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EVALUATION OF SOIL CONSERVATION TECHNOLOGIES FROM THE PERSPECTIVE OF SELECTED HYDRO-PHYSICAL SOIL PROPERTIES AND INFILTRATION CAPACITY OF THE SOIL

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Abstract

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This paper evaluates different technologies of soil cultivation (conventional and minimization) in terms of physical properties and water regime of soils, where infiltration of surface water is a major component of subsurface water. Soil physical properties (the current humidity, reduced bulk density, porosity, water retention capacity of soil, pore distribution and soil aeration) is determined from soil samples taken from the organic horizon according to standard methodology. To observe the infiltration characteristics of surface layers of topsoil, the drench method (double ring infiltrometers) was used. For the evaluation of field measurements of infiltration, empirical and physically derived equations by Kostiakov and Philip and the three-parameter Philip-type equation were used. The Philip three-parameter equation provides physical based parameters near the theoretical values, a good estimation of saturated hydraulic conductivity *Ks* and sorptivity C_1. The parameter *S* of Philip's equation describes the real value of the sorptivity of the soil. Experimental research work on the experimental plots H. Meziříčko proceeded in the years 2005–2008.

infiltration capacity, minimization tillage, conventional tillage, soil erosion, hydraulic conductivity

Soil belongs among the irrecoverable natural treasures of our country and is a characteristic component of the landscape. Fertility, which is influenced by many factors (soil processing technologies, crop-plant stands establishment), is an important characteristic of soil. The preservation of soil fertility and its ecological functions should always be the concern of the soil management (Hůla, 1997). Methods of soil processing influence the soil resistance to water and wind erosion. Currently, more than a half of the area of the topsoil in the Czech Republic is potentially endangered by water erosion and nearly 10% of the topsoil is endangered by wind erosion (Janeček *et al.*, 2002). The increasing erosion of soil is a global problem with high economical and environmental impact.

The infiltration capacity is an important factor within the soil protection against water erosion. When the infiltration capacity of the surface layers of the soil is low, the required water infiltration doesn't happen and surface drain and related negative phenomena take place. The proper infiltration capacity of the soil influences a wide range of soil parameters, hydro-physical soil properties, and chemical and biological soil properties.

By soil processing, the size and distribution of pores is changed and a suitable environment for the movement of water and air is created (Leij, 2002). The change of transportation characteristics of the system depends on the macropores and the spatial heterogeneity of the soil environment. The intensity of soil processing is then reflected in the orientation of the pore structure.

When soil is processed in a conventional way, a homogeneous layer with horizontal structure of the pores originates; when it is processed by the minimization, a vertical structure of the pores (earthworms, fissures) originates. The minimization soil processing offers an increase of the conductivity and infiltration capacity, the reduction of surface drain and the erosion risk. Conservative technology can reduce the surface drain and increase the infiltration (Schipitalo *et al.*, 2000).

MATERIALS AND METHODS

Description of the Experimental Area

The experimental areas are situated in the cadastre of Horní Meziříčko, Jindřichův Hradec district, near the Jilem-Strmilov road. From the geological point of view, it belongs to the area of the Mrákotín Highlands. The terrain is hilly with large differences in altitude. The elevation of the plots is 645 m above the sea-level.

The western part of the monitored area is situated in the basin of Nežárka; the eastern part in the basin of the river Dyje. The drainage network is composed of a number of small streamlets that run through terrain depressions from west to east and, gradually, leave the area of interest.

For the characterization of climatic conditions of the location, the data related to the closest weather station – Telč (527 m a. s. l.) – were used. It is a slightly cool area where the average year temperature is around 6.5 °C and the average year precipitation amount is 617 mm (The Climate of Czechoslovakia – charts, Hydrometeorological Institue Prague 1960).

Both experimental areas are situated close to each other; they are slightly steep with southern exposure. The layout of soil profile:

- 0–30 cm: Ap – topsoil horizon created by ploughing and common cultivation,
- 30–40 cm: B – transitional horizon,
- 40 cm and more: C–parent material.

On the soil forming substrate of paragneisses, the dystric cambisol emerged through weathering. The depth of the soil is limited by strong skeletal soil. The structure of the soil is indistinctive, the humus content reaches 1.5%. Basic soil type: light soil – loamy sand.

The Stagra Studená Company processes the soil by minimization since 1992. It uses the HORSCH SE3 No-Till Seed Drills, whose function is based on a shallow cutting of the top layer of the soil up to the depth of 150 mm with simultaneous printed sowing. The cutter creates a base for the seed which is then covered by the soil and post-harvest remains. The ploughs are not used for soil preparation. The private farmer Mr. Matoušek uses a conventional method of farming, based on a yearly ploughing with ploughs to the depth of 300 mm with subsequent operations aimed to prepare the land for sowing.

Since 2005, the lands were seeded alternatively with winter and spring crops. In the conventional way of soil processing: field pea (*Pisum sativum* L.), winter wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.) and rapeseed (*Brassica napus* L.); using the minimalization way of soil processing: field pea (*Pisum sativum* L.), Triticale, corn (*Zea mays* L.), winter wheat (*Triticum aestivum* L.). With regard to the different composition of cultivated crops, the results of the examination of infiltration characteristics of the soil processed by different technologies were mainly compared from the point of view of agrotechnical operations (winter and spring crops) at the same time and under the same conditions, but also for particular crops cultivated within the particular year.

Physical Characteristics of the Soil

Each experimental area was characterized by a borrow pit near the drench infiltration experiments, from which disturbed and undisturbed soil samples were taken (KV with a uniform volume of 100 cm^3) from the plough layer (10, 20, 30 cm) in three repetitions.

In the pedology laboratory of the Institute of Landscape Water Management of the Faculty of Civil Engineering at the University of Technology in Brno, the physical properties of the soil (the current humidity, reduced bulk density, porosity, water retention capacity, presentation of individual pores and aeration) were evaluated according to the standard methodology, i.e. by a basic analysis of intact soil samples, which was completed by pycnometric determination of density (Jandák, 2003).

In the monitored period 2005–2008, the taking of soil samples was performed at the same time as monitoring of the infiltration capacity of the soil on experimental areas.

Drench infiltration

The drench infiltration experiments using the double-cylinder method were carried out repeatedly on experimental areas. Four sets of infiltration cylinders were used, with inner diameters of: 25.4, 26.3, 35.7 and 35.8 cm. Outer cylinder diameters: 35.2, 35.7, 51.37 and 52 cm.

From 2005 to 2008, 10 sets of measurements were carried out. In 2005, two measurements were performed in June and one in August. In 2006, two measurements were performed in April and two in August. In 2007, two sets of measurements were performed in April and June and one in October. In 2008, two measurements were performed in each month of April, June and August.

Methodology of Measurement: two concentric steel cylinders were placed on the surface with cut vegetation cover and were pushed uniformly into the depth of ca. 15 cm. The surface joints by the cylinder walls were caulked by the soil. The inner cylinder was provided by a level check spire; its bottom was covered with a protective board preventing the surface from drifting in the point of the infusion of water doses. The cumulative infiltration i_t, depending on the time *t* was monitored in the inner cylinder; the infiltration of water from the outer cylinder ensured the verticality of the stream lines in the inner cylinder. During the experiment, the same minimum water level, overpressure minimalization (1–3 cm), was maintained in both cylinders.

The measurements were performed by adding a known amount of water (1 lt) over the reference level stabilized by the measurement spire (1 or 1.5 cm). The time of adding the dose of water was recorded. The particular experiments were terminated when a constant rate of infiltration was reached. In the case of cylinders with slow infiltration speed, the experiments were limited by time, each lasting a minimum two hours. Before the infiltration started, samples had been taken to evaluate the current humidity which influences the infiltration process at the beginning.

Algebraic infiltration equations, both empiric and physically derived, were used for the evaluation (Kutílek *et al.*, 1994). The equations of the above mentioned authors were selected due to the shallow soil horizon and the expected deformation of the vertical component.

The Kostiakov's equation is based on a hyperbolic shape of the curve; it is suitable for the initial stage of the process. The infiltration speed v_t and cumulative infiltration i_t are calculated from the following relations:

$$v_t = v_1 \times t^{-\alpha}, \tag{1}$$

$$i_t = \frac{v_1}{1-\alpha} \times t^{1-\alpha}, \tag{2}$$

where:

v_1 – infiltration speed at the end of the first time unit [cm.min^{-1}],

t – time elapsed from the beginning of the infiltration [min],

α – exponent depending on the characteristics of the soil and the beginning moisture.

The linear form of the equation for the evaluation of the infiltration is quoted in the following form:

$$\log i_t = \log \frac{v_1}{1-\alpha} + (1-\alpha) \log t \times t^{1-\alpha}, \tag{3}$$

which can be taken as the equation of the line $y = ax + b$, where $y = \log i_t$, $a = 1 - \alpha$, $x = \log t$, $b = \log v_1/1 - \alpha$. The parameters of the *a*, *b* line are determined by linear regression of the minimalization of the squares of the deviations.

The Philip's equation is based on a semi-analytic solution of the vertical infiltration by the perturbation method in the form of an infinite number series; it is suitable for relatively short and medium time periods. The algebraic equation only considers its first two members:

$$v_t = 1/2\, \mathrm{S}t^{-1/2} + A, \tag{4}$$

$$i_t = \mathrm{S}t^{1/2} + At, \tag{5}$$

where:

S – sorptivity [cm.min$^{-1/2}$], cumulative amount of water infiltrated within the time t = 1.

A – parameter with the speed proportion [cm. min^{-1}].

The parameters *S*, *A* are determined from a system of two equations with two unknowns using the determinants or using the GEM.

The parameter S of the equation (5) is the approximation of sorptivity; it favorably represents the real value of sorptivity, the error of approximation is theoretically not higher than 10% (Kutílek *et al.*, 2004).

The three-parameter Philip-type equation considers only the first three members:

$$v_t = \frac{1}{2} C_1 t^{-1/2} + C_2 + \frac{3}{2} C_3 t^{1/2}, \tag{6}$$

$$i_t = C_1 t^{1/2} + C_2 t + C_3 t^{3/2}, \tag{7}$$

where:

C_1 – estimation of sorptivity [cm.min$^{-1/2}$],

C_2, C_3 – equalizing process parameters, C_2 [cm. min^{-1}], C_3 [cm.min$^{-3/2}$].

It is solved as a system of three equations with three unknowns using the determinants or using the GEM.

From the equation (7), the "limit" time l_y is determined, as well as the speed of infiltration *K* within this time period, which represents a good estimation of the saturated hydraulic conductivity:

$$t_{\mathrm{lim}} = \frac{C_1}{3C_3}, \tag{8}$$

$$K = (C_1 C_3)^{1/2} + C_2. \tag{9}$$

To estimate the saturated hydraulic conductivity *Ks* from the drench infiltration measurement, the three-parameter Philip-type equation (7) and a relation derived from it were used.

RESULTS AND DISCUSSION

Physical Characteristics of the Soil

The results of physical characteristics of the soil are listed in the form of a table. Tab. I.a and I.b represent the average values of physical characteristics depending on the depth of taking from the topsoil horizon in the individual examination years for experimental fields with different types of soil processing.

The *current humidity* (θ) shows the current content of water in the soil; it influences the infiltration process at the beginning.

The *reduced bulk density* (ρ_d) depends on the density of the solid phase of the soil and the volume of the pores. It describes the situation of bulkage or com-

I: *a) Physical parameters of the soil, conventional soil processing*

Year	2005			2006			2007			2008		
Depth [m]	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30
ρ_d [g.cm^{-3}]	1.45	1.47	1.49	1.47	1.45	1.43	1.51	1.60	1.57	1.45	1.45	1.54
θ [% vol.]	26.13	25.25	23.00	25.20	26.42	21.20	18.60	21.31	20.81	17.30	18.75	17.56
θ_{RK} [% vol.]	25.36	24.80	21.60	25.01	23.00	18.62	23.34	21.71	21.90	21.72	20.26	19.71
P [% vol.]	45.00	43.20	42.80	43.48	42.85	41.71	42.12	38.00	40.38	42.10	40.73	37.25
P_K [% vol.]	25.36	24.80	21.60	25.01	23.00	18.62	23.34	21.71	21.90	21.72	20.26	19.71
P_S [% vol.]	9.15	10.50	9.25	7.88	10.29	7.78	8.88	9.26	9.06	8.59	8.38	6.84
P_N [% vol.]	12.10	8.94	12.64	10.58	9.56	12.31	9.90	7.03	9.42	11.79	12.10	10.70
V_Z [% vol.]	18.87	17.95	19.80	18.28	16.44	20.51	23.53	16.68	19.57	24.79	21.98	19.69

I: b) *Physical parameters of the soil, minimization soil processing*

Year	2005			2006			2007			2008		
Depth [m]	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30	0.10	0.20	0.30
ρ_d [g.cm^{-3}]	1.49	1.55	1.58	1.51	1.55	1.60	1.57	1.61	1.64	1.45	1.55	1.57
θ [% vol.]	26.00	25.19	22.35	26.36	24.46	22.50	18.32	21.01	17.94	18.42	18.07	17.47
θ_{RK} [% vol.]	27.20	24.15	21.05	24.15	22.18	18.16	23.58	22.55	19.86	22.56	20.90	19.85
P [% vol.]	43.20	41.00	40.00	42.22	40.10	39.50	39.63	37.74	38.24	41.41	37.14	36.65
P_K [% vol.]	27.20	24.15	21.05	24.15	22.18	18.16	23.58	22.55	19.86	22.56	20.90	19.85
P_S [% vol.]	8.45	8.95	10.00	6.35	6.82	9.10	8.38	9.54	11.96	7.47	6.57	7.05
P_N [% vol.]	11.05	10.12	12.65	10.02	9.53	12.23	7.68	5.65	6.43	11.33	8.37	9.51
V_Z [% vol.]	17.20	15.81	17.65	15.86	15.65	17.00	21.31	16.73	20.30	22.99	19.07	19.18

pression. The bulk density increases with the depth of the soil profile as well as in the individual years of examination. In the last year, a decrease is noted and the values are, in effect, nearly the same as in the first year of examination. In the case of minimization technology, the bulk density is higher than in the case of ploughing and it increases more uniformly with increased depth. The critical values, evidencing a harmful concretion of the soil (Lhotský, 1984: loamy sand $\rho_{d\ critical}$ = 1.6 g.cm^{-3}) were demonstrated in the case of conventional processing only in 2007 at the depth of 20 cm and, in the case of minimization, in the years 2007–2008 in major depths of the topsoil. According to the values of bulk density, the structural situation of humus horizon was roughly evaluated; in both technologies of soil processing it is characterized as unsatisfactory ρ_d = 1.4–1.6 *g.cm*$^{-3}$ (Kutílek, 1978).

The porosity reflects the instantaneous representation of the volume of the pores within the total volume of the soil. It is one of the main indicators of the spatial layout of the soil mass; in the pores, all physical, physiochemical and biological processes take place. In the soil pores, the development and growth of rootlets takes place. A small amount of pores or their unsatisfactory size disables the development of the root system. Based on the porosity values, the settlement of the soil and, indirectly, the soil structure is evaluated. The critical values of porosity (Lhotský, 1984: P_K < 40) were evidenced in both methods of soil processing. In the case of conventional processing, the critical values were evidenced in major topsoil depths; in the case of minimization, since 2006. The soil can be classified according to the porosity (Bretfeld). In the case of conventional processing, the topsoil was settled (P = 40–50 %) during the whole period of monitoring. In the case of minimization, the topsoil was settled in the first half of the period of monitoring and very settled (P < 40) in its second half.

The *water retention capacity* (θ_{RK}) characterizes the humidity of the soil that remains in the soil for a longer period after it being moisturized by seepage forces. It approximately characterizes the volume of the so-called capillary pores. It is practically identical with the field retention capacity. In the monitored period, both experimental areas showed progressive decrease of the retained water in the soil, related to the regional climatic conditions (decrease of precipitations, increased air temperature). In the particular years studied, the maximums are reached in the top layer of the topsoil and the values decrease with major depth. The retained water quickly disappears from the topsoil horizon to major depths of the soil profile (loamy sand). Its representation is significantly below the average, which manifests in the form of an unsatisfactory representation of capillary pores.

The *capillary pores* (P_k) lead the water against gravitation; their value is approximately the same as the value of the water retention capacity. The optimal share of capillary pores is about 2/3 of the values of porosity. An abundance of capillary pores makes the infiltration more difficult. The soil receives too little water, the moisturization only works in shallow depths, the precipitations are not efficiently used and surface drainage occurs with the danger of slope erosion.

The *non-capillary pores (P_n)* enable the water to enter the soil and reach major depths. An abundance of those does not make the surface layer more humid, as the speed of the infiltration cannot ensure the saturation of capillary pores. The roots of the plant are not supplied with sufficient water.

The *semi-capillary pores (P_s)* are a transition category between the capillary and the non-capillary pores; the gradual fixation of the groundwater level happens in them. They enable a good penetration of the water into the soil and, by its retention, enable the saturation of capillary pores in major depths. In both technologies of soil processing, the shares of the particular types of capillary pores are relatively negative during the whole period of examination. The representation of capillary pores does not reach the optimum level (ca. 55 %), and the share of non-capillary pores is also relatively high. In the case of conventional processing, they are prevalent practically all the time; in the case of minimalization, only in 2005, 2006, and 2008. There is not enough water for the vegetation in the soil, the water is outside the reach of the roots of the plants.

The *aeration* of the soil (instantaneous) indicates the proportion of the volume of the air in the sample and the column of the sample; it depends on the humidity of the soil. The optimum aeration of topsoil horizons in a good cultural condition is about 18–24% vol. If the aeration is low, the change of the air in the soil is too slow; a high value indicates an excessive activity of the aerobic organisms and a fast degradation of the humus. The optimum aeration was not reached, in the case of conventional processing, at a depth of 0.20 m within the years 2005–2007. In the case of minimalization, the aeration of the topsoil layer is insufficient in the first half of the monitored period; in the following year, it is only noted at a depth of 0.20 m.

From the results achieved we can appreciate the fact that physical characteristics of the soil are distinctively better in the case of conventional technology, compared to the minimization. The cam-

II: *The evaluation of the constant speed of infiltration and the total cumulative infiltration – conventional soil processing*

Crop	Year	Measurement	measured		Kostiakov		Philip		three-parameter Philip-type eq.	
			time	cumul. infiltrat.	constant speed of infiltration	cumul. infiltrat.	constant speed of infiltration	cumul. infiltration	constant speed of infiltration	cumul. infiltration
			t_c	i_T	v_c	i_T	v_c	i_T	v_c	i_T
			min	cm	cm.min^{-1}	cm	cm.min^{-1}	cm	cm.min^{-1}	cm
field pea	2005	1	122.18	36.56	0.19	33.77	0.24	36.07	0.22	35.77
		2	121.88	19.91	0.06	16.42	0.10	18.60	0.14	19.39
		3	130.08	36.73	0.22	37.73	0.26	38.88	0.22	37.96
winter wheat	2006	4	105.40	17.95	0.09	16.74	0.12	17.83	0.13	18.05
		5	110.00	18.00	0.09	17.54	0.12	17.85	0.13	18.07
		6	128.17	12.42	0.05	10.87	0.07	12.19	0.09	12.49
		7	121.70	38.48	0.27	39.26	0.27	38.42	0.23	37.68
spring barley	2007	8	118.67	45.88	0.21	40.28	0.30	45.15	0.32	45.56
		9	135.67	28.02	0.10	25.14	0.13	27.50	0.15	27.92
		10	150.80	44.76	0.24	53.03	0.18	46.93	0.20	43.45
		11	165.22	18.43	0.04	15.12	0.07	17.16	0.13	18.86
rapeseed	2008	12	150.00	21.72	0.06	21.73	0.06	21.77	0.08	22.38
		13	119.13	13.92	0.05	12.47	0.08	13.99	0.08	14.01
		14	129.42	25.67	0.09	22.81	0.13	24.61	0.19	25.92
		15	151.58	12.93	0.04	13.18	0.03	12.80	0.04	13.20
		16	138.37	14.92	0.05	13.01	0.07	14.53	0.09	14.79
		17	125.42	57.12	0.32	61.31	0.28	57.53	0.24	56.64
ø			130.81	27.26	0.13	26.49	0.15	27.17	0.16	27.18
ø winter crops			127.92	23.31	0.11	22.89	0.12	23.15	0.13	23.32
ø spring crops			134.93	32.90	0.15	31.64	0.18	32.90	0.20	32.70
ø field pea			124.72	31.07	0.16	29.31	0.20	31.18	0.19	31.04
ø wheat			116.32	21.71	0.13	21.10	0.15	21.57	0.15	21.57
ø barley			142.59	34.27	0.15	33.39	0.17	34.18	0.20	33.95
ø rapeseed			134.17	25.53	0.11	25.06	0.12	25.38	0.13	25.57

bisol reflects the change of the technology of soil processing quite quickly and significantly; it presents a higher variance of results of the indicator and a higher vulnerability.

Field Infiltration Measurements

In the years 2005–2008, 35 infiltration experiments were performed on the experimental areas with differing technologies of soil processing. The experiments were evaluated using the algebraic empiric equations (Kostiakov) and physically derived equations (Philip, three-parameter Philip-type equation). The results of the experimental measurements were processed using Excel and are summarized in the tables, Tab. II–IV, and in diagrams, Fig. 1–8.

In the upper part of the tables II and IV, the total time of the realization of the experiment t_c is stated, as well as the measured and calculated cumulative infiltration i_t and the constant speed of infiltration v_c.

In the lower part of the table, the averages, i.e. the arithmetic average of all infiltration experiments for every experiment area, are stated depending on the agrotechnical operation performed (winter crop, spring crop) and for the crop grown in the particular year.

In the upper part of the tables III and V, the parameters of infiltration equations are stated, as well as the estimation of the saturated hydraulic conductivity K_s for individual infiltration experiments.

In the lower part, the average parameters of infiltration equations and the *Ks* of all values reached for every experiment area are stated, depending on the agrotechnical operation performed (winter crop, spring crop) and for the crop grown in the particular year.

Since the data volume is not extensive, the average values can only serve as orientation indicator for the assessment of the differences between the results of the particular measurements.

For the evaluation of the infiltration experiments, the most efficient, from the point of view of the flexibility, time stability and quality of infiltration data smoothing, is the use of a three-parameter Philip-type equation, which offers a good estimation of the saturated hydraulic conductivity *K*, and the parameter C_1 can be awarded a physical importance (good sorptivity approximation). The parameter *S* of the Philip equation favorable represents the real

III: *Infiltration equations' parameters – conventional soil processing*

Crop	Measurement	Kostiakov			Philip		three-parameter Philip-type equation				
		i_1	v_1	α	S	A	C_1	C_2	C_3	t_{lim}	K
		cm	$cm.min^{-1}$	$(lnmin)^{-1}$	$cm.min^{-1/2}$	$cm.min^{-1}$	$cm.min^{-1/2}$	$cm.min^{-1}$	$cm.min^{-3/2}$	min	$cm.min^{-1}$
field pea	1	1.3210	0.6745	0.3255	1.3247	0.1754	1.0497	0.2511	−0.0048		
	2	1.7228	0.4694	0.5306	1.1242	0.0508	1.7800	−0.1333	0.0119	49.93	0.1186
	3	0.9013	0.7661	0.2329	0.8917	0.2207	0.2998	0.3829	−0.0103		
winter wheat	4	1.0673	0.5910	0.4090	1.0070	0.0711	1.1774	0.0195	0.0036	108.70	0.1324
	5	1.1113	0.5930	0.3925	1.0021	0.0696	0.9012	0.0201	0.0032	105.20	0.1311
	6	0.7479	0.8473	0.1527	0.5199	0.0492	0.8263	−0.0316	0.0050	55.64	0.0792
	7	0.6715	0.5690	0.1527	1.0419	0.2212	0.4336	0.3896	−0.0108		
spring barley	8	2.1779	0.6108	0.3892	1.7969	0.2156	2.0446	0.1432	0.0049	139.97	0.3160
	9	1.8876	0.5273	0.4727	1.5778	0.0672	1.9061	−0.0190	0.0053	120.98	0.1543
	10	1.6599	0.6906	0.3094	3.2575	0.0459	1.4166	0.5444	−0.0302		
	11	1.6639	0.4321	0.5679	0.8874	0.0348	2.1205	−0.2571	0.0160	44.04	0.0624
rapeseed	12	2.6815	0.4176	0.5824	2.1911	−0.0338	2.5364	−0.0123	0.0053	159.03	0.0781
	13	1.1176	0.5046	0.4954	0.8434	0.0402	0.8623	0.0348	0.0003	142.93	0.0649
	14	1.8520	0.5163	0.4837	1.4379	0.0638	2.4437	−0.2157	0.0177	46.06	0.1444
	15	1.6320	0.416	0.5840	1.3847	−0.0280	1.6210	−0.0903	0.0037	146.41	0.0437
	16	1.1427	0.4934	0.5066	0.7833	0.0384	1.0489	−0.0303	0.0041	85.64	0.0831
	17	2.6115	0.6532	0.3468	3.9082	0.1097	3.2467	0.2995	−0.0123		
ø		1.5276	0.5748	0.4079	1.4694	0.0830	1.5126	0.0762	0.0007	100.38	0.1173
ø winter crops		1.4635	0.5601	0.4106	1.4120	0.0601	1.5098	0.0383	0.0020	106.20	0.0946
ø spring crops		1.6192	0.5958	0.4040	1.5515	0.1158	1.5168	0.1303	−0.0010	88.73	0.1628
ø field pea		1.3150	0.6367	0.3630	1.1135	0.1490	1.0432	0.1669	−0.0011	49.93	0.1186
ø wheat		0.8995	0.6501	0.2767	0.8927	0.1028	0.8346	0.0994	0.0003	89.85	0.1142
ø barley		1.8473	0.5652	0.4348	1.8799	0.0909	1.8720	0.1029	−0.0010	101.66	0.1776
ø rapeseed		1.8396	0.5002	0.4998	1.7581	0.0317	1.9598	−0.0024	0.0031	116.01	0.0828

IV: *The evaluation of the constant speed of infiltration and the total cumulative infiltration – minimalization soil processing*

Crop	Year	Measurement	measured		Kostiakov		Philip		3PPT	
			time	cumul. infiltration	constant speed of infiltration	cumul. infiltrat.	constant speed of infiltration	cumul. infiltrat.	constant speed of infiltration	cumul. infiltration
			t_c	i_T	v_c	i_T	v_c	i_T	v_c	T
			min	cm	cm.min^{-1}	cm	cm.min^{-1}	cm	cm.min^{-1}	cm
field pea	2005	1	121.68	5.46	0.01	5.10	0.01	5.14	0.03	5.59
		2	127.00	30.40	0.09	25.41	0.15	28.89	0.21	29.87
		3	120.00	6.08	0.03	5.58	0.04	5.87	0.04	5.87
triticale	2006	4	126.00	9.06	0.03	7.85	0.04	8.81	0.06	9.32
		5	135.80	14.35	0.06	13.57	0.07	14.31	0.08	14.36
		6	135.00	17.19	0.06	14.87	0.08	16.27	0.11	16.92
corn	2007	7	180.00	29.54	0.08	28.11	0.11	31.30	0.10	30.69
		8	203.25	13.82	0.02	11.08	0.03	13.31	0.06	13.98
		9	169.18	27.99	0.06	24.20	0.11	26.25	0.13	27.86
		10	152.83	14.81	0.03	13.27	0.03	13.27	0.05	14.42
		11	163.28	16.59	0.04	13.99	0.06	15.28	0.09	16.13
		12	207.00	3.50	0.002	3.02	0.003	3.35	0.02	3.35
w. wheat	2008	13	157.30	11.99	0.03	11.18	0.03	11.74	0.05	12.30
		14	169.67	14.74	0.02	11.32	0.05	14.42	0.07	14.96
		15	153.35	12.49	0.04	12.41	0.03	12.07	0.04	12.30
		16	176.18	10.13	0.02	10.10	0.02	9.90	0.03	10.10
		17	107.28	9.87	0.05	9.21	0.07	9.87	0.08	9.96
		18	147.28	5.00	0.05	4.57	0.02	4.84	0.03	4.97
ø			152.89	14.06	0.04	12.49	0.05	13.61	0.07	14.05
ø winter crops			145.32	11.65	0.04	10.56	0.05	11.36	0.06	11.69
ø spring crops			143.49	14.82	0.04	12.94	0.06	14.38	0.08	14.82
ø field pea			122.89	13.98	0.04	12.03	0.06	13.30	0.09	13.78
ø triticale			132.27	13.53	0.05	12.10	0.06	13.13	0.08	13.53
ø corn			153.79	15.24	0.03	13.40	0.05	14.92	0.07	15.33
ø w. wheat			151.84	10.70	0.04	9.80	0.04	10.48	0.05	10.77

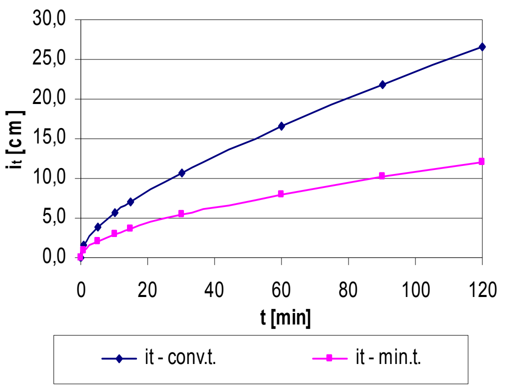
value of soil sorptivity. A higher sorptivity was evidenced in the case of conventional soil processing, where also a good conformity of parameters *S* and C_1 was noted. In the case of minimalization, the infiltration capacity of the top layers of the soil is significantly lower (53–60%) and practically does not change (winter crops, spring crops, individual types of crops); the conformity of the *S* and C_1 parameter was not demonstrated, as it was in the case of conventional processing.

For graphical representation, all equations were unified in time and, using the Philip equation, the cumulative infiltrations i_t and the infiltration speeds v_t in the time t = 1, 5, 10, 15, 30, 60, 90 and 120 minutes were calculated. The results are presented as averages, i.e. arithmetic average for experimental areas, in relation with the agrotechnical operation performed (winter crop, spring crop) and for the crop grown in the particular year, Fig. 1–8. The average cumulative infiltration is significantly higher in the case of conventional processing compared to the minimalization. This fact clearly results from the graphic presentation of cumulative infiltration $i_t(t)$ and the intensity of infiltration $v_t(t)$, Fig. 1–8. Both experimental areas, depending on the agrotechnical operation performed, show a higher cumulative infiltration in the case of spring crops; in the case of winter crops it is over 70 %. From the point of view of individual examination years, the highest cumulative infiltration was reached on the spring barley field (conventional processing) and the lowest, at the wheat field (minimalization).

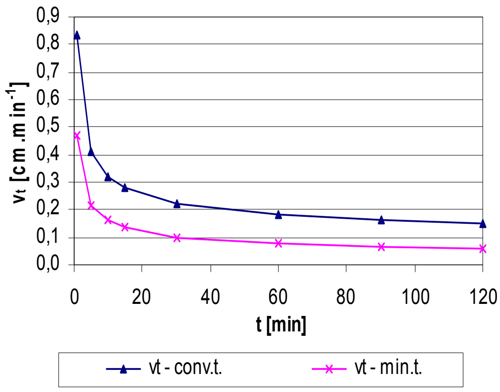
The estimated values of saturated hydraulic conductivity K_s are demonstrably higher in the case of conventional processing; in the case of minimalization they reach one third (spring crops average) to one half (total average, winter crops average). Similar results were documented by other authors, Šindelář *et al.*, 2007, Matula *et al.*, 2003.

V: *Infiltration equations' parameters – minimalization soil processing*

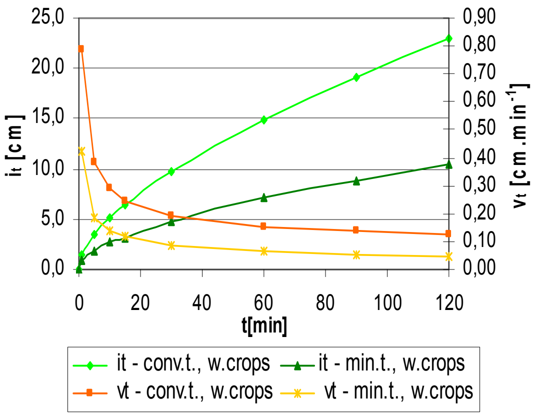
Crop	Measurement	Kostiakov			Philip		three-parameter Philip type equation				
		i_1	v_1	α	S	A	C_1	C_2	C_3	t_{lim}	K
		cm	$cm.min^{-1}$	$(lnmin)^{-1}$	$cm.min^{-1/2}$	$cm.min^{-1}$	$cm.min^{-1/2}$	$cm.min^{-1}$	$cm.min^{-3/2}$	min	$cm.min^{-1}$
field pea	1	1.3014	0.2843	0.7157	0.8274	−0.0328	1.1610	−0.1327	0.0066	58.15	0.0196
	2	2.5620	0.1737	0.5263	1.6346	0.0824	2.5222	−0.2160	0.0152	55.37	0.1792
	3	0.2658	0.6360	0.3640	0.2439	0.0267	0.2443	0.0265	0.00001	70.14	0.0288
triticale	4	1.0272	0.4205	0.5795	0.6515	0.0119	1.0233	−0.0090	0.0065	52.61	0.0511
	5	0.7351	0.5937	0.4063	0.7406	0.0418	0.7886	0.0294	0.0007	75.15	0.0713
	6	1.1957	0.5139	0.4861	0.9668	0.0373	1.3570	−0.0701	0.0068	66.85	0.0959
corn	7	1.8746	0.5214	0.4786	1.6315	0.0523	1.4100	0.1062	−0.0030		
	8	1.6872	0.3541	0.6459	0.8934	0.0028	1.3491	−0.0973	0.0050	89.76	0.0451
	9	2.4007	0.4503	0.5497	1.2924	0.0558	2.1025	−0.0860	0.0068	102.32	0.1218
	10	1.5489	0.4319	0.5681	0.8867	0.0242	1.7966	−0.1732	0.0103	58.25	0.0622
	11	1.9850	0.3777	0.6223	1.0648	0.0082	1.7438	−0.1534	0.0090	64.34	0.0640
	12	1.2575	0.1645	0.8355	0.3823	−0.0104	1.7438	−0.0988	0.0041	65.55	0.0015
w. wheat	13	1.7550	0.3660	0.6340	1.1599	−0.0178	1.5100	−0.1033	0.0049	103.31	0.0045
	14	2.2000	0.3190	0.6810	0.8724	0.0180	1.2935	−0.0789	0.0052	82.89	0.0632
	15	1.1830	0.4670	0.5330	1.1652	−0.0154	1.3258	−0.0561	0.0024	187.25	0.0408
	16	1.1333	0.4229	0.5771	1.0440	−0.0225	1.2350	−0.0665	0.0023	177.42	0.0262
	17	0.5511	0.6023	0.3977	0.4467	0.0489	0.5962	0.0058	0.0028	69.85	0.0772
	18	0.5382	0.4286	0.5714	0.3856	0.0011	0.5754	−0.0458	0.0027	70.93	0.0219
ø		1.4001	0.4182	0.5651	0.9050	0.0174	1.3210	−0.0677	0.0049	80.56	0.0573
ø winter crops		1.1465	0.4593	0.5407	0.8258	0.0115	1.0783	−0.0438	0.0038	98.47	0.0502
ø spring crops		1.4331	0.3351	0.5204	0.8658	0.0223	1.3699	−0.0746	0.0050	62.44	0.0573
ø field pea		1.3764	0.3647	0.5353	0.9020	0.0254	1.3092	−0.1074	0.0073	61.22	0.0759
ø triticale		0.9860	0.5094	0.4906	0.7863	0.0303	1.0563	−0.0166	0.0047	64.87	0.0728
ø corn		1.4615	0.3204	0.5130	0.8477	0.0208	1.4003	−0.0582	0.0039	63.18	0.0589
ø w.wheat		1.2268	0.4343	0.5657	0.8456	0.0021	1.0893	−0.0575	0.0034	115.28	0.0390



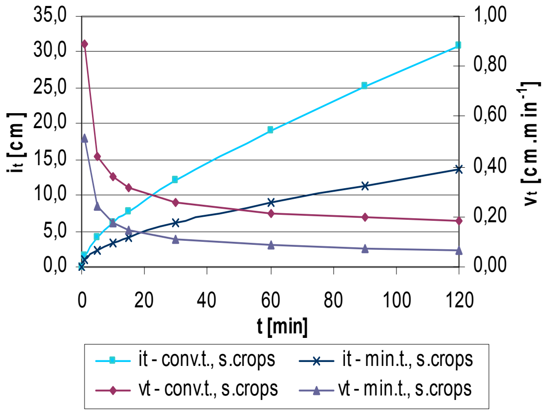
1: *Cumulative infiltration $i_t(t)$ – conv. and min. t. (total averages)*



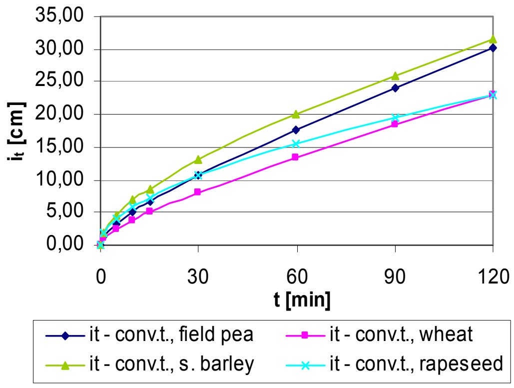
2: *Intensity of infiltration $v_t(t)$ – conv. and min. t. (total averages)*



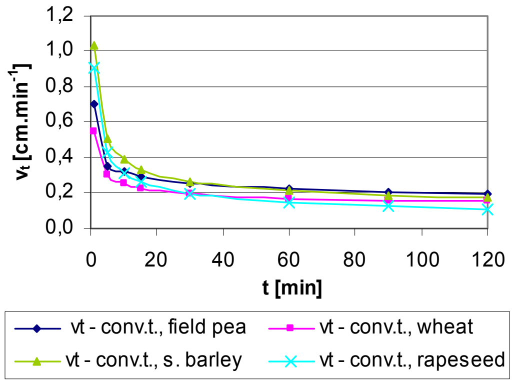
3: *Cumulative infiltration $i_t(t)$ and intensity of infiltration $v_t(t)$ – conv. and min. t. (spring crops)*



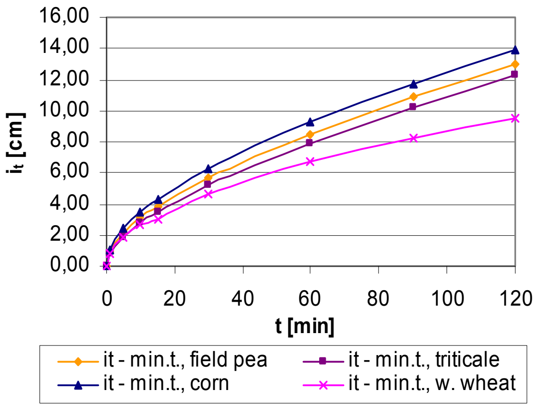
4: *Cumulative infiltration $i_t(t)$ and intensity of infiltration $v_t(t)$ – conv. and min. t. (winter crops)*



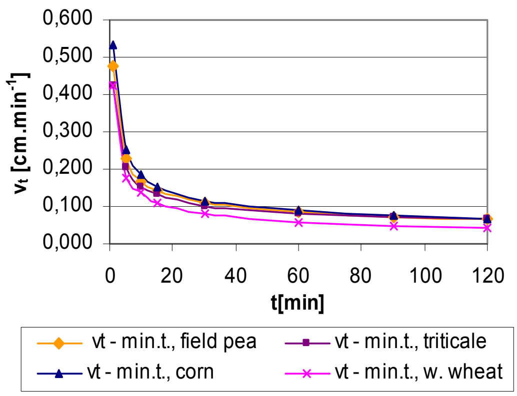
5: *Cumulative infiltration $i_t(t)$ – conv. t. (field pea, wheat, spring barley, rapeseed)*



6: *Intensity of infiltration $v_t(t)$ – conv. t. (field pea, wheat, spring barley, rapeseed)*



7: *Cumulative infiltration $i_t(t)$ – min. t. (field pea, triticale, corn, w. wheat)*



8: *Intensity of infiltration $v_t(t)$ – min. t. (field pea, triticale, corn, w.wheat)*

SUMMARY

During the years 2005–2008, the measurements of hydro-physical soil properties were performed on two experimental plots with different ways of soil cultivation, and area of minimizing cultivation (Stagra Studená) and a conventionally cultivated area (Matoušek company) in the Jindřichův Hradec District near the road Jilem – Strmilov. From the geological point of view this area belongs to the Mrakotin Highlands. The terrain is hilly with large differences in altitude. The altitude of the land is 645 m above the sea level. On the soil forming substrate of paragneisses, the dystric cambisol emerged through weathering. The depth of the soil is limited by strong skeletal soil. Basic soil type: light soil – loamy sand.

The Stagra have been farming by minimizing technology since 1992. This technology is based on shallow cutting the top layer of soil to the depth of 150 mm, together with printed sowing. The private farmer uses a conventional way of farming, based on ploughing by ploughs into the depth of 300 mm with subsequent operations to prepare land for sowing. There has been a rotation of winter crops and spring crops since 2005. Each experimental area was characterized by a borrow pit near the drench infiltration experiments. Disturbed and non-disturbed soil samples were picked from there (KV with a uniform volume of 100 cm^3) from the plough layer (10, 20, 30 cm) in three repetitions. The physical properties of soil (the current humidity, reduced bulk density, porosity, water retention capacity of individual pores and aeration) were evaluated according to standard methodology, i.e. by a basic analysis of intact soil sample, which was completed by pycnometric determination of density (Jandák, 2003). At the same time, the drench infiltration experiments using the double-cylinder method were carried out. Four sets of infiltration cylinders were applied, with inner diameters of: 25.4, 26.3, 35.7 and 35. 8 cm. The outer cylinder diameters were 35.2, 35.7, 51.37 and 52 cm. In 2005–2008, 10 sets of measurements were carried out.

During the reporting period 2005–2008 no significant changes in soil physical properties connected with the used soil treatment technologies were observed. For assessment of the structural condition of the soil as an indicator of the impact of the technology of soil cultivation, the values of porosity and density (the critical value of soil compaction, structural condition of organic horizon) were used. The experimental areas show considerably compressed topsoil and the structural condition of the organic horizon is characterized as unsatisfactory. Due to the long-term degradation of agricultural land in the Czech Republic, the adjustment will be slow and depending on many factors.

The state of the soil can be assessed on the basis of water movement in the soil, thus by measuring of the infiltration. The infiltration capacity of soils is significantly higher in the conventional treatment, while in the case of minimization it is less than half. This corresponds to the estimated values of saturated hydraulic conductivity *Ks*, which are one-third to one-half in size in the case of minimization. If that area showed a long-term decline in the values of *Ks*, then more negative effects would arise, i.e. compression of surface layers, increase of surface runoff, erosion hazards and reduction of crop yields.

If we classify the permeability of the soil according to the hydraulic conductivity K [$m.day^{-1}$], the plot with conventional cultivation belongs to different group of soils than the plot with minimizing processing (Holý *et al.*, 1984). According to Němec, the plot with the conventional treatment showed high permeability and the plot with minimizing treatment medium permeability, according to Kutílek it is moderate to large and medium, respectively.

To increase the infiltration and retention capacity of soil with minimizing processing a consultation with specialist is required to propose appropriate agricultural measures promoting the infiltration capacity of soils.

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