WEED CONTROL IN MAIZE (*Zea mays* L.) ON THE INTERFACE OF AGRO-CLIMATIC CONDITIONS OF MAIZE AND SUGAR BEET GROWING REGION

J. SMATANA[1], M. MACÁK[1], Š. TÝR[1], Marta ANDREJČÍKOVÁ[2]

Slovak University of Agriculture in Nitra, Faculty of Agrobiology and Food Resources, Department of Sustainable Agriculture and Herbology[1], Central Control and Testing Institute of Agriculture, Bratislava[2]

Slovak University of Agriculture in Nitra, Tr. A Hlinku 2, 949 76 Nitra, Slovakia e-mail: jozef.smatana@uniag.sk

Abstract: *In the experiment, we focused on the occurrence of weed density and weed diversity, in maize and sugar beet growing region and the effectiveness of herbicide treatments on field experiment performed on site Plavé Vozokany and Santovka in canopy of maize (Zea mays L.) in 1998 – 2000. Plavé Vozokany site is located in the south-eastern part of the district Levice in maize growing production region. The average daily air temperature in the region is a 9.6 °C, and the annual amount of rainfall represents 604 mm and 330 mm during the growing season respectively. Santovka, the second experimental site, is located in the north-eastern part of the district of Levice in sugar beet growing region. The average daily air temperature in the region is 9.2 °C and the annual amount of rainfall represents 637 mm and the annual amount of rainfall during the growing season is a 354 mm. Actual weed infestation was carried out by the counting method with a five replication on the control treatments (without herbicide application), as well as on the areas treated with herbicides. The occurrence of weeds in maize was assessed for 3 times per growing season. The evaluated sites were infested on the level of high weed infestation. The total abundance of weeds without herbicidal treatments ranged from 26.60 to 44.30 plants per m^2. Herbicides application effectively decreased the weed infestation in an average from 7.2 to 14.8 plants per m^2. The most dominant weed species were late–spring weeds Echinochloa cruss – galli (L.) P. BEAUV, Chenopodium album L. and Atriplex sp., at both experimental site. On Plavé Vozokany location, late–spring weeds Setaria viridis (L.) P. BEAUV and Persicaria lapathifolia (RAF) S. F. GRAY also counted high density. The average weed density was in negative relationship with the air temperature, but strongly related to rainfall. Higher weed infestation was noted in the growing years when early spring to early summer was warm and humid. Lower weed infestation was observed when this period was dry. Differences in overall weed infestation, as well as the effectiveness of the used herbicides between experimental sites were at the same level of importance.*

Keywords: *maize, herbicides control, weed density, weed diversity*

INTRODUCTION

The development and implementation of integrated weed management (IWM) strategies that provide good weed control is still a challenge that has to be met (VASILEIADIS, 2015). Control of weeds in maize is, very essential for obtaining good harvest. Suitable weed control practices in maize resulted in 77 to 96.7% higher grain yield than the weedy control in developing countries (KHAN et al., 2003).

All plants in the agrophytocenoses are strongly influenced by human activities and habitat factors, which includes primarily soil and weather conditions of particular year. Among these factors other factor is need to include, such as the structure of growing crops (ALDRICH and KREMER, 1997; STEPHENSON, 2000).

Maize is sown at the time when the soil is already sufficiently heated up and the plants growths during the 9 -12 days. Temperature conditions positively influences the emergence of weeds, what resulting to the necessity to maintain interrow area clean from emergence of

maize up to canopy establishment (LÍŠKA et al. 2002). As reported SMATANA and TÝR (2011), maize as row crops, even at optimal density, good condition, good health and the favourable weather is unable compete against weeds and suppress its below the biological and economical threshold of harmfulness during this relatively long period.

TÝR and VEREŠ (2012) mentioned the most dangerous species in canopy of maize as follows: *Chenopodium* spp., *Amaranthus* spp., *Echinichloa crus galli* (L.) P. Beauv, *Datura stramonium* (L.), *Fallopia convolvulus* (L.) A. Lôve, *Persicaria* spp., *Cirsium arvense* (L.) Scop, *Elytrigia repens* (L.) P. Beauv, *Avena fatua* (L.) and *Abutilon theophrasti* Medik in maize production region in Slovakia

In terms of sustainable and ecologically sound approaches would be appropriate gradually subside use of herbicides and begin to fully implement by preventive measures (cleaning seeds and, suitably date of harvest and post-harvest treatment, management of farmyard manure, weed control outside the agricultural production area, care of birds, etc.). We can broadly use indirect measures (properly crop rotation and appropriate cropping patterns, balanced nutrition and fertilization of plants, selection and cultivation of suitable crops and local varieties. Direct action, of which is significant mechanical tillage (primary, pre-sowing and cultivation interventions in vegetation during the growing season), followed by physical (flame weeder, electric current, infrared and gamma radiation) and biological (use of bioagents - natural enemies of weeds) (LEATHER, 1987; GRACE and TILMAN, 1990; RAWAT et al., 2013).

The aim of the research was to assess the density and species diversity of weeds in canopy of maize and herbicide activity protection in agro-climatic conditions at Slovak Republic maize production region (locality Plavé Vozokany) and sugar beet production region (locality Santovka) during three production years of 1998 - 2000 and evaluation of the impact of different agro-climatic conditions of the occurrence of weeds in maize fields.

MATERIAL AND METHODS

The first experimental site Plavé Vozokany is located in the south-eastern part of the district of Levice in maize production region. Altitude of area ranges from 150 m to 164 m above sea level. Soil is loamy and soil type consists of black and brown soils on loess and alluvial deposits. The average daily air temperature in the region (9.6 °C) classified the region as warm and very dry region. The annual amount of rainfall represents 604 mm and the annual amount of rainfall during the growing season reaches 330 mm. Santovka, the second location is located in the north-eastern part of the district of Levice in sugar beet production region. Altitude of the area ranges from 170 m to 220 m above sea level. Soil is loamy and soil type consists of brown soil on loess and alluvial deposits. The average daily air temperature in the region is less (9.2 °C) than the Plavé Vozokany site, but location is also classified as warm and very dry region with an average annual precipitation of 637 mm and 354 mm during growing season. Spring and summer weather condition of main experimental plots at Plavé Vozokany site are shown in the Table 1.

Table 1

Climatic conditions of spring and summer months on the locality Plave Vozokany in the years 1998 - 2000

Months		1998		1999		2000	
		Temperature °C	Rainfall mm	Temperature °C	Rainfall mm	Temperature °C	Rainfall mm
	IV.	12.3	54.7	12.2	67	14.1	56.3
Spring	V.	15.4	37	16.1	37.9	17.6	19,8
	VI.	20	122.8	19.1	142.2	21.7	3.5
Average IV - VI.		15.9	71.5	15.8	82.37	17.8	26.53
Sum IV - VI.		47.7	214.5	47.4	247.1	53.4	79.6
	VII.	20.8	83.3	21.4	159.1	21.4	77.4
Summer	VIII.	20.5	23.4	19.2	71	22.3	6.1
	IX.	14.9	166.9	18.3	8.3	15.2	15.5
Average VII. - IX.		18.7	91.2	19.6	79.47	19.63	33.00
Sum VII. - IX.		56.2	273.6	58.9	238.40	58.9	99.00

Year 2000, strictly differ in precipitation doses with comparison to the next two evaluated years.

Actual weed infestation was evaluated according of the occurrence of individual weed species under rating scale of current weed infestation shown in Table 2. The occurrence of weeds in maize was assessed for 3 times per growing season in five replications, on the control plots (without herbicide treatment), as well as on the areas treated with herbicides. The frame of 1 square meter was used. The first evaluation was conducted in the spring before application of herbicides on both sites equally. The second evaluation was carried out during the growing phase of 4 - 8 leaves. The third evaluation was carried out in the full flowering phase of maize. In addition the number of weeds and the total effectiveness of applied herbicides was evaluated according Abbott formula. Actual weed infestation was evaluated according Table 2.

Table 2

Actual weeds density scoring system

Group of weeds	*Actual weeds density description*				
	no	unique	weak	medium	strong
	degree of weedy				
	0	1	2	3	4
	Number of weeds plant per square meter				
Very dangerous	-	≤ 2	3 - 5	6 - 15	≥16
Less dangerous	-	≤ 4	5 - 8	9 - 20	≥ 21
Minor significance	-	≤ 8	9 - 15	16 - 30	≥ 31

Herbicides used (active ingredient - terms of applications (T1 – T2) and the commercial name of the herbicide) are shown in Table 3. In the Plavé Vozokany site, share of maize was grown annually on 58% - 79% in location Santovka grown annually on 56% - 75% fields. At both experimental sites maize was growing after cereal forecrop of winter wheat and spring barley.

Table 3

Herbicides used and date of application expressed in active ingredients and commercial name of herbicides at Plavé Vozokany and Santovka experimental site

Year	Herbicides used		
	term	Plave Vozokany site	Santovka site
1998	T1	atrazin (750 g ha^{-1}) – Atranex 50 SC (1.5 L ha^{-1}) + acetochlor (1536 g ha^{-1}) + dichlormid (256 g ha^{-1}) – Trophy (2 L ha^{-1})	atrazin (750 g ha^{-1}) – Atranex 50 SC (1.5 L ha^{-1}) + acetochlor (1536 g ha^{-1}) + dichlormid (256 g ha^{-1}) – Trophy (2 L ha^{-1})
1999	T1	atrazin (750 g ha^{-1}) – Atranex 50 SC (1.5 L ha^{-1}) + acetochlor (1536 g ha^{-1}) + dichlormid (256 g ha^{-1}) – Trophy (2 L ha^{-1})	atrazin (750 ha^{-1}) – Atranex 50 SC (1.5 l ha^{-1}) + acetochlor (768 g ha^{-1}) + dichlormid (128g. ha^{-1}) – Trophy (1 l. . ha^{-1})
	T2	-	clopyralid (240 g .. ha^{-1}) – Lontrel 300 (0,4 l ha^{-1}).
2000	T1	atrazin (750 g ha^{-1}) – Atranex 50 SC (1.5 L ha^{-1}) + acetochlor (1536 g ha^{-1}) + dichlormid (256 g ha^{-1}) – Trophy (2 L ha^{-1})	atrazin (750 ha^{-1}) – Atranex 50 SC (1.5 L ha^{-1}) + propisochlor (1680 g ha^{-1}) – Proponit 840 EC (2 L ha^{-1})

Term of evaluation: T1 – preemergent – during sowing or before crop and weed emergence (PRE); T2 – postemergent – after crop and weed emergence (POST)

RESULTS AND DISCUSSION

In 1988 spring with comparison to LTA was dry and warm, autumn vice versa wet and cold (Table 1). In this year at the locality Plavé Vozokany, the most abundant weed species in canopy of maize on control treatment without herbicide application listed in decreasing order of abundance were as follows: *Setaria viridis* (L.) P. BEAUV, *Echinochloa cruss – galli* (L.) P. BEAUV. and *Chenopodium album* L. All weeds belong to late-spring group of weeds. On herbicide control fields perennial weed *Cirsium arvense* (L.) SCOP. with average number of 2.9 plants per square meter was determined (Table 4).

The late-spring weeds created the largest pressure also at locality Santovka in 1998. The most abundant weeds were *Echinochloa cruss – galli* (L.) P. BEAUV, *Chenopodium album* L. *Echinochloa cruss – galli* (L.) P. BEAUV (Table 5).

On sprayed treatments the most abundant weed species was *Echinochloa cruss – galli* (L.) P. BEAUV.

The year 1999 was characterised by warm and moderately dry weather condition, summer was wet and warm, and autumn was cold and dry. On control treatments, the higher density was noted by *Echinochloa crus – galli* (L.) P. BEAUV. and *Atriplex* sp. The overwinter weed *Capsella bursa pastoris* (L.) MEDIC.) could be mentioned at the locality Plavé Vozokany. Pesticide control was very effective to the whole spectrum of weeds in canopy of maize.

On the herbicide treatments, the most abundant species at locality Santovka were *Echinochloa crus – galli* (L.) P. BEAUV and *Chenopodium album* L. from late-spring group, *Tripleurospermum perforatum* (L.) SCHULTZ-BIP from overwinter group, and perennial weed *Cirsium arvense* (L.) SCOP. Herbicide control was very effective except to perennial weed *Cirsium arvense* (L.) SCOP.

Year 2000 was characterised by wet and warm spring, and warm and dry summer and autumn. This year lack of precipitation creates very dry condition. In 2000, the most abundant weed species determined on control treatments were as follows: *Echinochloa crus – galli* (L.) P. BEAUV., *Chenopodium album* L., and *Persicaria lapathifolia* (RAF) S. F. GRAY, on the Plavé Vozokany site.

The Santovka experimental site was infested mainly by late-spring weeds as *Echinochloa crus – galli* (L.) P. BEAUV, *Chenopodium album* L., *Atriplex* sp. and *Setaria viridis* (L.) P. BEAUV in this year. Medium infestation (6 plants per m^2) of perennial weed *Convolvulus arvensis* L. was noted in both treated and untreated fields. Due to the deeper root system perennial weeds *Convolvulus arvensis* L. had better potential for growing in this dry period.

Table 4

Occurrence of weeds in the site Plave Vozokany in period of 1998 - 2000

Weeds		1998		1999		2000		Average 1998 - 2000	
		Without spraying	Treated	Without spraying	Treated	Without spraying	Treated	Without spraying	Treated
		number of weeds per m^2							
Early-spring	*Avena fatua* L	2.2	0.2	0.01	0.01	0.01	0.01	0.73	0.07
	Fallopia convolvulus L. A. LOVE	0.5	0.1	1.4	0.4	0.5	0.1	0.80	0.20
	total	2.7	0.3	1.4	0.4	0.5	0.1	1.53	0.27
Late-spring	*Echinochloa crus – galli* (L.) P. BEAUV	6.1	0.4	5.8	0.3	8.2	1.2	6.70	0.63
	Chenopodium album L.	4.2	0.2	3.4	0.1	5.4	0.6	4.66	0.33
	Atriplex sp.	3.2	0.3	4,5	0.3	2.6	0.1	2.76	0.23
	Setaria viridis (L.) P. BEAUV	7.3	0.5	2.7	0.2	4.5	0.2	4.83	0.3
	Persicaria lapathifolia (RAF) S. F. GRAY	1.5	0.1	2.5	0.1	9.1	1.2	4.36	0.45
	total	22.3	1.5	18.9	1.0	29.8	3.3	26.37	1.94
Overwinter weeds	*Tripleurospermum perforatum* (L.) SCHULTZ-BIP.	1.6	0.1	1.9	0.1	2.6	0.3	1.90	0.16
	Galium aparine L.	2.2	0.6	3.7	0.8	3.2	0.7	3.03	0.70
	Capsella bursa-pastoris (L.) Med.	2.3	0.2	4.7	0.9	2.2	0.3	4.06	0.27
	total	6.1	0.9	10.3	1.8	8.0	1.3	8.99	1.13
Perennial weeds	*Cirsium arvense* (L.) SCOP.	2.2	2.9	0.8	1.1	1.9	2.4	1.63	2.13
	Convolvulus arvensis L.	1.0	1.2	1.4	1.8	1.1	1.4	1.23	1.47
	total	3.2	4.1	2.2	2.9	3.0	3.8	2.86	3.47
total		**34.3**	**6.8**	**33.8**	**6.3**	**44.3**	**8.5**	**36.69**	**7.20**

According result of weed densities and weed diversity the group of late-spring weeds was dominant group of weeds in 2000.

In case of warm and wet condition during summer, the secondary weedness of *Tripleurospermum perforatum,Echinochloa crus-galli* (L.) P. BEAUV was noted. In this favourable condition regeneration capability of *Elytrigia repens* (L.) DESV was also increased. Warm and early spring of 1999 with deficit precipitation evoked germination of seeds and sprouting of vegetative reproductive organs from deeper soil layer such as *Cirsium arvense* (L.) SCOP. and *Convolvulus arvensis* L.

Total weed density in canopy of maize vary from 33.8 to 44.3 at Plave Vozokany fields and from 26.6 to 40 plants at Santovka fields with the highest density in dry year condition in 2000.

Herbicides application effectively decreased the weed infestation in an average from 7.2 at Plave Vozokany fields to 14.7 plants per m^2 at Santovka fields. During dry year condition the effectiveness of herbicides application was substantially less in Santovka fields with total weed density of 21 weeds per m^2.

The average weed abundance in different years was in the indirect dependence on the air temperature (r= -0.98317), but strongly dependent on rainfall (r =0.889926) at Plave Vozokany site.

Table 5

Occurrence of weeds in the Santovka in period of 1998 - 2000

Weeds		1998		1999		2000		Average 1998 - 2000	
		Without spraying	Treated	Without spraying	Treated	Without spraying	Treated	Without spraying	Treated
		number of weeds per m^2							
Early-spring	*Avena fatua* L.	0.01	0.01	0.01	0.01	5.7	2.0	1.9	0.66
	Fallopia convolvulus L. A. LOVE	2.5	2.0	1.5	1.0	1.0	1.0	2.0	1.33
	Polygonum aviculare (L.)	0.01	0.01	0.01	0.01	3.0	1.0	1.00	0,33
	total	2.5	2.0	1.5	1.0	9.7	4.0	4.90	2.32
	Echinochloa crus – galli (L.) P. BEAUV	17.0	8.0	15.0	0.3	16.0	5.0	16.0	4.43
	Chenopodium album L.	7.1	0.4	5.5	0.3	6.6	1.0	6.46	056
	Atriplex sp.	3.6	0.1	4.0	0.2	5.0	0.4	4.20	0.23
Late-spring	*Amaranthus retroflexus* L.	1.5	0.1	1.5	0.1	3.0	1.0	2.00	0.40
	Setaria viridis (L.) P. BEAUV	0.01	0.01	0.01	0.01	5.0	1.0	1.66	0.33
	total	29.2	8.4	26.0	0.9	35.6	8.4	30.32	5.95
Overwinter	*Tripleurospermum perforatum* (L.) SCHULTZ-BIP.).	0.01	0.01	5.0	1.0	0.01	0.01	1.66	0.33
	total	0.01	0.01	5.0	1.0	0.01	0.01	1.66	0.33
	Elytrigia repens (L.) DESV	0.01	0.01	0.01	0.01	2,0	2.7	0.66	0.90
Perennial	*Cirsium arvense* (L.) SCOP.	0.3	0.7	5.0	8.0	0.01	0.01	1.76	2.90
	Convolvulus arvensis L.	0.01	0.01	2.0	3.0	6.0	6.0	2.66	3.00
	total	0.32	0.72	7.01	11.01	8.01	8.71	5.08	5.80
total		32.00	11.30	26.60	14.90	40.00	21.10	39.96	14.76

Weed infestation was higher in the growing years when early spring to early summer was warm and humid. When this period was dry lower weed infestation was noted. The results we obtained correspond to the results reported by Líška et al. (2002), that in canopy of maize the most abundant weeds are: *Cirsium arvense* (L.) SCOP., *Persicaria* sp., *Echinochloa crus – galli* (L.) P. BEAUV, *Chenopodium* sp. and (*Elytrigia repens* (L.) DESV.

According results of TÝR and VEREŠ (2012) one of the most dangerous weed species in canopy of maize are *Chenopodium* spp., *Amaranthus* spp. and *Echinochloa crus – galli* (L.) P. BEAUV in maize growing region and *Persicaria* spp., *Atriplex* spp. *and Echinochloa crus – galli* (L.) P. BEAUV at sugar beet grooving region of Slovak Republic.

On the experimental plots treated with herbicides later occurred mainly perennial weeds and annuals late spring weeds which emerged after the expiry of applied herbicides, in all studied years in both locations. The effectiveness of the evaluated herbicides was very good even excellent (with respect for their ineffectiveness on perennial weeds). Differences in

overall weed infestation, as well as the effectiveness of the herbicide between monitored sites were not evident.

Our results confirm that during the study of short-term changes in plant communities, it is necessary to respect the fact that plant communities at every moment of its existence are going through various phases of seasonal development, as also mentioned LÍŠKA et al. (2008). We also agree with KOHOUT (1993), that knowledge of interactions between weeds and influences affecting its species and numerous representation on a plot, can significantly contribute to better decision-making process in a rational regulation of weeds.

In each farm, effective weed control system must be created, based on deep knowledge of the cause of reproduction of certain weed species and knowledge of its biological properties. It is necessary to use herbicides rationally and economically. Therefore it is necessary to precisely determine the prognosis of weed infestation, choose the most suitable herbicide, respectively combination of active substances and select the right method of its application (LÍŠKA et al., 2008). The crops sown into wide rows, including the maize are very sensitive to weed infestation and generally cannot be successfully grown without chemical or mechanical intervention (STEPHENSON, 2000).

CONCLUSIONS

The evaluated sites were infested on the level of strong weed infestation. The average abundance of weeds without herbicidal treatments ranged from 36.7 to 40 weed per m^2. Herbicides application decreased the weed infestation from 7.2 to 14.7 numbers per m2 in an average.

The average weed density in different years was in the indirect dependence on the air temperature (r= -0.98317), but strongly dependent on rainfall (r= 0.889926). Weed infestation was higher in the growing years when early spring to early summer was warm and humid. Lower weed infestation was noted when that period was dry. Differences in overall weed infestation, as well as the effectiveness of the used herbicides between monitored sites were at the same level of importance.

During dry year condition, the effectiveness of herbicides application was substantially less in Santovka fields with total weed density up to 21 weeds per m^2.

High pressure of late–spring weeds *Echinochloa cruss – galli* (L.) P. BEAUV, *Chenopodium album* L. and *Atriplex* sp. was noted at both experimental site. On Plavé Vozokany location also late–spring weeds *Setaria viridis* (L.) P. BEAUV and *Persicaria lapathifolia* (RAF) S. F. GRAY counted high density.

According weed densities and weed diversity evaluation, the late-spring weeds were dominant group of weeds occurred in maize field of south-western Slovakia.

ACKNOWLEDGEMENTS

This paper was supported by VEGA project 1/0544/13 “The research of agrienvironmental indicators of sustainability and production capability of agroecosystem by diversification of crop rotation pattern in changing climate.

BIBLIOGRAPHY

1. ALDRICH, R. J. - KREMER, R. J. 1997. Principles in Weed Management. 2. ed. Iowa : Iowa State University Press. 455 pp. ISBN 0-8138-2023-5.
2. GRACE, J. B., TILMAN, D. 1990. Perspectives on Plant Competition. San Diego : Academic Press, Inc.
3. KHAN, M.A., MARWAT, K.B., KHAN, N. 2003. Efficacy of different herbicides on the yield and yield components of maize. Asian J. Plant Sci. 2(3):300-304.

4. KOHOUT, V. 1993. Weed Control of Field, Praha : MZČR, (in Czech)
5. LEATHER, G. R. 1987. Weed control using allelopathic sunflowers and herbicide. In *Plant and Soil*, vol. 98, no. 1, pp. 17-23.
6. LÍŠKA, E., ČERNUŠKO, K., HUNKOVÁ, E., OTEPKA, P. 2002. Weed Biology. Nitra : SPU in Nitra (in Slovak).
7. RAWAT, L. S., MAIKHURI, R. K., NEGI, V. S. 2013. Inhibitory effect of leachate from *Helianthus annuus* on germination and growth of *Kharif* crops and weeds. In Acta Ecologica Sinica, vol. 33, no. 5, pp. 245-252.
8. SMATANA, J., TÝR, Š. 2011. Základy herbológie. 1. ed. Nitra : Slovak Agriculture University, 125 p. ISBN 978-80-552-0579-3
9. STEPHENSON, G. R. 2000. Herbicide use and world food production: Risk and Benefits. In Abstract of 3rd Intern. Weed Science Congress. Foz Do Iguassu, Brazil, pp. 240.
10. TÝR,Š., VEREŠ, T. 2012. Top 10 of most dangerous weed species in maize stands in the Slovak republic in the years 2000-2010. In Research Journal of agricultural Science, 44 (2), pp. 104- 107.
11. VASILEIADIS, V.P., OTTO, S., VANDIJK, W, UREK, G., LESKOVŠEK, R., VERSCHWELE, A., FURLAN, L., SATTIN, M. 2015. On-farm evaluation of integrated weed management tools for maize production in three different agro-environments in Europe: Agronomic efficacy, herbicide use reduction, and economic sustainability. Europ. J. Agronomy, 63, 71–78. doi:10.1016/j.eja.2014.12.001
12. LÍŠKA, E. (eds.) et al. 2008. General Crop Production. Nitra : SPU in Nitra (in Slovak).