Effect of tillage and crop rotation on weed infestation in maize

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Abstract: The aim of this study was to determine the effect of different tillage and crop rotation on weed infestation in maize. The observation was made at the experimental site in Žabčice, which belongs to corn production areas, in 2013 and 2014. The soil was treated in two variants. The first option was the traditional method of tillage (plowing). The second variant was shallow tillage to a depth of 0.05 m (minimum tillage). Crop rotation was another factor influencing weed infestation of maize (maize monoculture, Norfolk crop rotation). The obtained data were evaluated by multivariate analysis of ecological data. Different variants of tillage and crop rotation affect the occurrence and number of certain species, it follows from this analysis. The experimental results show, that the lowest weed infestation was on the variant of maize monoculture. Lower infestation was on the variant with traditional tillage.

Key-Words: weeds, maize, soil tillage, crop rotation

Introduction

Maize is one of the most grown crops on the planet today. The reason for this trend is a many-sided utilization of maize (e.g. human nutrition, animal feed, industrial and energy usage), [1].

While the average yield of maize is more than 8 $t.ha^{-1}$ in developed countries, it is only 3 $t.ha^{-1}$ in the developing countries [2]. Cultivation of maize faces a number of problems especially on soils threatened by erosion. A reduction of soil erosion is reliant on the structure of soil surface, which in principle are better at reduced tillage [3, 4]. Soil protective technologies of cultivation create a new framework for maize planting as well as for growth of weeds [5]. Soil cultivation approaches can affect hydraulic soil features. The differences in the porosity between the soil tillage practices are strongest in the depth of 0.08 m from the soil surface [6].

Miscellaneous ways of soil cultivation have influence on the bulk density. No-tillage increases bulk density by 48%, manual hoeing by 61%, disc cultivation by 55% and stubble breaking by 57% [7]. The stability of soil aggregates is then higher when no-tillage is used, which has direct impact on the soil resistance towards the water erosion [8]. Millions of growers of any size use no-tillage to their profit. This technology improves soil productivity by rising biological activity, reducing the use of fertilizers and decreasing manual and financial costs on farming [9]. The use of no-tillage is accompanied with higher content of soil water during dry months and with periods of unevenly distributed precipitation [10]. Interlinear content of soil water is also higher than in the row, due to the significantly lower soil density in the soil row [11].

Based on the experiments from the Illinois state, where adoption of no-tillage was not easily accepted and despite the environmental benefits, maize yields did not achieve satisfactory results. Lower soil temperatures during no-tillage suspended the development of planting and early growth compared to the conventional tillage at the beginning of the growing season [12]. Effect of tillage on weeds has been studied by number of authors [13, 14, 15]. However, most authors focus their attention on the growth of narrow-row cereals (wheat, barley). This is probably associated with the use of herbicides in stands of maize, which greatly limits the occurrence and harmfulness of weeds. Nevertheless, the presence and the spectrum of weed species in maize change depending on tillage.

Maize is crop in which the weed species spectrum is relatively narrow [16]. *Chenopodium*, *Amaranthus*, *Persicaria*, *Echinochloa crus-galli* are typical weeds of Czech Republic. *Setaria pumila* and other late spring weeds such as *Datura stramonium* may also occur in some locations.

Fallopia convolvulus belongs to typical weeds occurring in maize, particularly due to its high resistance against a number of soil and foliar herbicides. Perennial species such as *Elytrigia repens*, *Cirsium arvense* and *Artemisia vulgaris* are relatively easy to enforce in maize. Above-mentioned weed spectrum is typical for maize areas in the Czech Republic [17, 18, 19]. *Tripleurospermum inodorum, Capsella bursa-pastoris* and *Thlaspi arvense* are cosmopolitan species mainly from the group of overwintering weeds. Their incidence is mostly influenced by weather conditions during that year [20, 21, 22], [23]. The results of these studies show that the different intensity of weed infestation by various species may reduce the yield by 12 - 37%.

Material and Methods

Characteristic of Experimental Location

The experimental plots are located in the cadastral of municipality Žabčice (16° 37´ E, 49° 01´ N). Žabčice is located in the corn production area with a flat terrain and an altitude of 184 meters. The village Žabčice is approximately 25 km south from Brno. The geographical surrounding of Žabčice can be considered as very warm and dry. According to weather station, the annual rainfall in the last 30 years was around 483.3 mm with the average annual temperature of 9.2°C. The long-term data of an average rainfall as well as temperatures can be found in Table 1. The measured data were used from an experimental Meteorological station of Mendel University, in Žabčice.

The territory of Žabčice is located in the vicinity of Dyjsko-Svratka valley, which consists mainly of Neogene sediments. Farmland is partially represented by alluvial plain and quaternary gravel. The habitat is located in young flood plain of the gley-soil and is situated in the alluvial area of the river Svratka. These soils have been created in the holocene, calcareous alluvial sediments. Gluing process is significantly growing to a depth of the soil, which is cause due to the permanent groundwater. The color of the gley horizon is grayish brown and at a depth of up to 90 cm has a clayey structure. The soil reaction is in the arable horizon of the soil neutral, pH is 6.9 and the content of humus is average (2.28%).

Description of Field Trial

The first field trial is monoculture of maize, which has been consecutively grown since 2002. The size of one parcel is 5.3 m x 7.0 m. The crop rotation in the second field attempt is designed according to Norfolk crop rotation system and was established in 1970 and partially changed in 2002. The size of one parcel is 5.3 m x 7.0 m. Crop rotation is as follows: alexandria clover, winter wheat, maize (for grain) and spring barley. NK Silitop was used hybrid of maize in 2013 and SY Beautiful in 2014, with sowing rate 90 000 plant / ha.

Evaluation of Weed Infestation

The weed infestation was evaluated by using a numerical method. Weeds were counted in the area of 1 m^2 in 24 repetitions in each variant of tillage and crop rotation. The evaluation of maize growth was held every July two years in row (2013 and 2014). Names of found species were used according to Kubát [24]. A multivariate analysis of ecological data was used to determine the effect of tillage and crop rotation on the weed species in maize. Selection of the optimal analysis followed the length of the gradient (*Lengths of Gradient*), which was detected by segment analysis DCA (*Detrended Correspondence Analysis*). Furthermore, redundancy analysis RDA was used.
A total number of 499 permutations were calculated in Monte-Carlo test. Collected data were processed by a computer program called Canoco 4.0 [25].

Table 1 Long-term precipitation totals and temperature averages for each month (1961 to 1990)

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
Average temperatures (°C)	-2.0	0.2	4.3	9.6	14.6	17.7	19.3	18.6	14.7	9.5	4.1	0.0
Precipitation (mm)	25	25	24	33	63	69	57	54	36	32	37	26

Table 2 The average number of weed individuals found in maize

	Soil tillage		Crop rotation		Year	
	CT	MT	Mono	Norf	2013	2014
Amaranthus sp.	0.17	0.46	0.49	0.14	0.60	0.02
Anagallis arvensis	0.11	0.36	0.18	0.30	0.43	0.05
Cirsium arvense	0.25	0.25		0.50	0.48	0.02
Convolvulus arvensis	0.35	5.09	1.72	3.73	1.48	3.97
Datura stramonium	0.05	0.21	0.26	0.00	0.19	0.07
Echinochloa crus-galli	3.84	5.63	2.55	6.92	4.81	4.66
Euphorbia helioscopia	0.01			0.01		0.01
Fallopia convolvulus	0.82	0.22	0.32	0.72	0.54	0.50
Galium aparine	0.29	0.50	0.04	0.75	0.43	0.36
Chenopodium album	1.56	0.58	0.61	1.53	1.29	0.85
Chenopodium hybridum	0.16	0.00	0.16	0.00	0.14	0.02
Lamium amplexicaule	0.24	0.08	0.00	0.32	0.24	0.08
Malva neglecta	0.18	0.53	0.07	0.64	0.31	0.40
Microrrhinum minus	0.01		0.01			0.01
Persicaria lapathifolia	0.26	0.11	0.02	0.35	0.32	0.05
Polygonum aviculare	0.03	0.26	0.26	0.03	0.22	0.07
Stellaria media	0.11	0.16	0.05	0.22	0.26	0.01
Thlaspi arvense	0.01	0.19		0.20	0.16	0.04
Trifolium incarnatum	0.30	0.25		0.55	0.34	0.21
Triticum aestivum	0.00	0.18		0.18	0.09	0.08
Veronica persica	0.02	0.10	0.03	0.09	0.10	0.02
Veronica polita	0.00	0.04	0.04	0.00	0.03	0.01
Viola arvensis	0.11	0.00	0.02	0.09	0.09	0.02
Number of individuals	8.91	15.21	6.84	17.27	12.56	11.55

Results and Discussion

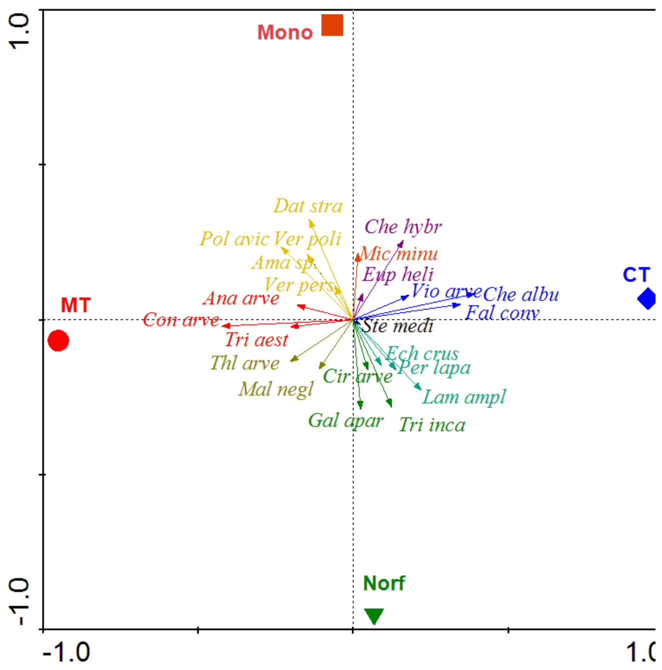
Twenty-three (23) various species of weeds were found within the monitoring period. The average numbers of weeds are shown in Table 2.

DCA analysis was used as first for statistical evaluation of the results. This analysis calculated the length of gradient (*Lengths of Gradient*), as 3.238. Based on this calculation and for further processing was selected redundancy analysis (RDA) . The RDA analysis defines the spatial arrangement of particular weed species, tillage variants and the crop rotation, on the basis of obtained data, which represent frequency of weed occurrence. This is subsequently graphically displayed in the ordination diagram. Weed species are represented by vectors (arrows), tillage options and crop rotation are displayed as the points of various form and color. In case that the vector of relevant weed species tends to the concrete point of tillage variant or crop rotation means that its occurrence is more bounded to this type of treatment.

Results of redundancy analysis, which evaluated the influence of tillage and crop rotation on weed occurrence are significant at the significant level $\alpha = 0.002$ for all canonical axes. Based on the RDA analysis (Fig. 1) it is possible to divide found weed species into 8 groups.

First group of weed occurred mainly when the minimum tillage (MT) was used and is represented by these species: *Anagallis arvensis*, *Convolvulus arvensis*, *Triticum aestivum*. Second group of weed species occurred in connection of minimum tillage together with growing in monoculture: *Amaranthus* sp., *Datura stramonium*, *Polygonum aviculare*, *Veronica persica*, *Veronica polita*. Third group of weeds occurred especially in monoculture: *Microrrhinum minus*. Fourth weed group was formed based on the combination of monoculture and conventional tillage: *Euphorbia helioscopia*, *Chenopodium hybridum*. Fifth group of weed occurred mainly in connection with conventional tillage: *Fallopia convolvulus*, *Chenopodium album*, *Viola arvensis*. Sixth group of weed is represented by the combination of Norfolk crop rotation and conventional tillage: *Echinochloa crus-galli*, *Lamium amplexicaule*, *Persicaria lapathifolia*. Seventh group of weeds occurred especially on the variant of Norfolk crop rotation and is represented by these species: *Cirsium arvense*, *Galium aparine*, *Trifolium alexandrium*. The last eighth group of weeds occurred mainly in combination of Norfolk crop rotation system and minimum tillage: *Malva neglecta, Thlaspi arvense*.

Fig. 1 Ordination diagram expressing relations between tillage variants, crop rotation and weed species in growths of maize



Legend: CT – conventional tillage, MT – minimum tillage, Mono – monoculture of maize, Norf – Norfolk crop rotation system.
Ama sp. – Amaranthus sp., *Ana arve – Anagallis arvensis, Cir arve – Cirsium arvense, Con arve – Convolvulus arvensis, Dat stra – Datura stramonium, Ech crus – Echinochloa crus-galli, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Gal apar – Galium aparine, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Lam ampl – Lamium amplexicaule, Mal negl – Malva neglecta, Mic minu – Microrrhinum minus, Per lapa – Persicaria lapathifolia, Pol avic – Polygonum aviculare, Ste medi – Stellaria media, Thl arve – Thlaspi arvense, Tri inca – Trifolium alexandrium, Tri aest – Triticum aestivum, Ver pers – Veronica persica, Ver poli – Veronica polita, Vio arve – Viola arvensis.*

Echinochloa crus-galli was the most frequently delegated species. Its presence was very strong especially in the combination of Norfolk crop rotation and minimum tillage. According to earlier studies, the annual grasses are more often represented on the soils with reduced soil tillage [26]. There have been problems with species *Setaria viridis* in North America, where this species was more frequently observed in the areas with minimum tillage [27].

Weed species *Chenopodium album* occurred the most in the variation of conventional tillage. According to the results of other experiments was its density around 500 plant.m^{-2}, while in the other variations was always lower [28]. Based on the experiment evaluation of four different systems of maize cultivation in the time period of five years monoculture was found, that the cultivation systems established on reduced tillage contained more weed especially by species *Chenopodium album* [29]. The findings of both authors are in disagreement with the results of our experiment. The reason will be most probably in high stock of *Chenopodium album* seeds in soil, which is caused by conventional tillage.

Conclusion

Soil tillage and crop rotation significantly affect both the intensity of weed infestation as well as the spectrum of the weed species. The experimental results show, that the lowest weed infestation was in the variation with maize monoculture. Fewer weed infestation was on the variant of conventional tillage. *Echinochloa crus-galli, Convolvulus arvensis, Chenopodium album* and *Fallopia convolvulus* were the most often occurring weed species.

Acknowledgement

This work arose as project output of Internal Grant Agency AF MENDELU, number: IP 12/2014 „ The influence of different tillage technologies on weeds in maize monoculture". The contribution was originated with financial support of project NAZV QJ1210008, with title: „Inovation of cereal cultivation systems in different agroecological conditions of Czech Republic".

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