# Water balance of young Norway spruce and European beech mountain stands in growing seasons 2005, 2006

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**Abstract**

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The study evaluated all components of the water balance of a young spruce and beech stand in growing seasons 2005 and 2006 (from May 1 to October 31) at the field long-term research station Deštné in the Orlické hory Mts. Both stands lie side by side on the slope of WSW aspect at an altitude of 890 m. In 2005, the 25 years old stands were fully stocked with close canopy. Total evaporation (interception + soil evaporation + transpiration) of both stands was markedly lower in 2006 due to rainy and also rather cold growing season than in 2005, amounting to 290.1 mm in the spruce stand (367.2 mm in 2005) and only 249.6 mm in the beech stand (319.6 mm in 2005). With respect to greater evaporation of the coniferous stand in growing seasons 2005 and 2006, less water – by 32 and 36 mm (5 and 4%) percolated through the soil mantle and subsequently drained into watercourses from the coniferous spruce stand than from the broadleaved beech stand. Both stands demonstrated also high retention capacity of soil. It was documented particularly in August 2006 during intensive rainstorms (3 August – 70.1 mm; 21 August – 73.8 mm; 25 August – 64.6 mm). Water of the rainstorms was virtually fully converted into harmless subsurface runoff.

**Keywords**

water balance, growing season, young forest stand, Norway spruce, European beech, mountains

## Introduction

In the 70s of the last century, in forestry-advanced countries of Europe, considerable attention was paid to the water-management function or hydric effectiveness of forest ecosystems (Mitscherlich, 1971; Benecke and Ploeg, 1978; Brechtel, 1976; Aussenac and Granier, 1979; Weihe, 1973; Raev, 1977; Voronkov, 1988; Item, 1981). Similar situation occurred also in the former Czechoslovakia where a number of research projects dealing the same problems were solved (Ambros, 1978; Krečmer, 1973; Peřina et al., 1973; Zelený, 1975; Tužinský, 1987). One of projects, which was dealt with by the Experiment Station Opočno was a project aimed at the study of water relations of fundamental forest tree species in mountain locations of the Czech Republic, viz spruce and beech (Kantor, 1984).

The position and importance of water-management functions of forest ecosystems were exceedingly emphasized after extreme floods in a number of European countries at the turn of the last millennium. In course of seven years, the Czech Republic was affected by three destructive floods (1997, 1998, 2002). The situation was described in a summary study entitled *Forest and Floods* (Kantor et al., 2003) published by the National Forest Committee and the CR Ministry of Environment.

Similarly also abroad, a number of papers evaluating problems of forests and water were published at that time (Gregor and Tužinský, 1999; Hammel, 2002; Škvarenina et al., 2004; Jost et al., 2005; Granier et al., 2007 etc.). Data on particular components of the water balance or on the total water regime of spruce and beech stands can be found eg in papers of Christiansen et al. (2006), Bucher-Wallin et al. (2000), Schume et al. (2003, 2005), Zirlewagen and Wilpert (2001), Tužinský (2000), Střelcová et al. (2004). It concerns data on mature stands; data on the water balance of young spruce and beech stands are, however, rather sporadic (Sonnleitner et al., 2001).

### Permanent field forest research station Deštné in the Orlické hory Mts

A project mentioned in the Introduction was dealt with at the permanent field forest research station Deštné in the Orlické hory Mts. The station was established in a mature spruce and immediately neighbouring mature beech stand in 1976. Research plots are situated there on a slope of WSW aspect of 16° at an altitude of 890 m. For the period of five years, ie until 1981, all components of the water balance were studied there (interception and transpiration of tree species, evaporation from the soil surface, changes in soil moisture content, surface runoff, infiltration of water, snow cover parameters, air temperature and humidity) in mature spruce and beech stands. In winter 1981/82, both mature stands were clear-felled and planted again with spruce and beech. At the same time, measurements and study were started on all items of the water balance of newly established forest stands. In 2006, both stands were 25 years old, being in the stage of small pole (beech) or pole stand (spruce).

At present, the density of the beech stand is considerable (in 1982 at the establishment 10,000 plants ha$^{-1}$). Through natural mortality and one very moderate silvicultural intervention (cleaning) it has decreased to 6,490 trees ha$^{-1}$.

On the other hand, spruce was tended by very intensive measures already from the stage of young-growth stand (due to the danger of snowbreaks), viz from the initial density of 4,600 plants ha$^{-1}$ in 1982 decreased to 1,180 trees ha$^{-1}$ in 2005. Moreover, due to the precipitation-extremely above-average winter season 2005/06, spruce was totally damaged by top breaks (95% trees!!). In some cases, it were also referred stem breaks and thus in spring 2006, only 1,040 trees ha$^{-1}$ were recorded. In addition, it is possible to suppose that the stand density will even decrease within the nearest two years due to the die-back of trees, which show only 2 to 3 living whorls at present.

## Methods

Methodically, the study of the water budget in permanent balance plots in the spruce and beech stand (each of a size of 40 × 30 m) is based on the measurement and analysis of all basic items of the water balance. Interception is determined by a common method from the difference between the open area precipitation and precipitation in the stand. Throughfall is measured by a number of trough rain gauges; stem flow in the beech and spruce stands is drained from sample trees by spiral collars to intercepting barrels.

Open area precipitation is monitored in the immediate vicinity of both stands. Evapotranspiration in both stands is evaluated by the method of the continuous measurement of soil moisture across the whole soil profile. Evaporation from the soil surface and evapotranspiration of ground vegetation are measured by the set of Popov evaporimeters.

Runoff of precipitation water is assessed in 3 separate forms. Surface and hypodermic lateral runoff is measured on runoff plots 5 × 3.5 m. Vertical infiltration of water through soil is determined by lysimetric method. In three pits in the spruce stand and in three pits in the beech stand, in total 60 lysimeters are installed (in each pit 10 lysimeters). The lysimeters are placed under the level of rhizosphere, so the water retained in them can be considered to be the water available for runoff. Changes in the water content in soil are determined according to the particular horizons by sensors of volume moisture content with the automatic data assembling from 3 stabilized measuring places. Air temperature and relative humidity are continually monitored in automatic stations of Noel Co.

## Results

### Precipitation conditions in assessed growing seasons

In the growing season 2005, the total amount of precipitation 634.8 mm fitted within the normal limits for the given area and altitude. Precipitation was recorded in 90 days of the growing season (frequency 49%) – see Table 1, May (196.0 mm) and July (169.6 mm) were markedly above-average from the aspects of precipitation. However, the last month of the vegetation period was markedly dry (October with only 17.4 mm precipitation).

On the other hand, the precipitation in growing season 2006 was markedly above-average, namely 875.1 (see Table 2). Extreme precipitation amount was noted in August, viz 322.0 mm within 17 days. Also May (174.6 mm) and September (133.8 mm) were extraordinary from the aspect of precipitation. It is of interest that

Table 1. Open area precipitation (mm) in the permanent field research station Deštné in the growing season 2005 (Noel meteorological station) – Sa = 634.8 mm

| May | | June | | July | | August | | September | | October | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. 5. | 2.4 | 1. 6. | 0.4 | 1. 7. | 8.6 | 3. 8. | 9.2 | 12. 9. | 6.6 | 2. 10. | 1.8 |
| 3. 5. | 1.2 | 4. 6. | 11.8 | 2. 7. | 15.8 | 4. 8. | 2.0 | 13. 9. | 0.2 | 3. 10. | 0.6 |
| 4. 5. | 13.4 | 5. 6. | 11.2 | 5. 7. | 13.8 | 6. 8. | 8.8 | 15. 9. | 0.6 | 16. 10. | 0.4 |
| 5. 5. | 0.8 | 6. 6. | 3.2 | 6. 7. | 11.8 | 7. 8. | 2.6 | 16. 9. | 34.4 | 17. 10. | 0.8 |
| 6. 5. | 9.6 | 7. 6. | 6.2 | 7. 7. | 0.6 | 8. 8. | 3.8 | 17. 9. | 1.0 | 20. 10. | 0.8 |
| 7. 5. | 6.2 | 8. 6. | 4.8 | 8. 7. | 17.2 | 9. 8. | 5.0 | 27. 9. | 14.6 | 23. 10. | 7.4 |
| 8. 5. | 6.2 | 10. 6. | 0.6 | 9. 7. | 0.6 | 10. 8. | 3.4 | 28. 9. | 2.2 | 24. 10. | 1.2 |
| 9. 5. | 16.2 | 11. 6. | 3.0 | 10. 7. | 19.0 | 11. 8. | 1.6 | 29. 9. | 7.8 | 25. 10. | 1.8 |
| 10. 5. | 11.0 | 12. 6. | 4.2 | 11. 7. | 2.0 | 13. 8. | 1.8 | 30. 9. | 2.4 | 26. 10. | 2.6 |
| 11. 5. | 6.8 | 13. 6. | 3.6 | 19. 7. | 16.8 | 14. 8. | 0.2 | | | | |
| 15. 5. | 2.8 | 15. 6. | 3.4 | 20. 7. | 2.4 | 15. 8. | 7.6 | | | | |
| 16. 5. | 0.2 | 16. 6. | 0.2 | 21. 7. | 15.2 | 16. 8. | 7.4 | | | | |
| 17. 5. | 18.4 | 18. 6. | 2.0 | 22. 7. | 14.6 | 17. 8. | 0.2 | | | | |
| 18. 5. | 22.2 | 22. 6. | 0.2 | 23. 7. | 3.6 | 22. 8. | 15.0 | | | | |
| 23. 5. | 48.6 | 25. 6. | 4.8 | 25. 7. | 2.0 | 23. 8. | 22.0 | | | | |
| 24. 5. | 1.0 | 26. 6. | 1.0 | 26. 7. | 0.2 | 24. 8. | 5.0 | | | | |
| 30. 5. | 25.2 | 30. 6. | 23.8 | 30. 7. | 14.6 | 25. 8. | 0.2 | | | | |
| 31. 5. | 3.8 | | | 31. 7. | 10.8 | 26. 8. | 1.6 | | | | |
| | | | | | | 27. 8. | 0.2 | | | | |
| ∑ [mm] | 196.0 | ∑ [mm] | 84.4 | ∑ [mm] | 169.6 | ∑ [mm] | 97.6 | ∑ [mm] | 69.8 | ∑ [mm] | 17.4 |

Table 2. Open area precipitation (mm) in the Deštné station in particular precipitation days of the growing season 2006 (Noel meteorological station ) – Sa = 875.1 mm

| May | | June | | July | | August | | September | | October | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. 5. | 30.4 | 4. 6. | 7.2 | 8. 7. | 1.9 | 1. 8. | 3.7 | 3. 9. | 34.1 | 1. 10. | 3.7 |
| 2. 5. | 1.2 | 5. 6. | 2.1 | 9. 7. | 23.3 | 2. 8. | 9.2 | 6. 9. | 2.1 | 2. 10. | 2.2 |
| 4. 5. | 16.6 | 9. 6. | 4.1 | 13. 7. | 2.9 | 3. 8. | 70.1 | 8. 9. | 30.0 | 3. 10. | 10.1 |
| 13. 5. | 23.7 | 10. 6. | 4.1 | 14. 7. | 1.0 | 4. 8. | 38.7 | 9. 9. | 1.1 | 4. 10. | 23.5 |
| 14. 5. | 11.9 | 17. 6. | 3.1 | 24. 7. | 11.7 | 7. 8. | 3.7 | 16. 9. | 3.2 | 9. 10. | 0.4 |
| 17. 5. | 30.8 | 20. 6. | 4.6 | 29. 7. | 35.1 | 11. 8. | 3.7 | 19. 9. | 62.2 | 24. 10. | 2.6 |
| 18. 5. | 10.1 | 21. 6. | 0.5 | 31. 7. | 2.0 | 12. 8. | 33.2 | 21. 9. | 1.1 | 25. 10. | 0.7 |
| 19. 5. | 3.6 | 22. 6. | 36.0 | | | 16. 8. | 1.8 | | | 27. 10. | 4.1 |
| 20. 5. | 9.5 | 28. 6. | 9.8 | | | 21. 8. | 73.8 | | | 28. 10. | 7.1 |
| 23. 5. | 1.2 | 29. 6. | 7.7 | | | 22. 8. | 5.5 | | | 29. 10. | 14.9 |
| 25. 5. | 7.7 | 30. 6. | 8.2 | | | 23. 8. | 3.7 | | | | |
| 26. 5. | 17.8 | | | | | 24. 8. | 1.8 | | | | |
| 27. 5. | 1.8 | | | | | 25. 8. | 64.6 | | | | |
| 29. 5. | 8.3 | | | | | 26. 8. | 3.7 | | | | |
| | | | | | | 28. 8. | 7.4 | | | | |
| | | | | | | 29. 8. | 3.7 | | | | |
| | | | | | | 31. 8. | 3.7 | | | | |
| ∑ [mm] | 174.6 | ∑ [mm] | 87.5 | ∑ [mm] | 77.9 | ∑ [mm] | 332.0 | ∑ [mm] | 133.8 | ∑ [mm] | 69.3 |

the number of precipitation days was markedly lower in 2006 (in total 66, ie frequency 36%) than in the preceding year.

## Water balance of spruce and beech in the growing season 2005

The water regime of the spruce and beech stand in the growing season 2005 is given in Table 3. The total amount of precipitation, viz 634.8 mm fits normal limits for the given area and altitude. Of the total amount of precipitation, 133.1 mm (21.0%) were intercepted and evaporated by crowns of spruce. As expected, interception losses of beech were lower, viz 99.4 mm (15.7%). Thus, an absolute difference between both stands was not dramatic being about 34 mm for the whole growing season.

In this connection, it is necessary to refer to significant values of stem flow in beech already in the stage of thicket or small pole stand. At intensive rainstorms (34 or 49 mm), the stem flow in dominant trees (h = 7 m; dbh = 11 cm) amounted to even 40 l water. Generally, stem flow participated very significantly in stand precipitation in the beech thicket (58.4 mm) within the whole growing season. On the other hand, stem flow in the spruce pole-stage stand was quite negligible (0.8 mm) for the whole growing season between the 1 May and the 31 October.

Unambiguously, the most important item of the water regime was evapotranspiration. It is important that similarly to the mature stands, this form of evaporation did not markedly differ even in young stands (spruce 234.1 mm, beech 220.2 mm).

Surface runoff and lateral runoff through soil were quite negligible in the two spruce and beech stands. In the precipitation above-average months May and July, the values of both forms of runoff did not exceed 0.7 or 0.6 mm (see Table 3). For the whole growing season, the surface runoff amounted to 1.9 mm (0.3%) in both stands; lateral runoff was even lower.

The part of atmospheric precipitation that was not necessary for physical and physiological evaporation of both stands infiltrated, therefore, through particular soil horizons to the subsoil. Somewhat higher infiltration in beech than spruce (318.6 mm /50.2%/ and 286.9 mm /45.2%/, respectively) can be explained by the lower interception and evapotranspiration of the broadleaved stand. An absolute difference of 31.7 mm cannot be considered to be significant from the viewpoint of total water balance or a possibility to suppress floods.

Changes in the supply of water in soil (±ΔV p) are the last item affecting the water regime of forest

Table 3. Water balance of spruce and of beech in the growing season from 1 May to 31 October 2005

| | Open area precipitation [mm] | Stem flow [mm] | Througfall [mm] | Stand precipitation [mm] | I [m] | ET [mm] | Surface runoff [mm] | Horizon-tal runoff [mm] | Infiltration [mm] | ± ΔVp [mm] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Spruce stand | | | | | |
| May | 196.0 | 0.2 | 144.9 | 145.1 | 50.9 | 51.3 | 0.4 | 0 | 92.5 | +0.9 |
| June | 84.4 | 0.1 | 70.9 | 71.0 | 13.4 | 51.1 | 0.3 | 0 | 43.4 | –23.8 |
| July | 169.6 | 0.2 | 135.9 | 136.1 | 33.5 | 43.6 | 0.6 | 0.5 | 79.8 | +11.6 |
| August | 97.6 | 0.1 | 84.1 | 84.2 | 13.4 | 46.0 | 0.3 | 0.2 | 47.6 | –9.9 |
| September | 69.8 | 0.2 | 53.1 | 53.3 | 16.5 | 23.3 | 0.3 | 0.1 | 23.6 | +6.0 |
| October | 17.4 | 0 | 12.0 | 12.0 | 5.4 | 18.8 | 0 | 0 | 0 | –6.8 |
| Total | 634.8 | 0.8 | 500.9 | 501.7 | 133.1 | 234.1 | 1.9 | 0.8 | 286.9 | –22.0 |
| % | 100% | 0.1% | 78.9% | 79.0% | 21.0% | 36.9% | 0.3% | 0.1% | 45.2% | –3.5% |
| | | | | | Beech stand | | | | | |
| May | 196.0 | 13.5 | 155.0 | 168.5 | 27.5 | 36.5 | 0.7 | 0.1 | 127.0 | +4.2 |
| June | 84.4 | 6.9 | 65.9 | 72.8 | 11.6 | 38.3 | 0.3 | 0 | 44.1 | – 9.9 |
| July | 169.6 | 18.3 | 120.8 | 139.1 | 30.5 | 54.9 | 0.4 | 0.1 | 75.1 | +8.6 |
| August | 97.6 | 9.1 | 76.0 | 85.1 | 12.5 | 52.0 | 0.2 | 0 | 43.0 | –10.1 |
| September | 69.8 | 9.4 | 47.5 | 56.9 | 12.9 | 22.8 | 0.3 | 0 | 29.4 | +4.4 |
| October | 17.4 | 1.2 | 11.8 | 13.0 | 4.4 | 15.7 | 0 | 0 | 0 | –2.7 |
| Total | 634.8 | 58.4 | 477.0 | 535.4 | 99.4 | 220.2 | 1.9 | 0.2 | 318.6 | –5.5 |
| % | 100 % | 9.2% | 75.1% | 84.3% | 15.7% | 34.7% | 0.3% | 0.0% | 50.2% | –0.9% |

ecosystems. These changes fluctuated in the course of particular months depending on the frequency of precipitation days and intensity of precipitation. Thus, at the end of the growing season, soil moisture was lower than at the beginning of May (spruce –22.0 mm, beech –5.5 mm) with respect to in precipitation markedly subnormal October.

**Water balance of spruce and beech stand in the growing season 2006**

The water balance of the spruce and the beech stand is given in Table 4. Primarily, it is necessary to note that in the growing season, the water regime of both stands was markedly affected by excessive precipitation – 875.1 mm in the open area. Of the total amount of precipitation, 69.3 mm (7.9% precipitation) were intercepted and evaporated by crowns of spruce trees. As expected, beech interception was lower, viz 48.3 mm (5.5% precipitation). An absolute difference between the two stands was not marked – reaching only 21.0 mm throughout the growing season.

Compared to the preceding growing season 2005, interception losses were markedly lower in both stands in summer months 2006. It can be explained by abundant horizontal precipitation particularly in May, August and October 2006 and by the marked reduction of the assimilatory apparatus after an extensive snow breakage in winter.

Also for 2006, it is necessary to stress the importance of stem flow in beech stands already in the stage of small pole stands. In the course of rainstorms in August (eg 3/8 – 70.1 mm), the stem flow amounted to even 65 litres. Generally, stem flow participated very significantly in precipitation in stands during 6 months of the growing season in the beech small pole stand (87.6 mm, ie 10.0% precipitation). On the other hand, in the spruce pole stand, stem flow represents quite insignificant item of the water regime (1.2 mm, ie 0.1% precipitation).

Thus, a decisive output item of the water regime of the spruce as well as beech stand is, as expected, evapotranspiration (ET). Similarly to the last year, it was determined by the method of continuous measurements of soil moisture across the whole soil profile.

In the development of the young spruce stand, an important change occurred in winter 2005/06. Winter storms of snow loaded spruce stands in such a way that 98% trees on the balance plot were damaged by top and stem breaks. In the studied segment of measurements of the volume soil moisture content, only one half remained from 6 spruce trees with the nearest bond to 9 VIRRIB sensors (installed at a depth of – 50, – 200, – 500 mm in three repetitions).

Table 4. Water balance of spruce and of beech in the growing season from 1/5 to 31/10/2006

| | Open area precipitation [mm] | Stem flow [mm] | Throughfall [mm] | Stand precipitation [mm] | I [mm] | ET [mm] | Surface runoff [mm] | Horizontal runoff [mm] | Infiltration [mm] | ± ΔVp [mm] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Spruce stand | | | | | |
| May | 174.6 | 0.2 | 163.4 | 163.6 | 11.0 | 49.0 | 0 | 0 | 125.8 | –11.2 |
| June | 87.5 | 0.1 | 73.9 | 74.0 | 13.5 | 48.0 | 0.1 | 0 | 34.2 | –8.3 |
| July | 77.9 | 0.1 | 70.7 | 70.8 | 7.1 | 36.9 | 0.5 | 0.1 | 45.4 | –12.1 |
| August | 332.0 | 0.3 | 312.5 | 312.8 | 19.2 | 26.7 | 2.4 | 0.4 | 256.1 | +27.2 |
| September | 133.8 | 0.4 | 118.1 | 118.5 | 15.3 | 46.8 | 1.1 | 0.6 | 79.8 | –9.8 |
| October | 69.3 | 0.1 | 66.0 | 66.1 | 3.2 | 13.4 | 0.3 | 0 | 46.1 | +6.3 |
| Total | 875.1 | 1.2 | 804.6 | 805.8 | 69.3 | 220.8 | 4.4 | 1.1 | 587.4 | –7.9 |
| % | 100.0 % | 0.1% | 92.0% | 92.1% | 7.9% | 25.2% | 0.5% | 0.1% | 67.2% | –0.9% |
| | | | | | Beech stand | | | | | |
| May | 174.6 | 16.8 | 154.8 | 171.6 | 3.0 | 47.1 | 0 | 0 | 129.8 | –5.3 |
| June | 87.5 | 4.9 | 69.4 | 74.3 | 13.2 | 40.5 | 0.3 | 0.1 | 39.6 | –6.2 |
| July | 77.9 | 2.3 | 71.0 | 73.3 | 4.6 | 33.3 | 0.4 | 0.1 | 49.8 | –10.3 |
| August | 332.0 | 36.1 | 280.2 | 316.3 | 15.7 | 27.5 | 2.3 | 0.6 | 263.4 | +22.5 |
| September | 133.8 | 22.9 | 101.3 | 124.2 | 9.6 | 42.9 | 1.2 | 0.1 | 89.8 | –9.8 |
| October | 69.3 | 4.6 | 62.5 | 67.1 | 2.2 | 10.0 | 0.3 | 0 | 51.0 | +5.8 |
| Total | 875.1 | 87.6 | 739.2 | 826.8 | 48.3 | 201.3 | 4.5 | 0.9 | 623.4 | –3.3 |
| % | 100.0% | 10.0% | 84.5% | 94.5% | 5.5% | 23.0% | 0.5% | 0.1% | 71.2% | –0.3% |

Values of evapotranspiration in particular months of the summer hydrological half-year 2006 are given in Table 4. Evaporation from the soil surface and ground vegetation transpiration evidently replaced reduction of the spruce layer transpiration. Total evapotranspiration in the spruce pole-stage stand (220.8 mm) slightly decreased compared to 2005; however, it was lower also in the beech small pole-stage stand (201.3 mm). A difference between both stands was statistically significant (p-value of the pair t-test = 0.032).

In Table 5, ET values are compared to obtain more lucidity, namely according to particular months in both growing seasons under evaluation. As compared with 2005, values of evapotranspiration in 2006 were mainly affected by the course of air temperatures, precipitation and air humidity. Lower evapotranspiration under high temperatures and low precipitation in July was caused by the low content of water in soil. On the other hand, low temperatures and the high frequency of precipitation days with markedly above-average precipitation totals caused lower evapotranspiration in August. On the contrary, favourable supply of soil water in September and above-average air temperatures resulted in rather high physiological evaporation.

Surface runoff and lateral runoff through soil were unsubstantial or even negligible both in the spruce and beech stands, similarly as in the preceding year. Even in the in precipitation extremely rich August (332.0 mm), these forms of runoff did not reach 3.0 mm (less than 1% of August precipitation). For the whole growing season, surface runoff in both stands participated in the water regime only by 0.5% precipitation and lateral runoff only by 0.1% precipitation.

An expected trend was noted in the infiltration of atmospheric precipitation through particular soil horizons to subsoil.

In consequence of markedly higher precipitation in 2006, also infiltration to the subsoil was markedly higher than in the preceding year 2005. Higher infiltration in beech, viz 623.4 mm (71.2%) compared to spruce, viz 587.4 mm (67.2%) is explainable again by lower interception and evapotranspiration of the broadleaved beech stand. However, an absolute difference (ie 36.0 mm) cannot be considered (similarly as in 2005) to be significant from the point of view of the total water balance or from the aspect of a possibility to reduce floods.

Changes in the soil water supply (±ΔVp) varied again in the course of particular months depending on the frequency of precipitation days and intensity of precipitation. Towards the end of growing season, soil moisture was lower than at the beginning of May (spruce –7.9 mm; beech –3.3 mm) with respect to the lack of precipitation in October.

## Discussion and conclusions

Kantor (1990) summarized foreign and Czech findings on the water balance of spruce and beech stands in growing seasons up to the 90s of the last century in a summary study. According to the findings, the summary evaporation (I + E + T) ranged from 330 to 440 mm in mature spruce stands of mountain locations in the summer half-year and in mature beech stands from 305 to 390 mm. Generally higher total evaporation of coniferous stands is particularly given by the higher interception of spruce. However, evapotranspiration of both types of stands is not markedly different. It is also documented by recent papers of Tužinský (2000), Schume et al. (2003), Christiansen et al. (2006), and Jost et al. (2005).

Table 5. Evapotranspiration of a young spruce and beech stand in growing seasons 2005 and 2006 (calculations from continuous measurements of the volume soil moisture)

| Evapotranspiration of a young spruce and beech stand [mm] | | | | | | |
|---|---|---|---|---|---|---|
| Precipitation/ET | Open area precipitation | | Spruce – ET | | Beech – ET | |
| [mm] | [mm] | [mm] | [mm] | | [mm] | |
| Month | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| May | 196.0 | 174.6 | 51.3 | 49.0 | 36.5 | 47.1 |
| June | 84.4 | 87.5 | 51.1 | 48.0 | 38.3 | 40.5 |
| July | 169.6 | 77.9 | 43.6 | 36.9 | 54.9 | 33.3 |
| August | 97.6 | 332.0 | 46.0 | 26.7 | 52.0 | 27.5 |
| September | 69.8 | 133.8 | 23.3 | 46.8 | 22.8 | 42.9 |
| October | 17.4 | 69.3 | 18.8 | 13.4 | 15.7 | 10.0 |
| Summer – total | 634.8 | 875.1 | 234.1 | 220.8 | 220.2 | 201.3 |

According to Tužinský (2000), interception of spruce stands in summer months was 8% lower than in beech stands. Due to the markedly different interception process of both species, Christiansen et al. (2006) even noted marked differences in the infiltration of precipitation water under the root zone (spruce 41 mm, beech 292 mm).

Finally, interesting data can be also obtained comparing the water regime of both stands in the Deštné field research station in the calibration period 1976 to 1981 (mature stand) and in the assessed period 2005 to 2006 (young 25-year-old stand). In 1976 to 1981, at 727 mm mean precipitation over the growing season, the total evaporation (I + E + T) of the mature spruce stand amounted to 408 mm and of the mature beech stand only 305 mm (Kantor, 1990). Thus, the total evaporation of the young spruce stand was lower (290 or 367 mm) in both 2005 and 2006 but comparable with the mature spruce stand. The total evaporation of the young beech stand (250 or 320 mm) in the growing season was virtually identical with the total consumption of water of a mature beech stand.

Our fundamental findings obtained based on the analysis of the water regime of the young spruce and beech stand at the Deštné permanent field experiment station in the Orlické hory Mts in growing seasons 2005 and 2006 can be summarized as follows:

- In the precipitation – normal summer half-year 2005 (634.8 mm), crowns of spruce trees intercepted and evaporated 21.0% precipitation and crowns of beech trees 15.7% precipitation. On the other hand, at markedly above-average precipitation in 2006, viz 875.1 mm (132% normal), very low values of interception losses were noted in both stands (spruce 7.9%, beech 5.5% precipitation). In addition to the significant occurrence of horizontal precipitation this fact was in spruce very markedly affected by the disturbance of crown canopy after an extensive winter snowbreak.
- In 2006, the summary evaporation of both stands was markedly lower than in 2005 because of wet and on average also cold weather as well as by the limited supply of water in soil in the hot July (markedly lower than in 2005) amounting to 290.1 mm in spruce (in 2005 – 367.2 mm). In beech, the trend was similar, viz 249.6 mm (in 2005 – 319.6 mm). Considering the higher evaporation of the coniferous stand, about 32 mm (5%) or 36 mm (4%) less water infiltrated through soil and then drained to watercourses in spruce than in the broadleaved beech stand in both years.
- From the viewpoint of possibility to reduce floods, the high retention potential of forest soils has been proved in both compared stands even during rainstorms – 23/5/2005 (48.6 mm), 3/8/2006, or 21/8/2006 (73.8 mm), which infiltrated to subsoil. Surface runoff was quite negligible (in both stands maximally 0.5% total precipitation). This fact can be considered to be the most important finding from both evaluated seasons.


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# Vodní režim mladého horského smrkového a bukového porostu ve vegetačních obdobích 2005 a 2006


## Souhrn

Stěžejní poznatky z analýzy vodního režimu mladého smrkového a bukového porostu na stacionáru Deštné v Orlických horách ve vegetačních obdobích 2005 a 2006 lze shrnout do tří následujících bodů:

Ve srážkově normálním letním půlroce 2005 (634,8 mm) se zadrželo a vypařilo z korun smrků 21,0 % srážek, z korun buků 15,7 % srážek. Naproti tomu při výrazně nadprůměrných srážkách v roce 2006 – 875,1 mm (132 % normálu) byly v obou porostech zaznamenány velmi nízké hodnoty intercepčních ztrát (smrk 7,9 %, buk 5,5 % srážek). Vedle významného výskytu horizontálních srážek byla ve smrku tato skutečnost velmi výrazně ovlivněna i narušením zápoje korun po rozsáhlém zimním sněhovém polomu.

V roce 2006 byl sumární výpar obou porostů v důsledku vlhkého a v průměru i chladného počasí, ale i omezené nabídky vody v půdě v horkém červenci, výrazně nižší než v roce 2005 a činil ve smrku 290,1 mm (v roce 2005 – 367,2 mm). V buku byl tento trend obdobný – 249,6 mm (v roce 2005 – 319,6 mm). S ohledem na vyšší výpar jehličnatého porostu prosáklo půdou a následně odteklo do vodotečí ve smrku, v obou letech o cca 32 mm (5 %), resp. 36 mm (4 %) vody méně než v listnatém bukovém porostu.

Z pohledu možností tlumení velkých vod byla potvrzena vysoká retenční schopnost lesních půd v obou srovnávaných porostech i při přívalových srážkách – 23. 5. 2005 (48,6 mm), 3. 8. 2006, resp. 21. 8. 2006 (73,8 mm), které v celém rozsahu prosákly půdou na podloží. Povrchový odtok byl zcela zanedbatelný (v obou porostech maximálně 0,5 % celkových srážek). Tuto skutečnost lze považovat za nejvýznamnější poznatek z obou hodnocených období.



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