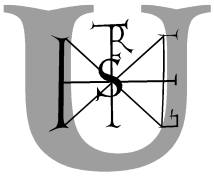

SZENT ISTVÁN UNIVERSITY

EFFECT OF CULTIVATION SYSTEMS ON SOIL CONDITION AND WEEDINESS IN WINTER WHEAT

Theses of PhD dissertation

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BACKGROUND AND OBJECTIVES OF THE STUDIES

The evaluation and comparative analysis of cultivation systems are significant parts of the cultivation research. The actuality of the cultivation experiments is determined not only by the various costs of the certain systems but their effect on soil condition and weeds as well. It is important to note that a significant part of Europe's arable lands – 33 million ha – is mildly or heavily compacted, with 1.4 million ha in Hungary. Besides compaction, errors of the cultivation include the dustiness, crackling and water and wind erosion. According to these reasons a comparative analysis of the soil conserving and conventional farming systems can prove useful.

In my essay therefore my objectives included:

- Determination of the weed-promoting capability (seed-bank) of the various tillage systems.
- Analysis of the yield influencing effect of different tillage methods and fertiliser doses in winter wheat.
- Study of the effect of the various tillage methods on soil condition, gathering information that can help the farmers.

In crop production the spreading of weeds belongs to the yield-reducing factors. According to the literature in this topic the yield loss may amount to 30% or in certain cases it can be even greater. The change of outlook upon weed control in the last few decades drew along that the eradication of the weeds and the completely weed-free cultures are no longer objectives and the only aim is to keep weed coverage below the danger-point. In the last 3-4 decades the changes in the agriculture, mainly the change of the structure – the morcellement of the land, the devolution of ownership -, the increase of fallows, the unsuitable agricultural methods, the lack of chemical application or the unprofessional herbicide treatments resulted in the change of weed composition on the fields and the proliferation of the aggressive, persistent weeds. The initial success of chemical protection reduced the employment of the former traditional technologies but after some time presented serious weed problems as well, like the appearance of tolerant and resistant weeds and the decrease of biodiversity. The unsuitable rotation of chemicals and the excessive chemical application promoted the appearance of resistant biotypes. Because of the losses caused by the weeds, plant protection is necessary, but according to the EU and international environment protection expectations the rational reduction of chemical application is also recommendable. The agricultural-environmental programmes can help the rediscovery and application of traditional and unduly de-emphasised protection methods, including soil cultivation.

MATERIAL AND METHOD

Conditions of the research

I carried out my research with winter wheat on the basis of the soil cultivation period experiments set by the Department of Agriculture of the Szent István University Crop Production Institute in 1991 (A) and 1994 (B). The mean annual precipitation is 564 mm on the experiment field, from which 313 mm falls during the vegetation period. The number of sunny hours per year is around 1950. The mean annual temperature is between 9.5 – 10 °C, the heat sum is 2700 °C. During the 4 years of the experiment the temperature has not shown any extremities, although 2000 was a very dry, droughty year.

The soil of the experiment field is brown forest soil. The fundamental rock is tertiary marl, which is covered by two different layers of loess. The humus content of the soil is low, the phosphorus and potassium content is mediocre.

The experiment is a two-factorial striped small-plot period experiment where factor (a) means the soil tillage methods and (b) the fertiliser treatments. The number of iterations was three. The size of the plots was 62,54 m^2 in experiment (A) and 35,51 m^2 in experiment (B). The forecrop of the winter wheat was maize in all cases.

In the experiment the following cultivation methods (a) and fertiliser treatments were applied:

Cultivation methods:

a_1 Non-tillage sowing (undisturbed)
a_2 Disk tillage (16-20 cm) (lightly disturbed)
a_3 Ploughing (22-25 cm) (medium deep tillage)
a_4 Loosening (35-40 cm) + disk tillage (16-20 cm) (loosened up to 35 cm)
a_5 Loosening (35-40 cm) + ploughing (22-25 cm) (loosened up to 35 cm)

Fertilisation since 1995

b_1 ∅
b_2 N: 80 kg/ha; P: 60 kg/ha; K: 60 kg/ha
b_3 N: 160 kg/ha; P: 120 kg/ha; K: 120 kg/ha

In the experiment winter wheat could not be sown in 1999 because of the wet autumn, therefore it was replaced by spring wheat that was utilised later as mulch. In 1997 the fields where non-tillage sowing was used, had to be treated with herbicides after the harvest of maize against the increased amount of weeds and this influenced the weed inspections in 1998. *Table 1.* contains the cultivation technology data of the period experiment.

Table 1. Cultivation technology data of the soil tillage period experiment (Gödöllő, 1997-2001)

Designation		1997.	1998.	1999.	2000.	2001.
Variety		Fatima	Fatima	Yantar	Mv. Magvas	Mv. Magvas
Preceding crop		maize	maize	maize	maize	maize
Basic tillage		17.10.1996	17.10.1996	11.11.1998	7.10.1999.	14.9-24.10.2000
Seed-bed preparation		21.10.1996	21.10.1996.	17.03.1999	21.10.1999	10.11.2000
Sowing		25.10.1996	22.10.1997	19.03.1999	21.10.1999	13.11.2000
Harvest		24.07.1997	27.07.1998	18.05.1999 mulch	17.07.2000	30.07.2001
Weed control		Pardner	Pardner		Segal 65 WG	Segal 65 WG
Stand density						
a_1	b1	210	201	-	210	230
	b2	332	302	-	322	340
	b3	356	351	-	360	360
a_2	b1	291	216	-	220	290
	b2	334	345	-	352	345
	b3	400	392	-	402	410
a_3	b1	318	341	-	350	330
	b2	495	465	-	472	490
	b3	500	502	-	524	510
a_4	b1	398	394	-	392	400
	b2	510	510	-	520	500
	b3	511	562	-	564	520
a_5	b1	402	405	-	410	440
	b2	520	534	-	540	510
	b3	521	573	-	582	530

Analytical methods

Method of weed seed analysis: The upper 20 cm layer of the soil was examined, which was divided into two layers (0-10 cm and 10-20 cm). Samples were taken in each iteration of each soil cultivation method. Separation of the weed seeds was carried out by $ZnCl_2$ decantation.

Method of weed inspection: Weed inspections were carried out according to the modified Ujvárosi method three times during the vegetation period. The data were obtained by direct estimation of the coverage in the $1m^2$ sample squares. Data were evaluated by one-way analysis of variance.

Method of yield analysis: The yield of the winter wheat was harvested separately from each plot and the results were estimated for hectare. The data were evaluated by one-way analysis of variance.

Method of soil condition analysis: The soil resistance was measured initially by the Dvorachek penetrometer and later by the Daróczi-Lelkes pressure probe. The resistance and the humidity of the upper 40 cm layer of the soil was measured every 5 cm. Data were evaluated by one-way analysis of variance.

RESULTS, CONCLUSION AND PROPOSALS

1. Results of the weed seed content analysis of the soil

The size of the seed bank determining the potential weed-promoting capability of the soils was evaluated for m^2on the basis of the seed content of 200 cm^3 units. Results show that the upper layer (0-10 cm) of the soil is the richest in weed seeds. The greatest weed infection was registered in the non-tillage (a_1), disk tillage (a_2) and the combined loosening+disk tillage (a_4) methods *(Table 2.).* Significantly less weed seed were found in the soil samples of the ploughing (a_3) and loosening+ploughing (a_5) methods *(Table 2.).* The highest number of weed seeds was 71 333 per m^2 in the upper 10 cm layer of the soil while the fewest seeds (11 833 per $m^{2)}$ were found in the a_5 treatment *(Table 2.).* Comparing these results with the data from the weed inspection a similar tendency may be observed, because the cover percentage of the weeds decreases in a similar sequence (usually a_1, a_2, a_4, a_3, a_5) in the soil tillage treatments. The relation is logical, since the larger weed coverage results in a higher weed yield, which during the soil tillage adds to the weed seed bank of the soil. During the examination of the upper 20 cm layer of the soil it turned out that the weed seed bank of the 0-10 and 10-20 cm layers are significantly different in most cases *(Table 2.).*

According to my results in case of ploughing the upper 10 cm layer contained more weed seeds than the 10-20 cm layer but the difference was not as significant as in the case of non-tillage cultivation or disk tillage. The weed-limiting and thus weed seed bank reducing effect of the ploughing in the examined layer was determined in our soil tillage period experiment. The majority of the weed seeds belonged to the T_4 weed species that are characteristic in the maize. It is possible that in a denser winter wheat stand the weed condition of the forecrop is determinant because of the smaller weed coverage. In the sparse stand of the maize a higher weed percentage was observed. By examining the weed seed bank of the soil samples the seeds of 26 weed species were registered. The weed seed content per m^2 was highest ***(113 83)*** in the a_1 treatment (0-20 cm), while it was the lowest in the a_5 treatment with ***26 667 per m^2*** *(Table 3.).*

Considering the alternation of maize and wheat 26 weed species is not too high. This tendency is general also on the fields and is probably the result of the decreased weed diversity caused by the groundless simplification of the production systems (neglecting of necessary soil tillage procedures, deficient exploitation of the agrotechnical possibilities, only chemical plant protection etc).

Table 2. The results of the weed seed content analysis of the soil in 0-10 and 10-20 cm layers in the various soil tillage treatments (Gödöllő, 1998)

Soil cultivation method	Depth	1. Number of iterations	2. Number of iterations	3. Number of iterations	Mean
a_1	0-10	148	116	157	**140**
	10-20	115	73	74	**87**
a_2	0-10	71	65	51	**62**
	10-20	43	42	32	**39**
a_3	0-10	39	45	39	**41**
	10-20	25	42	30	**32**
a_4	0-10	68	57	67	**64**
	10-20	33	30	30	**31**
a_5	0-10	22	26	30	**26**
	10-20	22	30	30	**27**

Table 3. The mean weed seed content of the various soil tillage treatments in the upper 20 cm layer of the soil (Gödöllő, 1998)

Soil cultivation methods	Depth (cm)	Mean weed content (seed/m^2)	Weed seed content compared to the tillage (%)
a_1	0-20	113 833	310
a_2	0-20	50 667	138
a_3	0-20	36 667	100
a_4	0-20	47 500	129
a_5	0-20	26 667	72

2. Results of the weed inspection

Summing the experience of the four years it can be stated that in winter wheat weeds are promoted mostly by non-tillage cultivation and annually repeated disk tillage. The most species and the most intensive weed development was observed in the non-tillage treatment. The initial (1997) 16.4 % mean weed coverage increased to 66.4 % in four years, which was promoted also by the less dense winter wheat stand. In the case of non-tillage cultivation weeds appeared the earliest and were the highest in number, which was mainly due to the great amount of weed seed near the soil surface. The upsurge of the perennials is typical on undisturbed soil where H type weeds *(Taraxacum officinale, Lolium perenne)* also appear besides the G type plants that are adapted to disturbance. Disk tillage resulted in general in smaller weed coverage than the non-tillage cultivation but the amount of weeds was still higher than at the other deeper treatments. Especially the G type weeds were abundant. The

presence of perennials capable of vegetative reproduction limits the use of the disk tillage and its annual utilisation. Weed condition remained economically favourable in the case of ploughing (a_3, a_5) and deep tillage(a_4).

The weed limiting effect of ploughing mentioned in the literature (FENYVES 1997, BIRKÁS and SZALAI et al. 1997, YOUNG and OGG et al. 1994) was verified again. The weed coverage measured in the first experimental year did not increase significantly during the four years of the experiment and with the exception of the year 1998 the total mean weed coverage did not exceed 10 %. The number and coverage of the perennials was limited most by the ploughing although the mild winters did not produce frosts that could destroy the hunger-grasses. The results of the experiment highlighted the favourable effects of the loosener as well. The increase of the weed coverage was higher in case of loosening+disk tillage than in case of ploughing (a_3, a_5) although yield exceeded that of the ploughing treatment (a_3) in both years. This treatment had similar good results as the a_5 (loosening and ploughing) plots but with more favourable soil tillage costs. The use of the loosener is important especially in the dry years. According to our experience, the frequent disturbing of the deeper soil layers (a_3, a_4, a_5) has a significant weed limiting effect.

3. The yield of the winter wheat

The crop used in the experiments is winter wheat, which followed maize in each year. Although maize is a mediocre forecrop for the wheat, due to the size of the land under these two crops they often follow each other on our fields. The experiment is modelling a frequent situation therefore the analysis of the results and the determination of the correlation between the soil tillage, the fertilisation and the yield may provide useful information for the practice. On the basis of the four years of experiment it can be observed that the fertiliser doses rising up to the optimum result in rising yields in both the dry and the wet years. Comparing the soil tillage treatments it can be stated that better results were obtained in case of deeper tillage, especially loosening. Non-tillage cultivation produced poor yields, with the exception of the year 2000. This was probably due to the increased weed coverage, the early weed competence and the irregular sprouting. The advantages of the less soil disturbance (for example the higher soil humidity) were seen only in the dry years where the drought allaying effect of the fertilisers could also be observed. The disk tillage, which is the most frequent base cultivation in the winter wheat production exceeded only the yields of the non-tillage cultivation and did not create as favourable soil condition as the loosening or the ploughing. This can be caused not only by the weeds but by the compacted layer also that forms after 2-3 years of disk tillage in the upper layers of the soil (12-15cm) and that limits the water and nutrient uptake by reducing the root zone.

On sandy loam soils the favourable effect of the deeper soil tillage could be shown especially in the loosening treatments (a_4, a_5), probably because of the water stored in the deeper layers of the soil, the general higher soil humidity caused by the loosener and the stronger weed-prohibiting effect of the combined methods. It is interesting that the a_4

treatment (loosening+disk tillage) provided a good yield in each year compared to the other tillage methods even if its weed coverage exceeded the a_3 and a_5 treatments. This affirms that the looseners reducing the humidity loss and the better soil condition increases the yield security. In the dry years (like the year 2000) also the a_4 treatments produced the highest yields.. In the same year the non-tillage plots that had a higher weed coverage also produced a better yield than the ploughed plots (a_3, a_5), therefore it can be stated that the humidity of the soil plays an important part in the crop production and yield stability. In the dry years the utilisation of looseners and other, not stirring equipment is especially important.

4. Results of the soil resistance measurement

At the beginning of the experiments 25-30 cm deep in the sandy loam soil of Gödöllő a compacted layer was measured with Mpa soil resistance. In the first years of the non-tillage cultivation the soil sedimentation was significant in the upper layers but after a while the condition of the 0-20 cm layer became more favourable and its resistance decreased. The sole-compaction existing at the beginning of the experiment was not influenced by the non-tillage treatment and no improvement could be observed. The decrease of the compaction of the upper layer can be explained by the less treading during the cultivation processes, the accumulation of the plant residues, the increasing lumbricus activity and the higher biological activity of the soil.

The annually repeated disk tillage compacts the soil in the upper layer below the tillage depth more than the non-tillage treatment, which effect increases with each repeat. The resistance of the 20-30 cm layer also increased as a result of the repeated disk tillage. The compacted layer in the 10-20 cm depth thickens in the dry years towards the surface and in the wet years towards the deeper layers. The depth of the near-surface loosened soil layer that is favourable for the crops is small and decreases in the dry years therefore the drought effect is also enhanced. It can be stated that on a soil that is disposed to sedimentation the repeated disk tillage has an adverse effect on the production of the winter wheat that is otherwise not sensitive to the soil condition.

Ploughing results in a favourable loos structure in the depth of the tillage especially if it can be done among optimal soil humidity conditions. A compacted layer, a so-called sole-compaction, forms after a few years of repeated ploughing below the tillage depth (22-25 cm). The compacting influences the deeper (30-40 cm) layers as well, and soil resistance increases as a result of ploughing. It can be stated for both cultivation methods that are combined with loosening that loosening generally creates favourable soil condition up to 30-40 cm and ends possible compacted layers.

Disk tillage (a_4) and ploughing (a_5) maintain the created loose structure if they are employed in two courses, although a mild re-compacting effect can be observed below the tillage depth which can become significant if the equipment are used on too dry or wet soil.

Yield can be increased by the regular loosening of the soil and the yield stability can also be maintained.

According to the soil resistance measurement used in the soil tillage period experiment it can be stated the employment of traditional equipment (disk, plough) can influence the soil condition unfavourably in the various layers, especially if the same tillage method is repeated annually or is used among inadequate soil humidity conditions. Non-tillage can be described as a soil condition maintaining method while tillage methods combined with loosening have an improving effect. In certain cases correlation was observed between the weed spread and the soil condition. The undisturbed, sedimented soil did not hinder the weeds and intensive sprouting could be seen. The compacted layer forming as a result of the regular disk tillage did not limit weeds either. The sole-compaction forming on repeatedly ploughed soil did not reduce the weed-killing effect of the method and if the ploughing was combined with 35 cm deep loosening the prohibition of the weeds could be increased. Base tillage without ploughing favours weed development while the weed-limiting effect of the loosening+disk tillage was higher than the effect of disk tillage.

5. New scientific results

1. In soils containing average amount of weed seed the seed content increased in case of weed-promoting soil tillage and soil condition. In the experiment such tillage method was the undisturbed soil condition (non-tillage cultivation), the shallow disk tillage and in a small extent the loosening+disk tillage.

2. A correlation was found between the disturbance of the soil and the weed seed content. After most of the analysed cultivation methods the majority of the weed seeds got into the 0-10 cm layer and this can be seen as a weed limiting factor.

3. It can be stated that in case of limited chemical plant protection the initially small weed coverage can extend in a few years if the ripening of the weed seeds is undisturbed and if the field is infected with perennial weeds. In this case strong weed competence can be expected as soon as the wheat sprouts.

4. The advantage of the physical effect of soil loosening on the reducing of the spread of perennial weeds was verified. Loosening limits the development of the hunger-grasses by cutting the vegetative parts. Loosening influences weed spread through the improvement of soil condition as well. The competitiveness of a quickly and equally developing crop is higher than in the case of unfavourable soil condition.

5. Ploughing resulted in average or good yields. A compacted layer forms below the depth of the annually repeated ploughing which is disadvantageous on the yield but the weed-limiting effect of ploughing decreased only a little. Ploughing+loosening increased the yield of the wheat through the improvement of the soil condition, with the exception of the dry years and enhanced the weed-limiting effect of the ploughing.
6. On the sandy loam soil of Gödöllő non-tillage cultivation with limited use of chemicals is a risky cultivation method from the first year.

CONCLUSION AND PROPOSALS

1.1. The increase of weed seed content in the soil and the larger weed coverage is promoted by tillage methods that do not destroy the seeds, the sparse stand density of the cultivated crop (in this experiment the treatments that did not get fertiliser) and the inadequate chemical plant protection.

1.2. The disturbance of the soil influences the weed seed content of the different layers. In case of shallow tillage methods the majority of the weed seeds get into the 0-10 cm layer of the soil. This is unfavourable but it also holds the opportunity for plant protection: the sprouting of the seeds and the following weed control is easier.

1.3. Disk tillage limits annual weeds effectively but its regular use promotes the spread of the perennials.

1.4. The weed-limiting effect of the deeper tillage can be expected only if the deeper layer brought to the surface is free of weed seeds, i. e. no seeds get near the surface that could add to the weed flora.

1.5. Systems based on ploughing are effective for the limiting of annual and perennial weeds. The limiting of perennials can be increased if the autumn ploughing is not harrowed or the ploughing is combined with loosening.

1.6. Loosening in itself has a small weed-limiting capacity but limits the vital functions of the perennial weeds by cutting the vegetative reproductive parts.

1.7. Loosening can limit weeds by improving the physical condition of the soil. The competitiveness of a quickly and equally developing crop is higher than in the case of unfavourable soil condition.

1.8. After observing the weed-promoting effect of the regular non-tillage cultivation a periodic weed-limiting tillage method is recommended to prevent the spread of the weeds.

1.9. On important conclusion of the experiment is that the sedimentation and unfavourable condition of the soil – disk or sole-compaction – are not a weed-limiting factors.

1.10. In Gödöllő non-tillage cultivation and non-fertilising resulted in the least yield in winter wheat. The presence of weeds was also a yield-reducing factor. It is important that non-tillage is effective only on soils that are not prone to sedimentation and compaction and are free from perennials.

11 On soils prone to sedimentation loosening made it possible to reach and maintain the yield standard of the given habitat in the years when precipitation was unstable. It is recommended to estimate the costs of loosening on the basis of the years of the period effect.

12 Ploughing resulted in average or good yields. A compacted layer forms below the depth of the annually repeated ploughing which is disadvantageous on the yield but the weed-limiting effect of ploughing decreased only a little.

The continuous employment of non-tillage improves the condition of the uppermost layer of the soil but the unfavourable condition in the deeper layers does not change.

13 The annually repeated use of the disk tillage leads to an unfavourable condition in the 0-15 cm layer of the soil which is worse than in the case of non-tillage. The compcted layer formed below the tillage depth spreads into the upper or lower layers of the soil depending on the soil humidity at the time of the tillage and the number of years of repetition. This condition can be ended by a tillage method deeper than the disk compaction layer.

14 The annually repeated ploughing creates favourable soil condition down to the depth of the cultivated layer.

15 The soil condition improving and maintaining effect of the loosening can be effectively used in the winter wheat production in Gödöllő.

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