

林木の耐寒性に関する研究(III)

スギの当年葉の耐凍性と乾燥抵抗性の季節変化

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 論 文

Studies on the Cold Resistance of Forest Trees (III)

Seasonal Change of Frost Hardiness of Current Year Needles of Sugi
and that of their Desiccation Resistance

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要 旨: 前報までの結果から^{2,3)}, スギの針葉の耐凍性に, それらの乾燥抵抗性が重要な役割を果たしているのではないかと推測された。このことを確かめるために, 季節を違えてスギの葉を低温下 (0°C) に置き, シリカゲルを用いて脱水した後, 10°C に置いて復水させ, その後の回復状況から, それらの乾燥抵抗性を調べた。このようにして得られた乾燥抵抗性と, これと並行して調べた耐凍性の季節的変動とから, 両者の関係を検討した。

スギの当年葉の乾燥致死限界 (L. R.) は, 9 月末には 130~95% (対乾重) 程度の含水率であった (図-2)。それは冬の訪れと共に低下し, 耐凍性の最も強まる 1 月から 2 月にかけて, 70~50% に達した (図-3~7)。このようなスギの針葉の乾燥抵抗性の季節的変動は, 先に述べた耐凍性と乾燥抵抗性との関係にある程度裏づけるものであろう。しかし, 本実験においては, スギの針葉のこれら二つの生理的特性の間に, 直接的な関係が存在するという証拠は得られなかった。

一方, 耐凍性の増大に伴って, 針葉の含水率の低下が観察された。この傾向は, 通常の含水率だけではなく, 飽和含水率においてもみられた (表-1)。しかし, これらの含水率と耐凍度とを比較すると, 両者の変動は必ずしも一致しないようだ。このことは, 含水率の低下が針葉の耐凍性の増大に対して, いわゆる water stress として間接的な影響を与えるとしても, 針葉の耐凍度の大きさと, その含水率との間に, 直接的な関係がないことを示していると考えられる。

Summary: From the previous experiments, it was supposed that frost hardiness of needles of Sugi (*Cryptomeria japonica* D. Don) was closely related to their desiccation resistance. To substantiate the above presumption, seasonal change of frost hardiness of current year needles and that of their desiccation resistance were simultaneously investigated.

At the end of September, desiccation resistance (lethal range) of current year needles was 130~95% (oven dry basis) (Fig. 2). It lowered during early winter and attained 70~50% at the middle of January (Fig. 3~7). At that time, their frost hardiness reached the maximum level (Fig. 1). These simultaneous change of desiccation resistance and frost hardiness appear to support the above-described estimation to some extent. In this experiment, however, no obvious evidence to prove that there is the causal relationship between these two physiological properties of Sugi has been obtained.

On the other hand, following the increase of frost hardiness water content of needles conversely decreased. This trend was observed not only in water content at usual state but also in ones at full turgor (Tab. 1). Comparing the seasonal change of frost hardiness with that of water content, these two changes did not necessarily agree. This appears to show that there is no direct relation between the degree of frost hardiness and total water content of needles.

It is a widely known phenomenon that hardy plant cells freeze extracellularly. This phenomenon was also observed in the mesophyll cells of Sugi²⁾. In frozen state, their hardy mesophyll cells were

severely dehydrated resulting from ice formation in intercellular space. After thawing, the needles of Sugi in such conditions will remain alive, if the freezing temperature is above their lethal point.

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From the above-described situation, it is of interest in understanding the nature of frost hardiness or frost injury of Sugi to study their desiccation resistance at low temperature. So, in this paper, seasonal change of desiccation resistance of needles of Sugi and that of their frost hardiness were simultaneously investigated.

Materials and Methods

1) Determination of frost hardiness of needles

Excised current year needles from two year old seedlings of Sugi (*Cryptomeria japonica* D. Don) were used for this experiment. These seedlings were potted in March 1970 and were grown in the open seed-bed of Mie University.

Needles from 10 seedlings (one needle from each seedling) were placed on the wetted filter paper in a Petri dish. Four Petri dishes were provided for a freezing test. These Petri dishes were put in a freezer kept at -5°C and air temperature in the Petri dish was recorded with a thermojunction and recorder. When temperature in the Petri dishes reached -5°C , except one Petri dish to be used for the determination of frost hardiness at -5°C , the rest were transferred to the freezer kept at -10°C . This process was repeated at -15° and -20°C . The cooling verocity was approximately 6°C/hr .

After two hours at each temperature, these Petri dishes were put in a refrigerator maintained at $3^{\circ}\sim 5^{\circ}\text{C}$ and needles were allowed to thaw. The thawing verocity of this experiment was approximately 5°C/hr . After thawing, these Petri dishes were kept at 25°C under continuous light for three weeks, and the viability of needles were classified according to the color change (browning) of needles by visual inspection.

2) Determination of desiccation resistance of needles

On the same day when frost hardiness of needles was tested, current year needles were excised from the same seedlings for the determination of their desiccation resistance. Each needle was weighed and was desiccated on silicagel in a desiccator (9cm in diameter and 15cm in height). One desiccator contained six needles and 10 desiccators were provided for each experiment. These desiccators were put in a refrigerator kept at 0°C . At intervals of three or four days, two desiccators were removed from the refrigerator. Each dried needle was weighed and remoistened in a closed test tube with a little water at 10°C for 24 hours. After remoistening, each needle was weighed again and was let stand in the test tube for about three weeks at 25°C under continuous light (approximately 2,000 lux) in order to estimate the degree of their

visible injury. After that, these needles were dried at 105°C overnight for the estimation of their water contents.

On remoistening, some needles absorbed water sufficiently and their fresh weight reached the original weight or more. But, some did not. The former were uninjured needles and the latter injured ones, judging from the degree of visible injury. Consequently, lethal range of water content of needles was determined by their recovery of a fresh weight after remoistening and by the degree of visible injury as an indicator of desiccation resistance of needles.

Results

1) Seasonal change of frost hardiness of needles of Sugi

Frost hardiness change of materials are shown in Fig. 1. At the end of September 1970 the needles of Sugi were injured with freezing at -5°C for two hours. From December to January, their hardiness markedly increased, until the needles were little damaged by freezing at -20°C for two hours. After that time, their hardiness decreased gradually and at the middle of March they were completely injured by freezing at -15°C .

DATE	FREEZING TEMPERATURE ($^{\circ}\text{C}$)			
	-5	-10	-15	-20
70 SEPT. 29	●	●		
NOV. 12	①	●	●	
DEC. 12	○	●	●	●
71 JAN. 14	○	○	○	●
FEB. 24	○	●	●	●
MAR. 16	○	●	●	●

○, ①, ●, ○, ●, ● : These signs show the degree of visible injury of needles; no injury, trace, slightly injured, moderately injured, severely injured, and killed in this order

Fig. 1. Seasonal change of frost hardiness of materials

2) Seasonal change of desiccation resistance of needles of Sugi

These results are shown in Figures (2~7) and in Tab. 1. Lethal range (L. R.) progressively lowered during the fall. Namely, lethal range was 130~95% (oven dry basis) at the end of September (Fig. 2) and they lowered to 70~50% January (Fig. 5). This lethal range was the minimum level in this experiment. After that, lethal range ascended to

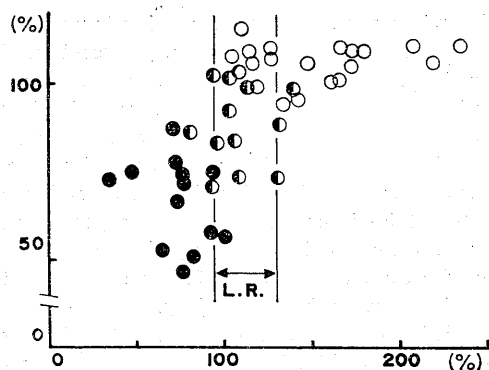


Fig. 2. Materials were collected on the 29th of September 1970

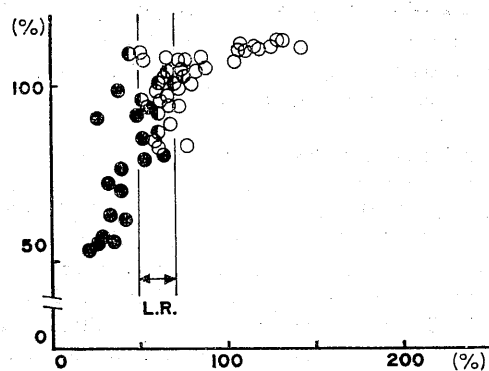


Fig. 5. on the 14th of Jan. '71

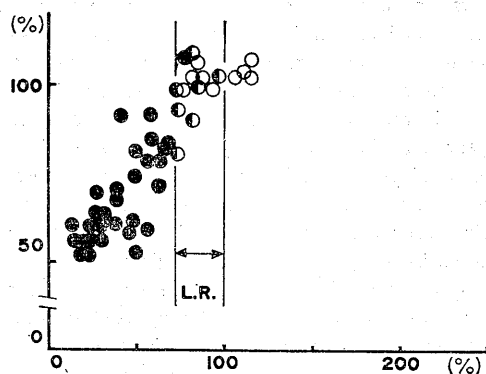


Fig. 3. on the 12th of Nov.

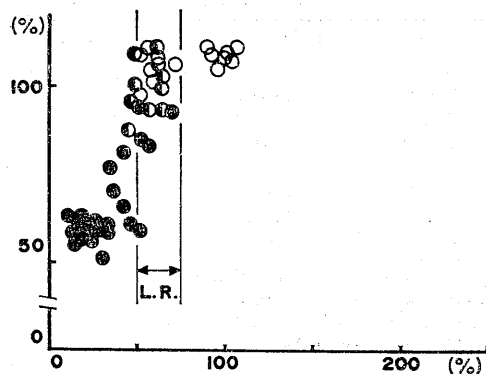


Fig. 6. on the 24th of Feb.

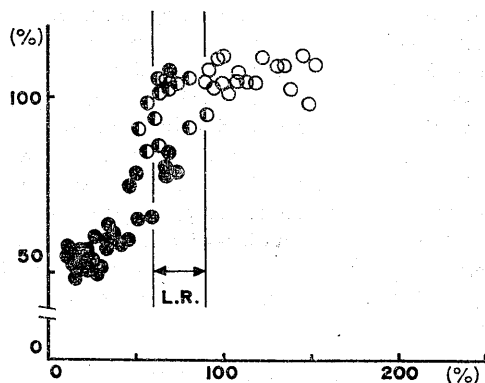


Fig. 4. on the 12th of Dec.

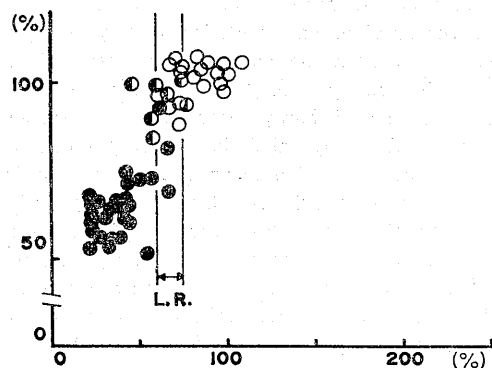


Fig. 7. on the 16th of Mar.

Fig. 2~7. Relation between water content of needles after desiccation treatment and recovery of their fresh weights after remoistening. Horizontal axis: Water content after desiccation treatment (% of dry weight). Vertical axis: recovery of fresh weight after remoistening (% of original weight).

Circles in figures show the degree of visible injury of needles; Open circle: no injury~trace, Half darkened circle: moderately injured, Darkened circle: severely injured~killed. L. R.: Lethal Range

some extent. From these observations, the desiccation resistance of needles of Sugi seemed to have the seasonal change like their frost hardness.

3) Seasonal change of water content of needles of Sugi

As indicated in Tab. 1, water content of current year needles were above 200% at the end of September. But it decreased markedly during the fall. This reduction in water content, however, did not cause severe wilt of needles, because water content at full turgor also decreased and remained at low level. Thereafter, water content of needles increased gradually till early spring but did not reach the level of previous autumn.

Table 1. Lethal range and water content of materials

Date	Lethal Range*	Water content*,**	
		A	B
'70			
Sept. 29	95~130%	244%	374%
Nov. 12	70~100	185	234
Dec. 12	60~90	157	237
'71			
Jan. 14	50~70	151	211
Feb. 24	50~75	174	210
Mar. 16	60~75	205	233

A: water content of needles at excision

B: water content at full turgor

*: percent on an oven dry basis

**: Mean from ten needles

Discussion

1) Relation between the frost hardness and the desiccation resistance of needles of Sugi

In the previous papers^{2,3)}, it has been suggested that the frost hardness of needles seemed to develop after the change from intracellular freezing to extracellular and hardy mesophyll cells seemed to be markedly dehydrated in the neighborhood of their lethal point. Moreover, the difference in frost hardness among varieties of Sugi was closely related to their resistance to desiccation⁴⁾. These observations seem to suggest that the ability of cells to endure the dehydration state will play an important role in the development of frost hardness of Sugi. If this view is true, the desiccation resistance of needles will vary with the change of their frost hardness in late autumn and in winter. Actually, the above-mentioned presumption was ascertained to some extent by the results of this experiment. Such parallelism between frost hardness and desiccation resistance has been observed in some evergreen⁵⁾ and deciduous trees⁶⁾. At present, however, whether or not there is causal relation between these two physiological properties is uncertain.

Several current studies on freezing injury reveal that the cause of injury is basically related to dehydration⁷⁾. Therefore, it may be easily assumed that internal factors correlated with frost hardness have some points in common with those which are responsible for desiccation resistance. But, direct evidence for the above-described assumption on needles of Sugi have not been found yet. Consequently, further studies on these problems are needed to clarify the mechanisms of injury and to devise methods of preventing that injury.

2) Relation between development of frost hardness of needles of Sugi and lowering of their water content

Low moisture content of plant tissue seems to be an obvious factor of frost hardness, because dried plants are difficult to freeze^{1,8)}. In some woody plants, good correlation between frost hardness and moisture content was observed but at the same time there were many exceptions¹⁾. In the case of Sugi, the lowering of water content of needles appeared to be followed by the increase of their frost hardness. The degree of frost hardness of needles, however, did not agree with the level of their water content. So, obtained data may not necessarily support that there is direct relation between the degree of frost hardness of needles and their water content. This view may be strengthened by the fact that many attempts to increase the frost hardness of plants by artificial decrease of their water content have failed¹⁾.

For the purpose of studying the relation between frost hardness of needles of Sugi and their water content, water content at full turgor rather than unstable one at usual state should be considered. As shown in Tab. 1, the lowering of water content of needles at full turgor during late autumn was observed. From the lowering of water content of needles at full turgor, increase of water stress in needles may be expected. Since water stress often has raised the frost hardness indirectly¹⁾, the same effect of water stress on the needles of Sugi also may be expected. Further studies on these problems are required.

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新刊紹介

○林木の生長と形態形成, 第I巻, タネの発芽, 個体発生, および樹高生長 (Growth and development of trees. Volume I. Seed germination, ontogeny, and shoot growth.) Theodore T. KOZLOWSKI 著, 443 ページ, 915 参考文献, 76 表, 147 図, Academic Press, New York and London 1971. (邦価 7,200 円)

著者 KOZLOWSKI は種々の生理問題についての総説を出してきたが, 本書においては林木の生長を動的に解説しようとして試みている。これまでの林木生理の教科書と違って, 林木の生長を形態的な分化発達に沿って記載しようと努力している。ややもすると断片的で専門的で特殊になりやすい林木の生理をばくだいな文献を使って大系づけたということは, 著者の大きな功績であると思う。本書は前後2巻よりなり, まず第1章では, 林業家および生理生態研究者のための復習として, 林木の形態学的な解説をしている。このため, それぞれ分野の違った林業技術者および研究者にとって, 本書を読むのに非常に助けとなっている。林木一般の形態学的な解説に続いて, 種子の発芽からメバエにいたる過程における形態的な発達, 生理と環境条件の作用を中心にして解説している。発芽からメバエにおける形態, 生理変化はきわめて顕著なものであり, ばくだいな研究があり, 限られた頁

数で解説することはきわめてむずかしい。著者は代表的な数例をあげることによって, 議論が複雑になるのを避けている。細かい種子の生理については現在著者が編集者となり, 別のシリーズが出版されることになっている。

種子の章について, 林木の幼齢期から成木期にいたる「態」の変化についての章がある。この章はきわめて生態学的な取り扱いが強い。態の変化についての細かい解説は, かなり生化学的になるために, 本書は現象論で止めたと思われる。

第4章では, Aging (老化) について論じている。特に, 心材形成の観察を細かく記載している。これまで Aging の問題は比較的軽視されてきたが, 永年植物である林木では, きわめて重要な研究分野である。将来, この分野の研究が進むことを期待する。

第5章から第8章まで, 著者は芽の発達, 生長, 葉の伸展, 生長, および樹高生長について述べている。特に樹種による特徴を形態および生理的な観点から論じている。これらの章には, 細かい生長の観察データが使われ, 造林技術者のための基礎知識として役立つと思われる。

総体的にみて, 本書は生理学的な細かい分析よりも, むしろ生態生理学の立場に立ち, 林木の生長および形態学的発達を観察するのを目的としている。

(佐々木恵彦)