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EFFECT OF VARIOUS COMPOST DOSES ON THE SOIL INFILTRATION CAPACITY

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Abstract

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In the years 2008–2012, the infiltration capacity was monitored in the different sites, viz. on the arable land and permanent grassland. In the permanent grassland site the soil was characterised as Leptic Cambisol, loamy sand with the depth of the top layer 0.20 m while on the arable land, it was classified as Eutric Cambisol, sandy loam with the maximum depth of the topsoil humus horizon 0. 40 m. Experimental variants with different doses of incorporated compost were as follows: Variant 1 –without compost incorporation, Variant 2 – compost incorporated in the dose of 80 $t.ha^{-1}$, Variant 3 – compost incorporated in the dose of 150 $t.ha^{-1}$. It was found out within the study period that the application of the higher compost doses showed a positive effect on infiltration rate in both localities. In Variant 3, the highest values of the water infiltration were recorded. It can be concluded that the highest dose of compost (150 $t.ha^{-1}$) improved and accelerated both the infiltration and water holding capacity of soil for a longer period. With the exception of the year 2009, increased values of water infiltration were recorded on experimental plots with arable land than with permanent grassland. It was found also that after five years have not been marked differences between variants. It follows that the regular supply of organic matter is necessary, preferably after three years.

Keywords: soil water regime, organic matter, arable land, permanent grassland

INTRODUCTION

When protecting the soil against water erosion, its infiltration capacity represents one of important factors. An insufficient infiltration capacity of soil surface limits the percolation of water into the soil and this, in combination with a high intensity of rainfalls (or their longer duration), may become a cause of runoff and of associated negative erosion phenomena (Badalíková & Hrubý, 2010).

In the Czech Republic, composting as a rational method of material use of waste materials of plant origin occupies the first place in the hierarchy of optimum methods used in the domain of biological waste management (Plíva *et al.*, 2005).

The structure and composition of fresh compost is the result of weight ratios of individual wastes and/or materials that are transported to and disposed into composting facilities. Organic waste material is a diversified mixture of substances that are differently resistant to the process of microbiological decomposition. The rate of decomposition of various organic residues can be explained on the base of a different ratio that exists between carbon and nitrogen (C:N). The practice of composting is based on the opinion that the content of carbon represents approximately one half of the total organic matter (i.e. combustible substances). Compostable materials with the narrow C:N ratio 10:1 are degraded very quickly and are easily available for microorganisms. However, substances with C:N ratio above 50:1 are usually decomposed very slowly (Váňa, 1994).

Physical, chemical, and biological properties of soil and, thus, its infiltration capacity, are influenced not only by quality but also by quantity of compost incorporated into the soil. This capacity differs also in dependence on the site, crop, and total degree of tillage. On cultivated plots, Hejduk (2009) observed a more intensive infiltration than on permanent grassland. On plots without tillage, the infiltration capacity was reduced more quickly than in loose, ploughed soils. Grassland increases infiltration into the subsoil (Kvítek *et al.,* 2004), which also leads to the reduction of water erosion (Uhlířová & Podhrázská, 2007; Janeček *et al.,* 2012).

On the soils without plowing was reduced infiltration more quickly, and this reduction was more intense than on loose soil after plowing. The relationship between infiltration and application of composts was investigated also by Stalker (2010). Morel-Seytoux (1982) and Kovář *et al.* (2011) dealt with model measuring of infiltration rate by constant or variable precipitation at small plots experiments. They contributed to the knowledge of the soil permeability and soil erosion prevention.

The aim of this paper was to evaluate influence of different compost doses on the soil infiltration at different land management.

MATERIAL AND METHODS

Within the period of 2008–2012, the infiltration capacity of soil was studied in two different localities, viz. on arable land and on a plot with permanent grassland. In both localities altogether three experimental variants with increasing doses of compost were established.

- Locality A – permanent grassland that was characterised as Leptic Cambisol with loamy-sandy soil and with the maximum depth of arable layer of 0.20 m.
- Locality B – arable soil was characterised as Eutric Cambisol, with sandy-loamy texture and the maximum depth of humus horizon 0.40 m.

Both localities are situated near the town Náměšť nad Oslavou (Czech Republic) at the altitude of 375 m; this territory is characterised as a moderately warm and moderately humid region with long-term average precipitations and temperatures of 594.4 mm and 7.2 °C, respectively.

Individual experimental variants with different doses of incorporated compost were as follows:

- Locality A – permanent grassland: Variant 1 – disturbed sod without compost incorporation; Variant 2 – compost incorporated in the dose of 80 $t.ha^{-1}$; Variant 3 – compost incorporated in the dose of 150 $t.ha^{-1}$. Permanent grassland was composed from suitable grass-clover mixtures for this area. The grassland was mowned twice a year.
- Locality B – arable land: Variant 1 – stubble breaking without compost; Variant 2 – stubble breaking with the compost dose of 80 $t.ha^{-1}$; Variant 3 – stubble breaking with the compost dose of 150 $t.ha^{-1}$. Arable land was determined this crop rotation: 2008 – Rye (*Secale cereale*), 2009 – Pisum arvense (*Pisum sativum subsp. Arvense*) + Triticale (*Triticosecale*), 2010 Oat (*Avena sativa*), 2011 – Spelt (*Triticum spelta*), 2012 – clover mix.

Experimental compost was produced using the technology of controlled microbial composting in belt heaps established on a free area protected against leakage of liquids. The major raw materials used for composting were cut grass from public lawns and the neighbouring airport, communal waste from gardens and vegetable residues.

Measurements of infiltration properties of soil were performed at the beginning and to the end of the growing season using concentric cylinders with diameters of 28 and 54 cm, always in triplicate respectively. The outer cylinder eliminates the leakage of water to sides and the inner one is used for measurements that are based on monitoring of water losses in time. Measured values of accumulative infiltration were thereafter used for calculations of the rate of ground water infiltration that was expressed in millilitres per minute per sq. meter ($ml.min^{-1}.m^{-2}$).

Along with the infiltration of soil moisture was measured by the gravimetric method and penetrometer resistance of soil. Compaction of soil profile was measured by mechanical penetrometer in five repetitions. The measurement is based on identifying of force required to push the normalized steel cone into the soil. Its advantage is high expedition with instant assessment of the results for the observed profile.

Obtained results were statistically processed using Analysis of variance the ANOVA method.

RESULTS

Results of measurements of water infiltration as recorded within the period of 5 years are presented in Tab. I. It was determined amount of water percolating into the soil and its speed. As shown in Tab. I, the infiltrating capacity of soil was dependent not only on the total dose of applied compost but also on the year, the date of measurements and the locality. It is interesting that a higher intensity of infiltration occurred at the end of the growing season.

In each locality, samples of soil for the estimation of its moisture were collected simultaneously with measurements of infiltration; the reason of this sampling was the fact that the content of water in soil also influenced the rate of water percolation in the course of the growing season. Values of soil moisture were dependent partly on the intensity of rainfalls in the region under study and partly on applied doses of compost. In variants with applied doses of compost, a higher moisture of soil was recorded in both localities. Similar values of water infiltration were recorded only in the last year of experiments, i.e. in 2012. Values of soil moisture, as measured in both localities, are presented in Tabs. II and III.

Tabs. IV and V show the penetrometer results of soil compaction in whole monitoring period. The obtained data showed that depth of measurements increased penetrometer soil resistance. Also, there were identified the lowest values of soil resistance in variants with the highest dose of compost compared to control variant with a lower dose of compost. The Permanent grassland

I: *Values of water infiltration at the beginning and to the end of growing season in variants with different doses of incorporated compost, in years 2008–2012*

Term of measuring	Locality	Variant	Infiltrationml.min^{-1}.m^{-2}				
			2008	2009	2010	2011	2012
Beginning of vegetation	Permanent grassland	1	10.10	13.66	20.15	26.61	38.58
		2	11.17	28.26	26.26	24.24	31.36
		3	11.71	36.67	30.24	81.10	41.60
	Arable land	1	82.07	10.56	68.35	34.06	22.69
		2	113.98	17.98	86.18	43.59	47.11
		3	112.92	22.48	87.61	54.97	37.98
Ending of vegetation	Permanent grassland	1	12.53	21.96	34.72	52.57	47.52
		2	16.72	53.73	34.52	80.49	40.52
		3	34.93	85.44	64.40	83.06	47.52
	Arable land	1	20.64	26.70	17.98	39.10	44.32
		2	45.92	36.82	21.91	89.29	28.41
		3	50.00	31.47	54.65	132.96	39.38

II: *Soil moisture, mean of annual measurement – Permanent grassland 2008–2012*

Variant	Depth (m)	2008	2009	2010	2011	2012
1	0.0–0.10	14.80	5.24	15.88	15.73	6.15
	0.10–0.20	10.19	5.28	15.34	11.75	7.19
	mean	12.49	5.26	15.61	13.74	6.67
2	0.0–0.10	12.16	6.07	19.99	15.59	6.11
	0.10–0.20	10.61	4.92	16.77	9.07	4.29
	mean	11.38	5.50	18.38	12.33	5.20
3	0.0–0.10	7.77	5.81	20.99	13.83	7.36
	0.10–0.20	6.61	4.73	15.94	10.39	5.01
	mean	7.19	5.27	18.47	12.11	6.19

III: *Soil moisture, mean of annual measurement – Arable land 2008–2012*

Variant	Depth (m)	2008	2009	2010	2011	2012
1	0.0–0.10	18.73	10.67	18.36	16.10	9.31
	0.10–0.20	19.23	13.66	20.64	15.93	11.30
	0.20–0.30	17.15	13.78	18.11	13.88	10.87
	mean	18.37	12.70	20.37	15.30	10.50
2	0.0–0.10	15.97	11.75	19.82	14.77	10.40
	0.10–0.20	15.56	15.84	20.82	14.04	11.59
	0.20–0.30	16.67	12.99	19.35	12.81	11.75
	mean	15.77	13.53	20.00	13.87	11.25
3	0.0–0.10	7.92	16.53	19.93	19.09	10.50
	0.10–0.20	8.93	17.96	22.98	18.27	12.26
	0.20–0.30	9.69	17.81	18.83	14.05	11.79
	mean	8.85	17.43	20.58	17.14	11.52

and Arable land in the last year of the research project showed a significant increases penetrometer of soil resistance for all variants. It was probably due to the absence of organic matter, which was last delivered in 2008.

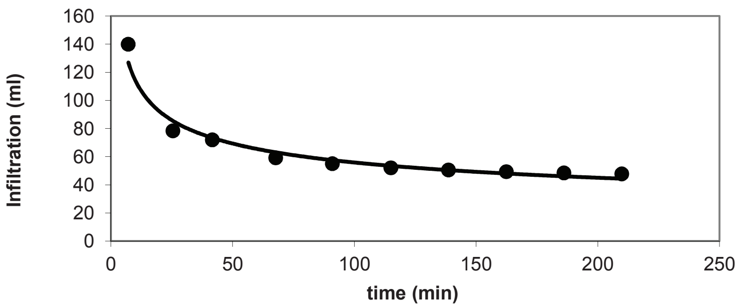
A graphical comparison of infiltration curves per unit of time, as recorded at the beginning of solving (2008) in Figs. 1, 2. As one can see, higher values of water infiltration were at first recorded at the beginning of measurements; this was caused by a decreased compaction of soil. On permanent grassland, however, the water percolation rate was much slower just at the beginning of the growing season, i.e. before the application of compost and grass seeds; the reason of this was a relatively high degree of soil compaction. This resulted

IV: *Soil compaction (MPa), mean of annual measurement – Permanent grassland 2008–2012*

Variant	Depth (m)	2008	2009	2010	2011	2012
1	0–0.05	0.53	3.28	0.61	1.37	2.28
	0.05–0.10	2.29	3.44	1.28	2.03	2.80
	0.10–0.20	2.29	3.75	1.31	1.97	3.06
2	0–0.05	2.03	1.78	0.41	0.61	2.53
	0.05–0.10	2.09	3.18	1.19	2.9	3.29
	0.10–0.20	2.09	3.49	0.55	2.47	3.81
3	0–0.05	2.69	2.78	0.28	1.09	2.28
	0.05–0.10	2.94	2.99	1.05	2.55	3.30
	0.10–0.20	2.94	3.49	0.71	2.31	3.56

V: *Soil compaction (MPa), mean of annual measurement – Arable land 2008–2012*

Variant	Depth (m)	2008	2009	2010	2011	2012
1	0–0.05	0.27	2.33	0.84	1.53	3.03
	0.05–0.10	0.27	1.89	0.82	2.21	2.79
	0.10–0.20	0.72	1.96	0.84	2.77	3.31
	0.20–0.30	0.93	2.66	0.44	2.52	3.31
2	0–0.05	1.18	2.28	0.33	1.41	2.78
	0.05–0.10	0.77	1.30	0.43	2.12	2.54
	0.10–0.20	0.52	2.45	0.69	2.40	3.06
	0.20–0.30	0.98	2.56	0.54	2.52	3.06
3	0–0.05	2.92	0.78	0.13	0.53	2.53
	0.05–0.10	2.98	0.60	0.38	1.09	2.54
	0.10–0.20	2.27	1.30	0.53	2.19	2.80
	0.20–0.30	2.73	1.55	0.49	1.91	3.06

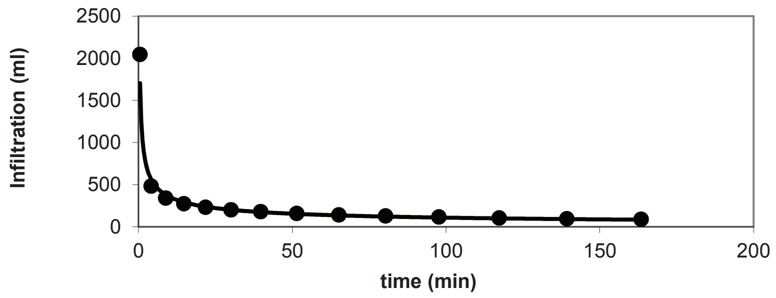


1: *Infiltration – Permanent grassland – starting values, 2008*

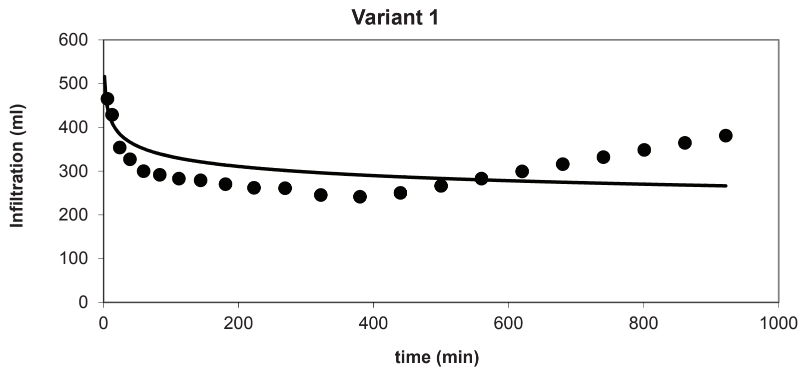
from differences in the type of soil and profile of the locality. The same conclusions were published by Sedláčková (2006) who mentioned that, in individual localities, differences in the type of soil enabled also the occurrence of differences in soil homogeneity, these difference might by also manifested as differences in the infiltration capacity of soil.

The results of the last year of the research project at the end of the vegetation period are showed in Figs. 3 (a, b, c) and 4 (a, b, c). To the end of this project, the differences in water infiltration rate in individual localities were nearly uniform. In this time it was quite obvious that the compost was already decomposed and that the content of organic residues in soil was at the same level in all variants.

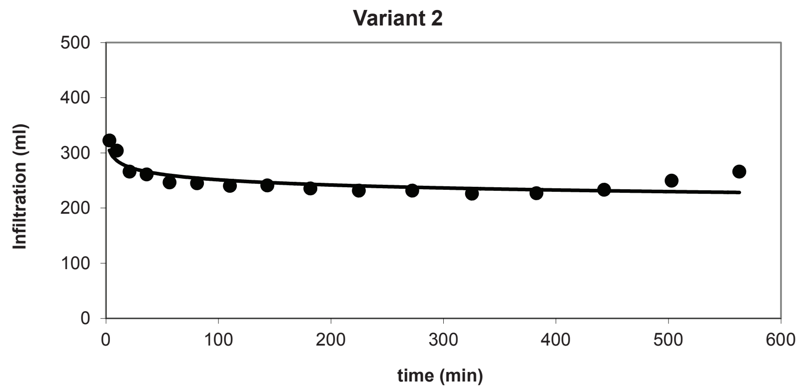
In the locality with permanent grassland, higher values of the infiltration coefficient were calculated only in 2009. The reason was that, during the whole growing season, the permanent grassland stand was in a good structural condition thanks to a very well developed root system of sward even during the period of draught. In the locality with the arable land, values of the infiltration coefficient were higher both at the beginning and to the end of the growing season in all experimental years. In this locality, water infiltration was influenced not only by the crop but also by the method of tillage. In 2012,



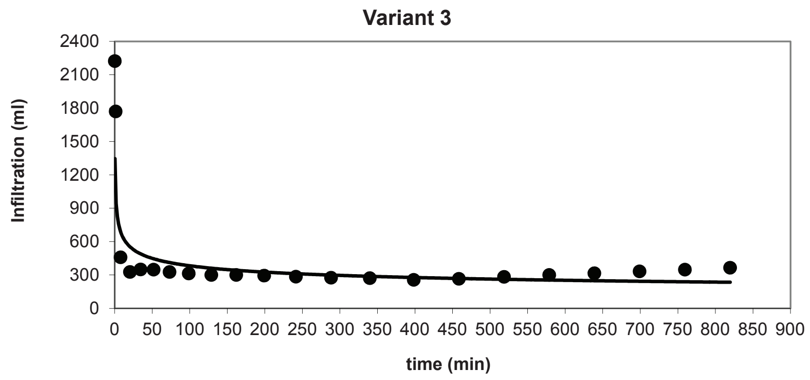
2: *Infiltration – Arable land – starting values, 2008*



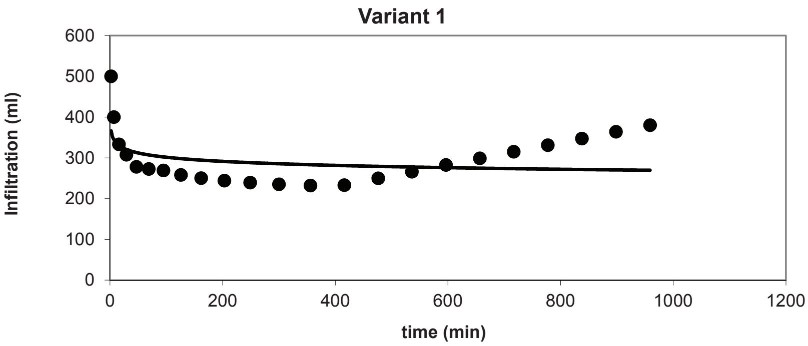
3a: *Infiltration – Permanent grassland – ending vegetation, 2012 – Variant 1*



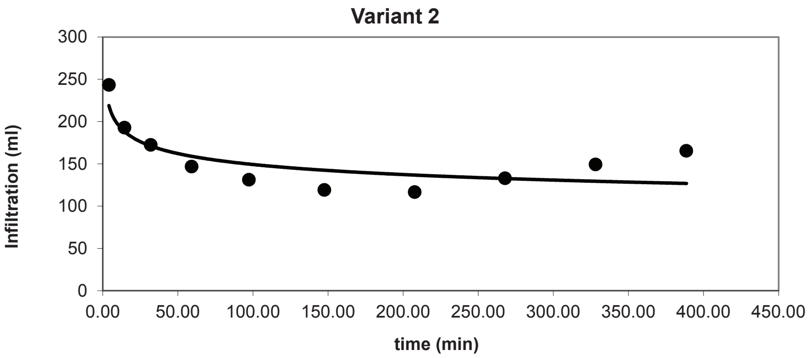
3b: *Infiltration – Permanent grassland – ending vegetation, 2012 – Variant 2*



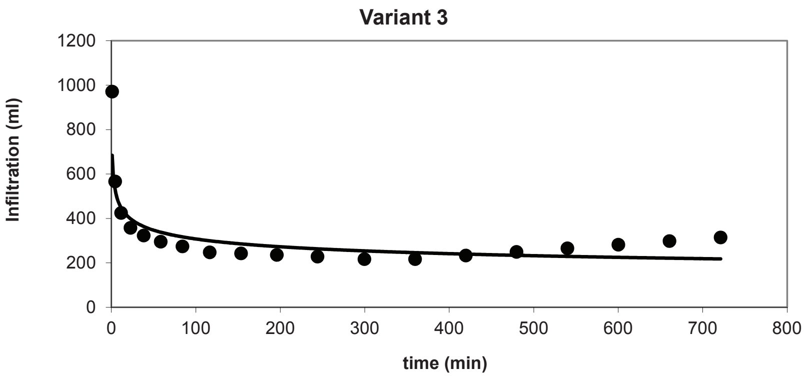
3c: *Infiltration – Permanent grassland – ending vegetation, 2012 – Variant 3*



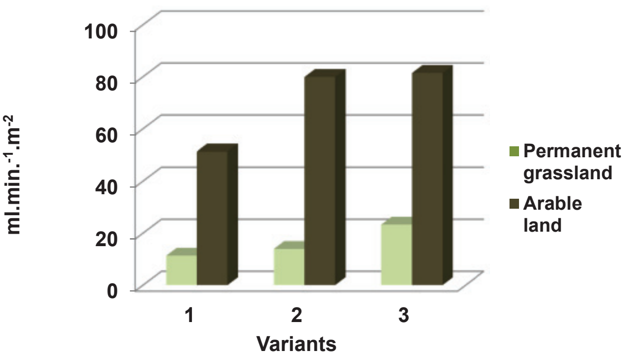
4a: *Infiltration – Arable land– ending vegetation, 2012 – Variant 1*



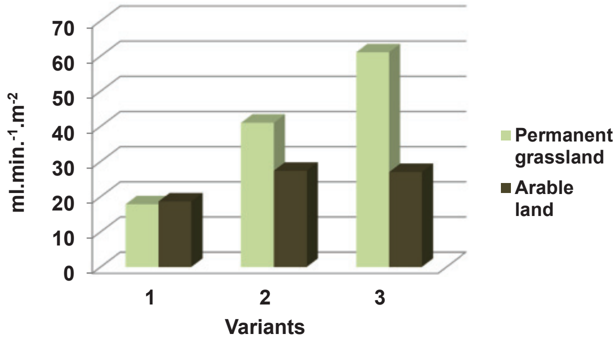
4b: *Infiltration – Arable land– ending vegetation, 2012 – Variant 2*



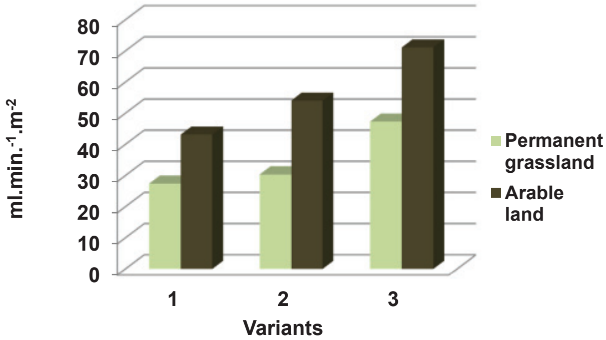
4c: *Infiltration – Arable land– ending vegetation, 2012 – Variant 3*



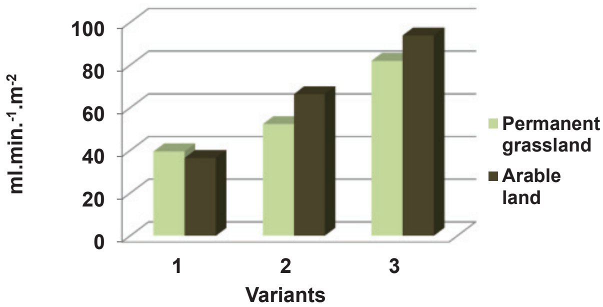
5: *Mean values of infiltration in year 2008*



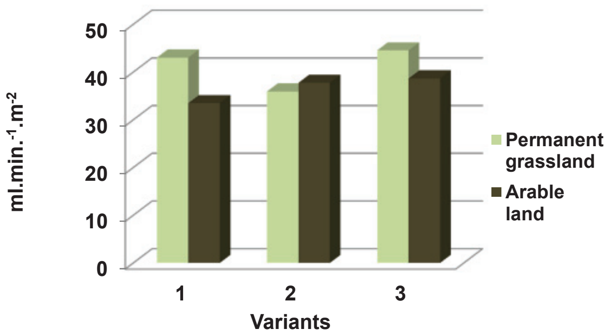
6: *Mean values of infiltration in year 2009*



7: *Mean values of infiltration in year 2010*



8: *Mean values of infiltration in year 2011*



9: *Mean values of infiltration in year 2012*

values of water infiltration were nearly the same in all variants established both on the permanent grassland and on the arable land.

Average values of water infiltration, as measured in both localities during all years of the experiment, are presented in Figs. 5–9.

VI: Analyse of variance for infiltration

Source of variation	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Main effects					
Term	0.03741	1	0.037408	0.015	0.9036 NS
Locality	14.64323	1	14.643230	5.972	0.0185 *
Variant	23.36753	2	11.683763	4.765	0.0133 *
Year	21.37900	4	5.344750	2.180	0.0865 NS
Residual	110.33734	45	2.451941		
Total	170.00710	53			

* denotes a statistically significant difference 95 % LSD

These figures contain a survey of values of water infiltration in both localities not only in individual variants but also in individual years. These graphs indicate an increased capacity of soil on arable land; the only exception was the year 2009, when the soil was over-saturated with water to the end of the growing season so that the infiltration capacity was small. The Fig. 9 shows that in year 2012 there were no more differences between the variants namely on both sites.

The statistical analysis (Tab. VI) indicated that during the years of this study there were significant differences of the infiltration between the locality and variants with different doses of applied compost. As far as the date of infiltration measurements was concerned, insignificant differences were found out between values recorded at the beginning and to the end of the growing season. At the same time, it was also found out that ploughdown of even higher doses of compost (Variants 2 and 3) showed a positive effect on infiltration of water into the soil in both localities. The highest values of soil infiltration capacity were recorded always at the beginning and at the end of the growing season in Variant 3 with an increased dose of applied compost. However, in 2011, the highest value of water infiltration into the soil was recorded in Variant 3 on arable land. This could be influenced by the crop cultivated in this locality, viz. clover-grass mixture that showed a positive effect on soil porosity (Beven & Germann, 1982; Blackwell, Green & Mason, 1990). Many authors found out that the infiltration capacity of soil was, among others, dependent also on the crop. So, for example Hejduk (2009) observed that in the course of ten monitored winter seasons the surface run-off from plots with perennial fodder crops was significantly (i.e. 2.05-times) higher than from plots under wheat.

DISCUSSION

The infiltration is influenced by a number of factors and these can be classified to the following four groups: soil properties; properties of the soil surface; method of soil management and natural conditions (Lal, 2002).

It is known that there were cases when compost was applied into humus-deficient sandy soils with the aim to improve their water regime and sorption properties. Its application is also one of the most important measures that are used when changing different cultures to the arable land, i.e. in case of reclamation (Horn *et al.*, 2006; Stoffela & Kahn, 2001), or when establishing and protecting stands of permanent grassland.

Important and indispensable is also the use of compost as an ameliorating (diluting) material when improving the texture of heavy soils. Kroulík *et al.* (2010) also found out that the application of compost increased the content of organic matter in soil and that this measure showed a long-term positive effect on infiltration of water into the soil.

In all experimental years, the lowest values of water infiltration into the soil were observed in Variant 1 (i.e. without compost). This observation indicates that the application of organic matter into the soil is very important (Six *et al.*, 2000). Different types of organic matter may show different effects on the retention capacity of soil.

Using well fermented compost, it is possible to supply already matured humus into the soil so that the process of its reclamation can be significantly accelerated. To assure a good balance of humus in soil, it is necessary to apply in average 1.5 t of pure organic mater into the soil on the area of 1 ha arable land (this corresponds with approximately 9 Mt of manure of the medium quality).

Beneficial effect of compost application into the soil was mentioned by many foreign authors. On the one hand, the supply of compost as a source of organic matter shows a positive effect on preservation of soil moisture, texture (Kutílek, 1978), gradual release of nutrients, and its biological activity while on the other it is important also for its protection against water erosion (mainly due to the retention of water in soil). Problems of water erosion of soils are very important worldwide and for that reason they are studied by many researchers (e.g. Schillinger, 2001; Seyfried & Flerchinger, 1994; Øygarden, 2003 and others). It should be said in this context that proper tillage and site-management interventions represent the simplest and the least demanding measures that enable to maintain soil in a good structural conditions. A good soil structure is one of important factors that contribute to the infiltration capacity of soil. Miháliková *et al.* (2013) studied problems concerning hydro-physical properties of soil (i.e. its capacity to hold water) and concluded that a good soil structure was very important.

Similar results were published by many other authors (e.g. White & Sully, 1987) and it can be concluded that just the application of compost is one of suitable measures how to improve the structure of soil. This means that compost can be used as an efficient helping instrument; in soil, it functions as a binding material of soil particles, improves its resistance against water erosion, and increases its water-holding capacity (Stratton *et al.*, 1995).

CONCLUSIONS

The obtained results indicate that compost application showed a positive effect on water infiltration of soil. Increased infiltration capacity of soil was observed on permanent grassland and arable land after the application of higher and medium dose of compost (150, 80 t.ha^{-1}) into the soil. With the exception of the year 2009, increased values of water infiltration were recorded on experimental plots with arable land than with permanent grassland. This resulted from the fact that on arable land the soil was looser because of tillage, management, and growing different crops. It was found also that in last research year have not been marked differences between the variants. It was caused by decrease of organic matter, which involved not only higher soil compaction on both sites, but also reduced the water infiltration into the soil.

It can be concluded that the organic matter in the form of compost incorporated into the soil is beneficial for water infiltration and the holding of water in soil. This is also very important for soil erosion control. It is therefore necessary to add to the soil well fermented, ripe compost with good quality at least once every three years.

SUMMARY

The paper was aimed at the determination of variability of infiltration in dependence on the different compost doses on the distinct habitats. These research results were studied on the arable land and permanent grassland. Experimental variants with different doses of incorporated compost were as follows: Variant 1 – without compost incorporation, Variant 2 – compost incorporated in the dose of 80 t.ha^{-1}, Variant 3 – compost incorporated in the dose of 150 t.ha^{-1}. It was found out within the study period that the application of the higher compost doses showed a positive effect on infiltration rate in both localities. The statistical analysis indicated that during the years of this study there were significant differences of the infiltration between the locality and variants with different doses of applied compost. As far as the date of infiltration measurements was concerned, insignificant differences were found out between values recorded at the beginning and to the end of the growing season.

The obtained results of measurements penetrometer soil resistance showed the lowest values of soil resistance in variants with the highest dose of compost compared to control variant with a lower dose of compost.

It was found also that after five years have not been marked differences in infiltration between variants. It follows that the regular supply of organic matter is necessary, preferably after three years.

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