on the sensitivity and resistance of cleavers populations to herbicides is important for farmers, thus giving them the opportunity to select the appropriate management strategy. The research aimed to assess the sensitivity of Galium aparine to sulfonylureas. The sensitivity of cleaver to sulfonylurea herbicides was determined by the percentage of control and wheat production, obtained in the experimental variants. The experimental field was established in western Romania, in Timiș County, Cornești locality (45 ° 54 ' 43 "N, 21 ° 17'21" E and 119 m altitude). The Romanian wheat variety Glosa was used in the study. The trial was placed according to the method of randomized blocks with four variants in 4 replicates. The herbicides used to reduce the population of Galium aparine in wheat crop were: Alliance 660 WG (diflufenican + metsulfuron-metil), Harmony Extra (tifensulfuron-metil 50% + tribenuron-metil 25%) and Saracen Max (florasulam 200 g/kg + 600 g/kg tribenuron-metil). At 14 days after the application of the treatments, the population of Galium aparine winter wheat was reduced by 42.5-83.75%. The herbicides efficacy in reducing the population of Galium aparine, decreases to four and six months after application, respectively. The significant positive yield results were directly proportional to the herbicides efficacy for Galium aparine. The yield losses caused by the Gallium aparine species were 1.33 t / ha, in the untreated variant.*

Keywords*: Galium aparine, sulfonylurea herbicides, sensitivity, wheat*

INTRODUCTION

Wheat is cultivated on large areas worldwide, but also in Romania (MANEA et al., 2016; ȘTEF R. et al., 2014). In 2018, Romania ranked fourth in the European Union on wheat production (10.27 million tons), according to the data of the European Statistical Institute - Eurostat (http://www.business24.ro). Wheat production is influenced by applied agrotechnics as well as biotic and abiotic factors. Among the biotic factors, which decrease the yield of wheat plants, weeds are highlighted (causing yield losses of 15-20% and even 60-80%, in the absence of control measures) (MANEA et al., 2015; ȘTEF R. et al., 2017). TKALICH Y. and al. 2020, claims that wheat production can be reduced by 40 to 100%, depending on the density of weeds and the composition of the species. Among the "problem" weed species present in the wheat agroecosystem is the *Galium aparine*. This species has its origins in North America (MALIK et al., 1988; DEFELICE, 2002, MENNAN and ZANDSTRA 2005) is an annual, broad-leaved weed that reproduces by seeds. The cleavers is found on arable land, in pastures, but also on the side of the road. The species *Galium aparine* is found on different soil types, but prefers those rich in nutrients (PAPAPANAGIOTOU, A.P. et al., 2019).

Galium aparine is a weed commonly found in wheat crops in Romania. This species is described by HOLM et al. (1991) as a major weed in ten countries. Worldwide, it has been

reported as a weed in 19 crops *(Avena sativa, Triticum aestivum, Beta vulgaris, Glycine max, Hordeum vulgare, Brassica napus var. napus, Oryza sativa, Rye cereals, meadows, etc.).* Although, *Galium aparine*, it is present in many crops, the greatest damage it is done to cereals (MENNAN et al. 2011, HOSSEIN and ISMAIL, 2018, HOSSARD et al., 2014). Rola (1969) (cited by BEKIE et al., 2012) reported a reduction in production potential by 30-36%. RODER et al. (1990) found that a plant of *Galium aparine*/m^2 causes a decrease in production of 0.24% in barley and 0.14% in wheat. Similar research, conducted in the UK, showed decreases in production of 0.7% - 2.9% throughout the presence of a plant of *Galium aparine*/m^2 (WILSON and WRIGHT, 1987).

In addition to reducing production, *Galium aparine* contains substances with allelopathic effects (which suppress the growth of *Querqus robur* seedlings) and anthraquinones that are toxic to mammals (BATRA, 1984), being also a host plant for pests. This species, in addition to the damages previously mentioned, creates difficulties in the process of harvesting crops, by wrapping up on the combine harvester and increases production costs (DURGAN and GUNSOLUS, 2013; SHANER and BECKIE, 2014). Therefore, in order to obtain the desired productions, both qualitatively and quantitatively, it is important to promptly apply different control methods (CHIRIȚĂ R., et al., 2007).

Studies on the chemical control of *Galium aparine* have begun since the 1960s (ROLA; 1969), while it has been observed that this species is resistant to herbicides with phenoxyacetic acid (BACHTHALER and DANCAU, 1970; LOVEGROVE et. al., 1985). Studies conducted by LOVEGROVE et al. (1985) by pre-emergence of the substances pendimethalin, trifluralin with linuron and bifenox with linuron did not control the populations of *Galium aparine*.

Satisfactory control was obtained by post-emergence application of mecoprop mixed with ioxynil and bromoxynil, cyanazine or bifenox (LOVEGROVE et al., 1985; CATIZONE and VIGGIANI, 1990; D'SOUZA et al., 1993). Good results in combating cleavers have been obtained by applying the following substances: dichlorprop alone or mixed with bentazone (HOFFMANN and PALLUTT, 1989); cyanazine plus MCPA, metazachlor and chinmerac (ADAMCZEWSKI and STACHECKI, 1994); mesosulfuron (MENNAN et al. 2011), tribenuron (VENCILL, 2002) and dicamba (GROSSMAN, 2000).

Chlorosulfuron, tribenuron and florasulam, acetolactate synthase (SLA) inhibitors, have been used mainly in the control of cleavers for the last twenty years. The research conducted by KALOUMENOS et al., 2009, 2011 and NTOANIDOU et al., 2017, showed that by applying the substances tribenuron + mecoprop-p; florasulam + 2,4-D; florasulam + aminopyralid; florasulam + fluroxypyr; florasulam + dicamba; there were not very good results in the control of cleavers, because it gained resistance (PAPAPANAGIOTOU, A.P. et al., 2019). In order for crop weeds not to become "resistant", researchers recommend the use of combined herbicides, because repeated application of the herbicide with the same mode of action favors its occurrence (BECKIE and HARKER, 2017).

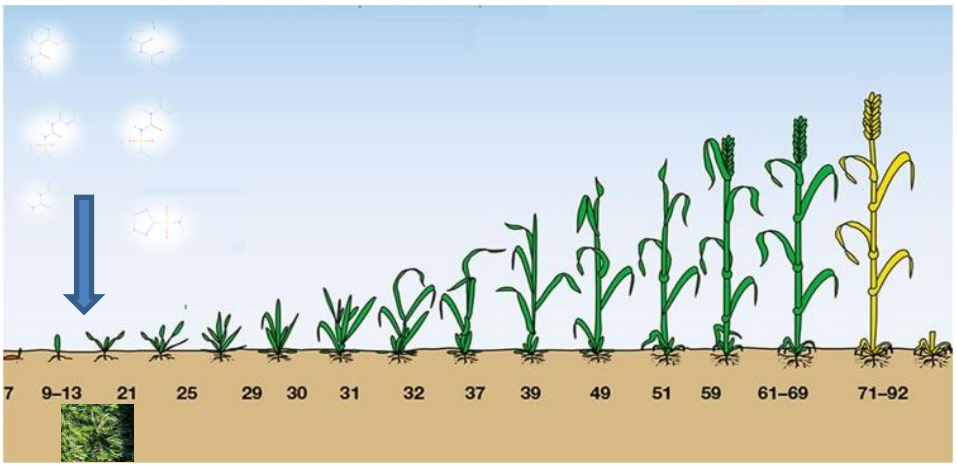
MATERIAL AND METHOD

The study on the sensitivity of *Galium aparine* species to sulfonylurea herbicides was carried out in Cornești (figure 1), Timiș County, during 2019/2020.

The trial was placed according to the method of randomized blocks with four variants in 4 replicates. The experimental variants presented a width of 3 m and a length of 10 m. The Romanian wheat variety Glosa was used in the study.

The post-emergent herbicides were applied in the first half of November (12.11.2019), when the wheat plants were in BBCH 16-18. The Stihl SR 430 atomizer, 3.9 hp, was used to apply the treatments.

Figure 1. Google Maps location of the experimental field



Treatments were applied in BBCH 16-18

The herbicides used to reduce the population of *Galium aparine* in wheat crop were: Alliance 660 WG, Harmony Extra and Saracen Max (table 1). The herbicide **Alliance 660 WG** consists of two active substances (methylsulfuron methyl and diflufenic), both with systemic action. Metsulfuron methyl, an active substance in the sulfonylurea class, inhibits cell division. Diflufenican acting by inhibiting the process of carotenoid synthesis. **Harmony Extra** contains two systemic substances (thifensulfuron-methyl and tribenuron methyl) from the sulfonylurea group. Tribenuron methyl inhibits the ALS enzyme causing cell division to cease (CODEX, 2019). ALS is a key enzyme in the biosynthesis of essential amino acids such as valine, leucine and isoleucine (DUGGLEBY and PANG, 2000). This enzyme is the target of herbicides belonging to five distinct chemical families: sulfonylureas, imidazolinones, triazolopyrimidines, pyrimidinyl-benzoates (thio- and oxy-benzoates) and sulfonyl-aminocarbonyltriazolinones (YU et al., 2010). **Saracen Max** is a complex herbicide containing methyl tribenuron and florasulam, both of which are systemically active substances (CODEX, 2019). Florasulam inhibits the biosynthesis of essential amino acids (valine, leucine, isoleucine).

Table 1

Experimental field of wheat agroecosystem

		Commercial products	Active substance	Applied dose
Variants	1.	Untreated variant	-	-
	2.	Alliance 660 WG	Diflufenican 60% + metsulfuron-methyl 6%	0,01kg/ha
	3.	Harmony Extra	Thifensulfuron-methyl 50% + tribenuron methyl 25%	0,04 kg/ha
	4.	Saracen Max	Florasulam 200 g/kg + 600 g/kg tribenuron methyl	0,025 kg/ha

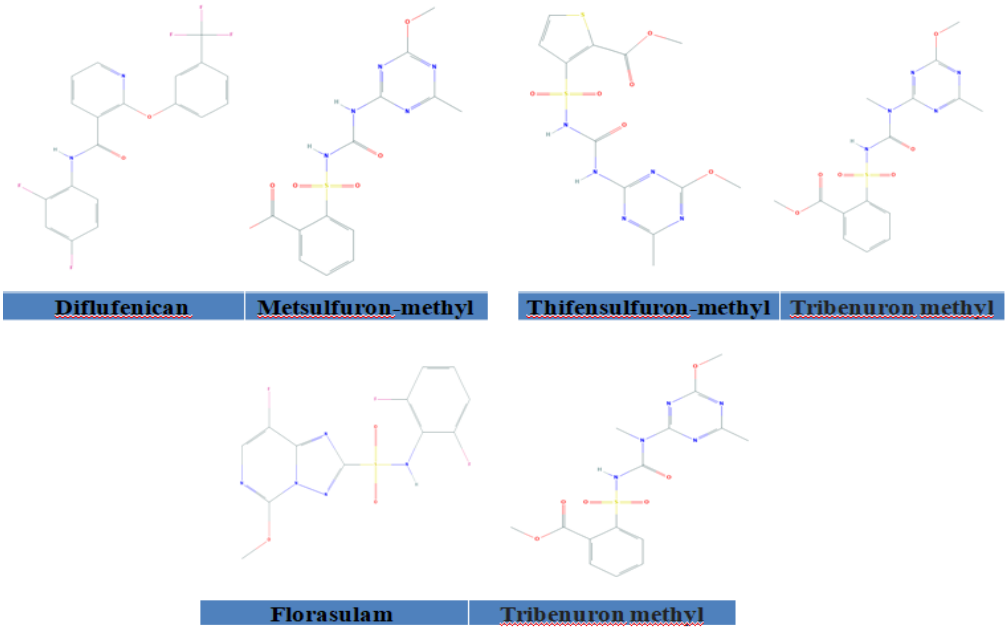
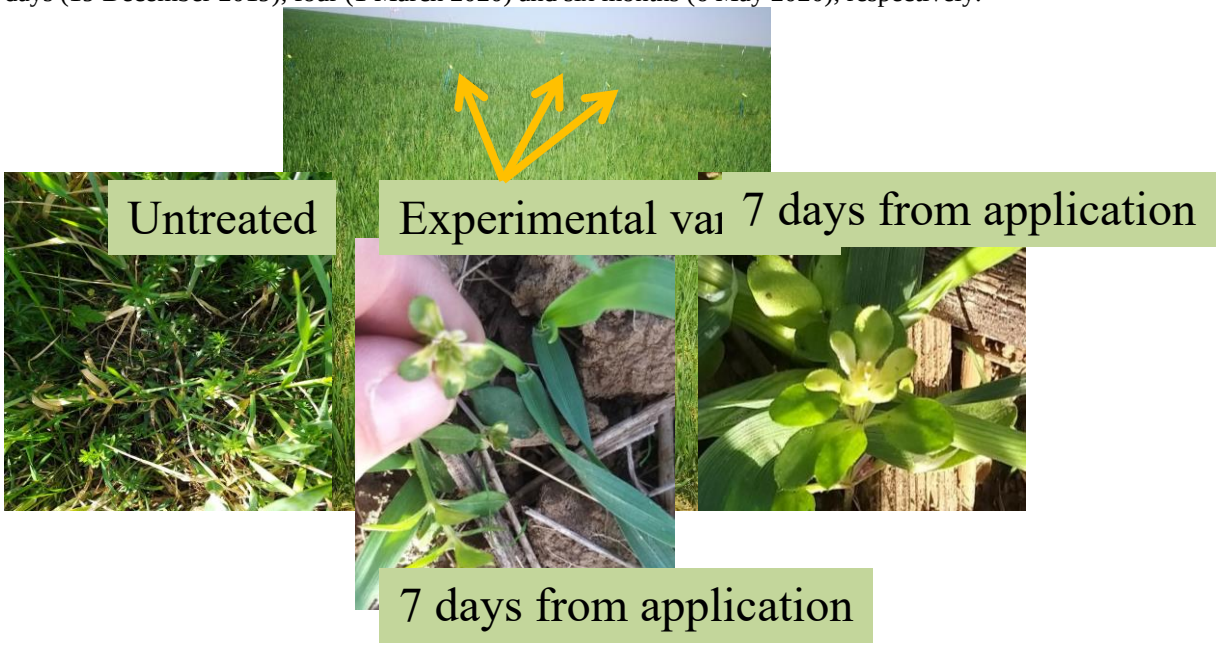


Figure 2 - Chemical structure of the substances used in the experiment
Sursa: https://pubchem.ncbi.nlm.nih.gov/compound/52999#section=Structures

The effectiveness of herbicides was assessed 2 weeks after application (26.11.2019), 39 days (19 December 2019), four (1 March 2020) and six months (6 May 2020), respectively.



At the maturity of the wheat plants, the production obtained in the treated variants was determined. The data gathered from the study were statistically interpreted by the variance analysis method.

RESULTS AND DISCUSSIONS

The weeds infestation degree of the experimental variants was 8-28 *Galium aparine* plants per hectare/m^2. Other weed species were present in the experimental variants, but they were removed by manual weeding. Weeding was done periodically (when necessary).

Table 2

The effectiveness of sulfonylurea herbicides on the population of *Galium aparine* to the wheat agroecosystem

No crt.	Herbicide	Active substance	Dose	Control of Galium aparine (%)			
				14 days	39 days	4 months	6 months
1.	Untreated/ control variant	-	-	0,0	0,0	0,0	0,0
2.	Alliance 660 WG	Diflufenican 60% + metsulfuron-methyl 6%	0,01kg/ha	42,5***	70,0***	52,5***	45,0***
3.	Harmony Extra	Thifensulfuron-methyl 50% + tribenuron-methyl 25%	0,04 kg/ha	75,0***	77,5***	75,0***	63,8***
4.	Saracen Max	Florasulam 200 g/kg + 600 g/kg tribenuron-methyl	0,025 kg/ha	83,75***	86,3***	88,80***	78,80***

At 14 days after the application of the treatments, the population of *Galium aparine* winter wheat was reduced by 42.5-83.75% (table 2). The herbicide Saracen Max controlled at highest the cleavers plants, due to the two active substances (tribenuron methyl and florasulam) and the mode of absorption both foliar and root, it acts by inhibiting the enzyme acetolactate synthesis (ALS), so in some days after application, weeds cease to compete with food and water crops. The results obtained are in line with those published by MEISAM M. (2019), who recorded a control of the *Galium* population of 84-91.8% at 2 WAA (weeks after application) of the simple or mixed tribenuron substance (tribenuron + fluroxypyr; tribenuron + metsulfuron, tribenuron + piroxsulam). Similar efficacies have been reported by OLIVEIRA et al. 2009; MACIEL et al. 2013, FERHATOGLU and BARRETT 2006; SHIMI et al. 2007. The control of *Galium aparine* population was not satisfying (42.5%, at 2WAA, figure 3) in the variants in which the substance metsulfuron-methyl was applied in combination with diflufenican. Poor results in combating tourism, also reported MEISAM M. (2019) by using the substances metsulfuron (52%) and fluroxypyr.

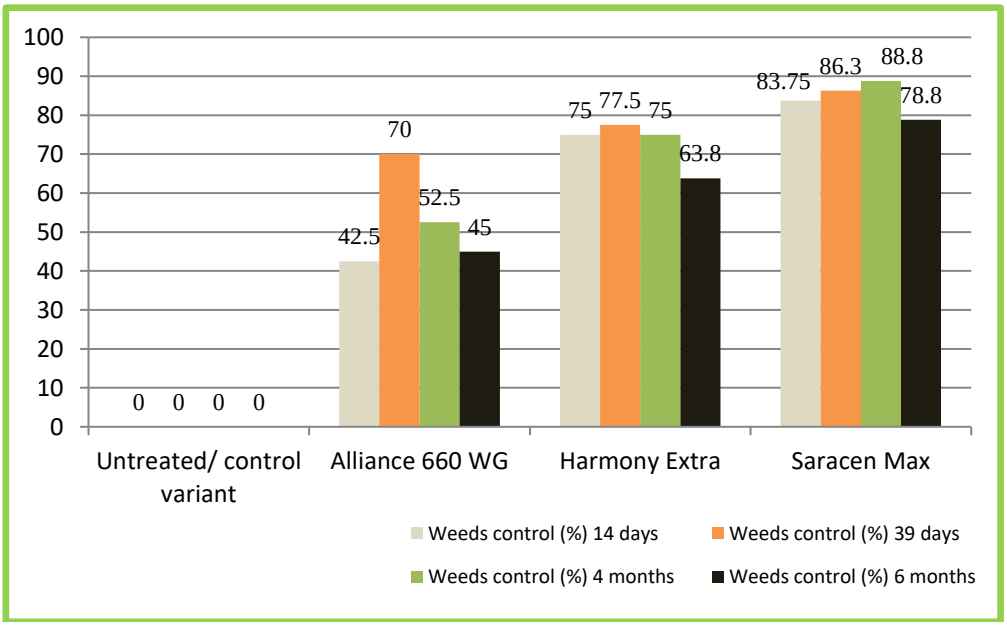


Figure 3 – Graphical representation of the reduction of the *Galium aparine* population

The results published by researchers in Greece (PAPAPANAGIOTOU A.P. et al., 2019) are not in line with those obtained in this study, claiming that *Galium aparine* is resistant to chlorsulfuron, tribenuron and florasulam (this is the first study published in Europe , on the resistance of this species to herbicides inhibiting ALS). The same researchers claim that they controlled cleavers with mixtures of tribenuron + mecoprop-p and florasulam + fluroxypyr, arguing that resistance was closely associated with wheat monoculture and the continued use of the same herbicide.

Research by BECKIE and TARDIF (2012) supports the use of auxin herbicides (2,4-D, dicamba, fluroxypyr, aminopyralid, mecoprop-p) in mixtures with herbicides that inhibit ALS to attenuate the evolution of resistance to these herbicides.

The second assessment (39 days after the application of the treatments) showed an increase in the control percentage of the *Galium aparine* species (70 - 86.3%). From the observations made, it was found that Alliance 660 WG herbicide reaches its maximum effectiveness (70%) (in cleavers control) 39 days after application, after this period the efficacy decreases to 45% (at six months). Herbicides composed of tribenuron-methyl showed a high efficacy throughout the period compared to metsulfuron-methyl treatment in combination with diflufenican. The herbicides efficacy in reducing the population of *Galium aparine*, decreases to four and six months after application, respectively. Compared to the control, all herbicides showed very significant positive differences.

The wheat production obtained in the experimental variants was between 4.75 t/ha, in the untreated control variant and 7.13 t/ha in the variant treated with Saracen Max (table 3).

Table 3

Efficacy of sulfonylurea herbicides in the control of cleavers expressed by wheat production

No crt.	Herbicide	Yield (q/ha)	Relative (Yield %)	Absolute differ.	Signific.
1	Untreated/ control variant	4,75	78,09	-1,33	000
2	Alliance 660 WG	6,11	100,38	0,02	-
3	Harmony Extra	6,37	104,60	0,28	-
4	Saracen Max	7,13	117,06	1,04	***
5	Mean of experience	6,09	100	-	-

5% = 0,499; 1% = 0,726; 0,1% = 1,089

In the variants in which Alliance 660 WG and Harmony Extra were applied, productions of over 6.11 t/ha were registered). The application of the combination thifensulfuron-methyl + tribenuron-methyl did not result in significant yields compared to the average experience. The slightest increase in wheat production, compared to the mean of experience, was observed in the variants treated with diflufenican + metsulfuron-methyl, due to the lower level of cleavers control (table 3). The application of Saracen Max herbicide determined an increase in production of 1.04 t/ha, showing very significant differences compared to the mean. The yield losses caused by the *Galium aparine* species were 1.33 t/ha, in the untreated variant. The results were in line with studies performed by CURRAN et al. (2015) and MEISAM M. (2019) who reported that treatments that included tribenuron led to higher wheat yields due to greater efficacy in controlling *Galium aparine* species.

CONCLUSIONS

The herbicide Saracen Max reduced the most the population of *Galium aparine* and has provided long-term protection of the wheat crop.

The effectiveness of the three herbicides (Alliance 660 WG, Harmony Extra and Saracen Max) persist maximum 39 days after application.

The herbicides used in the experiment resulted in production increases compared to the production obtained in the control variant.

According to the results of this study, the group of sulfonylurea herbicides is suitable for controlling cleavers in wheat crop.

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BIBLIOGRAPHY

ADAMCZEWSKI K, STACHECKI S., 1994 – Evaluation of new herbicide Butisan Star for control cleaver (Galium aparine L.) in winter oilseed rape, Oilseed crops. 16th Polish research conference, 15(2):115-118

BACHTHALER G., DANCAU B., 1970 – Influence of production technique on the weed flora in sugarbeet, with particular regard to chemical weed control. In: Proceeding of the 2nd International for Selective Weed Control in Beet Crops, Rotterdam, Netherlands, 1:221-233

Batra SWT, 1984 – Phytophages and pollinators of Galium (Rubiaceae) in Eurasia and North America Environmental Entomology, 13(4): 1113-1124

BECKIE HJ, HARKER KN., 2017 - Our top 10 herbicide-resistant weed management practices. Pest Manage Sci. 73:1045–1052.

BECKIE HJ, TARDIF FJ., 2012 - Herbicide cross resistance in weeds. Crop Protec. 35:15-28.

BECKIE HJ, WARWICK SI, SAUDER CA, KELLN GM., 2012 - Acetolactate synthase inhibitor-resistant false cleavers (*Galium spurium*) in Western Canada. Weed Technol., 26:151-5.

CATIZONE P, VIGGIANI P, 1990 - Aspects of the biology and control of Galium aparine L., European Weed Research Society, 421-428

CHIRITA R, GROZEA I, SARPE N, LAUER KF, 2007 - Control of *Sorghum halepense* (L.) species in western part of Romania. Commun Agric Appl Biol Sci 73:959–964

CURRAN WS, WALLACE JM, MIRSKY S, CROCKETT B., 2015 - Effectiveness of herbicides for control of hairy vetch (Vicia villosa) in winter wheat. Weed Technol. 29:509–518.

DEFELICE MS., 2002 - Catchweed bedstraw or cleavers, *Galium aparine* L. - A very 'sticky' subject. Weed Technol. 16:467-72.

D'SOUZA DSM, BLACK IA, HEWSONT RT., 1993 – Amidosulfuron – anew sulfonylurea for the control of Galium aparine and other broad-leaved weeds in cereals. Crop Protection Council (BCPC), vol. 2:567-572

DUGGLEBY RG, PANG SS., 2000 - Acetohydroxyacid synthase. Biochem Molec Biol., 33:1-36.

DURGAN, B.R., GUNSOLUS, J.L., 2013 - Developing weed management strategies that address weed species shifts and herbicide resistant weeds on wheat crop. Extension Weed Scientists, Department of Agronomy and Plant Genetics University of Minnesota, 23–31.

FERHATOGLU Y, BARRETT M., 2006 - Studies of clomazone mode of action. Pestic Biochem Physiol. 85:7–14

GROSSMAN K., 2000 - The mode of action of auxin herbicides: a new ending to a long, drawn out story. Trends Plant Sci.5:506–508.

HOFMANN B., PALLUTT B., 1989 – Studies on the control of Galium aparine L. with SYS Gebifan, SYS 67 g Gebifan + Basagran as well as tank mixes of these herbicides with bercema-Bitosen N or ammonium nitrate with urea solution. Nachrichtenblatt für den Pflanzenschutz in der DDR, 43(9):180-183

HOLM LG., PANCHO JV, HERBERGER JP., PLUCKNET DL., 1991 – Geographic atlas of word weeds, Malabar, Florida USA: Krieger Publishing Company

HOSSARD, L., PHILIBERT, A., BERTRAND, M., COLNENNE David, C., Debaeke, P., MUNIER-JOLAIN, N., JEUFFROY, M. H., RICHARD G., MAKOWSKI D., 2014 - Effects of halving pesticide use on wheat production. Sci Rep., 4, 4405.

HOSSEIN, M., ISMAIL, B.S., 2018 - Effect of Herbicides on the Density of Broad Leaf Weeds and their Effect on the Growth and Yield Components of Wheat (Triticum aestivum L.). Journal of Agronomy, 17, 11– 17

KALOUMENOS NS, ADAMOULI VN, DORDAS CA, 2011 - Eleftherohorinos IG. Corn poppy (*Papaver rhoeas*) resistance to ALS-inhibiting herbicides. Pest Manag Sci. 67:574-85.

KALOUMENOS NS, DORDAS CA, DIAMANTIDIS GC, 2009 - Eleftherohorinos IG. Multiple Pro197 substitutions in the acetolactate synthase of corn poppy (*Papaver rhoeas*) confer resistance to tribenuron. Weed Sci. 57:362-8.

LOVEGROVE AW, LUTMAN PJW, THORNTON ME, 1985 – Investigations into the control of cleavers (Galium aparine) with several pre- and post-emergence herbicides in winter cereals. Aspects of Applied Biology, 9:205-211

MACIEL CDG, NETO AMO, GUERRA N, MACIEL AMC, JARDIM CE, SILVA AAP., 2013 - Potencialization of mesotrione efficiency in tank mixture with inhibiting of photosystem II by distinct absorption pathways of crabgrass. Rev Bras Herbicidas. 12:210–219. In Portuguese.

MALIK N, VANDEN BORN WH., 1988 - The biology of Canadian weeds. 86. *Galium aparine* L. and *Galium spurium* L. Can J Plant Sci.1988;68:481-99.

MANEA D. N., I. PEȚ, ANIȘOARA AURELIA IENCIU, RAMONA ȘTEF, 2015 - Control of horse thistle (*Cirsium arvense* L. Scop.) in winter wheat crop, Research Journal of Agricultural Science, 47 (1):82-89

MANEA DAN NICOLAE, RAMONA ȘTEF, IOAN PEȚ, ANIȘOARA AURELIA IENCIU, IOANA GROZEA, ALIN CĂRĂBEȚ, 2016 - Control of *Avena fatua* species (Wild Oat) - a Weed in Expansion in Banat Area, Bulletin UASVM series Agriculture 73(1): 44-48

MEISAM ZARGAR, MARYAM BAYAT, ELENA ROMANOVA, EBRAHIM IZADI-DARBANDI, 2020 - POST herbicide programs utilizing tribenuron for cleavers (Galium aparine L.) control in winter wheat cultivars, Archives of Agronomy and Soil Science, 66:9, 1235-1243

MENNAN H, STREIBIGB JC, NGOUAJIOC M, CANKAYA S., 2011 - Response of two catchweed bedstraw (Galium aparine) populations to post-emergence herbicides in winter wheat. Int J Pest Manage. 54:347–356.

MENNAN H, ZANDSTRA BH. 2005 - Effect of wheat (Triticum aestivum) cultivars and seeding rate on yield loss from Galium aparine (Cleavers). Crop Protec. 24:1061–1067.

NTOANIDOU S, MADESIS P, DIAMANTIDIS G, ELEFTHEROHORINOS I., 2017 - Trp574 substitution in the acetolactate synthase of *Sinapis arvensis* confers cross-resistance to tribenuron and imazamox. Pestic Biochem Physiol.:2:9-14.

OLIVEIRA AR, FREITAS SP, VIEIRA HD., 2009 - Control of Commelina benghalensis, C. erecta, Tripogandra diuretica in the coffee culture. Planta Daninha. 27:823–830

PAPAPANAGIOTOU, A.P., DAMALAS, C.A., BOSMALI, I., MADESIS, P., MENEXES G.C., ELEFTHEROHORINOS, I.G., 2019 - Galium spurium AND G. aparine resistance to ALS-inhibiting herbicides in Northern Greece, Planta Daninha, v37, e019207288

RODER W, EGGERT H, KALAMUS A, 1990 - Occurrence and detrimental effect of cleavers, Galium aparine L., in grain fields. Nachrichtenblatt Pflanzenschutz, 44(11):253-256

ROLA J., 1969 – Causes and effects of weeds compensation in crop (www.cabi.org)

SHANER, D.L., BECKIE, H.J., 2014 - The future for weed control and technology. Pest Management Science, 70, 1329–1339.

SHIMI P, ABTAIL Y, JAMALI M, MAKNALI A., 2007 - Evaluating new herbicides in canola. Pak J Weed Sci Res. 13(4):199–207.

STEF R., I. GROZEA, C. PUIA, A. CARABET, M. VLAD, D. MANEA, 2014 - The effect of seed treatment on the main pathogens present in wheat agroecosystems, Comm. Appl. Biol. Sci, Ghent University, 79/3, PAG 473-479

ȘTEF RAMONA, VÎRTEIU ANA-MARIA, GROZEA IOANA, MANEA DAN, CĂRĂBEȚ ALIN, 2017 - Assessment of Allelopathic potential of extracts from Colvovulus arvensis on plant germination and growth of wheat, International Multidisciplinary Scientific GeoConference: SGEM, Volumu 17, Pagini 493-498

TKALICH YURIY, OLEXANDR TSYLIURYK, VOLODYMYR KOZECHKO, YURIY RUDAKOV, OLGA TKALICH, MARIA BAGORKA, 2020 - Weed chemical control in the winter wheat planting after non fallow predecessors in the Northern Steppe of Ukraine, Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 567-573

VENCILL WK., 2002 - Herbicide handbook of the weed science society of America. 8th ed. Lawrence (KS): Weed Science Society of America; p. 493 p.

WILSON BJ, WRIGHT KJ,, 1987 - Variability in the growth of cleavers (Galium aparine) and their effect on wheat yield. Proceedings 1987 British Crop Protection Conference, Weeds, Vol.3:1051-1058

YU Q, HAN H, VILA-AIUB MM, POWLES SB., 2010 - AHAS herbicide resistance endowing mutations: effect on AHAS functionality and plant growth. J Exp Bot. 2010;61:3925-34.

***https://pubchem.ncbi.nlm.nih.gov/compound/52999#section=Structures

***http://www.business24.ro
***Codexul Produselor de protecția plantelor omologate pentru utilizare în România, 2019, Editura Andagra