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The survival rate and stem moisture content after planting of *Larix kaempferi* container seedling according to thawing conditions

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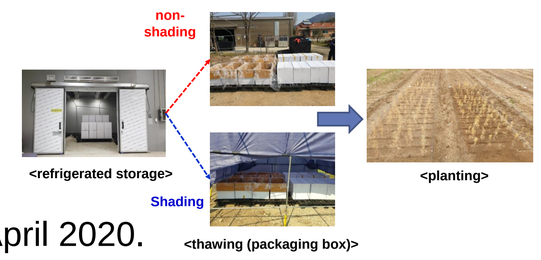
Inrtoduction

- Recently, due to extreme climate events, air temperature rise in spring and sudden cold wave in winter, damage to seedlings in the nursery stage and decrease in seedling survival rate after planting stage have occurred.
- The refrigerated storage techniques for seedlings are being applied as an essential process in nursery practices due to these problems.
- Because thawing techniques are related to storage, packaging, handling and shipping of seedlings before planting, they affect the quality of seedling in nursery and seedling growth performances in plantation stages.

▶ **This study was conducted to find out the optimal thawing conditions in connection with refrigerated storage in nursery stage in order to maintain high seedling quality until planting in plantation.**

Materials and Methods



- Material : *Larix kaempferi* conatainer seedling (one-year-old)
- The seedlings produced in 2019 at the Forest Technology Management Research, NIFoS.

And then seedlings are stored for a -2℃ in refrigerated store, and have been planted according to 32 thawing treatments from April 2020.

※ 32 thawing treatments : 2 thawing timings (April, May) × 2 shadings (shading, non-shading) × 2 packaging boxes (open, closed) × 4 thawing duration regimes (1, 3, 6, 12 days)

- We performed four-way ANOVA to test the effect of the thawing conditions on survival rate (SR) and stem moisture content (SMC) of thawed seedling after planting.

Results and Discussion

- The SR of *L. kaempfer* seedlings was statistically different in each of the four factors, such as thawing timing, shading, packaging box and duration, and significant interactive effects of four factors were also confirmed.
- Thawing showed a higher SR of seedlings in April than in May. In both thawing timings, it showed the highest SR of seedlings in the thawing condition in which light was shaded and packaging box was opened. As thawing duration increased, SR of seedlings decreased.
- The shading and thawing duration significantly affected SMC of *L. kaempferi* seedlings. The SMC of seedlings tended to increase as the thawing duration becomes longer, which is opposite to the result for SR.
- High temperature in the prolonged thawing duration may result in more active growth of seedlings with enhancing water movement in stem, as refrigerated dormant seedlings started growing with thawing.
- These results suggest that **the best thawing condition** is **thawing duration of less than 3 days before planting and opening package box in well-ventilated shady locations nearby plantation**.
- The optimal thawing condition will improve the quality of seedling production in nursery stages and increase seedling growth performances in plantation stages.

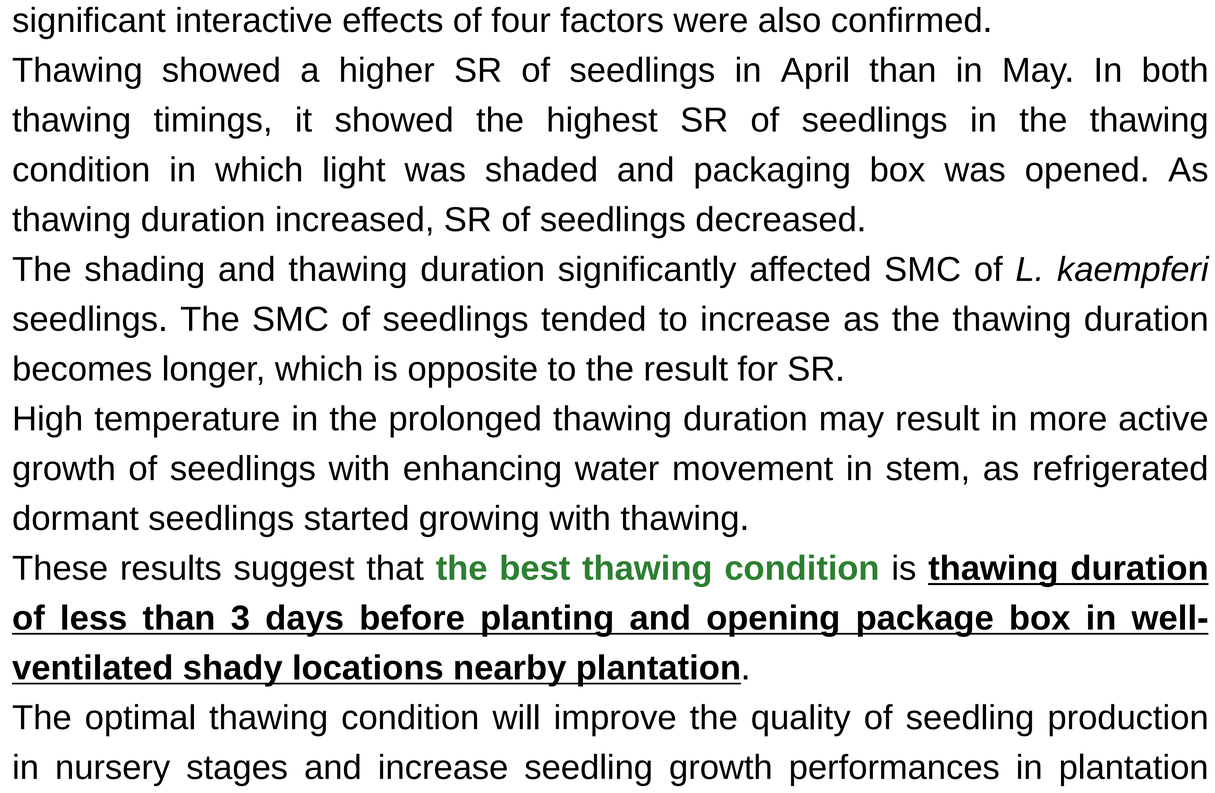


Figure 1. The effect of to thawing conditions on survival rate and stem moisture content after planting of *Larix kaempferi* container seedling (n=3 plots).

Table 1. The survival rate and stem moisture content after planting of *Larix kaempferi* container seedling according to thawing conditions

Thawing treatment				Survival rate (%)	Stem moisture content (%)
Timing	Shading	Packaging box	Duration (day)		
April	shading	open	1	97.2±2.5 ab	125.1± 7.4 i-m
			3	98.9±1.9 a	140.3±11.2 e-i
			6	83.9±3.5 ef	142.9±14.9 c-h
			12	83.9±1.0 ef	138.5± 7.1 d-i
		closed	1	93.9±1.0 abc	131.9± 8.1 e-k
			3	90.0±0.0 cde	138.7±16.8 e-k
			6	83.9±1.0 ef	127.0±13.0 h-m
			12	81.7±2.9 fg	145.4±10.9 c-g
	non-shading	open	1	92.8±2.5 bcd	130.6±11.2 f-l
			3	90.0±0.0 cde	158.6± 9.5 abc
			6	83.9±3.5 ef	147.0±17.9 cde
			12	77.8±3.8 gh	130.5± 9.7 g-l
		closed	1	87.8±3.8 de	129.5± 8.5 g-l
			3	88.9±5.1 cde	144.9± 2.7 c-g
			6	81.1±1.9 fg	149.9±10.3 bcd
			12	73.3±5.8 f	150.6± 8.1 bcd
May	shading	open	1	90.0±0.0 cde	117.6± 6.7 klm
			3	81.7±4.4 fg	141.9± 7.6 d-h
			6	52.8±5.4 j	144.6±10.6 c-g
			12	42.8±2.5 k	169.0±15.8 a
		closed	1	97.2±2.5 ab	115.9± 4.4 lm
			3	62.8±5.4 i	142.5±11.5 d-h
			6	45.6±5.1 k	146.7± 7.9 c-f
			12	37.2±2.5 l	163.4±19.2 ab
	non-shading	open	1	86.7±3.3 ef	114.8± 5.1 m
			3	63.9±3.5 i	135.5± 5.3 d-j
			6	45.0±1.7 k	149.4± 9.0 bcd
			12	21.7±2.9 m	172.8±23.8 a
		closed	1	85.0±1.7 ef	120.8±11.7 j-m
			3	73.9±3.5 h	142.3±10.1 d-h
			6	57.2±2.5 j	137.6± 5.8 d-i
			12	10.0±0.0 n	172.8± 9.0 a
timing				1761.6***	n.s.
shading				101.5***	6.0*
packaging box				17.5***	n.s.
duration				652.2***	54.5***
timing × shading				7.7**	n.s.
timing × packaging box				n.s.	n.s.
timing × duration				242.5***	25.8***
shading × packaging box				11.0**	n.s.
shading × duration				26.9***	n.s.
packaging box × duration				5.8**	n.s.
timing × shading × packaging box				9.62**	n.s.
timing × shading × duration				12.6***	3.29*
timing × packaging box × duration				4.1*	n.s.
shading × packaging box × duration				18.7***	n.s.
timing × shading × packaging box × duration				9.28***	3.34*

Values are means of 3 plots ± SD. Values with different letters in a column indicate statistical differences among thawing conditions at the 5% levels by Duncan's multiple range test. *F* values with asterisks are statistical significances in four-way ANOVA. *$P \le 0.05$, **$P \le 0.01$, ***$P \le 0.001$ and n.s. (non-significance) = $P > 0.05$.