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Soil moisture in mountain spruce stand

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ABSTRACT: Mountain forests are among the main components of natural environment in Slovakia. They grow mainly in areas with cold climate, on poor soils with unfavorable reaction, often very acidic (pH in H_2O < 4.5) and with nutrient deficit. Immissions and acid rain attack forests to a great extent. Global climate changes also represent a new threat. Extremes in air temperatures, excessive amounts of precipitation or on the other hand the lack of water from precipitation, torrential rains or long-lasting drought periods are recorded as a result of a higher amount of heat energy accumulation from the greenhouse effect. Spruce forests are most endangered. Spruce with its root system concentrated in the upper soil layers, where also the highest amount of toxic elements accumulates, suffers more and more from dry and warm periods and it begins to wither due to drought. The occurrence of hydropedological cycles with a low or insufficient supply of available water in the soil is most frequent during summer (July, August). If the soil water potential values approach the value of the wilting point, an expressive decrease in transpiration is observed during the day, whereas its daily course is also suppressed. Gradual soil drying up from the upper layers towards the deepest ones of the physiological profile of soil represents a change in soil moisture stratification, especially after moistening the upper layers of soil with water from atmospheric precipitation. The deeper soil layers need not be re-saturated in such a case. Under drought the whole physiological profile of soil dries up in a relatively short time. Trees are exposed to a strong physiological stress in such conditions and after long-lasting drought periods they can get into the state of total exhaustion.

Keywords: soil moisture; hydrolimits; physiologically available water; hydropedological cycles

Slovakia is characterized by vertical segmentation of the relief with different climatic and hydrological conditions, which results in a variety of plant communities. Water is among the main sources of biosphere. It also represents the main medium for nutrient transportation in plant communities and it takes part in photosynthetic processes, evapotranspiration, enzyme hydration, etc. Water use by forest trees is determined by their ecological demands, production ability and by atmospheric and soil water use efficiency. Spruce and beech, most frequent tree species in higher forest vegetation zones, have relatively high requirements for water. The physiological consumption of water by beech is considerably lower than that of spruce and the water balance, with respect to some of its components, e.g. the stem flow, is more favorable.

Spruce stands mostly grow on acidic soils with poor-in-minerals substrates, highly unbalanced nutrient content and water holding capacity. Continuous inputs of harmful elements, especially to the upper layers of soil profile, represent a serious danger to spruce stands. These inputs cause changes in the unfavorable chemical composition of soils and consequently changes in the availability and mobility of soil water. After the spruce trees are physiologically weakened in this way and in the case of long-lasting unfavorable stand and atmospheric conditions, they gradually decline or even die-back.

MATERIALS AND METHODS

The research plot Oravská Polhora – Borsučie was established in 1984, when the systematic monitoring of precipitation chemistry was initiated. In 1989 the scope of research was widened and some other water balance components were included, such as interception, stem flow, surface runoff, water seepage into deeper layers of soil profile. Research on the soil water regime on this research plot has been carried out since 1991.

The research plot is located mostly in the spruce stand (spruce 85, beech 13, fir 2) on the SW slope with a gradient of 15%, at 940 m above sea level. At the beginning of our research the age of trees was 90 years and the stocking was 0.7. Typologically this forest stand belongs to the FA forest type group, the soil is acid Cambisol.

Precipitation was collected in 5 buckets made of PVC with the collecting area of 500 cm^2. These buckets were placed crosswise at 1 m above the soil surface as well as

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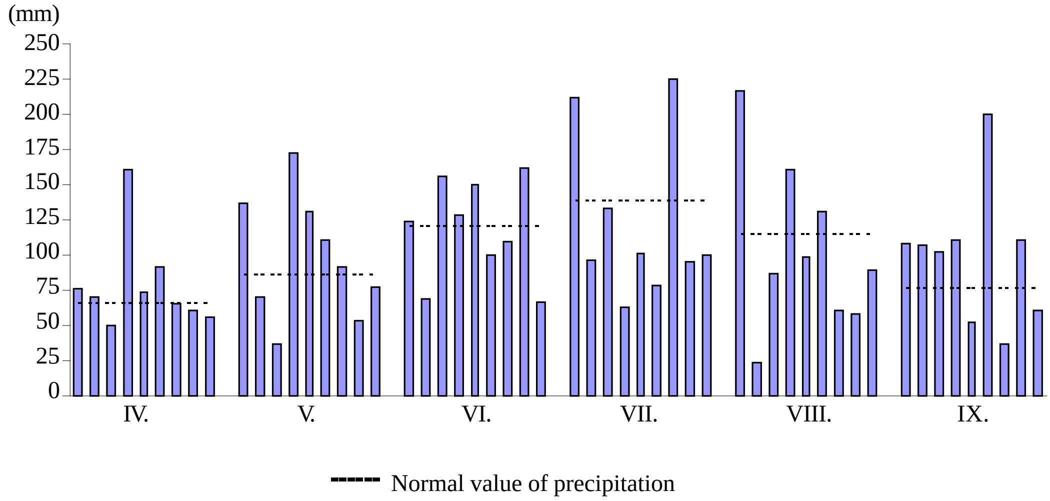

Fig. 1. Monthly (April–September) precipitation (mm) during the growing season of the years 1991–1999

under the grass and herb vegetation. The stem flow was collected from three spruce tree samples by means of leaden mangers, seepage water was collected into gravitational lysimeters made of PVC with the collecting area of 2,500 cm^2 installed under the surface humus horizon at a depth of 30 and 50 cm.

The actual soil moisture content was determined from soil samples that were taken in week intervals. A gravimetric method was used and soil samples were taken with a soil bore from 10cm sequences to the depth of 80 cm. Soil moisture conditions were evaluated in relation to the basic hydrophysical characteristics of the soil: maximum capillary capacity MCC, point of diminished availability PDA, and wilting point WP (TUŽINSKÝ 1990). The water consumption by evapotranspiration (*ET*) was calculated from a difference in water supply in the soil at the beginning and the end of monitored season (*dV*), amount of precipitation (*Z*) and water amount that infiltrated into the soil (*Ip*). The following equation was used:

$$ET = Z - dV - Ip$$

Ecological classification of the water regime was determined according to KUTÍLEK (1971).

RESEARCH RESULTS

Precipitation sums for the growing seasons 1991–1999 indicate that the growing seasons 1991 and 1994–1997 had sufficient amounts of water from precipitation. On the other hand, water supply in the growing seasons 1992, 1993, 1998, and 1999 was not high enough.

If the actual monthly precipitation sums are compared with a long-term value, these have a normal distribution of frequency of climatic characteristics within one month, with a slight shift towards the months with precipitation sums below normal (Fig. 1, Table 1).

When evaluating longer lasting periods without rain, we focused on the period from June 19 to August 21, 1992, when only two rainy days were recorded (June 30: 19.8 mm of the open area precipitation, 14.6 mm of forest stand precipitation; August 14: 1.9 mm stand precipitation). In the period from June 16 to August 27, 1995 there were 10 rainy days altogether, with stand precipitation sum of 9.9 mm. A period without rain in the spring 1996 lasted from May 29 to June 11. From August 15 to August 27 there were 6 rainy days and the forest stand sums amounted to 2.2 mm. During the growing season of 1997 a period with low rain was recorded from April 18 to May 18 (4.2 mm of forest stand precipitation), and from August 5 to August 28 (6.9 mm). During the growing season of 1999 a similar precipitation activity was recorded from June 24 to August 6 (1.7 mm) and from September 3 to September 25 (0.8 mm). In the other studied growing seasons normal or even above-normal precipitation amounts were recorded.

Interception, infiltration of water to the soil, evapotranspiration, stem flow and surface runoff belong among most significant components of the water balance that take part in the soil moisture regime (Table 2).

The interaction of crowns in the spruce stand causes that a certain amount of precipitation is intercepted that consequently evaporates to the air. The factors of interception process are as follows: meteorological factors (temperature, humidity, air movement), character of the forest stand crown layer, tree composition, stand age, canopy and stocking. A significant dependence upon the intensity of precipitation was observed on the research plot, determined by the relation of actual interception and selected forest stand characteristics (Fig. 2).

Monthly sums of stand precipitation on the research plot ranged from 68% to 89% of the open area precipitation amount. The highest interception losses were recorded in July (26% on average) and the lowest in September (16.8%). Total interception was highest in the growing season 1994 (26.9%) and lowest in the growing season 1997 (19.7%). Lower interception values in June 1993 and September of 1992, 1995, 1997, and 1999 (10.7–16.7%) can be explained by frequent rainfall events of low intensity (< 3 mm) and especially by fog occurrence.

Table 1. Characteristics of months during the growing season according to precipitation sums

Growing season	IV	V	VI	VII (mm)	VIII	IX	Σ
1991	74	134	121	208	216	107	860
1992	78	85	77	115	30	135	520
1993	49	36	151	130	85	98	549
1994	154	167	125	60	156	109	771
1995	76	128	146	103	95	50	598
1996	87	109	99	70	127	196	688
1997	76	100	117	234	67	41	635
1998	58	52	160	92	55	108	522
1999	56	77	63	99	88	56	439
Σ	708	888	1,059	1,111	919	900	
∅	79	99	118	121	102	100	
Month characteristic	NO	NO	NO	NO	NO	NO	
Normal 1901–1970	67	87	122	139	115	77	607

Growing season	Month					
	IV	V	VI	VII	VIII	IX
1991	NO	NN	NO	SNN	SNN	NO
1992	NO	NO	NO	NO	SPN	NN
1993	PN	SPN	NN	NN	NO	NO
1994	NN	SNN	NO	PN	NN	NO
1995	NO	NN	NN	NO	NO	PN
1996	NO	NO	NO	PN	NO	SNN
1997	NO	NO	NO	MNN	NO	PN
1998	PN	PN	SNN	NO	PN	NO
1999	PN	NO	PN	NO	NO	NO

Month characteristics	Abbreviation used	Interval of phenomenon (%)	Frequency of occurrence during the growing season (%)	
Extraordinarily above average	MNN	< 2	1	1.8
Strongly above average	SNN	2–9.9	5	9.3
Above average	NN	10–24.9	8	14.8
Normal	NO	25–75	28	51.9
Below average	PN	75.1–90	10	18.5
Strongly below average	SPN	90.1–98	2	3.7
Extraordinarily below average	MPN	> 98	0	0

The stem flow values ranged from 10.1 to 14.2 mm in the course of our research, which accounted for 1.6–1.9% of the open area precipitation amount. The stem flow process started after the tree bark was fully saturated with water, that means when precipitation reached about 4–6 mm.

The evaluation of surface runoff indicated very low values. As for the seasonal variations, the highest runoff values were recorded in May and June (1 mm on average) and the lowest in April (0.7 mm). Total runoff values within the growing season ranged from 2.3 mm (1999) to 8.7 mm (1994), i.e. 5.3 mm on average (less than 1% of the open area precipitation).

Water infiltration into the soil is one of the most significant components of water balance. In relation to soil permeability, its physical properties and moisture conditions the amount of water infiltrated into the soil ranged from 116 mm (1999) to 302 mm (1991), which equaled 26–35% of precipitation measured on the open area. The highest water loss, as for its infiltration, was recorded in May (382 mm) and the lowest in August (273 mm), which accounted for 43.3–29.5% of precipitation measured in the open area.

Table 2. Water balance in spruce stand during selected growing seasons

Growing season	Average air temperature (°C)	Open area precipitation (mm)	Interception (mm)	Interception (%)	Surface runoff (mm)	Surface runoff (%)	Water seepage (mm)	Water seepage (%)	Amount of water at the beginning and end of growing season (mm)
1991	11.3	875.1	232.8	26.6	7.6	0.8	278.5	31.8	339.5 283.4
1992	12.5	442.7	109.5	24.7	5.9	1.3	148.3	33.5	298.9 263.2
1993	12.2	573.2	135.5	23.6	4.8	0.8	201.8	35.3	307.3 255.4
1994	13.3	719.4	206.2	28.7	6.1	0.8	294.9	41.0	367.5 309.3
1995	12.1	607.6	129.4	21.3	8.7	1.4	240.8	39.6	329.9 246.5
1996	11.9	710.5	156.2	22.0	7.4	1.0	276.2	38.9	359.4 283.2
1997	11.8	589.3	129.7	22.0	5.6	0.9	229.6	39.0	349.2 230.1
1998	12.0	540.8	127.2	23.5	5.1	0.9	190.3	35.2	372.2 340.8
1999	13.1	452.1	111.3	24.6	4.2	0.9	159.2	35.2	369.5 276.4

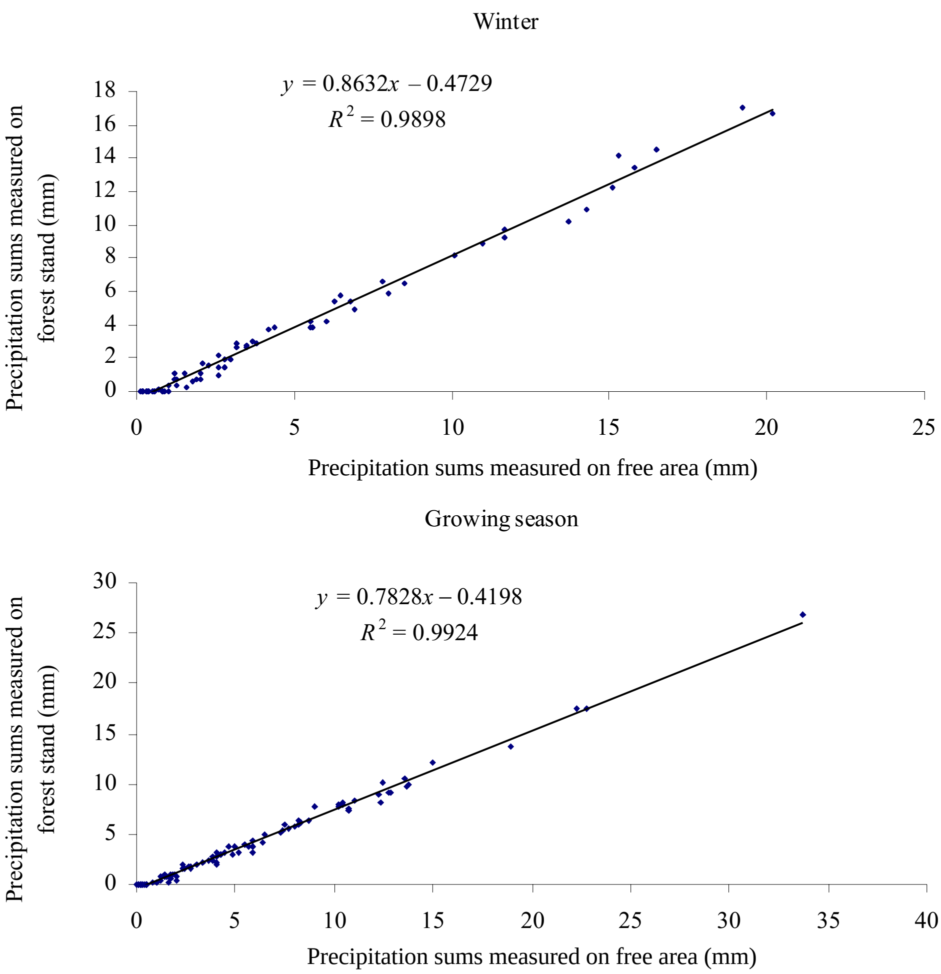

Fig. 2. Dependence between forest stand and open area precipitation

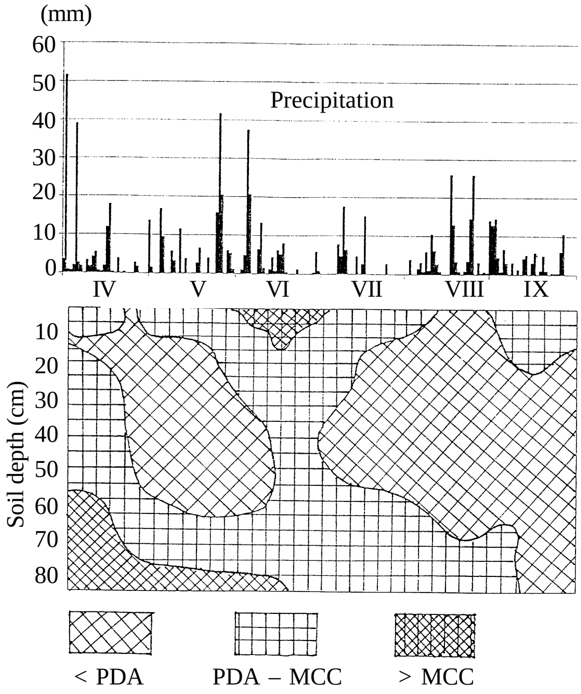

Fig. 3. Chronoisopleths of soil moisture during the growing season 1994

Soil moisture conditions are represented by soil moisture chronoisopleths in their relationship to individual hydrolimits. We chose three different growing seasons to be compared: average precipitation season (1995, 1997), below-average precipitation season (1992, 1999), and above-average precipitation season (1991, 1994).

In the growing season 1991 with above-average amount of precipitation (141% of the average), the whole soil profile was sufficiently supplied with water almost through the whole growing season. Soil moisture gradually increased towards the upper layers of soil profile (> MCC). During the seasons with frequent and longer lasting precipitation events the highest saturation with water was recorded in the upper (0–20 cm) and deepest (60–80 cm) layers of soil profile. Soil moisture in the growing season ranged from 29 to 41 weight %. At the beginning of the growing season and during the days following high precipitation activity the soil moisture in the upper soil layers was higher than 45 weight %; in the middle soil layers it ranged around the limit of 35 weight %; in the deepest layers of soil profile it decreased to the value of 40 weight %. The upper limit of the MCC hydrolimit was exceeded in all cases mentioned above.

The course of soil moisture was different during the above-average precipitation growing season 1994 (Fig. 3). A relatively high decrease in the soil moisture was recorded in October and November 1993. After the precipitation deficit in the following winter, the moisture content was considerably lower at the beginning of the growing season compared to the same period in the growing season 1991. The soil moisture at the beginning of the growing season 1994 ranged between 30 and 41 weight % in the upper soil layers, between 28 and 36 weight % in the middle layers of soil profile, and between 29 and 37 weight % in the deepest layers. An intensive decrease in the soil moisture in the following season (May–July) was recorded in the middle layers of soil profile (20–40 cm), whereby the water amount decreased to 21–38 weight %, which refers to 55–74 % of the MCC hydrolimit. The soil moisture content was more balanced in deeper soil layers and without larger fluctuations. It ranged from 71% to 85% of the MCC hydrolimit. In summer months the water amount in the whole physiological soil profile fluctuated between the hydrolimit of PDA and WP. The lowest water amount was in the upper and middle layers of soil profile (43–70% of MCC). In the layer of 0–20 cm the amount of available water ranged between 20 and 40 mm. That means the forest stand had a sufficient amount of available water (Fig. 4).

During average precipitation growing seasons (Figs. 5, 6) the whole soil profile had enough moisture only in spring. The length of the uvid interval (soil moisture amount > MCC) was determined by the amount and frequency of precipitation as well as by soil water supply that accumulated at the beginning of the growing season from winter supplies. During the growing season 1995 the supply of water from winter was lower compared to the growing season 1997 and in spite of more favorable precipitation conditions. The soil moisture decreased to the area between the hydrolomits of MCC and PDA in the upper and middle layers of soil profile (0–40 cm) already in the first decade of May, in the deepest layers (60–80 cm) a month later. During the growing season 1997 the soil moisture amount above the upper limit of the MCC hydrolimit was recorded practically in the whole soil profile until the end of June. The most expressive dynamics of soil moisture was recorded in the upper soil layers where the soil moisture ranged between the hydrolimits of MCC and PDA. The supply of available water ranged from good to sufficient supply during spring (> 40 mm), at the beginning of summer it was only sufficient (approx. 20 mm). In August and September the days when the soil moisture in the upper 20cm layer decreased below 20 mm occurred sporadically. This reflected an insufficient supply of available water.

During below-average precipitation seasons (1992 = 86%, 1999 = 72% of the average) the soil moisture regime was characterized by three soil moisture intervals. The uvid interval was recorded in spring after the accumulation of water from winter (Fig. 7) with the soil moisture above the upper limit of the MCC hydrolimit. In spring, during a low precipitation and quite cold period the semiuvid interval prevailed (Fig. 8) with soil moisture between the hydrolimits of MCC and PDA. Relatively big changes in the soil moisture, especially in the middle and deeper layers of soil profile (May, April 1999), very well reflect precipitation conditions as well as changes in the air temperature. After the air temperature increased and while the soil profile had a good supply of water, the consumption of water for evapo- transpiration processes increased (> 4 mm/day).

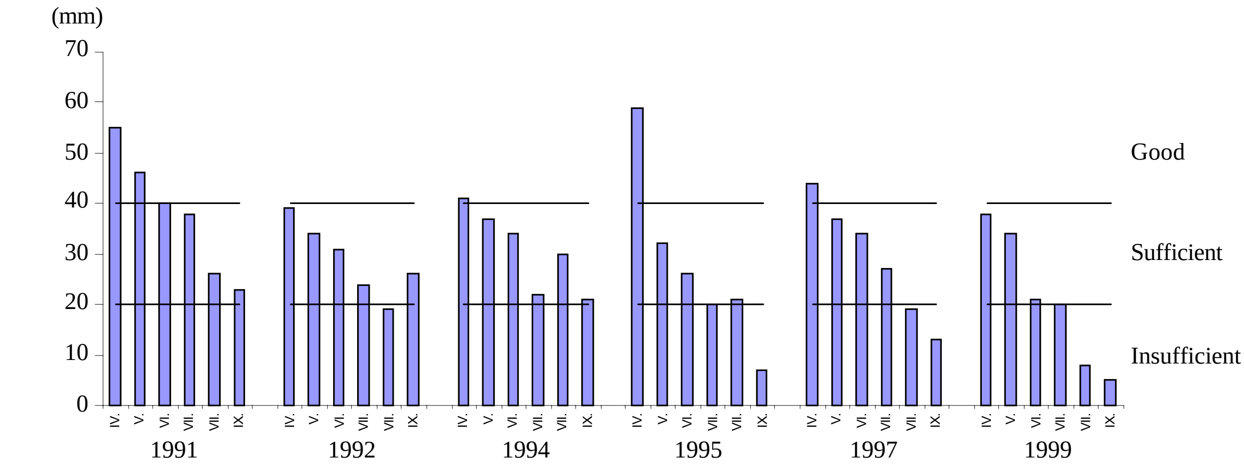

Fig. 4. Available water supply (mm) in the 0–20cm layer of the soil profile during the growing season

As a consequence of favorable precipitation distribution (except for August – 14% of the average) available water supply (> 20 mm) in the upper 0–20cm layer of soil profile was mostly sufficient at the beginning of the growing season 1992. During the growing season 1999 the amount of available water varied at the boundary of sufficient and insufficient supply. Periods with hardly available water supply in the upper layers of soil profile were often recorded in summer. This forced trees to utilize water from deeper soil layers. A critical situation occurred in September, when the increased consumption of available water took place almost in the whole soil profile. Trees disposed only of hardly available water during this period.

According to the degree of soil profile moistening, soil moisture duration and moisture stratification (KUTÍLEK 1971), three intervals of soil moisture were recorded in the physiological soil profile in the spruce stand during the growing season. In spring after the winter accumulation period and after sufficient precipitation events the uvid interval of the soil moisture prevailed (soil moisture > MCC). The most frequent interval was a semiuvid one with the soil moisture values between the hydrolimits of MCC and PDA. The optimal amount of soil moisture (60–80% of MCC) usually lasted until the end of June and in the case of the sufficient amount of soil moisture even later. A drying-up period culminated in summer when the amount of soil moisture decreased to the semiarid interval, which represents the soil moisture between the hydrolimits of PDA and WP. Such moist conditions occurred mostly in the upper layers of soil profile only. These moist

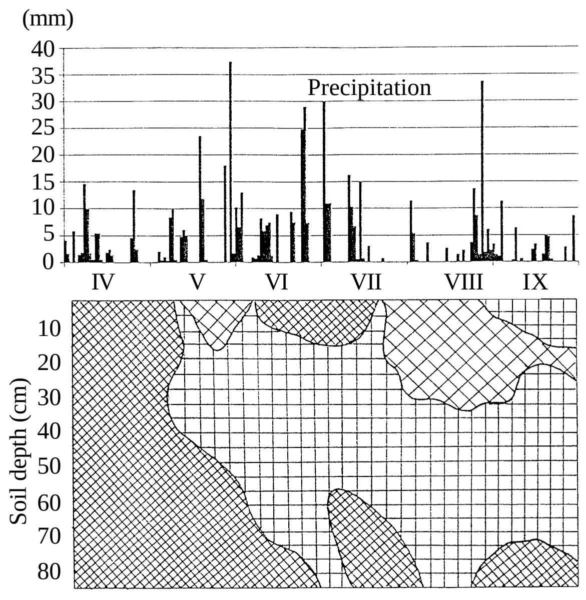

Fig. 5. Chronoisopleths of soil moisture during the growing season 1995

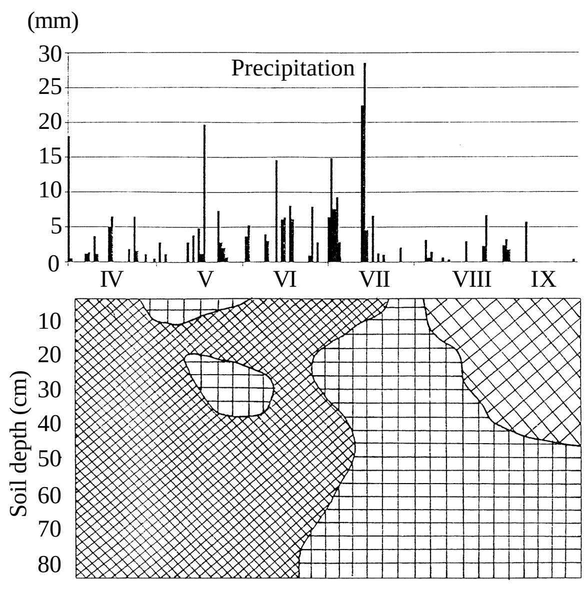

Fig. 6. Chronoisopleths of soil moisture during the growing season 1997

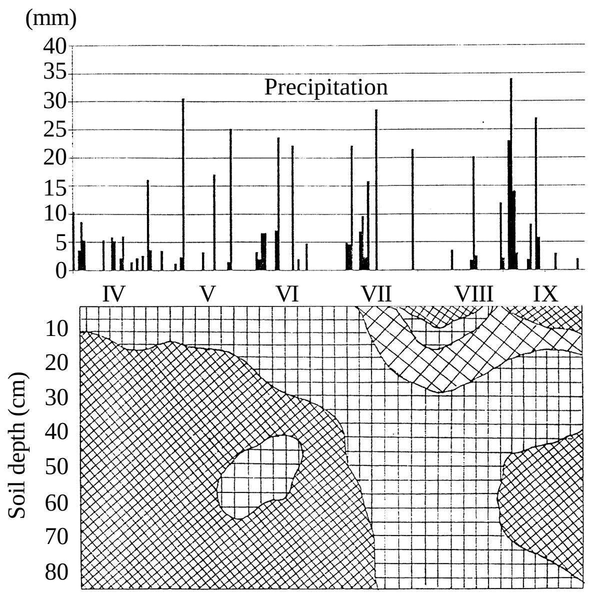

Fig. 7. Chronoisopleths of soil moisture during the growing season 1992

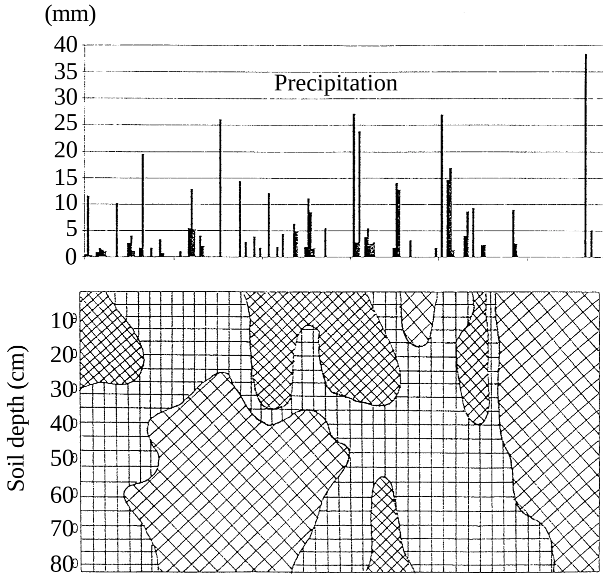

Fig. 8. Chronoisopleths of soil moisture during the growing season 1999

conditions influence the growth of trees and their physiological state was proportional to their duration and intensity. After longer-lasting dry and warm days the soil water deficit increased and it gradually hit also deeper layers of soil profile. Usually it had only a short-time character and occurred towards the end of the growing season.

DISCUSSION AND SUMMARY OF RESULTS

The development and state of water regime in forest soils depend upon the ratio of incoming to outgoing components of water balance, i. e. on the intensity of hydrological processes that affect an increase or decrease in soil water. Soil moisture changes on research plots are caused by the influence of atmospheric conditions, especially by the amount, intensity and time distribution of precipitation as well as by evaporation and temperature conditions, relief (slope, exposition) and water and physical characteristics of soil (texture, structure, water holding capacity, runoff conditions). The transforming effect of forest stand also influences the water regime in a significant way, especially by uneven throughfall distribution, vegetation interception and humus layer. Other factors are desuction and various spatial fluctuations in the forest soil permeability.

The actual precipitation amount is mostly modified by the forest stand structure and its stratification. In our case, the throughfall in the spruce stand accounted for 73–80% of the precipitation on average from the open area precipitation during the growing season. We observed a great variability in intercepted precipitation during individual months (11–33%). Relatively low values (< 10%) were registered in seasons with fog occurrence. The increase in forest stand precipitation influenced by advection fogs is discussed in papers published by several authors, e.g. KANTOR (1981), GREGOR et al. (1999), etc. Changes in interception processes in the presence of fog or without it were analyzed by KREČMER (1973) using the curve of throughfall without the presence of fog and the curve of maximal throughfall. A throughfall process has a linear character although its complicated course following the fluctuations in interception process, especially at its beginning, is often represented as markedly non-linear (BENETÍN 1983; KREČMER 1973; KREČMER et al. 1981; MINĎÁŠ 1999).

Precipitation total, its distribution and the stem surface are the main factors influencing the stem flow (INTRIBUS 1977; EIDMAN 1959; KORTÜM 1961). The stem flow in spruce stands is not significant as for its quantity and it does not usually exceed 2% of the open area precipitation (EIDMAN 1961; RAJEV, SERAFIMOV 1980; TUŽINSKÝ 2000; ZELENÝ 1967). Similar results of the stem flow measurements were confirmed on our research plot. Water started to flow only after precipitation higher than 4–6 mm and the amount of flown-away water did not exceed 2% of the open area precipitation amount.

The values of surface runoff are minimal with respect to total water balance. According to MIDRIAK (1992) the amount of runoff water on the soil surface in Slovakia ranges from 22 to 782 l/ha per day (255 l on average). This is 0.07–2.52% (ø 0.99%) of the total precipitation amount, depending on natural and management conditions of coniferous forest stands (spruce, fir, pine, larch). As for deciduous forest stands (beech, oak, hornbeam), the values of surface runoff range from 34 to 1,080 l/ha per day (323 l on average), i.e. 0.14–5.03% (ø 1.52%) of the total precipitation amount. Other research results also confirmed that in our conditions the surface runoff values do not exceed 3% in forests, in dependence on the slope, soil permeability and forest stand type. The values of surface runoff from agricultural lands range between 5 and 40% of total precipitation amount (ZACHAR, JŮVA 1987). Increased surface run in the forest stands can be observed only on uncovered and destroyed soil.

Water seepage to the bedrock represents a significant component of the water balance that influences the supply of water in the soil. During our research the amount of water that gravitationally penetrated through the soil profile was 26–35% of total precipitation amount. The amount of gravitational water depends upon the hydrological and physical properties of soil, precipitation intensity, and the soil moisture. A rich and well-developed root system in the forest soil contributes to a high infiltration of water.

Evapotranspiration, especially physiological evaporation, is a crucial outgoing component of water balance. Transpiration, except for solar radiation, air temperature, air movement, and inner factors (plant species and age, assimilation organ structure and orientation) are influenced especially by the water amount in soil. As the air temperature increases, the evapotranspiration also increases and reaches its maximum when the air temperature is about 25–30°C; the water intake is optimal at 60–70% of the maximum capillary capacity (PENKA 1985). Data acquired on different types of forest stands, according to their heterogeneous stand and climatic conditions, often obstruct the mutual comparison of transpiration values. Annual values of physiological evaporation in spruce stands range between 100 and 516 mm under European conditions (BRECHTEL, LEHNARDT 1982). As for evapotranspiration, its values range between 400 and 550 mm (GREMINGER 1984; MRÁZ 1973). Our research data were analogical, average evapotranspiration values from the spruce stand ranged between 327 and 406 mm/year.

Changes in the soil moisture are characterized and caused by the amount and intensity of precipitation, its spatial and time distribution, evapotranspiration, surface and underground runoff and other factors. We can state in general that soils are often insufficiently supplied with water at the beginning of the hydrological year. The soil moisture mostly ranges between the hydrolimits of the point of diminished availability and wilting point. The reason for such a state is an intensive consumption of water from the physiological soil profile in summer for evaporation and transpiration. Not even high precipitation is able to compensate the deficit of physiologically available water in the soil during summer. The soil profile is usually saturated with water in the winter accumulation period. Even though the lack of snow, elevated air temperature and possible evapotranspiration can worsen the unsuitable moisture regime. Then the onset of the growing season is quite unfavorable for the vegetation. The most expressive dynamics of the soil moisture can be observed in the upper soil layers, at the turn of winter and spring. When the ground is thawing, such an increase in soil moisture can result in temporary waterlogging. Water accumulation in the upper soil layers is explained by moisture movement forced by temperature gradient (BENETÍN 1983) and by an increase in the absolute value of soil water potential.

The above-mentioned facts show that the soil moisture conditions are very good at the beginning of the growing season. As for the soil moisture content expressed by hydrolimits, it ranges around the upper limit of the maximum capillary capacity. Very good supply of available water can also be observed in the middle and deeper layers of soil. An optimal amount of water in the soil (approx. 60–80% of the MCC) is available in the soil mostly until the end of the second decade of June. The available water is intensively used up during warm summer and the upper soil layers, where the bulk of active roots are also present, are dried up to the highest extent. The highest consumption of water for evapotranspiration (> 4 mm/day) was recorded in summer and the drying-up phase generally culminates in August.

It follows from the evaluation of available water amount in the upper 0–20cm layer of soil that it ranges between good (> 40 mm) and sufficient (20–40 mm) supply; in a dry and warm period it can even decrease to insufficient (< 20 mm) supply of water for a short time.

In the physiological soil profile of 0–100 cm, the supply of water in spring can be sufficient (90–130 mm) or even very good (> 160 mm) in dependence upon moisture conditions in autumn and winter, in a dry season it decreases to the low supply of available water (60–90 mm).

CONCLUSION

The existence and production ability of forest ecosystems depend upon water supply to a great extent. Development of the water regime of forest ecosystem soils is less known, compared to other hydrological factors. This applies especially to a complicated influence of forest upon individual components of water balance. The amount of water in the soil depends especially on the amount and time distribution of precipitation, which is the only source of water on our research plot at Oravská Polhora. The distribution and character of hydropedological cycles as well as spatial variability of water regime are influenced by the physical properties of soil and by the transforming effect of forest stand.

The following hydrophysical characteristics can be considered as positive ones on the research plot in question: low value of wilting point, high capillary, retention, and available water capacity, as well as lower water holding capacity.

It follows from research data on the soil moisture that during the growing season more expressive changes in the soil moisture are caused by desuction in the upper and middle soil layers, and by precipitation conditions in deeper soil layers. Normal stratification of moisture in the soil profile prevails. Gradual soil drying up beginning in the upper soil layers, followed by drying up of the deepest ones, starts on warm summer days after a period with insufficient precipitation and after desuction and transpiration processes. In such periods drying up of the soil will be intensive. The soil moisture expressed by hydrolimits ranges between the point of diminished availability and the wilting point; available water supply decreases to the area of a low supply.

Following the present research of soil moisture we can state that conditions with higher soil moisture prevail on research plots and the supply of trees with water is generally favorable. A decrease in the soil moisture below the 50% limit of MCC can appear sporadically, which consequently decreases the physiological activity of trees. After a long-lasting deficit of available water the process of physiological weakening can intensify. Contingent influence of stress factors increases the danger of damage (decrease in the number of assimilation organs; transpiration, assimilation, and increment decrease, as well as secondary pest occurrence) and the trees that are seriously damaged can even die back.

References

BENETÍN J., 1983. Analytické riešenie vzťahu medzi transpiráciou a výparom z intercepcie. Vodohosp. Čas., *31*: 354–368.

BRECHTEL H., LEHNERDT F., 1982. Einfluss der Grundwasserabsenkung auf Waldstandorten. 4 Fortbildungslehrgang Grundwasser. Nutzbares Grundwasserdargebot. 11 bis 14 October 1982 in Darmstadt. Hunn. München, Hessiche Forstliche Versuchsanstalt: 42.

EIDMANN F.E., 1959. Die Interception in Buchen und Fichtenbeständes. Ergebnis mehrjähringer Untersuchungen im Rothackergebirge (Sauerland). Assoc. Int. Hydrol. Sci., Publ. Genbrugge: 48.

EIDMANN F.E., 1961. Über den Wasserhaushaldt von Buchen und Fichtenbeständen. In: IUFRO Kongres, Wien, Berichte 1962, Teil 2.

GREGOR J., KONTRIŠ J., KONTRIŠOVÁ O., 1999. Forest stands precipitation of spruce ecosystem. Ekológia (Bratislava), *18*: 162–172.

GREMINGER P., 1984. Physikalish-ökologische Standortsuntersuchung über den Wasserhaushalt im offenen Sickersystem Boden unter Vegetation am Hang. Eidg. Aust. Forstl. Versuchswes., Mitt. 60, *2*: 151–301.

INTRIBUS R., 1977. Bilancia zrážok v lesnom bióme *Carpineto-Quercetum*. Lesn. Štúd., Zvolen, VÚLH, *28*: 63.

KANTOR P., 1981. Intercepce horských smrkových a bukových porostů. Lesnictví, *27*: 171–192.

KORTÜM F., 1961. Über den Einfluss der Bestockung auf dem Wasserhaushalt Grundwasser. Diluvialer Sand und Lehmstandorte. Deutsch. Akad. d. Landwirtschaftwiss., Sitzungsberichte 10: 11.

KREČMER V., 1973. Meteorologické podmínky výskytu kapalných srážek z mlhy a jejich význam pro intercepční proces ve středohorském lese. Meteorol. Zpr., *27*: 18–25.

KREČMER V., FOJT V., HYNČICA V., 1981. Intercepční proces ve smrkových porostech. Vodohosp. Čas., *29*: 593–614.

KUTÍLEK M., 1971. Ekologická klasifikace půdní vlhkosti. Vod. Hospod., *9*: 250–256.

MIDRIAK R., 1992. Výskum povrchového odtoku a eróznych pôdnych strát v lesných ekosystémoch. In: Ekologický a ekofyziologický výskum v lesných ekosystémoch. Zvolen – Poľana: 32–36.

MINĎÁŠ J., 1999. Kvantitatívna a kvalitatívna charakteristika zrážkového režimu jedľovo-bukového ekosystému. [Dizertačná práca.] Zvolen, LVÚ: 153.

MRÁZ K., 1973. Očekávané změny stanovištních poměrů Jihomoravských lužních lesů vlivem budovaných hospodářských úprav. Zpr. Lesn. Výzk., *19*, 3: 2–9.

PENKA M., 1985. Transpirace a spotřeba vody rostlinami. Praha, Academia: 250.

RAJEV I., SERAFIMOV V., 1980. Isledovane v archu izpareniеto ot počvenata poverchnost v zonata na iglolistnite gori v Rila Panina. Gorskostop. Nauka, *1*: 34–51.

TUŽINSKÝ L., 1990. Režim vlhkosti a zásob využiteľnej vody v pôde pod lesnými ekosystémami. Zvolen, Ved. Práce VÚLH, *39*: 95–110.

TUŽINSKÝ L., 2000. Water balance in Mountain spruce ecosystem. Meteorol. Čas., *3*: 23–28.

ZACHAR D., JŮVA K., 1987. Využití a ochrana vod ČSSR z hlediska zemědělství a lesního hospodářství. ČSAV – SAV, Praha, Bratislava: 567.

ZELENÝ V., 1967. Intercepce a horizontální srážky v Beskydech. Meteorol. Zpr., *6*: 154–157.

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Vlhkosť pôdy v horskom smrekovom poraste

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ABSTRAKT: Horské lesy patria na Slovensku k základným zložkám prírodného prostredia. Nachádzajú sa väčšinou v oblasti chladnej klímy, na prevažne troficky chudobných pôdach s nepriaznivou, už veľmi kyslou reakciou (pH v H_2O < 4,5) a nedostatkom živín. Sú vo veľkej miere atakované imisiami a kyslými zrážkami. V ostatnom období im hrozí nebezpečie aj vplyvom globálnych klimatických zmien. Výsledkom väčšieho množstva tepelnej energie skleníkového počasia vznikajú extrémy v teplotách, vyskytujú sa nadmerné zrážky alebo ich nedostatok, prívalové dažde, dlhšie trvajúce suché obdobia atď. Najväčšie nebezpečie hrozí smrekovým porastom. Smrek s koreňovým systémom, koncentrovaným v povrchových vrstvách pôdy, v ktorých sa hromadí najväčšie množstvo toxických látok, vplyvom suchých a teplých období začína stále vo väčšej miere trpieť suchom. Výskyt hydropedologických cyklov s nízkou, resp. nedostatočnou zásobou využiteľnej vody je najčastejší v letných mesiacoch (júl, august). Pri hodnotách vodného potenciálu pôdy, ktoré sa blížia k bodu trvalého vädnutia, je badateľný v priebehu dňa výrazný pokles transpirácie, pričom sa postupne stráca aj jej denný chod. Postupné preschnutie pôdy od vrchných vrstiev až po najhlbšie vrstvy fyziologického profilu pôdy znamená pri prípadnom zvlhčovaní povrchových vrstiev atmosférickými zrážkami zmenu stratifikácie vlhkosti. Opätovné nasycovanie hlbších vrstiev pôdy nemusí v takomto prípade nastať, v prípade suchého obdobia dochádza v relatívne krátkom čase k vysušeniu celého fyziologického profilu. Dreviny sú v takomto prípade vystavené silnému fyziologickému stresu, po dlhšie trvajúcom suchom období sa môžu dostať až do štádia vyčerpania.

Kľúčové slová: vlhkosť pôdy; hydrolimity; fyziologicky prístupná voda; hydropedologické cykly

Predmetom príspevku je analýza hydropedologických cyklov s rozdielnou zásobou využiteľnej vody vo fyziologickom profile pôdy v horskom smrekovom poraste. Smrek s koreňovým systémom, ktorý je koncentrovaný v povrchových vrstvách pôdy, kde sa hromadí najväčšie množstvo toxických látok, vplyvom suchých a teplých období začína stále vo väčšej miere trpieť suchom.

Výskumná plocha Oravská Polhora – Borsučie, na ktorej sa okrem vodného režimu pôdy sledovali aj ďalšie zložky vodnej bilancie (intercepcia, stok po kmeni, povrchový odtok, priesak vody do podložia), bola situovaná v prevažne smrekovom poraste (sm 85, bk 13, jd 2), na svahu orientovanom na JZ, so sklonom 15°, v nadmorskej výške 940 m. Vek porastu na začiatku výskumu (1989) bol 90 rokov, zakmenenie 0,7. Typologicky bol porast zaradený do slt FA, pôdnym typom je kambizem kyslá.

Zrážky sa zachytávali do piatich vedier z PVC (záchytná plocha 500 cm^2), voda zo stoku po kmeni z troch vzorníkov smreka prostredníctvom olovených žľabov, gravitačná voda pomocou lyzimetrov (2 500 cm^2) – pod horizontom nadložného humusu a v hĺbke pôdy 30 a 50 cm. Okamžitá vlhkosť pôdy sa určila z pôdnych vzoriek, ktoré sa odoberali v týždňových intervaloch, gravimetricky pôdnym vrtákom v l0cm vrstvách do hĺbky 80 cm. Z hydrolimitov boli stanovené maximálna kapilárna kapacita (MKK), bod zníženej dostupnosti (BZD) a bod vädnutia (BV). Ekologická klasifikácia vodného režimu sa stanovila podľa KUTÍLKA (1971).

K najvýznamnejším stratovým zložkám vodnej bilancie patrí intercepcia. Na sledovanej výskumnej ploche predstavovala v priemere 20–27 % z celkového množstva zrážok na voľnej ploche, preukazne nižšie hodnoty (okolo 10 %) sa vyskytovali v období s výskytom hmlových zrážok.

Merania stoku po kmeni potvrdili jeho veľmi nízky percentuálny podiel z celkového množstva zrážok; pri všetkých meraniach neprevýšili 2 %.

Minimálnou stratovou zložkou vodnej bilancie bol aj povrchový odtok, ktorého hodnoty sa v priebehu výskumu pohybovali okolo 1 % zrážok na voľnej ploche.

Množstvo gravitačnej vody, ktorá presiakla do podložia, predstavovalo 26–35 % zrážok, čo možno odôvodniť vo vrchných vrstvách pôdy silne vyvinutým koreňovým systémom, v stredných a hlbších vrstvách pôdy zníženou vododržnosťou pôdy (> 30 % skeletu).

Evapotranspirácia, vypočítaná z rozdielu počiatočnej a konečnej zásoby pôdnej vody, množstva zrážok a gravitačnej vody, predstavovala 327–406 mm/rok.

Podľa stupňa prevlhčenia pôdneho profilu, trvania prevlhčenia a stratifikácie vlhkosti pôdy vytvárali sa v pôde pod smrekovým porastom v priebehu hydrologického roka tri intervaly vlhkosti. V zimnom, akumulačnom období prevládal uvidický interval s vlhkosťou pôdy nad hornou hranicou hydrolimitu MKK. Na začiatku vegetačného obdobia, na rozhraní zimných a jarných mesiacov, pri topení snehu a rozmŕzaní pôdy bol pôdny profil maximálne prevlhčený. V priebehu ďalšieho obdobia vegetácie dochádzalo k postupnému znižovaniu vlhkosti. Intenzita straty pôdnej vody bola závislá na poveternostných podmienkach, osobitne na teplote vzduchu a pôdy a na množstve, intenzite a časovom rozdelení zrážok. Najčastejšie sa vyskytujúcim intervalom vlhkosti vo vegetačnom období bol semiuvidický interval (MKK – BZD), pričom optimálne množstvo pôdnej vody (60–80 % MKK) sa udržiavalo spravidla do konca júna, v zrážkovo zabezpečených obdobiach aj dlhšie. Vysúšacia fáza vrcholila v letných mesiacoch, kedy sa vlhkosť pôdy, prevažne v povrchových vrstvách pôdy (0–20 cm), znížila až do oblasti semiaridného intervalu (BZD – BV). Zníženie zásob využiteľnej vody do oblasti nedostatočnej zásoby (< 20 mm v povrchovej 20cm vrstve pôdy) sa vyskytovalo len sporadicky, aj to len na krátky čas (< 4–7 dní). Vzhľadom na očakávaný častejší výskyt a dlhšie trvanie takéhoto vlhkostného stavu môže dôjsť k zníženiu fyziologickej aktivity smreka a pri pôsobení ďalších stresových faktorov (napr. výskyt a premnoženie hmyzích škodcov) aj k výraznejšiemu poškodeniu jedincov, resp. skupín stromov.

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