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Improvement of tree condition diagnostics by external pathology characteristics

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Abstract. In manufacturing environments, the assessment of the state of plantations is carried out mainly by diagnosing trees according to external pathology characteristics. Pathological characteristics which are used in the accepted tree classifications do not satisfy modern requirements, both because of their weak differentiation, and because of their lack of objective explanation. Based on this, a ranking scale of pathological features has been developed depending on their development and fatality for the tree. The category of condition is defined according to the current Forests Code of the Russian Federation for each gradation of the pathological characteristic. As an example, a list of the most significant pathological characteristics for *Quercus robur* is given, with their gradation in terms of development degree and linkage to the status categories. This list does not include external characteristics that determine the 5 and 6 categories (fresh and old deadwood) because they are more unambiguous, well-descriptive ones and sufficiently described in the current rules. At the same time, a list of pathological characteristics is substantiated and significantly expanded. The presence of these characteristics does not indicate physiological weakening of a tree and, accordingly, can not be the basis for reducing the category of its condition.

1. Introduction

Various types of care are carried out repeatedly in the process of growing the stand, which should promote cultivation, sustainable, high-yielding stands with high quality commercial timber. Tree handlings are carried out, mainly in the form of selective felling, during which, weakened or damaged trees that are lagging behind in growth are selected. In addition, it is not uncommon to come into the forest during the period of growing, with so-called forest sanitation purpose, when the stand is significantly damaged by natural disasters or pests. In all these cases, the problem of selecting the most weakened, unpromising and uncompetitive trees arises. This is based only on visual damages, on the basis of external characteristics of pathology in manufacturing environments. According to a specialist who selects trees according to their condition, one needs to know the list of all possible

pathological signs, their differentiation and, most importantly, to what extent a particular sign reflects the real physiological state of the tree. [1].

2. Subjects and methods

It is necessary to use instrumental methods based on the existing principles of the dependence of certain physiological, biological, ecological parameters of the tree state on their actual viability and productivity in order to objectively assess the real state of a tree.

There are many parameters that can be measured, such as the intensity of photosynthesis, the intensity of breathing, the speed of movement of sap or gum, the saturation of plant sap with these or other substances, the bioelectric parameters of the tree, its hydrothermal state, and so on.

Many researchers have developed many classifications of trees based on the study of the dynamics of these indicators, depending on the state of the tree [2, 3]. However, in our country only one classification is used most often, which has been used for more than 70 years in guidance documents for assessing the state of the stand [4]. According to this classification, trees are divided into six categories: healthy, weakened, greatly weakened, dying, fresh deadwood and old deadwood.

Each of the listed categories of tree status has a fairly limited list of external (visual, habitual) pathological features that should theoretically be justified by the above objective methods of assessing the physiological state of the tree.

Despite the urgent need to improve visual methods for assessing the condition of trees, studies that are aimed directly at determining the degree of dependence of a pathological feature on any objective indicator of the viability of a tree are extremely inadequate [5].

3. The main part

To that end, we set out to identify the list of the most informative external signs of a weakening tree that attest to this or that level, using a number of the simplest principles underlying the definition of the viability of a tree.

The research has been carried out since 2007 and continues to be carried out, mainly, in the plantations of the Educational and Experimental Forestry of the VSUFT, as well as in the plantations of the Voronezh, Belgorod and Tambov Regions [6, 7].

The first principle that we have used is that a tree, like any living thing, has certain electrical characteristics that are essentially dependent on the condition of the tree. In particular, timber sap or pine sap (dip) is a solution of salts from the concentration of which the growth energy of the tree directly depends. But, it is commonly known that, the solution of salts is a good electrolyte and, placing two different-pole metals in it, we will obtain on these electrodes a potential difference, which can be measured [8, 9]. Accordingly, the healthier the tree, the higher the concentration of timber sap and the greater the potential difference is.

On the same principle, another method is also used to measure the current passing through the trunk, its voltage or the electrical resistance of the wood. All these parameters also have a close correlation with the state of the tree [10]. Since the parameters of this current are sufficiently significant (of the order of several tens of mill amperes), then it can be measured with a conventional household tester. The higher the amperage or higher its voltage, the better the state of the tree is. With the resistance, the situation is strictly opposite. The higher the electrical resistance, the worse the condition of the tree is [11, 12].

The next principle is based on the fact that a living tree has a temperature different from the ambient temperature in most cases. In summer, when the examinations are basically carried out, healthy tree has a temperature substantially lower than a temperature of the ambient air. This is due to the fact that root system of the tree is deep in the ground, where the temperature on summer day does not exceed 15 C⁰. Accordingly, timber sap moving from the roots to the head of the tree (with the speed of about 1 meter per 1minute) cools the trunk. The greater the temperatures difference between the trunk and the air, the healthier the tree is [13, 14].

And another simple principle that is convenient for diagnosing the condition of a tree is the presence of a direct relationship between the state of the tree and the interstitial pressure that is created by a timber sap or dip moving along the vessels. The method, which is based on this principle, is called the biopsy method or the method of a vital indicator [15, 16]. It is mainly used to assess the condition of coniferous species. In the living wood the standard hewing is done ($D = 18 \text{ mm}$) and the state of the tree is estimated from the intensity of sap leaking.

Using the listed principles and methods for diagnosing the state of trees, we have refined, expanded and differentiated a list of the most informative external pathological features for determining the category of tree condition.

Since these characteristics are very specific both for wood species (coniferous, hard-wooded broadleaved, soft-wooded broadleaved), and for individual wood species, in this work we give the most justified list of external pathological characteristics of *Quercus robur* (Table 1).

According to the Table 1, the number of external characteristics, taking into account their gradation in terms of development, is actually greater than their list for hardwoods, given in the Forests Code of the Russian Federation.

In determining the diagnostic significance of each characteristic, we proceeded from the condition that the tree with a detected pathology will live more or less than one revision (10-year) period.

The most informative characteristics, which have clear physiological confirmation, are those that testify to a fatal pathology that condemns the tree to a rapid dying off. These characteristics define the tree as a dying off (4th category), and, first of all, they include: carposome of wood-destroying fungus; desiccation of more than a half of the tree head or of the scaffold branches; obvious split of the trunk along with muntitrunk; thunder cracks or fresh frost cracks with timber saps; side drought, exfoliation, slab with more than $3/4$ of the diameter at the point of injury; well-defined cancers (more than $3/4$ of the diameter of the trunk or edging) of the butt block with developed stem rot and hollows on the trunk more than $1/4$ of the diameter of the trunk; a large number of xylophagous flying holes.

Characteristics that define the tree as severely weakened (3rd category) one are: one-year fruiting bodies of wood-destroying fungus on the trunk (honey fungus, hepatica, sulfur yellow fungus, etc.); drying from one-quarter up to a half of a tree head or scaffold branches; breaking of the scaffold branches; mechanical damages (scrapes, slab) more than $3/4$ of the diameter along the width of the trunk or more than 3 diameters in length; massive water shoots on the trunk; small ($1/4 - 1/2 d$ of the trunk) cancer; local areas with xylophages flying holes; rotten butt block or small (less than $1/4 d$ of the trunk) butt tree hollow and the same hollows on the trunk; fused trunks or their curvature; the dying of annual twig or most of the leaves (needles).

The beginning of the tree weakening, the decrease in its viability and competitiveness (2nd category or weakened trees) is evidenced by such characteristics as: drying-out of one scaffold branch or less than $1/4$ of the scaffold branches; small (less than $3/4 d$ of the trunk or less than 3 d in length) fraying and exfoliations; safe butt block; single groups of water shoots on the trunk; fresh or well healed (without rot or timber sap) frost cracks; germ cancer (less than $1/4 d$ of the trunk), as well as curly grain and knar of any sizes; single flying holes of xylophagus; multitrunks, saber-like or trunk inclination for more than 30 degrees; the curvature of the tree head due to shallow foliage or mass destruction of leaves with powdery mildew.

There is also a large group of characteristics that indicates a slight damage to a tree or its temporary, reversible weakening. The presence of these characteristics cannot serve as a basis for reducing the category of the tree condition, because the pathologies that caused them, on the one hand, do not reduce the competitiveness of the tree, and on the other hand occur in all trees, including trees with the highest viability. Among such features, there are: defoliation of tree head with needles-leaf-eating insects; leaves and needles damage by leaf-miners, gallfly, galls, as well as by thermal and chemical burns; shortened annual shoots; light or matte leaves color; well healed knots and frost cracks; some abnormal forms of the trunk (small inclination and saber-like, bouquet, butt swelling, twist of the trunk, constrictions, ovality and rhomboid shape of the trunk, etc.); mechanical damage less than 1 dm^2 or less than $1 / 4d$ of the trunk; single "witches brooms" and others.

Table 1. List of the most significant pathological characteristics for *Quercus robur*, their gradation in terms of development degree and distribution by category of status (CS).

Pathological characteristics	Gradation of the pathological characteristics in terms of development degree		
	Characteristic appearance (1)	Medium development (2)	Maximum development (3)
1	2	3	4
The shriveled scaffold branches	1 or < 1/4 of all, in case that there are > 5 of them on the tree	1/4 – 1/2 SSB	>1/2 or without SSB
The dried top	< 1/4 of the tree length	1/4 – 1/2 of the tree length	> 1/2 of the tree length
Fraying, exfoliation, slab, side drought	Width < 1/4 d of the trunk, height < 1 d of the trunk	Width 1/4 – 3/4 d of the trunk, height 1-3 d of the trunk	Width > 3/4 d of the trunk, height > 3 d of the trunk
Butt block (BB)	Fresh BB	Breakable BB	Rotten away BB
Butt tree hollow (BTH)	BTH < 1/4 d of the trunk	BTH 1/4 – 1/2 d of the trunk	BTH > 1/2 d of the trunk
Water shoots (WSh) on the trunk	Single and seldom (<10 units)	Single or (and) in groups, but < 25 % of the trunk surface	WSh cover >25 % of the trunk surface
Not blind knot	Withered, but whole branch	Rotten away, but not fallen off	Fallen off, but not blind
Hollow in the trunk	d of the hollow < 1/4 d of the trunk and without any rotten spots	d of the hollow 1/4 – 1/2 d of the trunk or (and) rotten spots	d of the hollow > 1/2 d of the trunk or (and) with obvious signs of destruction
Frost crack	Fresh without sap ooze or old, run wild	Fresh with sap ooze or old, partly run wild	Old, do not run wild with side drought or rotten spots
Thunder crack	Fresh, one side crack along the whole trunk	Old crack with side drought along all the trunk	Old rotten crack or missing segment
Trunk split	There is a visible crack between trunks	Open crack with boon denudation	Broken end of one of the trunks
Tumor	Curly grain, knar, any size or cancer < 1/2 d of the trunk	Cancer 1/2 - 1 d of the trunk	Cancer > 1 d of the trunk or edging cancer
Flying holes of the blocker insects	Singly (<10 units.), of one type and localized	> 10 units or different types, but which are not pecked up by birds	Massive, different types or which are pecked up by birds
Carposome of wood-destroying fungus	One-year in any part of the tree, but singly	Numerous one year or singly, small perennial	Old big or numerous perennial
Pathology of the trunk form	High butt swelling and decrease, heeling, increased, twist, ellipticity	Curvature, multitrunks and thick scaffold branches at young age	Curvature, multitrunks and thick scaffold branches at middle and old age
Openness of the tree head (defoliation)	Caused by defoliation of the leaf-eating insects	Because of the small and rare leaves	Because of the leaf-drought and annual twig
Powdery mildew attack	Several leaves and not intensively	Fragmentarily and with an average intensity	All the leaves fully and intensively

This list does not include external characteristics that determine the 5 and 6 categories (fresh and old deadwood) because they are more unambiguous, clearly visible and sufficiently described in the current rules.

Using this list of external signs of the pathology of the tree, in this gradation, will significantly increase the objectivity of diagnosing tree condition and reduce the negative consequences of all types of selective felling for planting due to incorrect evaluation of the prospects of a particular tree.

4. Conclusion

External pathology characteristics, used in the accepted tree classifications according to the tree state, no longer meet modern requirements, both because of their weak differentiation, and because of their lack of objective explanation.

External pathology characteristics, clearly visible, in most cases have a close correlation with the physiological state of the tree.

It is possible to objectively identify the connection between the level of tree viability and the most common visual characteristics of the pathology using a number of objective methods for diagnosing the state of trees (according to bioelectric potential, temperature gradient, etc.).

The list of external signs of a pathology with their gradation in terms of the degree of development resulted in the work will significantly increase the objectivity of diagnosis of the state of the tree.

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