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The effect of different soil tillage and weed control methods on soil physical properties under potato cultivation

Hanna Klikocka[1] and Claus Sommer[2]

Abstract

Field trials were conducted in Malice near Zamosc (South-east Poland) in the years 1996-2000 to assess the effect of different soil tillage methods and weed control measures on soil physical properties under a potato cultivation. The experiment maintained as a split-plot was carried out on leached brown soil, formed from light loamy silty soil (clay 13 %, pH 5.6, org.-C 10.4 g kg^{-1}). The soil tillage methods considered were: conventional tillage (CST), ridge tillage (ART) and spring reduced tillage (RST). The weed control measures considered were: mechanical (MWC), mechanical-chemical (MCC) and chemical (CWC). The results showed that the advantageous physical conditions of the soil for potato cultivation were ART and CST with CWC and MCC and RST with MCC. Also in these cases the yield of potato tubers was highest. The lowest yield of potato tubers was observed by using RST with MWC. In this case the yield of potato tubers was determined under low content of available water and higher penetrometer resistance conditions.

Key words: potato, soil tillage, weed control, physical parameters of the soil

Zusammenfassung

Auswirkungen unterschiedlicher Bodenbearbeitung und Beikrautkontrolle auf bodenphysikalische Parameter in einem Experiment im Kartoffelanbau

In der Nähe Malice/Zamosc (Südost-Polen) wurden in den Jahren 1996-2000 Feldversuche durchgeführt, um die Auswirkungen unterschiedlicher Bodenbearbeitungsverfahren und Unkrautkontrolle auf physikalische Bodeneigenschaften im Kartoffelanbau zu untersuchen. Ein Experiment wurde auf ausgelaugter Braunerde (lehmiger Schluff, Ton 13 %, pH 5,6, C_{org} 10,4 g kg^{-1}) nach der Teilflächenmethode in vier Wiederholungen angelegt. Es umfasste zwei Faktoren:

Faktor 1- Methoden der Bodenbearbeitung: CST - konventionelle Bodenbearbeitung; ART - Anbau mit Herbstdämmen; RST - reduzierte Bodenbearbeitung im Frühjahr.

Faktor II - Unkrautkontrolle: MWC - mechanisch; MCC - mechanisch-chemisch; CWC - chemisch.

Die Herbstdämme (ART), konventionelle Bodenbearbeitung (CST) mit Herbizid (CWC und MCC) und reduzierte Bodenbearbeitung (RST) mit mechanisch-chemischer Unkrautkontrolle (MCC) beeinflussten die Bodeneigenschaften für den Kartoffelbau positiv. Im letzteren Fall wurde auch der höchste Kartoffelertrag erzielt. Reduzierte Bodenbearbeitung mit mechanischer Unkrautkontrolle (RST mit MWC) minderte den Kartoffelertrag. Als Ursachen wurden geringe verfügbare Wassermenge und hoher Penetrometerwiderstand nach Bodenbearbeitung und Unkrautkontrolle festgestellt.

Schlüsselwörter: Kartoffel, Bodenbearbeitung, Unkrautkontrolle, physikalische Eigenschaften des Bodens

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1 Introduction

The mean yield of potatoes in Poland is about 20 t ha^{-1} fresh mass, although under good agro-technical conditions, farmers receive a yield of about 35-45 t ha^{-1} (Mazurczyk 1994). According to Dziezycowa et al. (1997) the level of tubers yield in Poland is influenced by the quality and quantity of tubers per m^2 and the weather during the growing season. The climate in Poland is continental-marine with intermediate features. In North-west Poland it is a marine climate, while in Central and in East Poland it is a continental climate, meaning large fluctuations in air temperature and rainfall over the years. This phenomenon determines the yield of potato tubers. According to Mazurczyk (1990), the decrease of yield of tubers in Poland following a lack of water ranges up to 25 %. Dmowski (1997) claims that potato yield in Poland depends on climate conditions (11 %), type of soil (20 %), type of forecrop (15 %), time of planting (46 %), and all these factors can affect the yield from 16.9 to 21.7 %. Many authors observed that other factors also play a role, including mineral fertilizer, organic manure, crop system, mulching, depth of planting, shape of ridge, size of seed tubers and granulometric composition of the soils. Previously no publication has dealt with the condition of the soil and yield of potato tubers in Poland. Starczewski et al. (1984) claimed that the highest penetrometer resistance with the highest soil bulk density presents problems for plants and root systems during growth. This, in consequence, leads to a reduction in the yield of potato tubers. Starczewski et al. (1984) further stated that the pressure of tractor wheels exerts a negative influence on the yield of potato tubers.

The effects of autumn ridging and reduced soil tillage for potato cultivation can be found in various literature (Klikocka, 1999, 2000; Marks, 1996; Neubauer, 1995; Spiess et al. 1997). This tillage consists of forming ridges in autumn with the help of a furrow plough and in maintaining them over the winter, and then planting potatoes into the formed ridges with the planting machine in the spring. Marks (1996) and Scholz (1989) recommend such methods of simplification (without earlier cultivation), particularly in soils which tend to clod and which are located in areas with defined climatic conditions in winter (mountainous and piedmont areas). Such a tillage method has an improvement effect on physical conditions in the soil (Scholz, 1989).

Table 1:
Physical and chemical characteristic of the soil conducted before starting the experiment (Malice, 1996)

Specifications	Unit	Depth of soil (cm)		
		0-25	25-70	70-150
		Layer		
		A/A_3	B(B)	C
Granulometric composition				
1.0-0.1mm		58	64	64
0.1-0.02 mm	%	29	24	20
<-0.02 mm		13	12	16
Soil colour		grey-brown	brown	yellow
Structure		fine- crumb	prismatical	prismatical
Soil bulk density	Mg m^{-3}	1.38	1.43	1.59
Gravitational water	%	11.3	14.2	12.3
Accessible water	%	10.6	7.0	7.0
Absorption water	%	1.7	0.9	1.0
Porosity	%	47.5	45.6	40.4
Macropores >30 µm	%	18.2	23.3	19.5
Mesopores 30-0,2 µm	%	17.1	12.9	12.2
Micropores <0,2 µm	%	2.4	1.3	1.6
Soil compaction	MPa	0.33	0.81	-
Hydrolitic acidity	mmol(H) kg^{-1}	19.0	9.7	10.5
Sum of exchangeable bases	mmol(+) kg^{-1}	26.0	10.6	120.0
Calculated cation exchange capacity	mmol(+) kg^{-1}	45.0	20.3	130.5
Saturation with cations	%	57.8	52.1	91.9
pH H_2O		7.2	7.5	7.2
pH (1 mol dm^{-3} KCl)		5.9	6.3	5.9
organic-C	g 1 kg^{-1}	10.4	8.9	2.0
$CaCO_3$	%	<1	<1	<1
N-total	g 1 kg^{-1}	0.8	0.7	0.3
P	mg 1 kg^{-1}	72.6	26.0	36.5
K	mg 1 kg^{-1}	63.1	28.4	87.1
Mg	mg 1 kg^{-1}	37.0	22.0	67.0

The purpose of this paper is to show the effect of different methods of soil tillage and systems of weed control on the physical properties of the soil and yield of potatoes, as well.

2 Material and methods

The experiment was conducted in the years 1996 - 2000, by split-plot method in four replications, in Malice - a village near Zamosc, Poland. The experiment was carried out on leached brown soil, formed from light loamy silty soil (clay -13 %) (Table 1). Soil pH was 5.6 (pH in 1mol dm^{-3} KCl, electrometrically). Organic-C content was on average 10.4 g kg^{-1}, determined by I. W. Tiurin - oxidisation with $K_2Cr_2O_7$ (Ostrowska et al., 1991). Total-N was 0.8 g kg^{-1} (Kjeldahl method); P - 72.6 mg kg^{-1} and, K - 63.1 mg kg^{-1}, vanadium-molybdene method according to Egner-Riehm, phosphorus with colometric method and potassium with photometric method, Ostrowska et al., 1991); Mg - 37.0 mg kg^{-1}, according to Schachtschabel method (Ostrowska et al., 1991) (Table 1). Thirty six plots of 30 m^2 each were marked for cultivation of "Mila" potato cultivar. In every year of the experiment the preceding crop was spring Triticale (cultivar "Migo").

The experiment was carried out with two factors: three methods of soil tillage and three methods of weed control in potatoes.

Factor I-methods of soil tillage: Conventional soil tillage (CST) - after harvesting of spring Triticale - shallow ploughing, harrowing, 30 t cattle-manure per hectare, ploughing, pre-winter ploughing (25 cm). Ridge tillage (ART) - after harvesting of spring Triticale - shallow ploughing, harrowing, 30 t cattle-manure per hectare, ploughing. In autumn - forming 20-25 cm ridges with a furrow plough ridger. Spring reduced soil tillage (RST) - after harvesting of spring Triticale - shallow skimming, harrowing, 30 t cattle-manure per hectare, ploughing.

Factor II - methods of weed control: Mechanical (MWC) - mechanical treatments with generally available cultivation implements. Mechanical-chemical (MCC) - mechanical treatments from potato planting until germination. After germination - herbicides Sencor 70 WP [Bayer] (metribuzin) dose of 0.5 l ha^{-1}, without other treatments. Chemical (CWC) - after planting - herbicide Afalon 50 EC [Hoechst] (linuron) dose of 1.5 l ha^{-1}, after germination - herbicide Sencor 70 WP [Bayer] (metribuzin) dose of 0.5 l ha^{-1}.

The harvested plot area was 19.5 m^2. Mineral fertilisation in kg ha^{-1} was: N - 100, P_2O_5 - 100, K_2O - 180. Row-space was 67.5 cm with 44,000 tubers ha^{-1} planted. Chemical spraying was used against diseases. Agrofags were eliminated chemically after appearing.

Total rainfall in the seasons 1997, 1999 and 2000 was higher than the long-term sum with 74.6, 29.0, and 77.5

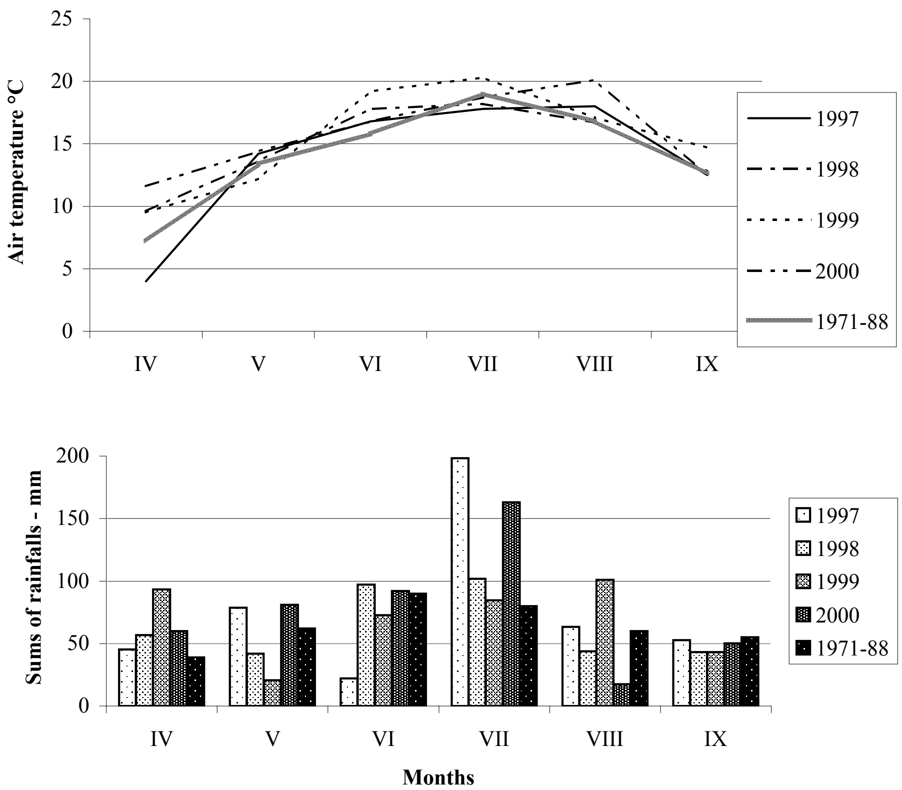

Fig. 1:
Sums of rainfalls and air temperature in the year 1997-2000 and in long-term period (Research station Werbkowice)

mm, respectively. In 1998, total rainfall was 1.5 mm lower. Only June, - 1997 (first 10 days), and May (last 10 days 1997) and September (first 20 days 1997) and August and September, 2000 were dry, but other months of the three years had higher rainfalls. The monthly averages of the air temperatures in the growing season in 1997-2000 were much higher than over the long term. June, July and August were particularly hot months. Generally, we can say that the growing seasons in 1997-1999 were very warm and wet, and the vegetation season of 2000 was very hot and dry (Fig. 1).

In the years 1997 and 1999, the soil samples from the layers 0-25 and 25-40 cm were taken before the potatoes were harvested (first 10 days of September). With three replications in the soil samples from each plot, the following parameters were determined (according to the obligatory methods after Mocek et al., 1997, and Ostrowska et al., 1991): soil bulk density (in Kopecky's cylinders of 100 ccm volume); water properties and porosity (calculated from pF-curve, which is derived from measurements on gypsum blocks); content of structural soil aggregates (with sieves); stability of soil aggregate to water (methods with sift in the water, with Bakszejew apparatus); penetrometer resistance - with soil probe (method of Kaczynski); the amount of organic carbon with method of I. W. Tiurin (oxidization with $K_2Cr_2O_7$); soil temperature (in the depth of 5 cm with laboratory thermometer, with precision to 0.1 °C), every seventh day, from the beginning of April up to germination of the potato.

The results obtained were analysed with a statistical method calculating the lowest significant differences (*P<0.05) with the Turkey-test. The regression analysis and coefficients were also determined (Tretowski and Wojcik 1998).

Table 2:
Trend change of properties of the soil in comparison of conventional soil tillage with mechanical system (CST + MWC)

	CST		ART			RST		
Specifications	MCC	CWC	MWC	MCC	CWC	MWC	MCC	CWC
Soil bulk density	+	0	+	+	-	-	-	-
Soil phase density	-	0	+	+	+	+	-	-
Porosity	0	-	-	-	-	-	+	-
Macropores (>30 µm)	-	-	+	-	-	+	-	-
Mesopores (30-0.2 µm)	+	+	-	-	+	+	-	-
Micropores (<0.2 µm)	+	+	-	-	+	-	-	-
Gravitational water	-	-	+	+	+	+	-	+
Available water	+	+	-	+	+	+	+	-
Absorption water	+	+	-	-	+	-	-	+
Soil aggregates >5.0 mm	-	-	+	+	-	-	-	-
Soil aggregates 5.0-1.0 mm	+	+	+	+	+	+	+	+
Soil aggregates 1.0-0.25 mm	0	+	-	-	+	+	+	-
Soil aggregates <0.25 mm	+	-	-	-	-	+	-	+
Stability of soil aggregates to water >5.0 mm	-	+	+	-	+	-	0	-
Stability of soil aggregates to water 5.0-1.0 mm	-	+	-	-	+	+	+	-
Stability of soil aggregates to water 1.0-0.25 mm	+	-	—	-	++	+	++	+
Stability of soil aggregates to water <0.25 mm	-	+	+	+	-	-	-	-
Penetrometer resistance	+	+	+	+	+	-	+	+
Content of organic-C	0	+	+	-	—	—	—	—

Explanations:
"++" - improvement, statistical safe,
"+" - improvement, no statistical verified,
"0" - without change,
"-" - decline, no statistical verified,
"—" - decline, statistical safe

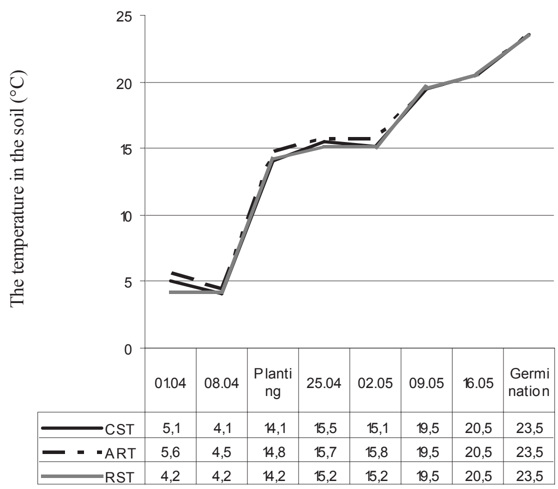

Fig. 2:
Temperature in the soil (°C) in year 1997

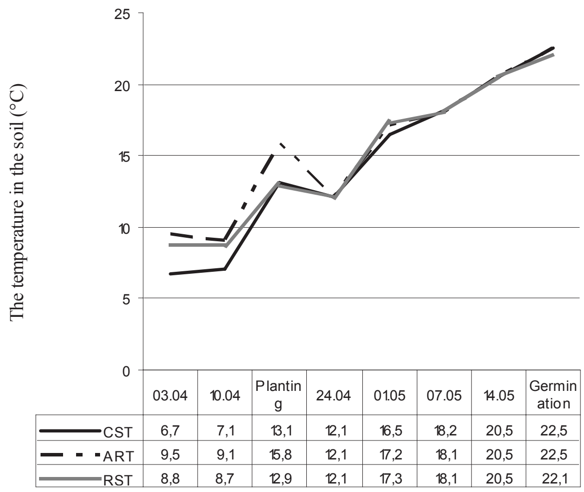

Fig. 3:
Temperature in the soil (°C) in year 1999

Table 3:
Compilation of number of observations of properties in the soil comparing of conventional soil tillage with mechanical system (CST + MWC)

Specifications	CST		ART			RST		
	MCC	CWC	MWC	MCC	CWC	MWC	MCC	CWC
++	0	0	0	0	1	0	1	0
+	9	11	10	8	11	10	6	6
0	3	2	0	0	0	0	1	0
-	7	6	8	11	6	8	10	12
--	0	0	1	0	1	1	1	1
Total improvemnet	9	11	10	8	12	10	7	6
Without change	3	2	0	0	0	0	1	0
Total decline	7	6	9	11	7	9	11	13

Explanations: Table 2

Table 4:
Regression equations for the relation between the yield of potato tubers and physical properties in the soil with potato cultivation

Variables	Regression equations	Determination coefficients
Soil bulk density	y = 37.5 - 9.01x	r^2 = 0.0617
Macropores (>30 µm)	y = 37.5 - 0.55x	r^2 = 0.6194
Mesopores (30-0,2 µm)	y = 20.2 + 0.35x	r^2 = 0.1216
Micropores (<0,2 µm)	y = 26.5 - 0.43x	r^2 = 0.0009
Gravitational water	y = 37.5 - 0.74x	r^2 = 0.4834
Available water	y = 13.5 + 1.09x	r^2 = 0.4601
Absorption water	y = 16.2 + 6.80x	r^2 = 0.1067
Soil aggregates >5.0 mm	y = 24.1 + 0.06x	r^2 = 0.0253
Soil aggregates 5.0-1.0 mm	y = 28.3 - 0.15x	r^2 = 0.0270
Soil aggregates 1.0-0.25 mm	y = 24.5 + 0.04x	r^2 = 0.0085
Soil aggregates <0.25 mm	y = 38.0 - 0.55x	r^2 = 0.2809
Stability of soil aggregates to water >5.0 mm	y = 25.0 + 0.88x	r^2 = 0.0582
Stability of soil aggregates to water 5.0-1.0 mm	y = 27.5 - 0.59x	r^2 = 0.0278
Stability of soil aggregates to water 1.0-0.25 mm	y = 25.7 - 0.002x	r^2 = 6E-05
Stability of soil aggregates to water <0.25 mm	y = 25.6 + 0.001x	r^2 = 1E-05
Penetrometer resistance	y = 31.8 - 0.02x	r^2 = 0.6026
Content of organic-C	y = 20.6 + 0.56x	r^2 = 0.0073

3 Results

The highest temperatures, at a depth of 5 cm, before planting of potato tubers were in plots with ART (Fig. 2, 3). In these plots, temperature was higher in comparison to CST and RST by about 0.3 °C and 0.4 °C, in 1997, and about 2.5 °C and 1.4 °C in 1999. Before and after germination, no change of temperature in the soil was observed.

The most beneficial physical conditions in the soil for potato cultivation were observed in plots with ART and CST with CWC (Table 2, 3). In plots with ART and CWC it was stated that eleven variables of physical soil properties (in consequence - retention properties of the soil, in comparison to CST with MWC) cause an improvement: content of mesopores and micropores, content of gravitational, available and absorption water, volume of soil aggregates: 5.0-1.0 mm and 1.0-0.25 mm, stability of soil aggreagates to water: above 5.0 mm, 5.0-1.0 mm, 1.0-0.25 mm and penetrometer resistance. Six variables influenced a decline: soil bulk density, macropores, soil aggregates above 5.0 mm and below 0.25 mm, stability of soil aggregate to water below 0.25 mm and content of organic-C. However significant difference was seen occured in stability of soil aggregates to water from 1.0 to 0.25 mm. By CST with CWC (in comparison to CST, cultivated with MWC) eleven variables of physical soil properties also lead to an improvement: content of mesopores and micropores, content of available and absorption water, volume of soil aggregates: 5.0-1.0 mm and 1.0-0.25 mm, stability of soil aggregate to water: above 5.0 mm, 5.0-1.0 mm, below 0.25 mm, penetrometer resistance and content of organic-C. One variable caused no change: soil bulk density; while five variables caused a decline: macropores, gravitational water, soil aggregates above 5.0 mm and below 0.25 mm, stability of soil aggregate to water 1.0-0.25 mm. Also positive physical conditions of the soil for potato cultivation were observed by ART and CST and RST using MCC management of weed control. In these plots content of available water and low stability of soil aggreagate to water (above 0.25 mm and 1.0-0.25 mm) were increased, whereas penetrometer resistance was decreased.

The highest amount of variables (eleven) which affected a decline of soil properties for potato cultivation was seen in RST with CWC. The decline was statistically proven in the case of content of organic-C. Generally it was stated, that RST with herbicides has less favourable physical soil properties. Because pore structure (and in consequence, retention properties of the soil) decreased and there was less available water. The stability of soil aggregates to water (valuable for agriculture) decreased from 1.0 mm to above 5.0 mm, and penetrometer resistance also was higher.

The most variable structural and physical status of the soil using different soil tillage with different systems of weed control was characterised with diverse reactions.

It was observed that some parameters of soil properties were statistically different in the comparison of soil samples based on depth. In subsoil depth (25-40 cm), soil bulk density was higher compared to a depth 0-25 cm by about 9 % (Fig. 4). Contents of macropores and micropores were less by about 13 %, and 18 %, respectively (Fig. 5, 6). The contents of gravitational, available and absorption water were also lower, about: 21 %, 15 % and 25 %, respectively (Fig. 7, 8). Also the content of organic-C in the depth 25-40 was about 9 % lower in comparison to depth 0-25 cm (Fig. 12).

Variability of further parameters: soil bulk density, volume of pores, content of water, volume of soil aggregates according to statistical calculation parameters studied were not important (Fig. 4-9). Variation analysis for most examined parameters, important for scientists, showed no significance, therefore qualitative comparisons were made. One very important observation was, that statistical difference was shown by nearly every parameter, regardless of the depth of the soil and time of sample-taking.

The highest yield of potato tubers was obtained by using ART with MCC (100 %) and by using CST with CWC (98 %) and by using CST and RST with MCC (average 97 %) and by using ART with CWC (95 % in comparison to ART with MCC (Fig. 13). The lowest yield was shown by using RST with MWC (84 % in comparison to ART with MCC), because only a small content of gravitational water was available and high penetrometer resistance was found under soil tillage and plant system cultivation. The highest yield of potato tubers was observed in the year 1997 (average 31.19 t ha^{-1}) and in the year 1999 the yield decreased to 20.16 t ha^{-1} (about 35 %).

Generally the yield of potato tubers depended on the physical status of the soil (Table 4). Content of soil mesopores (30 - 0.2 μm), content of available and absorption water, volume of soil aggregates above 5.0 mm and stability of soil aggregates to water above 5.0 mm increased the yield of potato tubers. Soil bulk density, percentage content of soil macropores (> 30 μm), content of gravitational water, volume of soil aggregates 5.0-1.0 mm and below 0.25 mm, stability of soil aggregates to water 5.0-1.0 and and penetrometer resistance reduced the yield of potato tubers. Content of micropores (<0.2 μm) in the soil and volume of soil aggregates 1.0-0.25 mm, stability of soil aggregates to water 1.0-0.25 and below 0.25 mm and content of organic-C in the soil did not influence the yield of potato tubers.

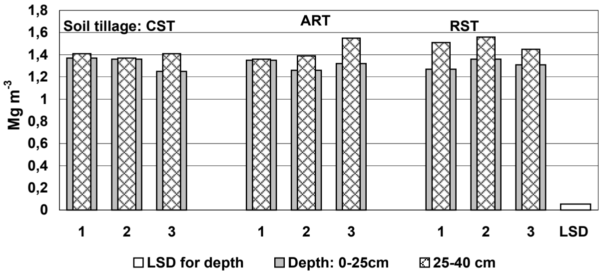

Fig. 4:
Soil bulk density (Mg m^{-3})

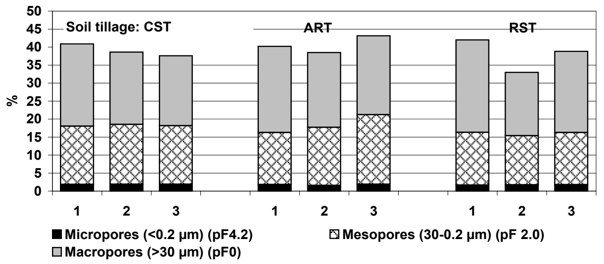

Fig. 5:
Percentage content of the pores in porosity of soil layer in the depth 0 - 25 cm

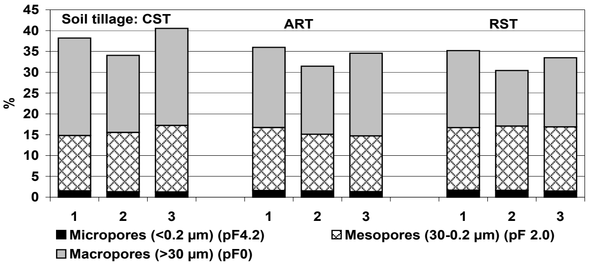

Fig. 6 :
Percentage content of the pores in porosity of undersoil leyer in depth 25-40 cm

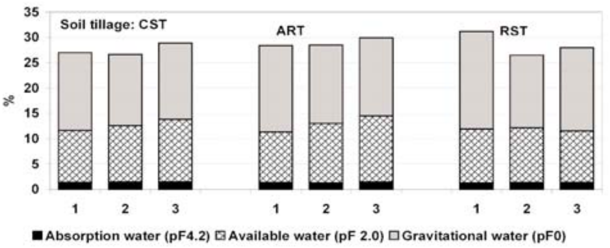

Fig. 7:
Content of water in the soil layer of the depth of 0 - 25 cm (%)

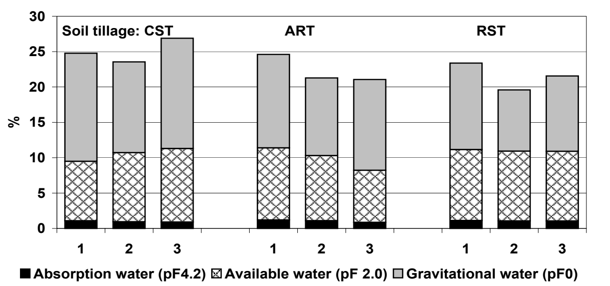

Fig. 8 :
Content of water in the undersoil layer of the depth of 25 - 40 cm (%)

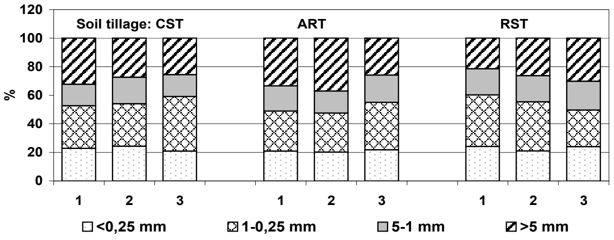

Fig. 9:
Aggregate stability in the soil layer of depth 0-25 cm (%)

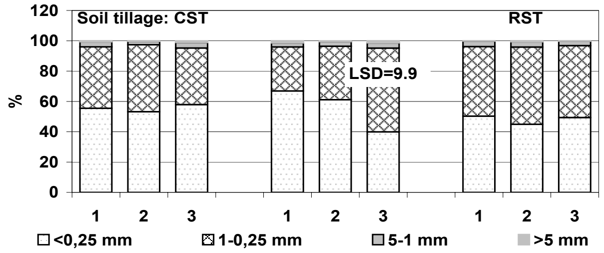

Fig. 10:
Aggregate stability to water in the soil layer (%)

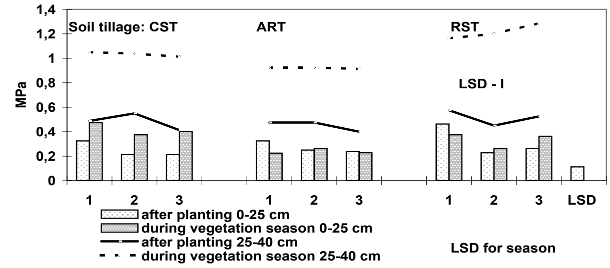

Fig. 11:
Penetrometer resistance under soil tillage and plant system cultivation (MPa)

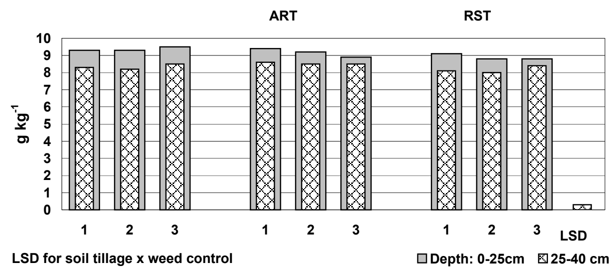

Fig. 12:
Content of C-organic (g kg^{-1})

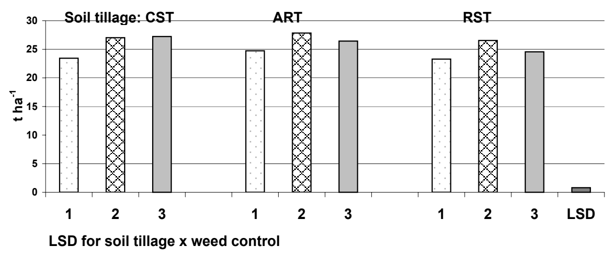

Fig. 13:
The yield of potato tubers (t ha^{-1}) (mean from years 1997 and 1999)

Explanations: Soil tillage - CST - conventional, ART - autumn ridge, RST - reduced; Weed control - 1 - mechanical, 2 - mechanical-chemical, 3- chemical; LSD - lowest significant differences (*P<0.05)

4 Discussion

In the presented paper it is stated that different soil tillage cultivation changed temperature in the soil. It was observed that soil temperature in the ridges at a depth of 5 cm in the spring-time, before potato planting was higher than in ridges made in autumn when using CST and RST. Similar observations were made by Galiën (1966) and Scholz (1989). Demmler (1990) says that the temperature in the ridge is about 4-5 °C higher than in the soil under conventional soil tillage, and this allows an earlier planting of potatoes by about one week. Struik et al. (1989) claim that the temperature in the vegetation season caused complex effects on stolon development and reduced synchronization of their initiation. The adverse effects of high air temperature on tuber quality can be reduced by lowering the soil temperature, but the adverse effect in temperature is valid for potato growing. Struik et al. (1989) say that tuber yield of high quality is maximized when temperatures in all compartments are low. The highest yield of potato tubers was achieved by using ART and CST with MCC and CWC, and by using RST with MCC. This was also observed in investigations by Marks (1996). Other authors demonstrated that autumn ridge tillage has positive influence on higher yield of potato tubers in comparison to conventional and simplified soil tillage. Galiën (1966), Scholz (1989) and Neubauer (1995) have observed that yield of potato tubers in this case increased by about 6 % to 10 %. Reduced soil tillage with mechanical-chemical weed control decreased the yield of potato tubers. Similar results were found by Neubauer (1995).

Physical parameters of the soil were not dependent on different methods of soil tillage and systems of weed control. Baranowski (1980), Dzienia (1990), Mackiewicz et al. (1998) and Sommer (1998) claim that different systems of ploughing and reduced soil tillage did not show significant differences due to soil bulk density or porosity. This was also observed in the presented experiment. Only zero-tillage (no-tillage) increases soil bulk density (and decreases porosity). Domzal and Slowinska-Jurkiewicz (1989) and Radecki (1986) demonstrated, that soil bulk density is not static, and changes in vegetation seasons under natural conditions (gravitation, weather, plant, etc.) or is influenced by mechanical activities (instruments, machinery, tractors). Pagliali et al. (1995) claim that the soil with minimum tillage has highest content of microaggregates. This phenomenon was also observed by using autumn ridge tillage and by reduced soil tillage with mechanical-chemical weed control. Lenart (1997) and Mackiewicz et al. (1998) claim that in plots with simplified soil tillage, the aggregate stability increased. In the presented study, a similar effect was observed. Chmielnicki et al. (1995) instead claim that with an increase of humidity in the soil, an increased content of macroaggregates can be observed. Wlodek et al. (1998) consider that deep soil tillage has positive influence on the humidity of soil, and Mackiewicz et al. (1998) claim that the highest humidity is in soil on fields using simplified soil tillage. According to Wlodek et al. (1998) soil compaction is not determined by methods of soil tillage and systems of weed control. They consider that direct sowing brings a significant increase of soil compaction in the topsoil. Miatkowski (1998) demonstrated that penetrometer resistance by natural factors is also affected by the technique of soil cultivation. Comia et al. (1994) did not find that methods of soil tillage changed the penetrometer resistance of the topsoil. In this experiment, in the plots with reduced soil tillage and mechanical weed control and in topsoil of all plots, penetrometer resistance was higher.

The investigations carried out in Malice (Poland) have shown that physical properties of the soil were changed by methods of soil tillage and systems of weed control. It was observed that the most beneficial physical condition of the soil were attained using ART and CST with CWC. A decline of soil properties is shown by RST. The highest yield of potato tubers was obtained in the plots where the physical status of the soil was positive for potato cultivation (using ART and CST with MCC and CWC and by using RST with MCC - in comparison to ART with MCC). The lowest yield was shown by using CST and RST with MWC, because of the low content of available water and high penetrometer resistance under soil tillage and plant cultivation system.

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