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DEFICIENCIES OF READILY PLANT AVAILABLE WATER IN SELECTED ALBELUVISOLS IN CENTRAL WIELKOPOLSKA*

NIEDOBORY WODY ŁATWO DOSTĘPNEJ DLA ROŚLIN W WYBRANYCH GLEBACH PŁOWOZIEMNYCH CENTRALNEJ WIELKOPOLSKI

Summary. This study presents the results of research on the deficiencies of water content in the Albeluvisols within central Wielkopolska during 2009-2011. The objective was to determine the soil water deficiencies in relation to the lower limit of plant available water (LLPAW) calculated at a matric potential of –31 kPa ($LLPAW_{31}$), –49 kPa ($LLPAW_{49}$), –59 kPa ($LLPAW_{59}$) and –88 kPa ($LLPAW_{88}$). The research results indicate that crop water deficiency and the depth of soil drying up were mainly determined by the rainfall. During periods of vegetation the strongest and deepest drying up was observed in 2011. In this year, in the Stagnic Albeluvisols at a depth of about 70 cm the soil matric potential of –59 kPa was observed, while in Gleyic Albeluvisols, a depth of 60 cm was also observed. The highest soil water deficiencies were observed from the third decade in May to the second decade in July. These deficiencies in 100 cm thickness were 7 mm, 19 mm, 25 mm and 40 mm, in relation to $LLPAW_{88}$, $LLPAW_{59}$, $LLPAW_{49}$ and $LLPAW_{31}$ respectively. Considering the 30 cm soil thickness, the water deficiencies were noted from the third decade in April to the second decade in July. In the analysed Albeluvisols, the calculated average soil matric potential depth equal to the field capacity was about 65-70 cm in 2011, whereas in 2009 and 2010 it was 50-55 cm.

Key words: Albeluvisols, soil water deficiencies, soil water matric potential

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Introduction

Understanding and prediction of soil water dynamics and thus soil water deficits are not only the starting point of detailed recognition of the pedogenesis. The genesis of soils is directly related to the diversity of soil-forming processes and feedback (GŁAZOWSKA 1981, YAALON 1997, MARCINEK and WIŚLAŃSKA 1984, MARCINEK et AL. 1994, 1998, KOMISAREK 2000, KOMISAREK et AL. 2008, KOZŁOWSKI and KOMISAREK 2011). This also has important practical significance for optimum plant production, protection and development of water and soil resources (BOUMA 1983, 1989, MARCINEK 1992, RAO 1998, EITZINGER et AL. 2002, 2004, KOMISAREK 2008, KOZŁOWSKI and KOMISAREK 2011). Knowledge of the amount of water available to the plant, or plant available water, is needed to determine the agricultural or ecological potential of soil and is used in many agronomic applications. It helps define the water content limits beyond which plant growth is affected because of insufficient amount of water. Soil water deficiencies from the perspective of crops have special importance for central Wielkopolska. This area is on the one hand characterised by intense agriculture, on the other hand has the least amount of rainfall in the country, a low outflow coefficient and a high probability occurrence of drought during the growing season (KOWALCZAK et AL. 1997, KOWALCZAK 2001, KĘDZIORA et AL. 2005, PRZYBYŁA and TYMCZUK 2005). Many studies have focused their attention on the assessment of water deficits for the Polish territory, as well as for Wielkopolska (DZIERŻYC 1988, RICHI 1994, WIERCIOCH 1994, KĘDZIORA et AL. 2005). These assessments concentrated mainly on climate balance, but less attention was paid to assess soil water deficiency of the water potentially and readily available to plants, which would be taken directly to particular well-defined soil units.

Material and methods

The study was conducted in seven areas of research, where 13 representative pedons of Albeluvisols and Chernozems/Gleysols (Fig. 1) were determined. Among the Albeluvisols, the PRZYBRODA research area is represented by the Cutanic Stagnic Albeluvisols (Eutric) (PRZ1), the DAKOWY MOKRE – the Cutanic Stagnic Albeluvisols (Eutric) (DAK1), the PAKOSŁAW – the Cutanic Stagnic Albeluvisols (Eutric) (PAK1), the BOROWO – the Cutanic Stagnic Albeluvisols (Eutric) (BOR1), the POLSKA WIEŚ – the Cutanic Gleyic Albeluvisols (Eutric) (PWI1), the ŻYDOWO – the Cutanic Gleyic Albeluvisols (Eutric) (ŻYD1) and the SIERNICZE WIELKIE research area – the Cutanic Stagnic Albeluvisols (Eutric) (SIE1).

The parent material of the investigated soils is a glacial till which, as a result of the glacier meltwater and the englacial water, was decalcified and made sandy in the upper layers. Terms of geomorphological, representative pedons were located within an undulating ground moraine of the Baltic Glaciation of the Poznań Phase (PRZ1), a flat ground moraine of the Leszno Phase (DAK1, BOR1, ŻYD1) and of the Poznań Phase (PWI1) of the Baltic Glaciation and end moraines hills (PAK1, SIE1) (STARKEL 1987, KRYGOWSKI 1961).

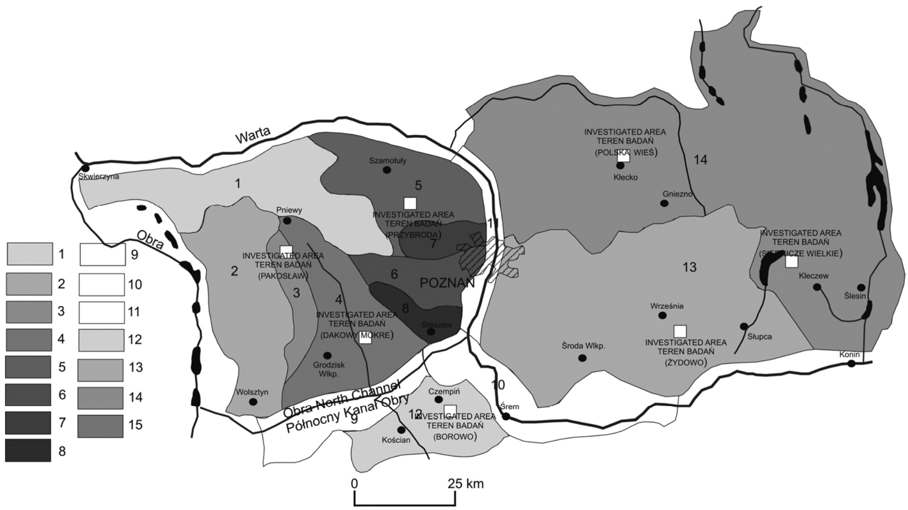

Fig. 1. Location of investigated area (KONDRACKI 2001, modified map): 1 – Międzychód–Pniewy Lakeland, 2 – Nowy Tomyśl Plain, 3 – Lwówek–Rakoniewice Rampart, 4 – Opalenica Plain, 5 – Szamotuły Plain, 6 – Poznań Plain, 7 – Owińska–Kiekrz Hills, 8 – Stęszew Lakeland, 9 – Central Obra Valley, 10 – Śrem Basin, 11 – Warta River Poznań Ravine, 12 – Kościan Plain, 13 – Września Plain, 14 – Gniezno Lakeland

Rys. 1. Lokalizacja terenu badań (KONDRACKI 2001, mapa zmodyfikowana): 1 – Pojezierze Międzychodzko-Pniewskie, 2 – Równina Nowotomyska, 3 – Wał Lwówecko-Rakoniewicki, 4 – Równina Opalenicka, 5 – Równina Szamotulska, 6 – Równina Poznańska, 7 – Wzgórza Owińsko-Kierskie, 8 – Pojezierze Stęszewskie, 9 – Dolina Środkowej Obry, 10 – Kotlina Śremska, 11 – Poznański Przełom Warty, 12 – Równina Kościańska, 13 – Równina Wrzesińska, 14 – Pojezierze Gnieźnieńskie

In any pedon from all horizons, undisturbed (in order to determine the soil water retention curves and hydraulic conductivity) and disturbed (in order to determine their physical and chemical properties) monolithic soil samples were collected. Field studies included the installation of soil moisture sensors (TDR) to measure soil moisture (to a depth of 100 cm) and piezometers constructed of 80-mm polyvinyl chloride (PCV) cubes to measure groundwater level. In 2009-2011, the dynamics of soil water content was measured every hour and every two weeks or monthly. The groundwater levels in selected pedons were also measured monthly. In addition, within the selected areas of representative pedons, simple recorders of temperature, rainfall, wind speed and direction, and relative humidity were installed. These recorders were installed in Poznań, Granowo and Siernicze Wielkie.

Soil water retention curves up to 100 kPa were made using pressure plate apparatus (KLUTE 1986), whereas lower values of the pressure head were indicated using the method of water vapour pressure over a solution of sulphuric acid (KLUTE 1986). Following this, the RETC programme (VAN GENUCHTEN et AL. 1991) was used to optimise the parameters of the Van Genuchten equation (VAN GENUCHTEN 1980).

Temporal variability of the soil matric potential was determined using the geostatistical analysis in which the semivariance ($\gamma_{(k)}$) is the basic function:

$$\gamma_{(k)} = \frac{1}{2 \cdot n(k)} \cdot \sum_{i=1}^{n(k)} \left[z(x_i) - z(x_{i+k}) \right]^2$$

where $z(x_i)$ indicates the soil matric potential at time i, $z(x_{i+k})$ is the soil matric potential at time $i+k$ and $n(k)$ is the total number of experimental pairs of observations separated by k (temporal lag). Semivariance illustrates the degree of temporal dependence between soil matric potentials as a function of time (k). Relations between values of semivariance and time correlation ranges were determined using the Variovin programme (PANNATIER 1996) or Surfer programme (SURFER 8... 2002). The Gaussian and the spherical Variogram models were fitted to the experimental data in order to obtain the major parameters of the temporal soil matric potential variability. Based on the structure of the temporal variability and using the Kriging interpolation method (WARRICK et AL. 1986), the soil matric potential isolines in 100 cm layers were plotted.

The deficiencies of soil water content were estimated using the critical pressure head defining the limits of optimal possibilities of water uptake by the plant's roots. At high evaporation rates, the soil may be unable to transport enough water to meet transpiration demands and the plant may go into water stress at higher soil water contents than it would at evaporation rates. For most crops under Wielkopolska Plain, inhibition of growth and development occur at a soil matric potential Ψ_m from –59 kPa to –31 kPa (Wesseling – after FEDDES et AL. 1997, Taylor and Ashcroft – after VAN DAM et AL. 1997). Table 1 contains the critical soil matric potential values for major crops cultivated in central Wielkopolska. This data indicates that most plants show inhibition of growth at a Ψ_m of –59 kPa during unfavourable conditions for the maximum rate of transpiration. For optimum conditions at maximum potential transpiration inhibition of plants, growth due to the deficiency of the water readily available to plants (WRAP) can occur at a Ψ_m of –31 kPa. Therefore, the soil water deficiencies with respect to Ψ_m at

Table 1. Critical soil matric potential Ψ_m values for some crops in central Wielkopolska (cm) (Wesseling – after FEDDES et AL. 1997)
Tabela 1. Wartości krytyczne potencjału macierzystego wody glebowej Ψ_m dla wybranej roślinności środkowej Wielkopolski (cm) (Wesseling – za FEDDESEM i IN. 1997)

Crop Roślina uprawna	High Ψ_{m1} Duża Ψ_{m1}	Low Ψ_{m2} Mała Ψ_{m2}
Winter crops Zboża ozime	–500	–900
Sugar beets Buraki cukrowe	–320	–600
Potatoes Ziemniaki	–320	–600
Corn Kukurydza	–325	–600

a –31 kPa, –49 kPa, –59 kPa and –88 kPa were defined. Quantitatively, these deficiencies were calculated (in 30-, 50-, and 100-cm thicknesses) as a difference between the actual soil moisture storage and the soil moisture storage at a LLRPAW (lower limit of readily plant available water) for the above mentioned critical values of matric potential ($LLRPAW_{31}$, $LLRPAW_{49}$, $LLRPAW_{59}$, $LLRPAW_{88}$,) and the soil moisture storage at a $LLRPAW_{2/3}$ calculated conventionally ($LLRPAW_{2/3}$ = PWP + 1/3 · (FC – PWP), where FC – field capacity, PWP – permanent wilting point).

Results

Sandy ochric and luvic horizons having texture from loamy sand to sandy loam of Albeluvisols are characterised by low water content at FC (0.202-0.284 $m^3 \cdot m^{-3}$) and PWP (0.066-0.092 $m^3 \cdot m^{-3}$) (Table 2). Therefore, the amount of stored water in the 50 cm soil thickness at FC ranges from 107 to 130 mm. In iluvial argic horizon water content at FC is significantly larger (0.227-0.302 $m^3 \cdot m^{-3}$) than in the upper horizons, which is related to the content of the clay separates and a permanent blocky angular and/or subangular structure. The amount of stored water in the 100 cm rooting zone at FC ranges from 227 to 268 mm.

Table 2. Selected properties of investigated soils
Tabela 2. Wybrane właściwości analizowanych gleb

Soil horizon Poziom glebo-wy	Depth Głębo-kość (cm)	Percentage of soil separates at diameter Φ Procentowa zawartość frakcji o średnicy Φ			Soil texture Grupa granu-lometryczna		OM (%)	θ_C	θ_{PPW}	θ_{WTW}	α	*n*
		2,00- -0,05 mm	0,05- -0,002 mm	< 0,002 mm	KLASYFIKACJA... (2009)	SOIL... (1975)		$m^3 \cdot m^{-3}$				
1	2	3	4	5	6	7	8	9	10	11	12	13
PRZ1 – Stagnic Albeluvisols (Eutric) – Gleba płowa z cechami glossic												
Ap	0-32	74	19	7	gdrp	fSL	1.65	0.385	0.212	0.039	0.0520	1.3457
E1t	32-41	70	20	10	gdrp	fSL	0.80	0.368	0.223	0.056	0.0550	1.2793
E2t	41-50	73	17	10	gdrp	fSL	0.37	0.348	0.208	0.052	0.0576	1.2810
E/B	50-60	69	15	16	gdrp	SL	0.45	0.348	0.230	0.082	0.0659	1.2098
B1t	60-70	63	16	21	gpi	SCL	0.44	0.328	0.251	0.123	0.0557	1.1462
B2t	70-92	61	18	21	gpi	SCL	0.23	0.321	0.259	0.139	0.0465	1.1283
Ck	92-120	64	21	15	gl	fSL	0.17	0.312	0.240	0.105	0.0405	1.1695
DAK1 – Stagnic Albeluvisols (Eutric) – Gleba płowa z cechami glossic												
Ap	0-28	80	15	5	pgdr	LS	1.10	0.319	0.218	0.042	0.0254	1.3394

Table 2 – cont. / Tabela 2 – cd.

1	2	3	4	5	6	7	8	9	10	11	12	13
Et	28-37	82	11	7	pgdr	LS	0.23	0.305	0.202	0.034	0.0255	1.3699
E/B	37-51	70	16	14	gpdr	fSL	0.37	0.321	0.236	0.085	0.0368	1.2109
Bt	51-72	65	19	16	gpdr	fSL	0.23	0.315	0.245	0.097	0.0311	1.1912
Ck1	72-100	67	19	14	gpdr	fSL	0.14	0.310	0.226	0.086	0.0434	1.1980
Ck2	100-120	67	19	14	gpdr	fSL	0.15	0.307	0.205	0.075	0.0664	1.2034
PAK1 – Stagnic Albeluvisols (Eutric) – Gleba płowa z cechami glossic												
Ap	0-32	71	21	8	gpdr	fSL	1.73	0.340	0.247	0.060	0.0237	1.2957
E/B	32-46	62	22	16	gl	fSL	0.51	0.322	0.249	0.100	0.0324	1.1892
B1t	46-65	63	21	16	gl	fSL	0.53	0.315	0.265	0.113	0.0188	1.1810
B2t	65-85	43	36	21	gz	L	0.52	0.337	0.297	0.118	0.0106	1.2067
B3t	85-105	39	38	23	gz	L	0.31	0.344	0.296	0.123	0.0145	1.1908
Ck	105-130	51	31	18	gz	L	0.17	0.328	0.258	0.103	0.0284	1.1915
BOR1 – Stagnic Albeluvisols (Eutric) **–** Gleba płowa z cechami glossic												
Ap	0-28	82	14	4	pgdr	LS	1.27	0.345	0.236	0.039	0.0226	1.3743
AE	28-35	81	14	5	pgdr	LS	0.72	0.320	0.215	0.041	0.0264	1.3443
E/B	35-41	67	17	16	gdrp	fSL	0.28	0.294	0.206	0.092	0.0842	1.1629
B/E	41-53	64	17	19	gl	fSL	0.40	0.307	0.249	0.116	0.0311	1.1581
Bt	53-83	62	17	21	gpi	SCL	0.41	0.325	0.280	0.131	0.0171	1.1644
Ck	83-120	66	21	13	gdrp	fSL	0.20	0.305	0.261	0.086	0.0115	1.2454
PWI1 – Gleyic Albeluvisols (Eutric) – Gleba płowa zaciekowa gruntowo-glejowa												
Ap	0-28	71	25	4	gdrp	fSL	2.69	0.364	0.277	0.059	0.0172	1.3268
AE	28-51	73	21	6	gdrp	fSL	1.05	0.349	0.229	0.050	0.0329	1.3144
E/B	51-71	72	16	12	gdrp	fSL	0.41	0.340	0.207	0.065	0.0791	1.2348
B/E	71-84	72	15	13	gdrp	fSL	0.34	0.329	0.230	0.074	0.0408	1.2329
Btg	84-105	68	19	13	gdrp	fSL	0.33	0.319	0.222	0.078	0.0481	1.2136
Cg	105-120	69	16	15	gdrp	fSL	0.12	0.309	0.219	0.089	0.0594	1.1839
ŻYD1 – Gleyic Albeluvisols (Eutric) – Gleba płowa zaciekowa gruntowo-glejowa												
Ap	0-29	84	15	1	pgdr	fSL	1.38	0.373	0.187	0.028	0.0439	1.4624
AE	29-38	82	14	4	pgdr	fSL	1.34	0.349	0.184	0.034	0.0490	1.3986
Et	38-47	82	13	5	pgdr	fSL	0.22	0.291	0.176	0.044	0.0474	1.3213
E/B	47-60	71	15	14	gdrp	fSL	0.31	0.304	0.217	0.088	0.0527	1.1982
B/E1	60-90	73	12	15	gdrp	fSL	0.19	0.303	0.210	0.086	0.0640	1.1968
B/E2	90-130	71	12	17	gdrp	fSL	0.07	0.303	0.216	0.104	0.0853	1.1591

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Table 2 – cont. / Tabela 2 – cd.

1	2	3	4	5	6	7	8	9	10	11	12	13
SIE1 – Stagnic Albeluvisols (Eutric) – Gleba płowa z cechami glossic												
Ap	0-22	75	20	5	pgdr	fSL	2.88	0.407	0.284	0.086	0.0376	1.2456
Et	22-30	72	18	10	gpdr	fSL	1.03	0.352	0.217	0.062	0.0618	1.2545
E/B	30-36	58	19	23	pgi	SCL	1.03	0.323	0.227	0.103	0.0835	1.1608
B1t	36-60	55	19	26	gpi	SCL	0.76	0.337	0.264	0.136	0.0520	1.1365
B2t	60-82	59	20	21	gpi	SCL	0.10	0.379	0.302	0.121	0.0257	1.1913
Ck	82-100	63	23	14	gl	fSL	0.08	0.352	0.218	0.064	0.0637	1.2479

OM – organic matter content, θ_C – saturated moisture content, θ_{PPW} – field capacity, θ_{WTW} – permanent wilting point, α and n – parameters of Van Genuchten equation.

OM – zawartość materii organicznej, θ_C – pełna pojemność wodna, θ_{PPW} – polowa pojemność wodna, θ_{WTW} – wilgotność trwałego więdnięcia, α i n – parametry równania Van Genuchtena.

Figure 2 shows the cumulative precipitation in the growing seasons in relation to the average cumulative precipitation for long-term. During the growing seasons of the study in terms of the amount of rainfall in 2009, 2010 and 2011 we can qualify to the average (2009, 2011) and very wet (2010), according to KACZOROWSKA (1962) criteria. Analysing each month, we can say that April 2009 was very dry in terms of rainfall, while May was wet. In June 2009, the total rainfall was 150% of the long-term average, which qualifies this period to be extremely wet. In July 2009 there was also a higher rainfall than the average from long-term and therefore this month was very wet. August was extremely dry and September was dry. In April and May 2010, the amount of precipitation was significantly above the average rainfall long-term, which meant that these months were very wet and extremely wet respectively. In June 2010, there was a small amount of precipitation, which did not exceed 50% of the sum long-term, which places this month as extremely dry. July 2010 was an average month in terms of rainfall, while August and September was extremely wet and very wet, respectively. A completely different distribution of rainfall was in 2011. In April and May, rainfall does not exceed 50% of the average long-term rainfall, and therefore, these months were classified as extremely dry. The next month (June) was average in terms of the amount of rainfall, while July was extremely wet, which was influenced by the large amount of rainfall that occurred at the turn of the second and third decades of this month. In the following months, rainfall was much lower than the average long-term sum, therefore these months were classified as dry (August) and extremely dry (September).

Figure 3 shows the diversity of Ψ_m in 100 cm soil thickness for the growing seasons 2009, 2010 and 2011 covering the period from the first decade of April to the third decade of September, while in Figure 4, dynamics of soil moisture storages (Ra) against $LLRPAW_{31}$, $LLRPAW_{49}$, $LLRPAW_{59}$, $LLRPAW_{88}$, $LLRPAW_{2/3}$ in 30, 50 and 100 cm thickness of PRZ1 and SIE1 pedons is presented. In the spring in all analysed Albeluvisols Ψ_m values greater than or close to –10 kPa (pF 2) were observed, which was connected with water content higher than FC or close to FC. Then, in surface horizons and defaulting directly underneath subsurface horizons in 2009, a gradual increase of soil

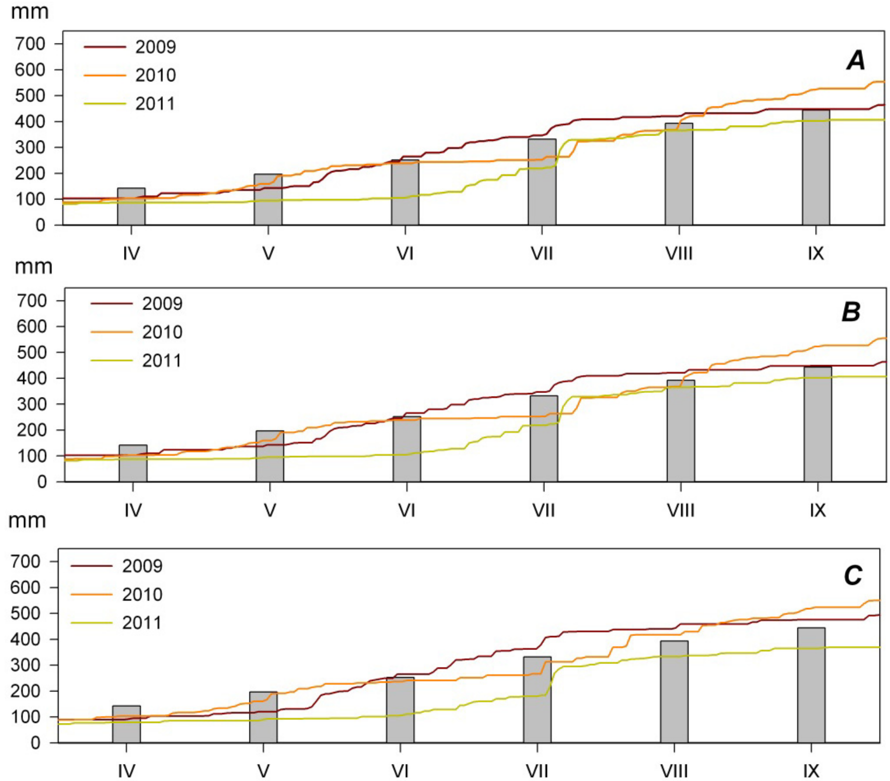

Fig. 2. Cumulative precipitation in growing seasons (lines) in relation to the average cumulative precipitation from long-term (bars) for Poznań (A), Siernicze Wielkie (B) and Granowo (C)

Rys. 2. Skumulowany opad atmosferyczny w sezonach wegetacyjnych (linie) na tle średniego z wielolecia skumulowanego opadu (słupki) dla Poznania (A), Siernicz Wielkich (B) i Granowa (C)

suction to the third decade of May was observed. In these soils, values of Ψ_m at –59 kPa were usually observed to a depth of 30-35 cm. In the coming months due to above-average rainfall, the drying up of surface and subsurface horizons was not observed. Analysing 1 m rooting zone in the growing season 2009, there were no observed water deficiencies in relation to $LLRPAW_{2/3}$ as well as to the lower limit of readily plant available water calculated at a Ψ_m = –59 kPa ($LLRPAW_{59}$). Considering the 50 cm soil thickness, deficiencies in relation to $LLRPAW_{59}$ occurred and usually did not exceed 10 mm (with respect to soil moisture storage at a Ψ_m = –59 kPa). These deficiencies calculated for plants such as sugar beet, potato and corn under optimal conditions for high potential transpiration in relation to $LLRPAW_{31}$ were more than 20 mm in Albeluvisols having the sandy ochric and luvic horizons, while in the remaining soils do not exceed 20 mm. Taking into account the 30 cm soil thickness from the first to third decade of May, there were observed lower water storages than the amount of water stored

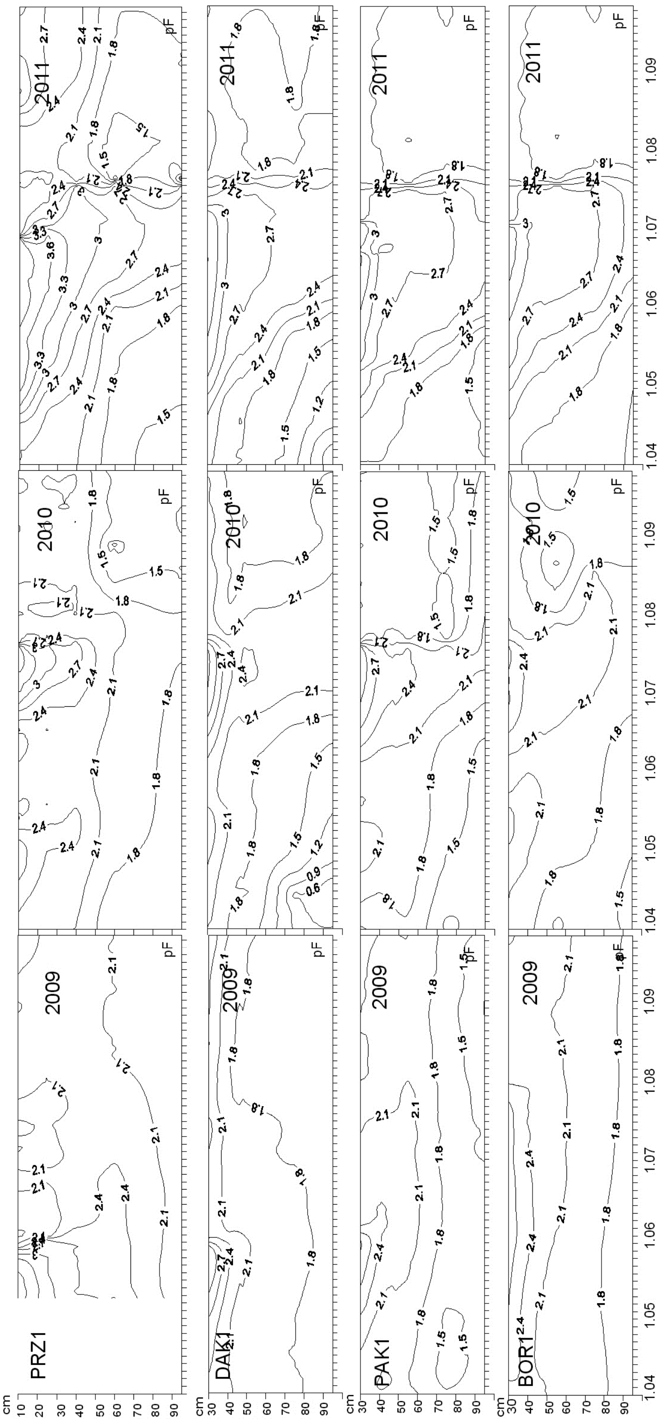

Fig. 3a. Temporal variability of the soil matric potential Ψ_m in PRZ1, DAK1, PAK1 and BOR1 soils
Rys. 3a. Chronoizoplety potencjału macierzystego wody glebowej Ψ_m w glebach PRZ1, DAK1, PAK1 i BOR1

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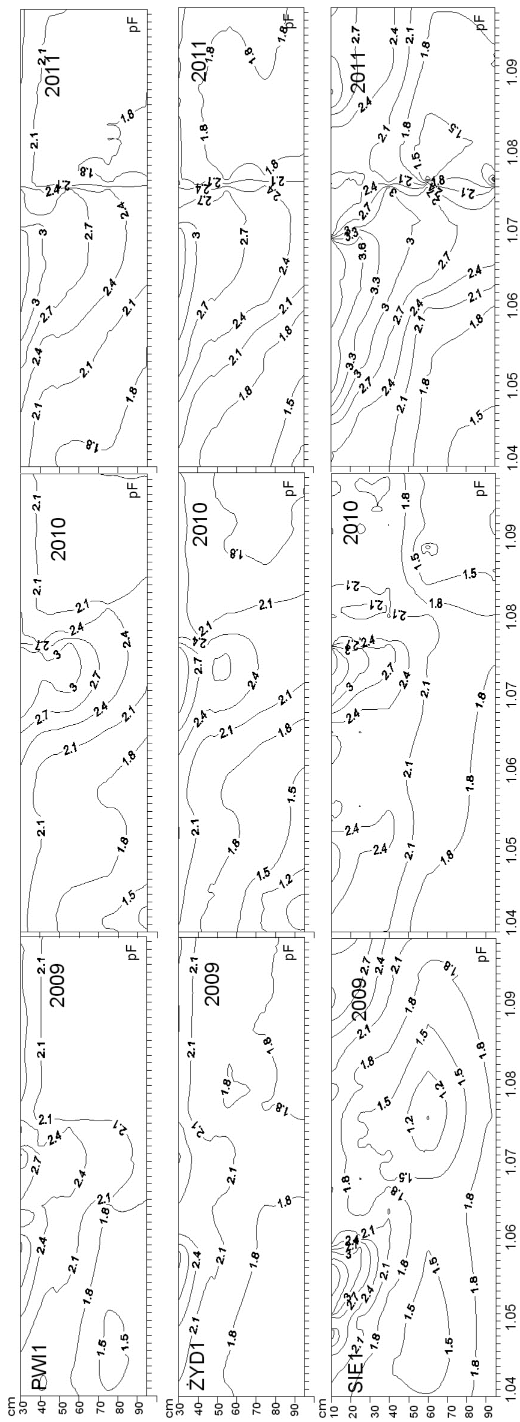

Fig. 3b. Temporal variability of the soil matric potential Ψ_m in PWI1, ŻYD1 and SIE1 soils

Rys. 3b. Chronoizoplety potencjału macierzystego wody glebowej Ψ_m w glebach PWI1, ŻYD1 i SIE1

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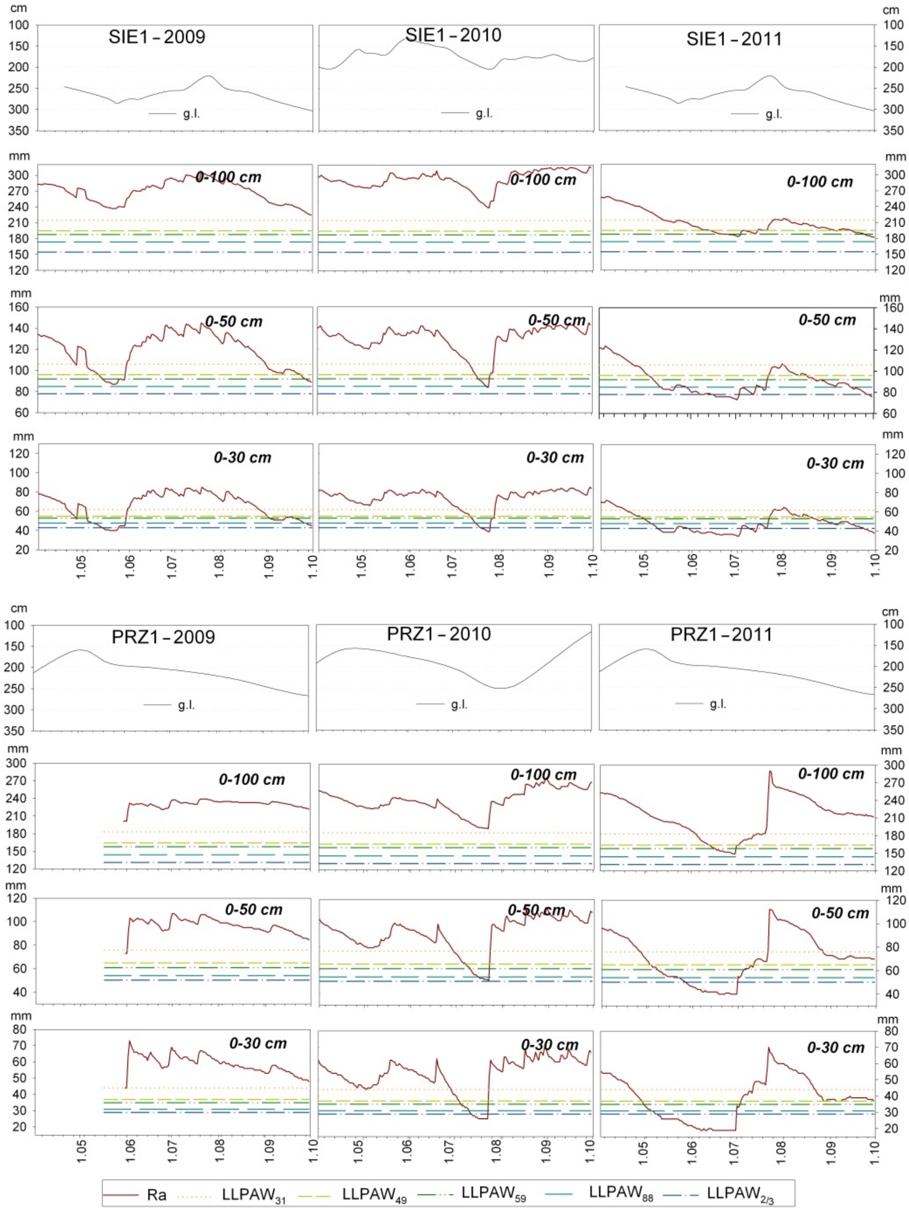

Fig. 4. Dynamics of soil water retention and groundwater level (g.l.) in SIE1 and PRZ1 pedons in 100, 50 and 30 cm soil layers for 2009, 2010, 2011 growing seasons

Rys. 4. Dynamika stanów retencji wody glebowej oraz zwierciadła wód gruntowych (g.l.) w pedonach SIE1 i PRZ1 w 100, 50 i 30 cm miąższości w sezonach wegetacyjnych 2009, 2010, 2011 at $LLRPAW_{31}$, $LLRPAW_{49}$, $LLRPAW_{59}$, $LLRPAW_{88}$ and $LLRPAW_{2/3}$. In the growing season of 2010 to the third decade of June high Ψ_m values were observed related to heavy rain in April and May. Then, due to the small amount of precipitation a decrease of Ψ_m was recorded. To a depth of 40-45 cm values of Ψ_m = –59 kPa were observed. From the end of second decade in July, values of Ψ_m significantly increased. This was associated with a high amount of rainfall recorded during this period. Then, due to the very large amount of rainfall in subsequent months, values of Ψ_m were close to 10 kPa, which corresponded to FC. Taking into account the 1 m rooting zone in the analysed Albeluvisols there were no deficiencies of water in relation to $LLRPAW_{2/3}$ but taking into account the Ψ_m = –59 kPa as the limit between the water readily and difficult available to plants, deficiencies occurred. The period of their occurrence was in the second and third decade in July. In Albeluvisols having the sandy ochric and luvic horizons, these deficiencies were more than 13 mm, while the other pedons do not exceed this value. In the 30 cm thickness, the period occurrence of deficiencies of the water readily available to plants covered a longer period (from the first to the third decade in July). Two months extremely dry (April and May) followed by an average month (June) in terms of the amount of rainfall occurred and contributed to the drying up of analysed Albeluvisols during the growing season of 2011. From the third decade in April, these soils showed a significant depletion of water readily available to plants. This resulted in the decrease in the value of Ψ_m. In Stagnic Albeluvisols (PRZ1, DAK1, PAK1, BOR1, SIE1) usually to a depth of 70 cm, the water content corresponded to the Ψ_m = –59 kPa, whereas in Gleyic Albeluvisols (PWI1, ŻYD1) to a depth of 60 cm. These conditions remained to the end of the second decade in July, followed by a rapid rebuilding of soil moisture storage and growth value of Ψ_m was observed. In the 1 m thickness of analysed Albeluvisols there were no deficiencies of water in relation to $LLRPAW_{2/3}$ but taking into account the Ψ_m = –59 kPa, as the limit between the water readily and difficult available to plants, water deficiencies occurred. The deficiencies were observed from the third decade in May to the second decade in July and amounted to 7 mm, 19 mm, 25 mm and 40 mm, respectively with reference to $LLRPAW_{88}$, $LLRPAW_{59}$, $LLRPAW_{49}$ and $LLRPAW_{31}$. Considering the 50 cm soil thickness, water deficiencies in relation to $LLRPAW_{2/3}$ amounted to 11 mm and spanned from the third decade in May to the second decade in July, while reference to $LLRPAW_{59}$ from the second decade in May to the second decade in July. In the 30 cm rooting zone deficiencies of the water readily available to plants already appeared in the third decade in April and lasted to the second decade in July ($LLRPAW_{31}$) amounting to a maximum of 25 mm.

Discussion

From the point of view of the soil genesis, evolution and crop production it is important to determine how deep, when in the growing season and to what values of Ψ_m drying up and deficiencies occur (KOZŁOWSKI and KOMISAREK 2011).

Based on three years of research, it can be concluded that Albeluvisols during the growing season are strong and deep soil drying up, whereas the soil water dynamics and thus soil water deficiencies during the growing season are determined mainly by precipitation. The cyclic strong drying up and wetting of the Albeluvisols in ground moraine have been observed by MARCINEK et AL. (1994), SPYCHALSKI (1998), KOMISAREK (2000), MARCINEK and KOMISAREK (2000), KOMISAREK et AL. (2008), KOZŁOWSKI and KOMISAREK (2011) and KOZŁOWSKI et AL. (2011). This is a typical feature of these soils in terms of their genesis and evolution (SOIL... 1975, RUST 1983, SHARMA et AL. 1998, KOMISAREK 2000).

Obtained results do not conform to those observed by MARCINEK et AL. (1994) drying up of Albeluvisols to the value of Ψ_m –1500 kPa to a depth of 100 cm, as well as those by KOZŁOWSKI and KOMISAREK (2011) to a depth of 90 cm. Analysed soils on the one hand are characterised by a low water holding capacity, especially in sandy ochric and luvic horizons, on the other, a deep groundwater level during the growing season. Consequently, the stored water is quickly used by plants, which are forced to take the water from the illuvial argic horizon. Despite the high water holding capacity of this horizon, in Stagnic Albeluvisols to a depth of 70 cm the water content corresponded to the matric potential of –59 kPa, resulting in the inhibition of growth and development of most cultivated plants in central Wielkopolska. This drying up in Gleyic Albeluvisols (PWI1, ŻYD1) reached a depth of 60 cm. This was due to the presence of deficiencies of water readily available to plants, which took place from the beginning of third decade in May to the second decade in July 2011. During this period, the maximum values of deficiencies were observed. Quantitatively, these deficiencies amounted to 7 mm, 19 mm, 25 mm and 40 mm for plants showing inhibition of growth and development at

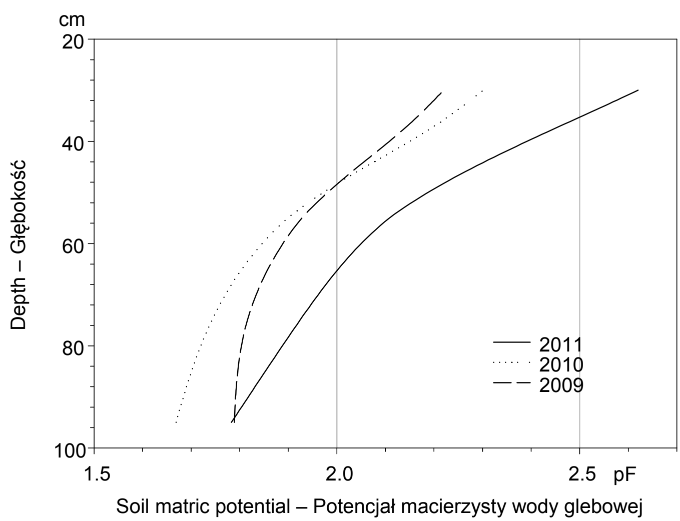

Fig. 5. Average value of the soil matric potential Ψ_m of analysed Albeluvisols in 2009, 2010, 2011
Rys. 5. Średnia wartość potencjału macierzystego wody glebowej Ψ_m w analizowanych glebach płowoziemnych w latach 2009, 2010, 2011

$-\Psi_m$ of 88 kPa, 59 kPa, 49 kPa and 31 kPa respectively in 100 cm soil thickness. For plants with a shallow rooting zone, soil water deficits in the 30 cm thickness already appeared in the third decade in April and lasted to the second decade in July (in relation to $\Psi_m = -31$ kPa) and maximum amounted to 25 mm. This strong soil drying up during the growing season 2011 determined that the mean matric potential depth equal to the field capacity occurred at the depth of 65-70 cm, which does not confirm the results obtained by KOMISAREK et AL. (2008) and KOZŁOWSKI and KOMISAREK (2011). In the growing seasons of 2009 and 2010, these depths amounted to about 50-55 cm (Fig. 5).

Conclusions

1. Albeluvisols strongly and deeply dry up during the growing season, in which the dynamics of soil water content and thus soil water deficiencies are determined mainly by rainfall.
2. In Stagnic Albeluvisols to a depth of 70 cm the water content corresponded to the matric potential of –59 kPa, resulting in the inhibition of growth and development of most cultivated plants in central Wielkopolska. This drying up in Gleyic Albeluvisols reached a depth of 60 cm.
3. The highest soil water deficiencies occurred during the growing season of 2011, which in 100 cm thickness amounted to 7 mm, 19 mm, 25 mm and 40 mm in relation to $LLRPAW_{88}$, $LLRPAW_{59}$, $LLRPAW_{49}$ and $LLRPAW_{31}$ respectively and lasted from the third decade in May to the second decade in July. In the 30 cm rooting zone deficiencies of water readily available to plants already appeared in the third decade in April and lasted until the second decade in July amounting to a maximum of 25 mm (in relation to $LLRPAW_{31}$).
4. The average soil matric potential top depth equal to the field capacity was about 65-70 in the analysed Albeluvisols during the 2011 growing season, while in 2009 and 2010 about 50-55 cm.

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NIEDOBORY WODY ŁATWO DOSTĘPNEJ DLA ROŚLIN W WYBRANYCH GLEBACH PŁOWOZIEMNYCH CENTRALNEJ WIELKOPOLSKI

Streszczenie. W pracy przedstawiono wyniki badań prowadzonych w latach 2009-2011 nad niedoborami wody łatwo dostępnej dla roślin w czarnej ziemi z poziomem cambic w środkowej Wielkopolsce. Celem badań była ocena niedoborów wody w relacji do dolnej granicy wody łatwo dostępnej dla roślin (DGWŁD) obliczonej przy potencjale macierzystym wynoszącym –31 kPa ($DGWŁD_{31}$), –49 kPa ($DGWŁD_{49}$), –59 kPa ($DGWŁD_{59}$) i –88 kPa ($DGWŁD_{88}$). Wyniki badań wskazują, że niedobory wody dla roślin i głębokość przesychania gleb były zdeterminowane głównie przez opady. Najsilniejsze i najgłębsze przesychanie obserwowano w sezonie wegetacyjnym 2011 roku. W sezonie tym w glebach płowych z cechami glossic i płowych zaciekowych opadowo-glejowych obserwowano do głębokości około 70 cm wartości potencjału macierzystego wynoszące –59 kPa, podczas gdy w glebach płowych zaciekowych gruntowo-glejowych – do głębokości 60 cm. Największe niedobory wody obserwowano w okresie od trzeciej dekady maja do drugiej dekady lipca. Niedobory te w 100 cm miąższości wynosiły 7 mm, 19 mm, 25 mm and 40 mm, w relacji do $DGWŁD_{88}$, $DGWŁD_{59}$, $DGWŁD_{49}$ i $DGWŁD_{31}$. Biorąc pod uwagę 30-centymetrową miąższość, niedobory wody obserwowano od trzeciej dekady kwietnia do drugiej dekady lipca. W analizowanych glebach płowych średnia głębokość strefy potencjału macierzystego wody glebowej równa polowej pojemności wodnej wyniosła około 65-70 cm w sezonie wegetacyjnym 2011 roku, a w sezonach 2009 i 2010 roku – około 50-55 cm.

Słowa kluczowe: gleby płowoziemne, niedobory wody glebowej, potencjał macierzysty wody glebowej

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