The influence of precipitation and soil tillage on weeds in winter wheat

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Abstract

The field trial is located at an experimental station of Mendel University in Brno (location Žabčice, Czech Republic). Long-term annual average temperature is 9.3 °C and long-term annual precipitation is 483.3 mm. Temperature and precipitation data were obtained from meterological site at the experimental station in Žabčice. It was used a seven-step crop rotation system at this field attempt. Three variants of soil tillage (conventional tillage, minimum tillage, no-tillage) were applied to each crop within the seven-step crop rotation system. A weed infestation was evaluated by counting method in growths of winter wheat. It was found 44 weed species within the ten years of monitoring. We can state based on the results of canonical correspondence analysis, that the higher precipitation during the months of December and January support the higher occurrence of *Fallopia convolvulus*. Lower precipitation during February boost the incidence of species *Medicago sativa* and *Papaver rhoeas*, and on the contrary higher precipitation in this month support the occurence of species *Veronica persica.*

Keywords: weeds, precipitation, tillage, weed infestation forecast, winter wheat

Introduction

Weed occurrences significantly affected by the cultivated crop species, crop rotation, and primarily by the weather conditions in individual years. A number of works points out to excessive differences in the weed infestation intensity and the species composition of weed communities (Légère, Stevenson and Benoit 2005, Tuesca, Puricelli and Papa 2001).

The amount of precipitation influences not only soil bulk density and soil water content, but also the values of soil penetration resistance. Long-term processing of soil without plowing or shallow processing by a disc cultivator contributes to the soil compactness and water content and it was ascertained that the relationship between the penetration resistance of the soil, bulk density and soil water is linear (Carter, 1988).

The most decisive meteorological parameters affecting the intensity of weed infestation include rainfall. What is important is the amount of precipitation and the time of occurrence. All of these factors affect weed seeds in the soil and co-determine their germination. The technology of soil tillage significantly affects soil properties and changes the impact of precipitation. Ultimately, these facts may jointly influence the occurrence of weeds. This contribution deals with the relation between rainfall in selected months and subsequent weed infestation of winter wheat and suggests possibilities of a certain forecast of weed intensity based on the overall precipitation amount in the month concerned.

Materials and methods

The field experiment was performed at Mendel University agricultural enterprise in Žabčice, Czech Republic. This area is part of the geomorphological territory of Dyje and Svratka Basin. The altitude of the experiment is 185 meters above sea level in a flatland.

Long-term average annual temperature is 9.3 °C and long-term annual aggregate precipitation is 483.3 mm. Data concerning temperature and amount of precipitation were obtained from the meteorological station in the experimental enterprise in Žabčice.

The field experiment was established in 2010 and covers the area of 2.3 ha (100 m x 225 m). The size of individual parcels is 1,000 m^2 (100 x 10 m). The seven-step crop rotation was applied in the field experiment. The succession of crops was as follows: gourd alfalfa (*Medicago sativa*) – the first year, alfalfa wheat – the second year, **winter wheat** (*Triticum aestivum*), forage maize (*Zea mays*), **winter wheat**, sugar beet (*Beta vulgaris*), spring barley (*Hordeum vulgare*).

Three variants of tillage were applied for each crop type within the seven-step crop rotation.

Tillage variants:

- *Conventional tillage (CT)*: After the harvest of a precursor crop, the stubble is treated with Kverneland chisel cultivator to the depth of ca 0.1 m. Imposition is suitable in dry summer. The subsequent operation is plowing to the depth of 0.2 - 0.24 m. It is performed by a Lemken double-sided rotary plow. The Accord seed combination is used for sowing.
- *Minimum tillage (MT):* Stubble cultivation is performed by Kverneland chisel cultivator to the depth of ca 0.1 m, ensuring shallow cultivation. The Accord seed combination is used for sowing.
- *No tillage (NT):* The soil surface is leaved uncultivated after the harvest of the precursor crop. The Accord seed combination is used for direct sowing.

The weed infestation was evaluated using a numerical method. Weeds were counted in area of 1 m^2 in 48 repetitions in each variant of tillage. The evaluation was held everytime each spring in the phase of spring barley tillering and before herbicide application, in 2004 and 2013. Names of found species were used according to Kubát (Kubát, 2002).

The precipitation were recorded in one-day interval. Data about precipitation totals were used from standard meteorological station, which is located directly in the experimental enterprise. Monthly totals for the months (October and April) were calculated from measured values of precipitation totals.

Multivariate analysis of ecological data were applied for detection of influence of precipitation totals on weed species. The variants of tillage and precipitation totals for the months of October and April were used as a factor of environment. Optimal analysis was based on the length of the gradient (*Lengths of Gradient*), detected by segment analysis DCA (*Detrended Correspondence Analysis*). Furthermore, CCA (*Canonical Correspondence Analysis*) was used. A total number of 499 permutations was calculated in Monte-Carlo test. Collected data were processed by a computer program Canoco 4.0 (Ter Braak, 1998).

Results

Within the monitored years was found 44 weed species in winter wheat. The average number of individuals of found weed species are shown in Tab. 1. The data of monthly total precipitation from October to April are listen in Tab. 2. These monthly total precipitation of monitored period were used in the CCA analysis.

Data about weed infestation of winter wheat were initially processed by DCA analysis. Its result was the length of gradient (*Lengths of Gradient*), which amounts 5.423. On the basis of this calculation the canonical correspondence analysis (CCA) was selected for further processing. CCA analysis defines the spatial arrangement of individual weed species and total precipitation for selected months. The spatial structure is determined by the relations of total precipitation, tillage and occurrence of weed species.

The results are subsequently expressed using the ordination diagram. Weed species and soil tillage are presented as points, total precipitation for particular months are shown as vectors (arrows), which determine the amount of rainwater. The smallest amount of precipitation is displayed at the beginning of the vector and the maximum is at the end.

The results of CCA analysis (Fig. 1), which evaluated the influence of precipitation (in selected months) to the occurrence of weeds in conventional tillage conditions, are significant at the significance level of $\alpha = 0,002$ (Trace = 1.075; F-ratio = 19.792).

Based on the CCA analysis is possible to conclude, that higher precipitation during the months October, December and January contributed to the higher weed infestation of following species: *Atriplex sagittata, Convolvulus arvensis, Fallopia convolvulus, Galinsoga parviflora, Chenopodium album, Chenopodium hybridum, Persicaria lapathifolia, Silene noctiflora* and *Symphytum officinale.* Conversely, lower or average rainfall during these months supported the occurrence of species *Erophila verna* and *Poa annua.*

Higher precipitation during February conduced to the higher weed infestation by these species: *Fumaria officinalis, Plantago major, Polygonum aviculare, Taraxacum officinale* and *Veronica persica.* Nevertheless lower rainfall in this month supported the incidence of species *Medicago sativa* and *Papaver rhoeas*.

Higher precipitation during March contribute to the higher weed infestation caused by these: *Beta vulgaris, Geranium pusillum, Microrrhinum minus, Phacelia tanacetifolia, Rumex obtusifolius* and *Vicia villosa.* Average and lower precipitation in March fit better to the occurence of *Cirsium arvense, Consolida orientalis, Galium aparine* and *Sinapis arvensis.*

Higher rainfall in September support higher incidence of species *Euphorbia helioscopia, Sonchus oleraceus* and *Veronica polita.*

However, some of the species appeared more significantly on the variant of no tillage, namely: *Descurainia sophia, Lactuca serriola, Senecio vulgaris, Sonchus arvensis, Stellaria media, Tripleurospermum inodorum, Veronica hederifolia* and *Viola arvensis.*

Discussion

The results show, that precipitation totals in chosen months significantly affect the occurrence of most of the weed species. The amount of precipitation supposedly influence the dormancy of seeds in soil seed bank and perhaps also the regenerative ability of perennial weeds. The dormancy and the conditions of its termination are very specific for each species. The effect of precipitation at different times may terminate or extend the course of dormancy. This may result into decrease or increase of weed infestation of certain species.

The occurrence of species *Veronica polita* was strongly affected by precipitation in September. Therefore during the sufficient amount of precipitation in September we can expect higher weed infestation by this species in winter wheat. Species *Veronica persica* was promoted by higher amount of precipitation in February.

The incidence of number of late spring weeds (*Atriplex sagittata, Galinsoga parviflora, Chenopodium album, Chenopodium hybridum, Persicaria lapathifolia*) was supported by the higher amount of precipitation in December. The precipitation in this month most probably abbreviate the dormancy of seeds of these species, which subsequently germinate more in spring. Lower precipitation in spring (February, March) promote weed infestation by species *Medicago sativa* and *Galium aparine*. Lower precipitation may limit the competitiveness of wheat and allow to these species the higher weed infestation.

Conclusion

The results show, that the precipitation in chosen months significantly influence the incidence of various weed species in winter wheat. However, the response of particular species was markedly different. The causes of the different reactions we may seek in the influence of precipitation on the dormancy of weed species and in the influence on the competitive ability of wheat, which may limit the weed infestation. Clarification of relations between precipitation and weed occurrence may provide a basis for predicting of weed infestation. This forecast would be important for efficient herbicide selection and other regulatory methods.

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Summary

Polní pokus se nachází v pokusné stanici Mendelovi university v Brně (lokalita Žabčice, Česká republika). Dlouhodobá průměrná roční teplota je 9,3 °C a dlouhodobí roční úhrnu srážek činí 483,3 mm. Teplotní a srážkové údaje byly získány z meteorologické stanice v pokusné stanici v Žabčicích. V polním pokusu byl použit sedmihonný osevní postup. V rámci sedmihonného osevního postupu byly ke každé plodině použity tři varianty zpracování půdy (konvenční technologie zpracování půdy, minimalizační technologie zpracování půdy, bez zpracování půdy). Zaplevelení bylo hodnoceno pomocí početní metody v porostech ozimé pšenice. V průběhu 10 let sledování bylo nalezeno 44 druhů plevelů. Na základě výsledků kanonické korespondenční analýzy můžeme konstatovat, že vyšší srážky v měsících prosinci a lednu podporují vyšší výskyt druhu *Fallopia convolvulus*. Nižší srážky v měsíci únoru podporovaly výskyt druhů *Medicago sativa, Papaver rhoeas* naopak vyšší srážky v tomto měsíci podporovaly výskyt druhu *Veronica persica.*

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Table 1 Average number of individuals of particular weed species found in monitored years and variants of tillage (pcs.m^{-2}).

Weed species	Years of monitoring										Tillage		
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	CT	MT	NT
Atriplex sagittata			0,03										0,01
Beta vulgaris				0,01							0,00		
Capsella bursa-pastoris		0,22	0,11	0,10	0,94	1,33	0,84	1,29	1,39	2,43	0,28	0,67	1,41
Cirsium arvense	0,47	0,08	0,21	0,62	0,25	0,02	0,01	0,21		0,01	0,14	0,09	0,41
Consolida orientalis	0,06	0,02	0,01	0,06	0,02	0,01		0,03		0,01	0,04	0,03	0,01
Convolvulus arvensis	0,05		0,15								0,02	0,02	0,03
Descurainia sophia				0,01			0,01		0,01	0,01	0,00	0,01	0,00
Erophila verna			0,01			0,01						0,00	0,00
Euphorbia helioscopia			0,01	0,01						0,05	0,00	0,02	0,00
Fallopia convolvulus	1,76	0,09	1,72	0,03	0,02	0,01	0,03	0,17	0,31	1,38	0,79	0,57	0,63
Fumaria officinalis				0,06	0,01		0,01			0,01	0,01	0,02	0,00
Galinsoga parviflora			0,65									0,07	0,10
Galium aparine	1,04	1,31	0,52	0,59	0,24	1,40	0,72	0,26	0,02	0,09	0,56	0,72	0,69
Geranium pusillum				0,01								0,00	
Chenopodium album	1,24	0,03	2,28					0,01	0,10		0,50	0,52	0,32
Chenopodium hybridum	0,11		0,15								0,08		0,02
Lactuca serriola		0,08	0,01			0,06	0,01		0,01	0,01	0,00	0,02	0,03
Lamium amplexicaule	0,04	0,35	0,30	0,53	0,40	0,53	1,48	0,31	1,39	1,76	0,60	0,65	0,69
Lamium purpureum		0,01	0,10		0,22	0,11	0,12	0,11	0,11	1,05	0,10	0,28	0,12
Medicago sativa	0,22	1,13	1,04	0,74	0,22	3,15	0,60	0,22	0,67	0,13	0,14	0,49	1,64
Microrrhinum minus				0,04	0,01						0,01	0,01	
Papaver rhoeas	0,01	0,02		0,02	0,02	0,01	0,02	0,03	0,01	0,02	0,03	0,01	0,00
Persicaria lapathifolia			0,09		0,01						0,01	0,01	0,01
Phacelia tanacetifolia	0,00			0,03							0,01	0,00	
Plantago major						0,01							0,00
Poa annua			0,03			0,02						0,01	0,01
Polygonum aviculare	0,01		0,01					0,38	0,01		0,00	0,00	0,11
Rumex obtusifolius				0,15							0,02	0,01	0,01
Senecio vulgaris					0,03		0,01				0,00	0,00	0,01
Silene noctiflora	0,84	0,06	0,83	0,08	0,01	0,08	0,01	0,01			0,45	0,20	0,11
Sinapis arvensis	0,16	0,01	0,27	1,01	0,10			0,01	0,03	0,09	0,32	0,11	0,07
Sonchus arvensis					0,01								0,00
Sonchus oleraceus			0,02		0,04							0,00	0,02
Stellaria media	0,02	1,20	0,25	1,08	1,47	0,97	1,28	0,56	0,98	2,20	0,60	0,94	1,20
Symphytum officinale			0,01										0,00
Taraxacum officinale	0,00		0,06	0,13	0,28	0,50			0,01		0,01	0,05	0,20
Thlaspi arvense	0,01	0,01	0,04	0,06	0,19	0,13	0,17	0,20	0,18	1,22	0,17	0,13	0,31
Thlaspi perfoliatum									0,01				0,00
Tripleurospermum inodorum	0,01	0,56	0,02	0,13	0,01	0,11	0,20	0,03	0,51	0,02	0,19	0,11	0,14
Veronica hederifolia					0,27	0,01		0,03	0,01		0,02	0,03	0,04
Veronica persica		2,28		8,03	1,92	0,46	0,75	0,87		3,47	1,16	1,79	1,91
Veronica polita	0,95	1,21	1,27	1,51	1,01	1,63	1,38	1,99	0,42	6,28	1,61	1,63	1,83
Vicia villosa				0,01								0,00	
Viola arvensis		0,06	0,03	0,01			0,02	0,31	0,04	0,15	0,02	0,02	0,12
Number of species	2,66	3,55	3,22	3,66	3,24	3,17	3,46	3,33	2,87	4,44	3,22	3,36	3,31
Number of individuals	7,00	8,72	10,25	15,07	7,69	10,20	7,65	6,96	6,18	20,01	7,89	9,24	11,98

Table 2 Monthly precipitation totals (mm) for chosen months of monitored period

Years of monitoring	October	November	December	January	February	March	April
2003/2004	57,6	31,6	51,0	41,9	27,6	59,8	34,0
2004/2005	66,2	35,0	18,0	19,4	44,4	5,8	49,5
2005/2006	6,2	23,4	30,2	22,2	26,4	46,2	50,5
2006/2007	13,9	21,4	20,8	22,7	42,2	80,8	4,4
2007/2008	37,9	30,5	26,0	15,7	10,4	32,9	29,3
2008/2009	27,3	22,1	31,1	20,0	57,6	78,1	3,6
2009/2010	21,2	55,4	37,6	46,8	22,8	9,8	53,1
2010/2011	10,4	32,8	11,1	21,4	4,6	39,3	33,2
2011/2012	22,6	1,6	14,6	27,4	7,4	2,4	19,8
2012/2013	49,2	19,4	35,6	20,2	42,1	40,8	20,2

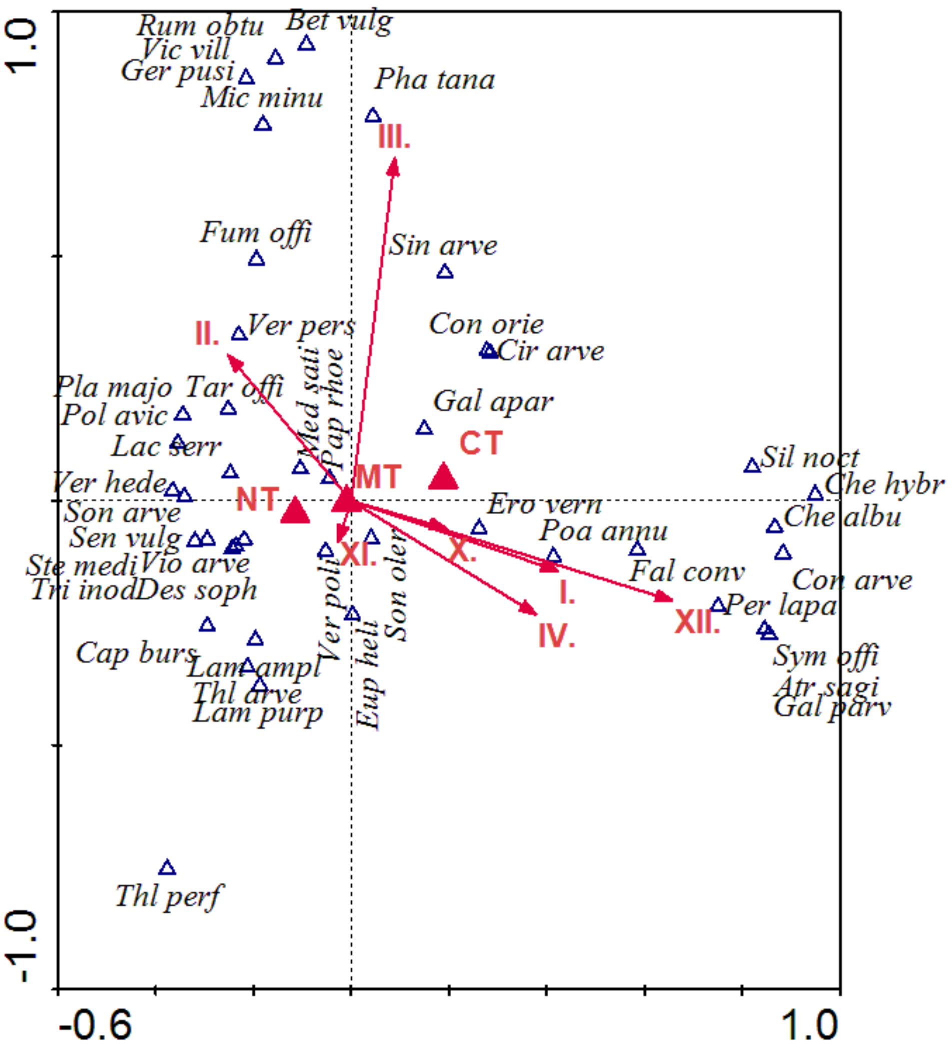

Fig. 1 The ordination diagram expressing spatial layout of the monthly precipitation effect in monitored months, soil tillage and found weed species

Notes to Fig 1: →X. aggregate precipitation for October, →XI. aggregate precipitation for November, →XII. aggregate precipitation for December, →I. aggregate precipitation for January, →II. aggregate precipitation for February, →III. aggregate precipitation for March, →IV. aggregate precipitation for April, NT – no-tillage, MT - minimization tillage, CT - conventional tillage.

Atr sagi – Atriplex sagittata, Bet vulg – Beta vulgaris, Cap burs – Capsella bursa-pastoris, Cir arve – Cirsium arvense, Con orie – Consolida orientalis, Con arve – Convolvulus arvensis, Des soph – Descurainia sophia, Ero vern – Erophila verna, Eup heli – Euphorbia helioscopia, Fal conv – Fallopia convolvulus, Fum offi – Fumaria officinalis, Gal parv – Galinsoga parviflora, Gal apar – Galium aparine, Ger pusi – Geranium pusillum, Che albu – Chenopodium album, Che hybr – Chenopodium hybridum, Lac serr – Lactuca serriola, Lam ampl – Lamium amplexicaule, Lam purp – Lamium purpureum, Med sati – Medicago sativa, Mic minu – Microrrhinum minus, Pap rhoe – Papaver rhoeas, Per lapa – Persicaria lapathifolia, Pha tana – Phacelia tanacetifolia, Pla majo – Plantago major, Poa annu – Poa annua, Pol avic – Polygonum aviculare, Rum obtu – Rumex obtusifolius, Sen vulg – Senecio vulgaris, Sil noct – Silene noctiflora, Sin arve – Sinapis arvensis, Son arve – Sonchus arvensis, Son oler – Sonchus oleraceus, Ste medi – Stellaria media, Sym offi – Symphytum officinale, Tar offi – Taraxacum officinale, Thl arve – Thlaspi arvense, Thl perf – Thlaspi perfoliatum, Tri inod – Tripleurospermum inodorum, Ver hede – Veronica hederifolia, Ver pers – Veronica persica, Ver poli – Veronica polita, Vic vill – Vicia villosa, Vio arve – Viola arvensis.