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DETERMINATION OF SPRUCE SEEDLINGS IRRIGATION SCHEDULING IN LITHUANIA

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Abstract

The field study was conducted in the period of 2002–2005. Seedlings were planted in Land reclamation department experimental fields at the Lithuanian University of Agriculture. Seedlings were grown under standard nursery cultural practices until being transplanted into new fields in mid of April 2002 and 2004. It was cared out about two irrigation regimes, one started at 70 % FC, second at 80 % FC. At 2002, seedlings were irrigated 8 times and got 1750 m^3/ha water. In field were irrigation started at 70 % FC seedlings was irrigated 6 times, irrigation norm - 1500 m^3/ha. In 2003 and 2004 seedlings were irrigated 4 times and got 1000 m^3/ha water. At 2005, seedling got 750 m^3/ha water. The main objective of nursery irrigation is to avoid unwanted seedling moisture stress and its negative consequence for seedlings. Therefore, the objectives of this study were to (1) determine the irrigation regime for Picea abies seedlings and (2) to study the effect of different year on dynamic of irrigation regimes calculated by HYFRAN.

Keywords: soil moisture, irrigation, field capacity, *Picea abies* seedlings.

1. INTRODUCTION

Classical theory of water accessibility, in order for plants to grow, states that plants reach maximum productivity only at an optimal soil humidity, which ensures their maximum transpiration and photosynthesis. Not only does soil water participate in production of organic material, it also acts as solution which carries nutrients from soil to tree roots. Naturally, woodland plants and environment constantly interact movement of water, conditioned by energy flows, and dissolved nutrients in the system of plant-soil-atmosphere [6, 5].

Artificially planted plants are most sensitive to soil humidity deficiency because they lack for bigger part of roots. According to Swedish scientists [3, 4, 8], reduced growth of needles and sprouts of newly replanted seedlings is partly caused by water stress which occurs during a planting of seedlings, therefore renewal of normal root activity of newly replanted seedlings requires optimal soil humidity and favorable climatic conditions. For seedlings in woodland plantations to grow, light, warm, nutrients as well as sufficient amount of humidity are essential. Quality growth of forest trees involves environmental factors [4, 10].

The distribution of vegetation over the earth's surface is controlled more by the availability of water than by any other single factor [9]. The use of quality seedlings in reforestation programs has a major effect on forest plantation establishment, physiology, survival and growth [10]. Irrigation is among the cultural techniques that affect seedling quality, but are difficult to optimize in forest nursery practice [11]. So why, the calculation of irrigation norms are necessary for Lithuanian nurseries.

In Lithuania *Picea abies* seedlings are usually planted in spring, when they are dormant and soil water is available. The planting period lasts usually for only 2 or 3 weeks (i.e. from the beginning to the end of May) before seedlings start to grow and soil is considered too dry for survival and growth.

2. MATERIAL AND METHOD

Research object. 2002-2005 m. irrigation regime for Norway spruce (*Picea abies*) seedlings.

Place of the research - Lithuanian University of Agriculture (LŽŪU). The geographical position of experimental plot corresponds to 54°88' NL and 23°09'EL. The investigations were carried out in loamy soils; in the research site of water-balance elements of the LŽŪU in the district of Kaunas, settlement of Noreikiškės. Soil composition - soft loam, stratified above heavy loam, humus 2-3 %.

The research site contains evaporators and 8 lysimeters [7]. in which spruce seedlings were grown and studied. Lysimeters amount 42 m^2 and 30 m^2. The whole perimeter of lysimeters is isolated with concrete walls which protect lysimeters from surface-water.

Plan of experiment.

For irrigation regime for outdoor experimentation, plan recommendable in the literature was chosen: watering norm during vegetation period - changeable (depending on dynamics of root development), watering terms in fields - changeable, irrigation norm – changeable

(depending on growing year). Watering terms are determined according to humidity of vegetative soil layer of 0-30 cm in two fields.

In the first field, seedlings are watered according to theoretical formulae at calculated regime; prior to watering, humidity level in the active layer (0-30 cm) must not be below 80% FC, in the second - below 70% FC. To determine irrigation efficiency, research was carried out in a reference field. Planted in summer, seedlings in the first field are watered as soon as humidity in the active layer (0-30 cm) approximates 80% FC, in the second field - 70% FC, and in the reference field - no additional irrigation is carried out.

The irrigation regime was investigated by the method of field experiments, aimed at the determination of the influence of one factor - irrigation. Soil moisture reserves were investigated by the thermostatic method in three repetitions at every 10 cm to the depth of 30 cm. Soil samples were taken every ten days also before and after irrigation and after heavy precipitation (more than 20 mm).

Irrigation rate was calculated according to the formula of A. Kostiakov [1, 2]. After spruce seedlings with developed root system (seedling height 10-12 cm) are replanted and soil humidity is maintained (80-100%) FC, fixed watering norm is 100 $m^3 \cdot ha^{-1}$. After a month, norm is increased to 150 $m^3 \cdot ha^{-1}$, after a second month - to 250 $m^3 \cdot ha^{-1}$. Same watering norm was applied during the second year of seedlings.

During the first year of seedlings, thickness of the vegetative layer is changeable (10-30 cm), during the second year - constant (30 cm).

Evaluation of meteorological conditions was based on the data registered at Kaunas Meteorological station (located in 1 km distance). Amount of precipitation was specified by using Tretiakov rain-gauges in experimental plots.

3. RESULTS AND DISCUSSIONS

Meteorological conditions during the research period (2002-2005 m.) Change of meteorological conditions corresponded to the general climatic condition characteristic to the Lithuanian territory and to the tendencies of distribution according to the humidity of vegetation period (dry 2002, wet 2004, average humidity 2003 and 2005). In 2002-2005 year rainfall during vegetation period was highly changeable. In 2002, during vegetation period, the rainfall totaled 234 mm (69% average). In 2003, rainfall amounted 302 mm (90% of average). In 2004, there was 96% of average distribution. In 2005, rainfall reached 378 mm which is more than average (337 mm). Comparison of average air temperatures shows that in 2002, air temperature was 2.6 °C higher than average, in 2003 – 1.1 °C higher, in 2004 and 2005; air was cooler and reached respectively – 0.2 °C and – 0.7 °C. Air humidity deficiency in 2002 and 2003 exceeded average and in 2004 as well as 2005 was below average.

Investigation under natural soil moisture conditions.

Water moisture content in non-irrigated fields was studied in 2002-2005. Water moisture content dynamics changed depending on meteorological conditions as well as biological characteristics of spruce seedlings.

As changes of water moisture content were observed (figure 1), it was noticed that the amount of rainfall had an influence on growing reserve of soil humidity.

In the beginning of vegetation period, water moisture content amounted approximately 84 mm, which is 80% FC. In 2002, water moisture content was twice recorded as close to 80% FC (Figure 1), that is, in the beginning and the middle of vegetation period, during the first ten-day period of July.

In 2004, it was found that during the first year of growth of seedlings they did not suffer from water moisture content deficiency in the beginning of vegetation.

In 2003, since the first ten-day period of June until the third ten-day period of May rainfall averagely totaled 35 mm, therefore deeper layers were filled with humidity and during this period water moisture content was approximately 80% FC.

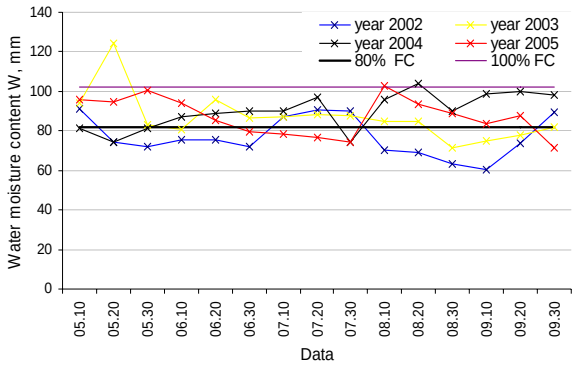

Figure 1. Soil moisture (W) dynamics in active soil (0-30 cm) layer in irrigated treatment in 2002-2005

It was found that in 2003, during 73% of ten-day periods soil humidity exceeded 84 mm. During other periods, water moisture content dropped to 72

mm and less. In 2005, two periods were unfavorable for growth of seedlings. First unfavorable period was since the second ten-day period of June until the third ten-day period of May, later after rainfall of 130 mm fell all layers were filled with humidity and since the third ten-day period of September humidity reserve dropped to 70 mm. The research showed that water moisture content in 3 active layers 0-10, 10-20 and 20-30 changes quite gradually; rainfall first influences the upper layer of 0-10 cm. If the amount of rainfall is below 10 mm, deeper layers are also filled with humidity. Experimental research revealed that thickness of irrigated layer during the first year of growth should be shifting, i.e. during the first month of growth 0.10 cm, during the second - 0.15 cm, and during the later period of growth as well as during the second year of growth - 0-25 cm. Irrigation norm depends on the thickness of active layer which is 10-25 mm.

Experimental irrigation regimes, with keeping soil humidity of 80-100% FC.

In 2002, first year spruce seedlings were watered 8 times. Watering norm in the field totaled 1750 $m^3 \cdot ha^{-1}$. In the beginning of vegetation, seedlings were watered by 100 $m^3 \cdot ha^{-1}$; in the end of June, they were watered by 150 $m^3 \cdot ha^{-1}$; and in the end of vegetation, as root mass of seedlings developed, watering norm was 250 $m^3 \cdot ha^{-1}$ (figure 2). Seedlings planted in 2004 were irrigated 4 times, irrigation norm totaled 600 $m^3 \cdot ha^{-1}$. In 2003, during the second year of growth, seedlings (planted in the spring of 2002) were irrigated by 250 $m^3 \cdot ha^{-1}$. During the year of the research, seedlings were watered 4 times, irrigation norm was 1000 $m^3 \cdot ha^{-1}$. In 2005, during the second year of growth, seedlings were watered 3 times; watering norm was constant, i.e. 250 $m^3 \cdot ha^{-1}$, watering norm of 750 $m^3 \cdot ha^{-1}$.

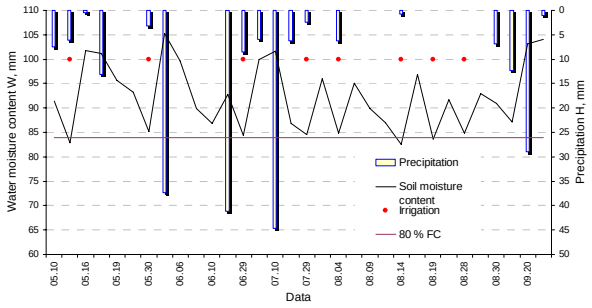

Figure 2. Soil moisture (W) dynamics in active soil (0-30 cm) layer in irrigated treatment in 2002

With keeping soil humidity of 70-100% FC. In 2002, during the first year of growth, seedlings were watered as soon as soil humidity dropped to 70% FC. Seedlings were watered 7 times. During the second year of growth (2003), seedlings were watered 3 time, with irrigation norm of 750 $m^3 \cdot ha^{-1}$. During the second year of growth in 2005, seedlings were watered 2 times. They were watered by 250 $m^3 \cdot ha^{-1}$, with irrigation norm of 500 $m^3 \cdot ha^{-1}$.

Watering and irrigation norms for spruce seedlings.

Irrigation norms for spruce seedlings were estimated by using data from Kaunas weather-station (years 1946-2006) and applying water balance equation (according to soil humidity deficiency). Irrigation norms were estimated for first and second year seedlings. With data obtained from 60 years of observation, irrigation regime can be estimated with precision of one watering, with probability of 90-95% [2].

Calculations have been carried out since the 1 of May until the 30 of September, since 1945 until 2007.

Evapotranspiration was estimated by application of biological coefficients seedlings of various years of growth. As irrigation norm was estimated, probability curves for individual years were drawn (figures 3-4); curves show that if probability is higher than 50%, irrigation norm increases. HYFRAN program helped to identify confidence intervals (figure 3) which show fluctuation limits of irrigation norm under various probabilities. The program helps to perform analysis of statistical distributions by checking data according to its dependence and uniform dispersion.

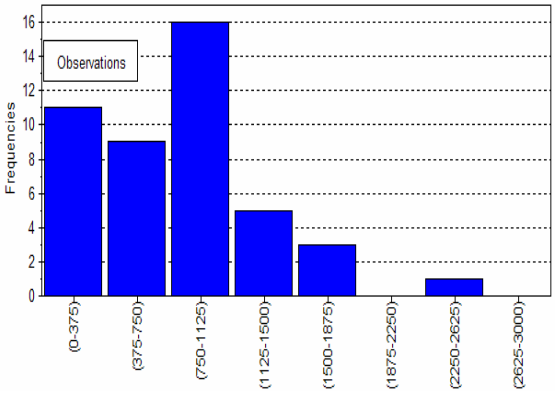

Figure 3. Irrigation norm rates during the first year of seedlings planted at spring

As the histogram shows, most frequent irrigation norm falls into the range of 750-1125 $m^3 \cdot ha^{-1}$, less frequent norm ranges from 2250 to 2625 $m^3 \cdot ha^{-1}$.

Figure 4 shows that there is non-recurring value of irrigation norm between fifth and sixth rate interval, i.e. the frequency of its recurrence throughout all 46 years except 9 years of observation (when irrigation norm was 0) was not established.

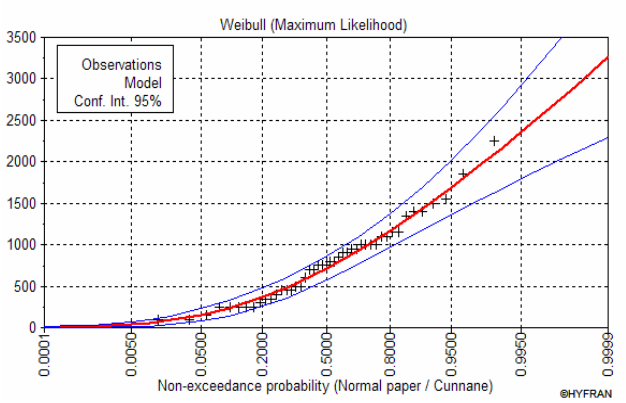

Figure 4. Theoretical curve for estimation of irrigation norms for first year spruce seedlings, with different probability years

Explanation: blue lines mark limits of confidence interval, red marks average.

Most frequently recurring average values of irrigation norm are 16 times per research period and the least frequent are extreme years with the highest irrigation norm. Obtained calculation data (empirical probability curve) is best described by Weibull and Normal distributions, since values (of irrigation norm) of standard deviation are lowest if these distributions are applied.Values of first and second year parameters according to Weibull distribution are presented in Table 1.

Table 1. Parameters of maximum irrigation norms for first and second year seedlings

T	q	%	XT (first year)	XT (second year)	Standard deviation (first year)	Standard deviation (second year)
1.05	0.9500	95	1690	2170	167.0	194.0
1.11	0.9000	90	1450	1870	133.0	156.0
1.25	0.8000	80	1170	1530	103.0	121
1.50	0.6670	70	937	1240	84.5	101.0
2.00	0.5000	50	715	956	73.4	88.8
3.30	0.3000	30	484	659	64.0	78.8
5.00	0.2000	20	368	507	57.9	72.3
10.00	0.1000	10	237	333	47.9	60.9
20.00	0.0050	5	155	222	38.4	49.8

With seedlings planted in spring, during the second year of their growth, as unvaried irrigation norm is applied, the most frequent irrigation norm ranges from 375 to 750 $m^3 \cdot ha^{-1}$, two equally frequently applied irrigation norms, including limits of 750-1500 $m^3 \cdot ha^{-1}$.

HYFRAN program helped to identify irrigation norm of first and second year seedlings for separate months under different probabilities.

Table 2. Irrigation norm for spruce seedlings for separate months $m^3 \cdot ha^{-1}$, with different probability years

Probability %	Month				
	5	6	7	8	9
First year seedlings					
95	277	570	634	535	234
90	235	482	540	448	193
80	185	376	426	342	144
70	137	276	320	244	98.1
50	87.3	172	209	141	50.0
30	26.7	44.9	73.9	15.5	0
20	0	0	0	0	0
Second year seedlings					
95	524	614	807	711	304
90	450	523	686	604	251
80	359	412	539	474	187
70	275	308	402	354	126
50	186	200	259	227	63.6
30	78.8	68	84.5	73.4	0
20	13.6	0	0	0	0

Explanations: 87.3 grey color marks numbers which indicate watering necessity, however under such probability watering norm is lower than calculated one, therefore it is not recorded. 0 indicates absence of watering. Watering norm for first year seedlings in May is 100 $m^3 \cdot ha^{-1}$, in June - 150 $m^3 \cdot ha^{-1}$, July and September - 250 $m^3 \cdot ha^{-1}$. Watering norm for second year seedlings is 250 $m^3 \cdot ha^{-1}$.

During the first year of growth, spruce seedlings were watered during the year of 70% probability. Monthly irrigation norm in digits is lower than monthly irrigation norm and equals 137 $m^3 \cdot ha^{-1}$. Second year spruce seedlings were watered under 60% probability. In this part of the Figure, seedlings in September were watered only under 90% probability.

However, particular irrigation norm each month has confidence interval, maximum value of which is higher and may condition the beginning of irrigation. In Lithuania, irrigation norm for spruce seedlings planted in spring (May-September) is 1201 mm, 542 mm, 225 mm for the first year seedlings with probability of 80%, 50%, and 30%; for the second year seedlings it is respectively 1752 mm, 807 mm, 365 mm.

4. CONCLUSIONS

In Lithuania, Norway spruce (*Picea abies* (L.)Karst.) seedlings planted in spring (the period of May-September) under conditions of natural soil humidity used approximately 239 mm of water during the first year of growth, during the second year - 271 mm.

During the vegetation period, humidity of active layer should be 80-100% FC.

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It is possible to use HYFRAN for planning irrigation water management at Lithuanian Forest nursery.

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