The effect of soil tillage on development of harmful biotic factors

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ABSTRACT

Soil tillage is an essential cultivation practice in many agricultural systems. It can be a powerful tool for managing many harmful biotic factors. Although soil tillage is closely associated with weed control, the various methods of tillage can also have important effects on plant fungi pathogens and insect pests. The effects of different methods of soil tillage (conventional, minimum and zero tillage) were evaluated in long-term field trials in the Czech Republic. The impact of tillage on incidence of other fungi pathogens (*Mycosphaerella graminicola* on winter wheat and *Pyrenophora teres* on spring barley) was significant only in interaction with soil tillage, forecrop and straw management. Reduced soil tillage resulted in increased occurrence of some pests, e.g. *Dasineura brassicae*, larvae of family *Elateridae* and *Ostrinia nubilalis*. The changes in technologies of soil tillage caused changes in actual weed infestation of many crops. Minimum tillage creates conditions that are suitable for lower number of weed species, therefore the diversity of species is decreasing. On the other hand the number of weed individuals is often rapidly increasing. The long-term effect of soil tillage influenced also quality and quantity of weed seedbank in the soil. The differences between conventional and reduced tillage are mostly in vertical distribution of weed seeds in the soil, seed viability and dormancy. Differences in seed burial depth can also have important implications for relative time of weed emergence, survival of weed seeds, and distribution of weed species.

KEYWORDS: soil tillage, pests, diseases, weeds

Soil tillage is an essential cultivation practice in many agricultural systems. It can be a powerful tool for managing many harmful biotic factors. Although soil tillage is closely associated with weed control, the various methods of tillage can also have important effects on plant fungi pathogens and insect pests. The effects of different methods of soil tillage (conventional, minimum and zero tillage) were evaluated in long-term field trials in the Czech Republic.

Soil tillage and weeds

Tillage systems affect weed emergence, management and seed production. Changes in tillage practices consequently changes the composition, vertical distribution and density of weed seedbanks in agricultural soils (Buhler, 1995). Many authors (Triplett and Lytle, 1972; Froud-Williams et al, 1981; Knab and Hurle, 1986; Moyer et al., 1994) have reported changes in weed communities connected with less intensive tillage. Most research has indicated that less intensive tillage favours perennial species, species disseminated by wind, annual grasses and volunteer crops. However, in some cases, tillage has no selective effect on weed flora (Swanton et al., 1993).

The impact of soil tillage on weeds was monitored in three field trials and on the selected plots of two agricultural enterprises. Actual weed infestation was evaluated in the newly established field trial in Branišovice (***short-term*** effect, established in 2000), where three variants of soil tillage were used, namely conventional tillage (CT), minimum tillage (MT) and zero tillage (ZT). The other place of evaluation was a ***medium-range*** field trial in Ivanovice na Hané (established in 1989), where the crops were grown in three crop rotations with different ratios of cereals (33.3 %, 50.0 % and 66.6 %). For the winter wheat and spring barley, four different variants of soil tillage were used, namely the variant with ploughing to depth of 0.22 m, the variant with ploughing to depth of 0.15 m, the variant with disk tillage to depth of 0.10 m and the variant with sowing into zero-tillage soil. The third ***long-term*** field trial with a monoculture of spring barley was established in 1970 in Žabčice. Two variants of primary soil tillage were used, first one with ploughing to depth of 0.22 m and second one with shallow loosening to depth of 0.12 m. Numeric method was used for evaluation of weed infestation during years 2000-2004. The long-term effect of soil tillage on weed soil seedbank was evaluated in trial in Žabčice as well.

The impact of different variant of soil tillage on weeds was evaluated under operation conditions in two agricultural enterprises. On the plots of the cadastral area of Olomouc-Holice conventional tillage was used, while in the cadastral area of Bohuňovice minimum tillage was used. The method of phytosociological relevés was used for the evaluation of the spectrum of weed species. The obtained data were evaluated using analysis of variance (ANOVA) and the means were compared by the Fisher LSD test. The impact of the monitored factors on the individual species of weeds was evaluated by means of a multidimensional analysis of ecological data, using either Redundancy Analysis or Canonical Correspondence Analysis.

The ***short-term*** use of different variants of soil tillage resulted differences in weed infestation among crops and years. In the first years of observation, the variant with zero-tillage sowing of winter wheat showed the highest weed infestation, which then gradually decreased. This tendency was also apparent in the other variants of soil tillage in stand of winter wheat. In the stand of spring barley, weed infestation was fairly steady. It can be assumed that the decrease in weed infestation took place due to high quality chemical control. The species mainly occurred in the variant with zero-tillage sowing in the stand of spring barley were *Echinochloa crus-galli, Conyza canadensis, Lamium amplexicaule, Cirsium arvense, Viola arvensis, Tripleurospermum inodorum, Veronica polita, Stellaria media,* and in stand of winter wheat there were *Conyza canadensis, Capsella bursa-pastoris, Tripleurospermum inodorum* and *Veronica polita*. The variants with minimum tillage in stand of spring barley had the highest occurrence of *Descurainia sophia, Amaranthus sp., Veronica hederifolia,* while the winter wheat showed the highest occurrence of *Cirsium arvense, Descurainia sophia* and *Veronica hederifolia*. The species of *Chenopodium album, Chenopodium hybridum, Consolida regalis* and *Fallopia convolvulus* were mostly found in stands of spring barley with conventional tillage. *Consolida regalis, Fallopia convolvulus* and *Viola arvensis* were the most common weed species in winter wheat stands in the same variant of soil tillage.

The ***medium-range*** trial suggested certain trends in weed infestation. With the decreasing depth of soil tillage, the number of weed species also decreased, but the number of specimens increased. The reduced variants of soil tillage (disk tillage and zero-tillage) facilitate more favourable conditions for a higher occurrence of certain weed species. In stand of spring barley there were mostly late-spring species such as *Amaranthus sp., Echinochloa crus-galli* and *Chenopodium album* in particular. In stand of winter wheat it was *Capsella bursa-pastoris* and *Medicago sativa*. From these results it is apparent that reduced soil tillage is entirely unsufficient for the control of the pre-crop (lucerne). Weed infestation and species

composition were significantly affected by the impact of weather conditions in each year, but also by the type of crop rotation.

As the results of the field trials showed, the ***long-term*** use of minimum soil tillage causes both a decrease of number of species and a decrease in weed specimens. The minimum tillage showed in particular occurrence *Avena fatua, Convolvulus arvensis, Fallopia convolvulus* and *Sonchus arvensis.* In the variant with conventional tillage it was the species of *Persicaria lapathifolia* and *Veronica polita*. Weed infestation was also significantly affected by the way of straw management. Here it turned out that straw burning decreased overall weed infestation, as opposed to variants which are commonly used in practice.

The results of weed seedbank in soil showed, that 30 years after establishment of spring barley monoculture, the higher number of weed seeds is on variant with minimum tillage (32237 pc m^{-2}) than on conventional tillage (47072 pc m^{-2}). Annual weed species *Chenopodium album, Amaranthus retroflexus* and *Melandrium noctiflora* were the most often on CT. Higher occurrence of *Convovulus arvensis* was on MT.

Areas where minimum tillage is used, showed the spreading of *Equisetum arvense* in general, in stand of spring barley it was the species *Avena fatua, Galium aparine, Poa annua* and *Veronica polita,* while in stand of winter wheat *Apera spica-venti* and *Fallopia convolvulus*. In most cases these are species which are difficult to control and which are capable of producing seeds or fruit very quickly.

In conclusion it can be said that the areas where minimum tillage is used, show those species in particular which produce seeds and fruit very quickly. Furthermore, these are species which are hardly controlled using herbicides. The occurrence of perennial weeds is apparently affected more by the quality of chemical control, which can overlap with the impact of the way of soil tillage. In addition, it is necessary to realise that the method of soil tillage affects the weed species as merely one of many factors, and also the fact that these act as a multifunctional factor in conjunction with many other factors.

Soil tillage and fungi pathogens

Reduced tillage leaves some crop residues on the soil surface and this is a cause for accumulation of disease inoculum. An increase in leaf diseases was reported in wheat in minimum tillage systems compared to conventional tillage (Sutton and Vyn, 1990; Brandt and Zentner, 1995; Krupinsky and Tanaka, 2001). But on the other hand Abrahamsen and Weiseth (1999) reported that no-tillage did not result in more disease than mouldboard ploughing.

The effect of some factors (soil tillage and straw treatment) on the incidence of *Pyrenophora teres* on spring barley and *Mycosphaerella graminicola* on winter wheat was determined in small-plot field trial during the years 2004-2007. The field trial was established in locality Žabčice as a model concept for farming without animal husbandry (all straw is cut and incorporated into the soil). This locality (179 m above sea level, 49°01′ N, 16°37′ E) is situated 25 km southwards from Brno (South Moravia region, Czech Republic). It is a warm and dry region with average annual temperature and precipitation of 9.2°C and 480 mm. The principle of this experiment was a 5-year crop rotation with a high concentration of cereals (spring barley, safflower, winter wheat, winter wheat, grain maize). The following two experimental factors were assessed: soil tillage (conventional or minimum tillage) and straw treatment with different fertilizers (variants A-D, see below). By winter wheat the third factor – pre-crop was evaluated (safflower – *Carthamus tinctorius* or winter wheat). The variant of conventional tillage consisted of stubble breaking after harvest and ploughing down to the depth of 0.20-0.24 m. The variant of minimum tillage included stubble breaking after harvest followed by a shallow loosening to the depth of 0.15 m. Straw and crop residues of all crops were treated with four different liquid fertilizers (variants A-D); the aim of this treatment was

to increase microbial activity and straw decomposition by nitrogen addition. The individual variants were as follows: Variant A involved the application of Beta-liq liquid fertiliser at the dose of 1 t ha^{-1}, Variant B the application of DAM 390 at the dose of 100 kg ha^{-1}, and in Variant C the fertiliser Unifert was applied at the dose of 230 kg ha^{-1}. All doses of fertilisers mentioned above corresponded to 30 kg of nitrogen ha^{-1}. The last variant, D, was used as control and it was without any fertilizer.

More detailed characteristics of fertilizers used:

A – Beta-liq – (a liquid molasses-based organo-mineral fertilizer containing 3% of N and 5% of K_2O); the applied dose was 1 t ha^{-1},

B – DAM 390 – (a nitrogen fertilizer solution composed of urea and ammonium nitrate, containing 30% N) – the applied dose was 100 kg ha^{-1}

C – Unifert – (liquid organo-mineral fertilizer on the base of alimentary waste products, containing 13% of N and 3% of K_2O) – the applied dose was 230 kg ha^{-1}

D – Control – without fertilizers

The spring barley variety Amulet and winter wheat variety Sulamit were sown at the rate of 4 million of germinating seeds (MGS) per hectare. The experimental dose of fertilizers for spring barley was 60 kg N ha^{-1} (applied prior to sowing as calcium ammonium nitrate, CAN, 27.5 %). The experimental dose of fertilizers for winter wheat was 120 kg N ha^{-1} (30 kg N prior to sowing as ammonium sulphate, 50 kg N in the spring for regeneration as calcium ammonium nitrate (CAN, 27.5 %) and 40 kg N till the end of tillering as DAM 390.

Experimental plots were harvested by a small combine harvester SAMPO 2010. Fungicide treatments were not applied.

The incidence of leaf spots caused by *Pyrenophora teres* was different on particular variants in all years. In the year 2004 variants treated with DAM were significantly less infected by this pathogen in comparison with untreated control and variants treated with Unifert. The influence of soil tillage was not proved in this year. On the contrary, in the year 2005 the influence of soil tillage was statistically significant, variants grown after reduced tillage were much more infected by *P. teres.* The influence of straw treatment was not proved in this year. In the year 2006 the influence of tillage was not significant, but differences between straw management variant were found. Variants with untreated straw were significantly less infected than variants treated by DAM and Beta-liq. As can be seen from these results, the incidence of *P. teres* in particular variants was influenced by the year and it can not be concluded, which soil and straw treatment is the best in the point of view of spring barley health status.

The effect of soil tillage, straw treatment and also pre-crops (safflower – *Carthamus tinctorius* or winter wheat) were evaluated on incidence of *Mycosphaerella graminicola* in the same field trial. We found different influence of particular factors on the incidence of this pathogen on winter wheat leaves. The statistically significant differences were found in factor pre-crop, in the years 2004, 2005 and 2007 variants after winter wheat were infected more than variants after safflower, but contrary, we found more infections on variants after safflower in year 2006. The factor soil tillage influenced also incidence of *Mycosphaerella graminicola.* Variant which were grown after reduced tillage were much more infected than variants after ploughing in years 2006 and 2007, but we can not find any differences in previous two years. Factor straw treatment did not influence the infection of winter wheat by this pathogen. We do not recommend to use reduced tillage for winter wheat if the pre-crop is also winter wheat.

Soil tillage and insect pests

Tillage strongly influences the essential conditions for insect fauna in fields. This is the case for both pests and beneficial organisms. Reducing the tillage influences different pest species in different ways due to different life strategies. A review of 45 investigations showed that 28% of the pest species increased with decreasing tillage, 29% showed no significant influence of tillage, and 43% decreased with decreasing tillage (Stinner and House, 1990).

Currently with implementing of different methods of reduced soil tillage, soil protection and plants founding is the question, how *Arthropoda* react will, which lives in the soil and on the surface. That includes the pests and also some groups of beneficial insects. In last years there was evaluated the influence of different soil cultivation on occurrence of pod midge (*Dasineura brassicae*), wireworms (larvae of family *Elateridae*) and European corn borer (*Ostrinia nubilalis*).

The differences in occurrence of pod midge were observed between variants of conventional (CT) and minimum tillage (MT) in winter oilseed rape. The traps were fit in place into stand of winter wheat (pre-crop was winter oilseed rape) in spring before emergence of this pest. These traps were transparent boxes from PVC painted with adhesive inside (Chemstop Ecofix). The surface of the box was 500 cm^2. There were three variants of soil tillage: CT – stubble breaking into the depth of 0.12-0.15 m (straw was incorporated into the soil) and followed by ploughing to the depth of 0.22 m, MT 2 – stubble breaking into the depth of 0.12-0.15 m (straw was incorporated into the soil) and MT 3 – stubble breaking into the depth of 0.12-0.15 m (straw was harvested). The obtained results are in Table 1.

Table 1. Influence of different soil tillage on number of pod midge in 2002 and 2003

Variants	Number of pod midge on 4 traps		Number of pod midge per m^2	
	2002	2003	2002	2003
CT	17	9	85	40
MT 1	77	52	385	260
MT 2	80	41	400	205

The results in table 1 showed big differences in numbers of pod midge in observed variants. The occurrence of pod midge was 4.5 – 6.5 times higher on variants with reduced tillage (variant MT 1 and 2) in comparison with conventional variant (CT).

The impact of two variants of soil tillage on occurrence of wireworms was evaluated in the field trial for farming with animal husbandry in locality Žabčice in 2004-2007. The principle of this trial is 7-year crop rotation with 2-year lucerne (lucerne - 1. year, lucerne - 2. year, winter wheat, silage maize, winter wheat, sugar beet, spring barley). CT – conventional tillage includes stubble breaking after harvest, ploughing to the depth of 0.20-0.24 m (depending on crop). NT – no tillage is a variant with direct sowing without any soil tillage, only before sowing of maize and sugar beet seedbed preparation is used on the depth of sowing.

The occurrence of wireworms was observed in winter wheat grown after lucerne using soil traps in spring. The results are given in Table 2. The differences in number of wireworms among years were observed, the lowest occurrence of wireworms was in 2005 (only 1 on variant NT and 3 on variant CT). The four years results show, that the number of wireworms was higher on NT variant (68 wireworms per m^2) than in CT (9 wireworms per m^2).

Table 2. Influence of different soil tillage on number of wireworms in winter wheat - Žabčice 2004 – 2007

Year	Number of wireworms genus *Agriotes* per m^2	
	CT	NT
2004	0	12
2005	3	1
2006	6	43
2007	0	12
Total	9	68

The impact of conventional tillage (CT) and minimum tillage (MT) on occurrence of larvae of European corn borer was evaluated in 5-year crop rotation with high concentration of cereals (description of this trial is already above mentioned). Comparable observation was done in grain maize monoculture. No kind of protection against *Ostrinia nubilalis* was used. During the assessment the whole plants were picked up, the stems and cobs were cut and the number of hallways and larvae per plant was counted. Broken plants (over and below cobs) were counted before harvest (200 plants from each variant in total). The results are in Table 3. The ratio of attacked plants 37.5 % - 80.0 % was on variants of conventional tillage and 62.5 % - 96.7 % on minimum tillage. Also the number of hallways, larvae and the ratio of broken plants were higher on variants with minimum soil tillage.

Table 3. Influence of different soil tillage in grain maize on occurrence of European corn borer in 2004 – 2006

year	Variant of soil tillage	Ratio of attacked plants	Total number of hallways per 10 plants	Number of larvae per 10 plants	Ratio of broken plants
2004	CT	37.5	*	4	5.2
	MT	62.5	*	8	9.8
2005	CT	80.0	17	8	3.0
	MT	96.7	28	14	6.0
2006	CT	43.3	17	4	3.0
	MT	66.7	36	8	7,3

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