REGULARITIES OF WATER RETENTION PROCESS BY CUT FIR-TREE RAMULUSES

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In the known publications the processes of desiccation and water retention ability of fir-tree needles are unsufficiently investigated, and also the estimated parameters for diagnostics of fir-tree habitat pollution are not developed.
The offered method of an evaluation of desiccation by the cut samples of fir-tree ramuluses allows to define such parameters, as an initial mass of a water in the samples, constant mass of dry sample particle, first passage time of constant mass. Using of a parameter of an average sample desiccation rate will allow to determine ecological conditions of fir-tree habitat.
Keywords: fir-tree, verticil, needle desiccation rate, water retention process, ecological monitoring

The plants, especially woody, are capable to occlude many industrial discharging components [1]. Therefore ecological evaluation of territories can be conducted by fir-tree needle properties. An ecological state of forest ecosystem is evaluated using physiological parameters [2]. However in the known publications deliquification and water retention ability of fir-tree needles are unsufficiently investigated and the estimated parameters as applied to diagnostics of pollution about a fir-tree habitat are not developed.

The purpose of the given article - to show approach of fir-tree needle desiccation regularities analysis, and basis of this analysis to enunciate a technique of ecological fir-tree habitat evaluation.

For consummation this purpose problems sequentially were decided:

1) the statistical characteristics of desiccation process by cut fir-tree ramuluses were determined;

2) using methods of statistical modelling [4], model of the water retention by fir-tree needles process was developed;

3) theoretically availability of ramule deliquification parameters for ecological monitoring realization was justified.

For an environmental investigation of territory the fir-trees Picea abies [3] were taken. For experiments small fir-trees at the age of 12-15 were taken. Investigations were conducted on territory of scientific-experimental forestry enterprise of Mari state technical university: 46 compartment, 1 subcompartment (distance from a auto-road more than 50 meter).

From each small fir-tree from fourth verticil counting from above fir-tree, from four cardinal directions one ramule was collected from tip of lateral wings, then one lateral wing from northern cardinal direction was sniped about a stick.

In a fig. 1 two projections of a fir-tree are represented, from which control samples were collected (front elevation and top view).

As it is visible in a fig. 1, lateral wings, and also ramules are assembled in verticils. In a fig. 2 wing from which have sniped ramule R-0 for realization of experiment is represented.

As it is visible in a fig. 2 for realization of experiment only central ramule was sniped.

Samples were packed in paper packets, on which number of a tree, cardinal direction, and also time of sample snipping were fixed.

Ramules were weighed at intervals of an hour the after snipping in laboratory on laboratory scales ELB 600 to within 0,05 g. The next weighings were completed in every three hours per the first day, in the next some day - 2-3 times in the day, and then during two weeks - once in day and further once per one week.

In table 1 the obtained statistical data of desiccation by ramules of a fir-tree № 1 after snipping in four cardinal direction are represented.

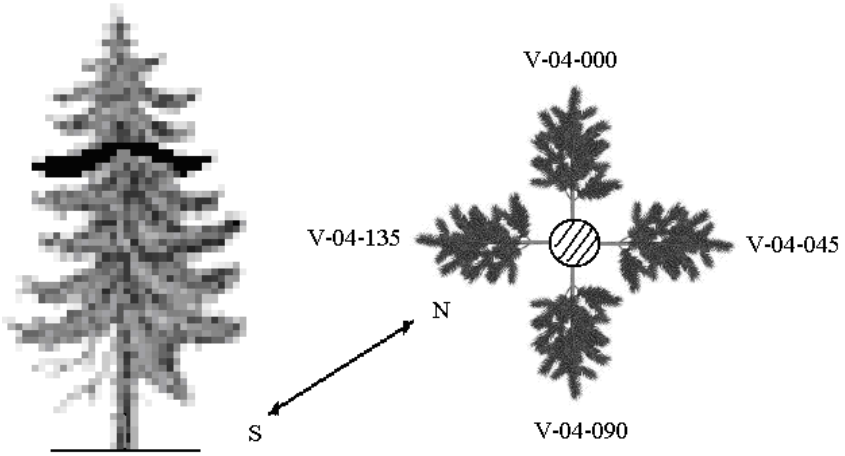

Fig. 1. A fir-tree, from which control samples were collected

Table 1. Dynamics of desiccation by verticil tips of a fir-tree № 1

Interval, days	Ramule mass, g				Interval, days	Ramule mass, g			
	South	North	West	East		South	North	West	East
0,04	1,45	1,00	1,00	1,05	11,00	0,70	0,45	0,40	0,50
0,17	1,35	1,00	0,95	1,00	12,00	0,70	0,45	0,45	0,50
0,29	1,30	0,95	0,90	0,95	13,00	0,65	0,45	0,45	0,45
0,42	1,30	0,95	0,90	0,95	14,00	0,65	0,45	0,45	0,45
0,54	1,30	0,95	0,90	0,90	15,00	0,65	0,45	0,45	0,45
0,67	1,25	0,95	0,85	0,90	15,00	0,65	0,45	0,45	0,45
0,79	1,25	0,90	0,85	0,90	18,00	0,65	0,45	0,40	0,45
0,92	1,25	0,90	0,85	0,90	20,00	0,65	0,45	0,40	0,45
1,04	1,25	0,90	0,85	0,90	22,00	0,65	0,45	0,40	0,45
1,17	1,25	0,90	0,80	0,85	25,00	0,65	0,45	0,45	0,45
1,79	1,20	0,85	0,75	0,80	27,00	0,65	0,45	0,45	0,45
2,14	1,15	0,80	0,75	0,80	29,00	0,60	0,40	0,45	0,45
3,79	1,00	0,70	0,65	0,70	35,00	0,65	0,45	0,45	0,45
4,00	1,00	0,70	0,65	0,70	36,00	0,65	0,45	0,45	0,45
5,00	0,95	0,65	0,60	0,65	43,00	0,65	0,40	0,40	0,45
6,00	0,90	0,60	0,55	0,60	55,00	0,60	0,45	0,45	0,45
8,00	0,80	0,50	0,45	0,50	63,00	0,65	0,45	0,45	0,45
9,00	0,75	0,50	0,50	0,50					

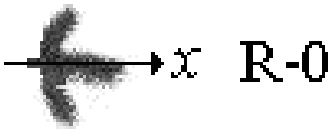

Fig. 2. Ramule R-0

On experimental data the formulas of a sample mass variation were obtained, the graphs of air drying are constructed by dint of software envelope Curve Expert - 1.3.

From the southern cardinal direction the model of desiccation by ramule, sniped from lateral wing tip of fir-tree № by the procedure [5] the form:

$$m = m_m + m_d = 0{,}7304\exp(-0{,}1537t^{1{,}1028}) + 0{,}6313, \quad (1)$$

where m - mass of sample in the course of air drying process, g;

m_m - variable mass of moisture, which is lost by sample, g;

m_d - constant mass dry needles with ramule inclusive of their air-dry moisture, g;

t - air drying time from the moment of sample snipping, day.

The formula (1) shows, that a model of fir-tree ramule air drying process has two components. First component m_m shows, that air drying process occurs by the death distribution in the general form, and second component m_d - that desiccation will occur up to some constant value of sample moisture mass.

In a fig. 3 the graph of desiccation by cut ramule of fir-tree № 1 is represented.

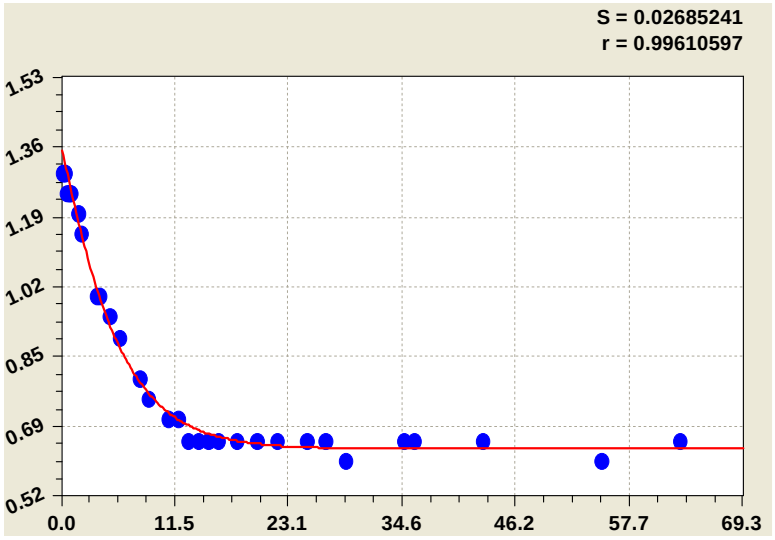

Fig. 3. The graph of desiccation by cut ramule of fir-tree № 1

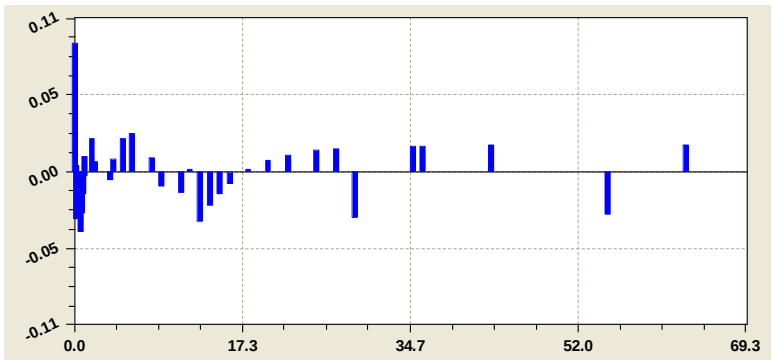

Fig. 4. The residuals or absolute errors of a statistical cut firtree ramule air drying model

As it is visible in a fig. 3 during desiccation by ramules of fir-trees moisture mass in test samples decreases, however deliquification rate is gradually reduced. The residuals or absolute errors of a statistical cut fir-tree ramule air drying model are represented in a fig. 4.

In a fig. 4 it is visible, that the residuals are almost equal to 0,025 g, that speaks about high model adequacy. The adequacy of the deduced statistical model is equal to 6,31 % and, accordingly, probability belief of the formula – 93,69 %. Thus, the given formula of a statistical model can be applied for long-term forecasting [5].

The models of desiccation by ramules of fir-tree № 1 from northern cardinal direction, western cardinal direction and eastern

cardinal direction, and also the models of desiccation by ramules of other fir-trees have a similar character. The differences in moisture mass in tests from the all cardinal directions, the differences in activity and intensity of air drying of ramule tests, and also the differences in first passage time of constant mass by tests during air drying were revealed.

As it is visible from the formula (1), after reaching the certain time t the test mass becomes a constant. Because of the model has a high probability belief, it is possible theoretically to calculate a first passage time of a constant ramule mass t and initial moisture mass in ramule test m_{m0}.

In a fig. 5 the scheme of process of water retention by fir-tree ramule is shown.

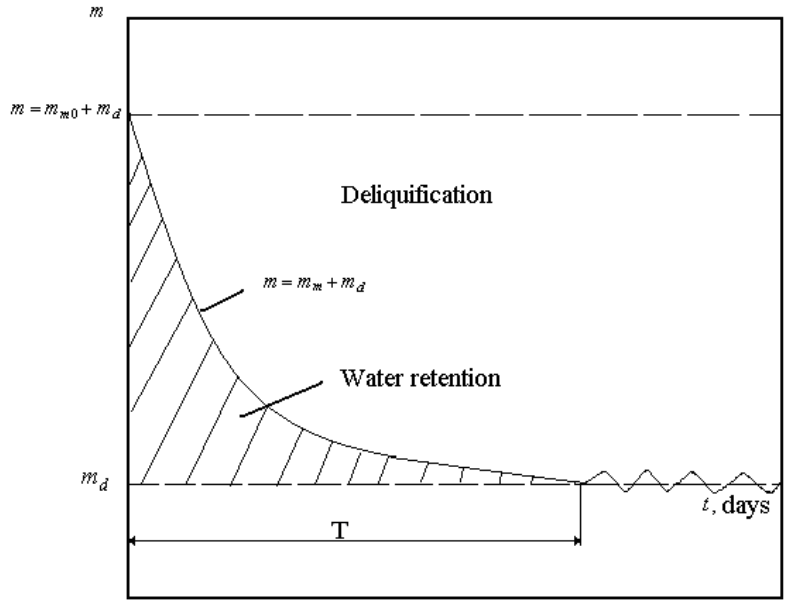

Fig. 5. The water retention process scheme

The square designated on the scheme by cection lining, shows dynamics of decrease of ramule mass, and it is equal to:

$$S_{wr} = m_{m0} \exp(-a_1 t^{a_2}) + m_d, \quad (2)$$

where S_{wr} - test water retention significance, or moisture mass in ramule test, g;
m_{m0} - initial moisture mass in ramule test, g;
m_d - constant mass of dry residues, g;
a_1 - model parameter, indicating activity of air drying of test;
a_2 - model parameter, indicating intensity of air drying of test.

For all control samples mean deliquification rate was estimated on formula:

$$V = \frac{m_{m0}}{t}, \quad (3)$$

where V - mean deliquification rate, g/day;
t - the first passage time of ambient air - dry mass m_d, days.

In table 2 the deliquification rates of fir-tree ramules during air drying of all ramules for four fir-trees are represented.

Table 2. Mean deliquification rate of tests

Number of fir-tree	Mean deliquification rate, g/day			
	South	North	West	East
1	0,028	0,038	0,042	0,028
2	0,040	0,035	0,036	0,036
3	0,040	0,030	0,037	0,057
4	0,039	0,035	0,037	0,040
mean	0,03675	0,0345	0,038	0,04025

In a fig. 6 a histogram of significances of a deliquification rate of ramules from the all cardinal directions for each fir-tree are represented.

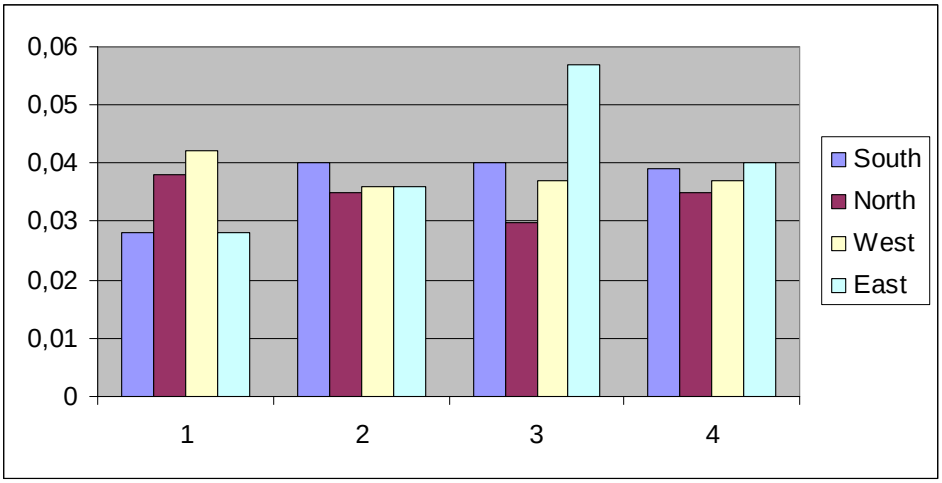

Fig. 6. Mean deliquification rate of fir-tree ramules

For comparison of obtained data Student's test for want of 5-percentage significance point was used. In table 3 the data of a comparison of deliquification rate of fir-tree ramules, cut from southern cardinal direction and northern cardinal direction are represented.

Table 3. Mean deliquification rate of ramules cut from northern cardinal direction and southern cardinal direction

Parameter	South	North	Student's test	Significance point
Deliquification rate	0,037	0,035	0,67	0,53

From table 3 it is visible, that both samplings among themselves have not significant differences (for want of significance point more than 0,05).

For comparison of significances of deliquification rate of ramules cut from other cardinal directions the similar findings were obtained. The process of desiccation by ramules of fir-tree verticils occurs by law of decreasing up to a constant mass, and on which it is possible to define differences on ecological conditions of fir-tree habitat. The further analysis has shown, that the process air drying has wave constituents, which allow to estimate influence of the hydrometeo-

rological factors of an experiment realization place.

Feature of novelty of an offered method is:

At first, the fir-tree ramule air drying method allows to reveal a general tendency of desiccation process by cut fir-tree ramules;

Secondly, the use of processes statistical modelling methods rather than mathematical allows to define statistical performances of drying process such, as an initial moisture mass in tests, constant a mass of dry test residues, first passage time of a constant mass;

Thirdly, use of a parameter of mean deliquification rate of control samples allows to define persistence of fir-trees, and on persistence - ecological conditions of fir-tree habitat.

The positive effect consists that the revealed statistical regularities of desiccation process ву fir-tree ramules will allow to operate wood plantations of fir-trees, to determine their persistence, and also ecological relations on investigated wood territories. Because of the fir-tree well adapts in urban environment, including a high level of pollution, the use of statistical given process regularities for ecological monitoring of urban environment is possible. The simplicity of an approach consists also that the measurements can be conducted on accountable trees, not carrying through harvesting of experimental trees.

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