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Effect of Tillage Technology on Species Composition of Weeds in Monoculture of Maize

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***Abstract*—**The effect of tillage technology of maize on intensity of weed infestation and weed species composition was observed at experimental field. Maize is grown consecutively since 2001. The experimental site is situated at an altitude of 230 m above sea level in the Czech Republic. Variants of tillage technology are CT: plowing – conventional tillage 0.22 m, MT: loosening – disc tillage on the depth of 0.1 – 0.12 m, NT: direct sowing – without tillage. The evaluation of weed infestation was carried out by numerical method in years 2012 and 2013. Within the monitoring were found 20 various species of weeds. Conventional tillage (CT) primarily supports the occurrence of perennial weeds (*Cirsium arvense, Convolvulus arvensis*). Late spring species (*Chenopodium album, Echinochloa crus-galli*) were more frequently noticed on variants of loosening (MT) and direct sowing (NT). Different tillage causes a significant change of weed species spectrum in maize.

***Keywords*—**Weeds, maize, tillage, loosening, direct sowing.

I. Introduction

MAIZE is one of the most grown crop on the planet today. The increase in growing area of maize is apparent both in Europe and worldwide. The reason for this trend is many-sided utilization of maize (human nutrition, animal feed, industrial and energy usage), [1].

Approximately 96 million hectares of maize accrue to the developing countries, from 140 million hectares of maize cultivated around the world. More than half area of grown maize is formed by four countries, China (26 million ha), Brazil (12 mil. ha), Mexico (7, 5 mil. ha) and India (6 mil. ha). Although up to 68% of total area of planted maize is situated in the territory of developing countries, their participation on world maize production is only 48%. Low average yields in developing countries are responsible for wide gap between global share of area and production. The average yield of maize is more than 8 $t.ha^{-1}$ in developed countries, while it is little less than 3 $t.ha^{-1}$ in developing. Considerable differences in climatic conditions and levels of agricultural technology form up to 5 $t.ha^{-1}$of yield variance between developing and developed countries [2].

Cultivation of maize faces a number of problems especially on soils threatened by erosion. Reductions of soil erosion is reliant on soil surface layer structure, water infiltration into the soil and water resistance of soil aggregates, which in principle are better at reduced tillage [3], [4]. Soil protective technologies of cultivation create new framework for maize planting and equally for weeds [5].

Unfavourable intensification of maize production systems has specific consequences on high degree of soil erosion, particularly on hillsides of tropical lowlands and in area of middle altitude. Lack of investments to the antierosion soil protection and widened use of soil protective tillage are the main reasons of soil erosion [6]. Minimum tillage reduces the impacts of soil erosion and increases the efficiency of soil water utilization, in supposition of presence remaining biomass on soil surface, which often leads to colder and moisture soil than after traditional plowing [7], [8].

Soil cultivation approaches can affect hydraulic soil features and dynamical processes, influencing chemical actions and plant growth in place and time. The differences in porosity between soil tillage practices are strongest in the depth of 0.08 m from soil surface [9]. Miscellaneous ways of soil cultivation have influence on bulk density. No-tillage increases bulk density for 48%, manual hoeing for 61%, disc cultivation for 55% and stubble breaking for 57% [10]. The stability of soil aggregates is higher with use of no-tillage, which certainly has direct impact on soil resistance towards the water erosion [11].

Millions of growers, big or small, use no-tillage to their profit. This technology has been used on 111 million ha over the world recently. It is one of the most effective methods, how to protect and make better soil. This technology improves soil productivity by rising biological activity, reducing the fertilizers usage and decreasing working and financial costs on farming [12].

Use of no-tillage is accompanied with higher content of soil water during the dry months and with periods of unevenly distributed precipitation [13]. Mostly interlinear content of soil water is higher than in the row, due to the significantly lower soil density in soil row. Considerably higher drought in row causes bigger differences in content of soil water in the nearest future of vegetation [14].

Based on the experiments from the Illinois state, where adoption of no-tillage were not easily accepted despite the environmental benefits, maize yields did not achieve

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satisfactory results. Lower soil temperatures during no-tillage suspended development of planting and early growth compared to the conventional tillage at the beginning of the growing season. Decreased soil temperatures are directly related to amount of surface residues. Similarly, higher soil moisture and lower soil temperature may delay maize sowing in no-tillage [15].

Effect of tillage on weeds was and is studied by number of authors [16]-[18]. However, most authors focus their attention on growths of narrow-row cereals (wheat, barley). The growths of maize are neglected from this point of view. 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 spectrum of weed species in maize changes depending on tillage.

Maize is crop in which the weed species spectrum is relatively narrow [19]. *Chenopodium*, *Amaranthus*, *Persicaria*, *Echinochloa crus-galli* are typical weeds of Czech Republic. *Setaria pumila* and other late spring weeds such as *Datura stramonium* may occur in some locations.In view of the fact that *Datura stramonium* germinates at higher temperatures, this weed speciesmostly eludes to the herbicidal intervention and is capable to create considerable biomass in very short time. Subsequently *Datura stramonium* degrades silage maize thanks to its toxicity. *Fallopia convolvulus* belongs to typical weeds occurring in maize, particularly due to its high resistance againts 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 characteristic for typical maize area of Czech Republic. The occurrence of these weeds in maize is confirmed by other studies [20]-[22]. *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. There are a number of authors, who have dealt with intensity of weed infestation of maize and its resulting impact on yield [23]-[26]. The results of these works showed that at the different intensity of weed infestation by various species, it may lead to reduction of yield about 12-37%.

Attention will be given to assess the impact of maize cultivation technology on intensity of weed infestation and weed species composition in this submitted contribution. The results conduce to understanding of relations and links between tillage technology and weeds. Furthermore those species, which can become problematic on lands with minimum tillage in growths of maize, will be identified.

II. Materials and Methods

A. Characteristic of Experimental Locations

A field experiment was established to monitor the impact of various tillage on the maize production by Agroservis 1. Zemedelska corp. in 2001.Experimental field is located at Visnove (South Moravia, Czech Republic) in altitude of 230 m a.s.l. Long-term average temperature reaches 8.5°C and average annual precipitation is 470 mm.

B. Description of Field Trial

The field trial is designed as long-term, when maize is consecutively grown on as monoculture since 2001. The experimental field was divided into three parts, where three different soil cultivations are applied. The area of one part is 150 m x 100 m. The method of tillage is an agricultural intervention, which is unchanged for whole duration of trial. Observed soil tillage variants:

- CT: plowing – conventional tillage to the depth 0.22 m, harrowing in spring, loosening before sowing, sowing with fertilizer under the heel, flattening,
- MT: minimum tillage – disc tillage to the depth 0.10 – 0.12 m, loosening before sowing, sowing with fertilizer under the heel, flattening,
- NT: direct sowing–no-tillage, sowing with fertilizer under the heel

C. Evaluation of Weed Infestation

The weed infestation was evaluated using a numerical method. Weeds were counted in area of 1 m^2 in 30 repetitions in each variant of tillage. The evaluation of growths of maize was held every August in 2012 and 2013. Names of found species were used according to Kubát [27].

D. Statistical Data Processing

A multivariate analysis of ecological data was used to determine the effect of tillage on 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, canonical correspondence analysis CCA (*Canonical Correspondence Analysis*) was used. A total number of 499 permutations were calculated in Monte-Carlo test. Collected data were processed by a computer program Canoco 4.0 [28].

III. Results and Discussions

It was found 20 various species of weeds during the monitoring. The average numbers of weeds in tillage variants and years of monitoring are shown in Table I.

DCA analysis was used as first for statistical evaluation of the results of weed infestation in maize. This analysis calculated the length of gradient (*Lengths of Gradient*), as 4.387. On the basis of this calculation was selected canonical correspondence analysis CCA for further processing. This method defines spatial arrangements of individual weed species and tillage variants, based on the data with the frequency of weed species occurrence. The results are consequently graphically expressed by using the ordination diagram. Weed species and observed variants of factors (tillage) are displayed by points with different shape and color.

Results of CCA analysis, which assessed the effect of tillage on weed occurrence, are significant at the significance level $\alpha = 0.002$ for all canonical axes (Fig. 1). There were found four groups of weed species based on the analysis of

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CCA.

The first group consists of weed species which could be found primarily on the variant of conventional tillage (CT): *Cirsium arvense, Convolvulus arvensis, Sonchus oleraceus, Thlaspi arvense, Lathyrus tuberosus, Conyza canadensis, Veronica polita.*

The second group of weeds occurred primarily on variant with loosening (MT) and these are following species: *Chenopodium album, Urtica dioica, Datura stramonium, Persicaria lapathifolia.*

The third group of weeds was especially on variant with direct sowing (NT): *Echinochloa crus-galli, Fallopia convolvulus, Polygonum aviculare, Anagallis arvensis, Rubus* spp., *Viola arvensis.*

Species that occurred mainly on both variants with reduced tillage (loosening – MT, direct sowing – NT), can be classified into the fourth group. It is these species: *Amaranthus* spp., *Mercurialis annua, Setaria pumila.*

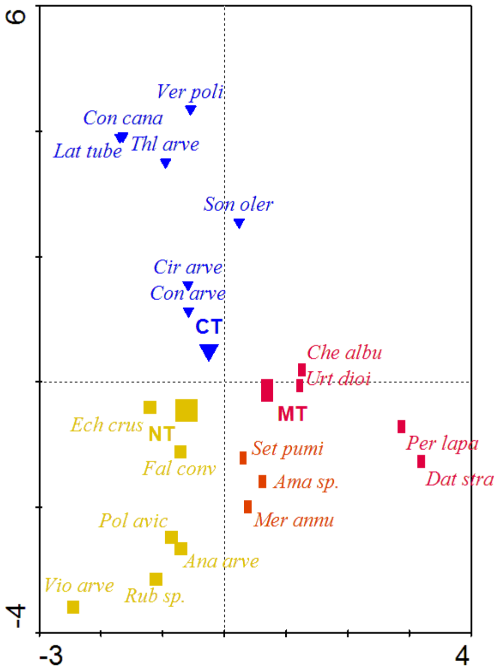

Fig. 1 Ordination diagram expressing relations between tillage variants and weed species in maize monoculture (Trace = 0.895, F-ratio = 7.931, P-value = 0.002)

Explanatory notes: CT: plowing – conventional tillage, MT: minimum tillage, NT: no-tillage. *Ama* sp. – *Amaranthus* spp., *Ana arve – Anagallis arvensis, Cir arve – Cirsium arvense, Con arve – Convolvulus arvensis, Con cana – Conyza canadensis, Dat stra – Datura stramonium, Ech crus–Echinochloa crus-galli, Fal conv– Fallopia convolvulus, Che albu–Chenopodium album, Lat tube– Lathyrus tuberosus, Mer annu–Mercurialis annua, Per lapa– Persicaria lapathifolia, Pol avic–Polygonum aviculare, Rub sp.– Rubusspp., Set pumi–Setaria pumila, Son oler– Sonchus oleraceus, Thl arve–Thlaspi arvense, Urt dioi– Urtica dioica, Ver poli– Veronica polita, Vio arve–Viola arvensis*

TABLE I
AVERAGE NUMBER OF WEEDS

Weeds species (pcs.m^{-2})	Soil tillage			Year of monitoring	
	CT	MT	NT	2012	2013
Echinochloa crus-galli	2.85	1.25	4.07	3.68	1.77
Chenopodium album	1.97	5.47	0.63	5.27	0.11
Cirsium arvense	2.38	0.62	0.70	0.81	1.66
Convolvulus arvensis	1.65	0.47	0.65	0.31	1.53
Urtica dioica	0.58	1.07	0.23	0.06	1.20
Mercurialis annua	0.07	0.38	0.42		0.58
Amaranthus sp.	0.07	0.33	0.25	0.08	0.36
Datura stramonium		0.62			0.41
Polygonum aviculare	0.03	0.17	0.38	0.09	0.30
Setaria pumila	0.10	0.20	0.20		0.33
Fallopia convolvulus	0.08	0.18	0.22	0.32	
Rubus spp.		0.07	0.30		0.24
Sonchus oleraceus	0.12	0.03			0.10
Viola arvensis			0.10	0.01	0.06
Thlaspi arvense	0.10				0.07
Anagallis arvensis		0.03	0.05	0.02	0.03
Persicaria lapathifolia		0.03		0.02	
Lathyrus tuberosus	0.02			0.01	
Conyza canadensis	0.02			0.01	
Veronica polita	0.02			0.01	
Number of individuals	10.05	10.92	8.20	10.70	8.74

CT: plowing – conventional tillage, MT: loosening – minimum tillage, NT: direct sowing – no-tillage.

The results show, that there are significant changes in weed species spectrum under different tillage variant in maize monoculture. According to statistical analysis, main differences were found between conventional tillage on the one hand and loosening and direct sowing on the other hand.

Conventional tillage (CT) supports the occurrence of perennial weed species (*Cirsium arvense, Convolvulus arvensis, Lathyrus tuberosu*) and overwintering weeds (*Thlaspi arvense, Veronica polita*).

Late spring species (*Chenopodium album, Datura stramonium, Persicaria lapathifolia, Echinochloa crus-galli,Amaranthus* spp., *Mercurialis annua, Setaria pumila*) were more frequently observed on variants with loosening (MT) and direct sowing (NT). We can assume that by introducing the reduced soil tillage (loosening, direct sowing) could be expected mainlythe increase of late spring species such as *Chenopodium album, Datura stramonium, Echinochloa crus-galli, Amaranthus* spp.

Echinochloa crus-galli was the most frequently delegated species. Its presence was very strong especially on the variant of direct sowing (NT). According to earlier works are annual grasses more often represented on soils with direct sowing [29]. Related species is *Setaria pumila*, which occurred also mainly on variants with reduced tillage (MT, NT). There have been problems with species *Setaria viridis* in North America, where this species was more frequently observed on variant of minimum tillage [30]. Compared to conventional tillage, the incidence of species *Setaria viridis* and *Setaria glauca* in maize was highest in loosening or direct sowing variant [31].

The most numerous species on the variant of loosening (MT) was *Chenopodium album*. According to the results of other experiments was its density around 500 plant.m^{-2} , while on the other variants was always lower [31]. Based on the experiment evaluation of four different systems of maize cultivation in five years monoculture was found, that the cultivation systems established on reduced tillage were weedier especially by species *Chenopodium album* [32]. The findings of both authors are in agreement with the results of our experiment. They confirmed a higher incidence of *Chenopodium album* at the loosening (MT).

Occurrence of species *Cirsium arvense* was mainly on the variant of conventional tillage, where was as the second most common weed. However, according to the results of other authors, the population of perennial weeds, such as *Cirsium arvense*, is increasing by reduction of the tillage depth [33]. On the other hand, the occurrence of perennial weeds has not been influenced by any tillage [34]. From our results is apparent that the presence of *Cirsium arvense* was lower in reduced tillage. This might be caused by accumulation of crop residues from maize on the soil surface or just below the surface.

Except of common weeds, some other weed species which are not typical for Czech Republic were found, such as *Urtica dioica, Rubus* spp. and *Mercurialis annua.* All occurred mainly on the variants of reduced tillage. Specific conditions of maize monoculture probably enable to these atypical weed species to assert on arable lands. Further, it is obvious that reduced tillage supports their occurrence.

For some certain weed species are new conditions of reduced tillage satisfactory and they can quickly adapt to them. This allows them to survive or expand eventually on this environment.

IV. Conclusion

Different soil tillage causes significant change in weed species spectrum in maize. Conventional tillage (CT) supports the occurrence of perennial weed species (*Cirsium arvense, Convolvulus arvensis*). Late spring species (*Chenopodium album, Echinochloa crus-galli)* were more frequently observed on variants with loosening (MT) and direct sowing (NT).

If there were a change in cultivation technology from conventional tillage to reduced (loosening, direct sowing), we can expect an increase particularly of late spring species, namely *Chenopodium album, Datura stramonium, Echinochloa crus-galli, Amaranthus* spp.

The occurrence of some species which usually don't belong to typical field weeds for this locality (*Urtica dioica, Rubus* spp*., Mercurialis annua*) is another interesting finding. We can assume that their incidence is supported by minimum tillage and monoculture of maize.

Soil cultivation may act as selective factor on weeds and prefer individuals with features, thanks to them they survive. This is a base of process called microevolution on arable soil [35].

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