CHILLING HOURS

David South
Auburn University

AUBURN

FORESTRY AND
WILDLIFE SCIENCES

Importance of Chilling

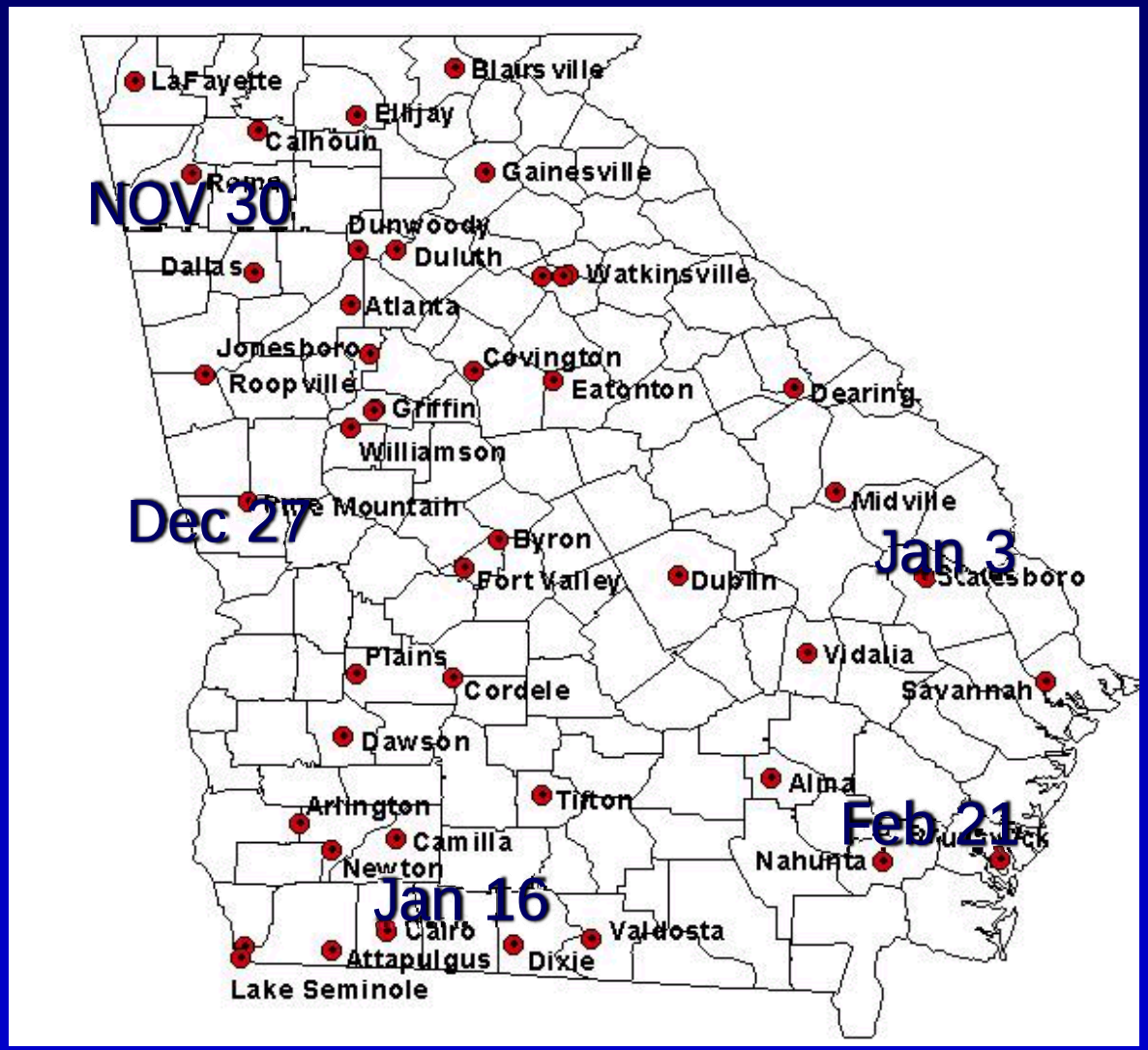
- Flower formation (horticulture)
- Seed stratification
- Freeze tolerance
- Bud dormancy (in limited situations)
- NOT RELIABLE FOR PREDICTING SEEDLING STORAGE!!!

(the COOP has been questioning this for more than a decade!)

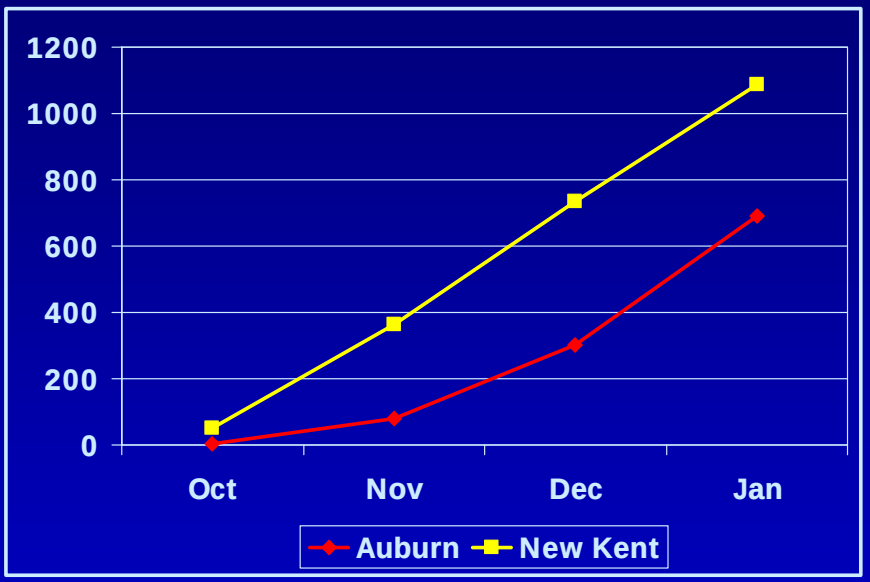
Various chilling hours

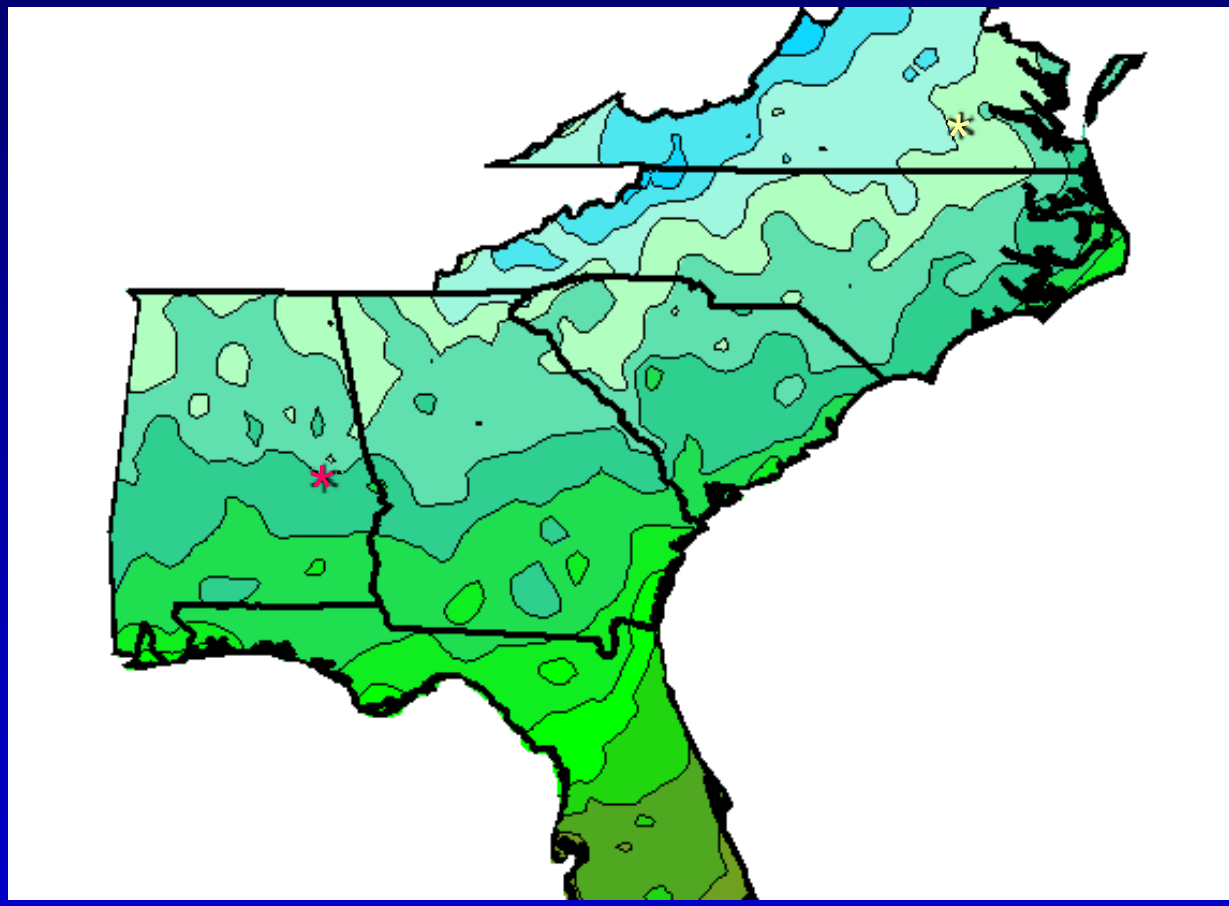
- < 41 F (Canada)
- < 50 F (Canada)
- < 46 F (Peaches)
- >31 and < 46 F (Peaches and Pine)
- > 33 and number varies with temp....
  (Chill unit)

400 chilling hours
Varies with region



It gets cold sooner in NC and Virginia





Flower formation (horticulture)

University of California
fruit & nut
RESEARCH AND INFORMATION CENTER

Weather

About Chilling Units

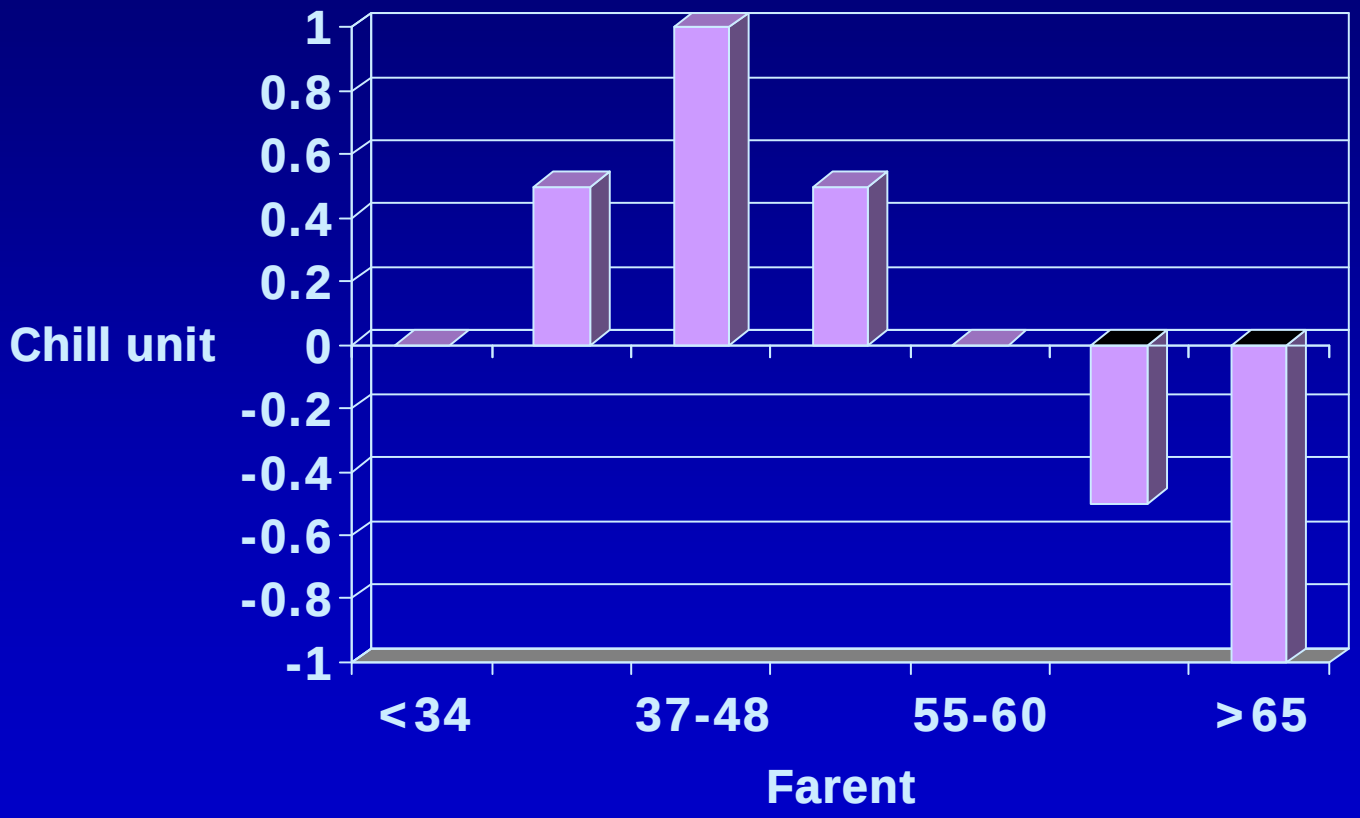
Stone and pome fruit trees rely on enough chill hours for flowers and leaf buds to develop normally. If the buds do not receive sufficient chilling temperatures during winter to completely release dormancy, trees may develop physiological symptoms such as delayed and extended bloom, delayed foliation, reduced fruit set and reduced fruit quality. Growers and industry keep track of chilling hours beginning in November to get a sense of the orchard management practices needed and comparison of past year's weather and crop load. The approximate number of hours needed for normal development varies depending on variety and species. For more information contact local nurseries or farm advisors.

Flower formation (horticulture)

Chilling hours for 2001-2002 season final count		
Month:	Method 1 No. of hours ≥32/≤45 F	Method 2 No. of hours ≤45 F
October	63	63
November	87	94
December	240	276
January	243	319
February	224	295
Cumulative	855	1045

Utah model

Flower formation (horticulture)



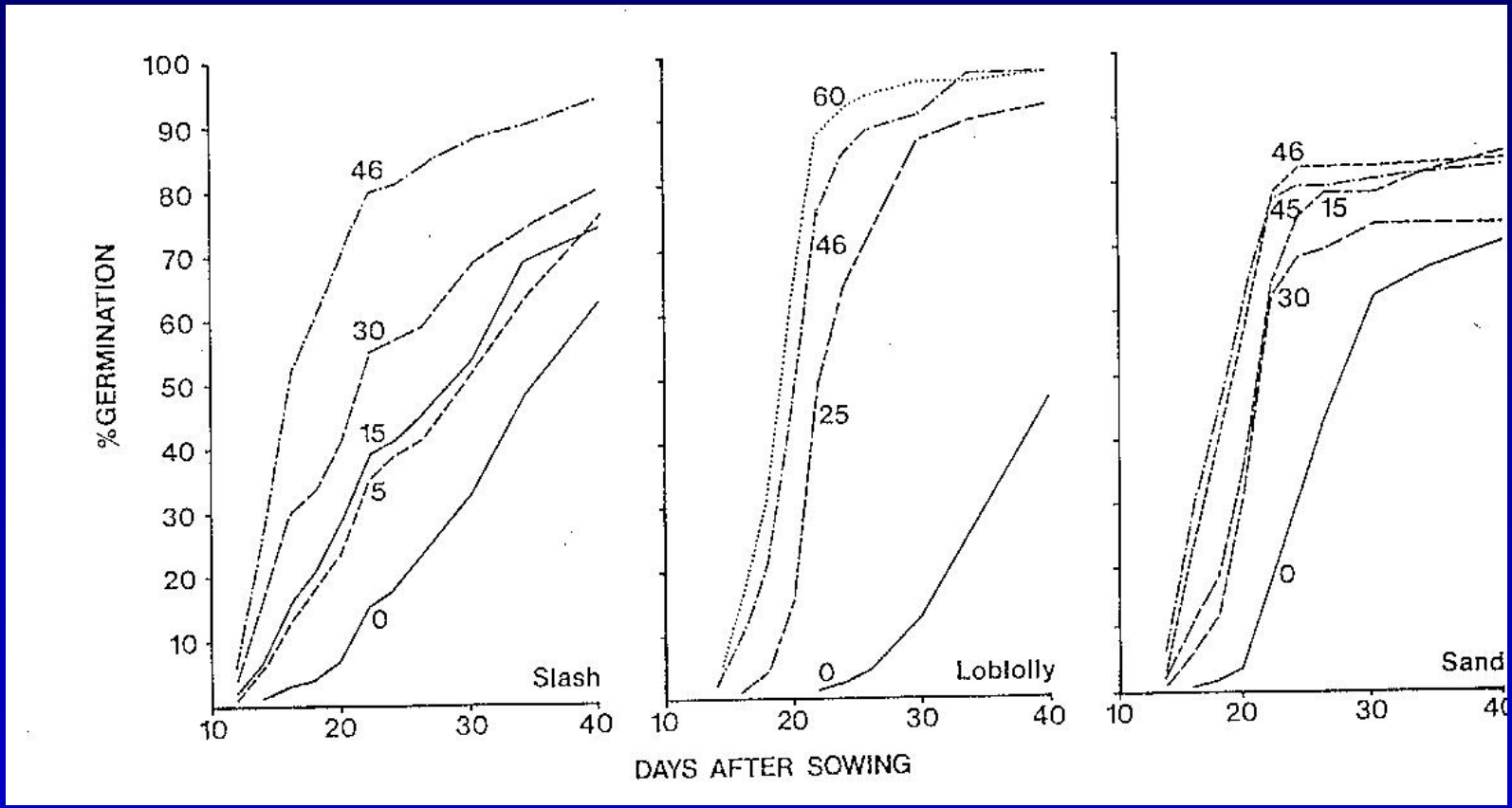
Flower formation (horticulture)

Table. General Chilling Requirements of Various Fruits and Nuts Fruit or Nut Chilling Requirement (hours)

Almond 400 - 700	
Apple 300 - 1200	Avocado NONE
Apricot 300 - 1000	Citrus NONE
Chestnut 400 - 750	Grapes 100 - 500
Fig 100 - 500	Olive 400 - 700
Kiwi 400 - 800	Pear 150 - 1500
Peach 150-1200	Persimmon 100 - 700
Pecan 150 - 1600	Plum 275 - 1000
Nectarine 150 - 1200	Quince 100 - 500
Pomegranate 100 - 300	Walnut 400 - 1500

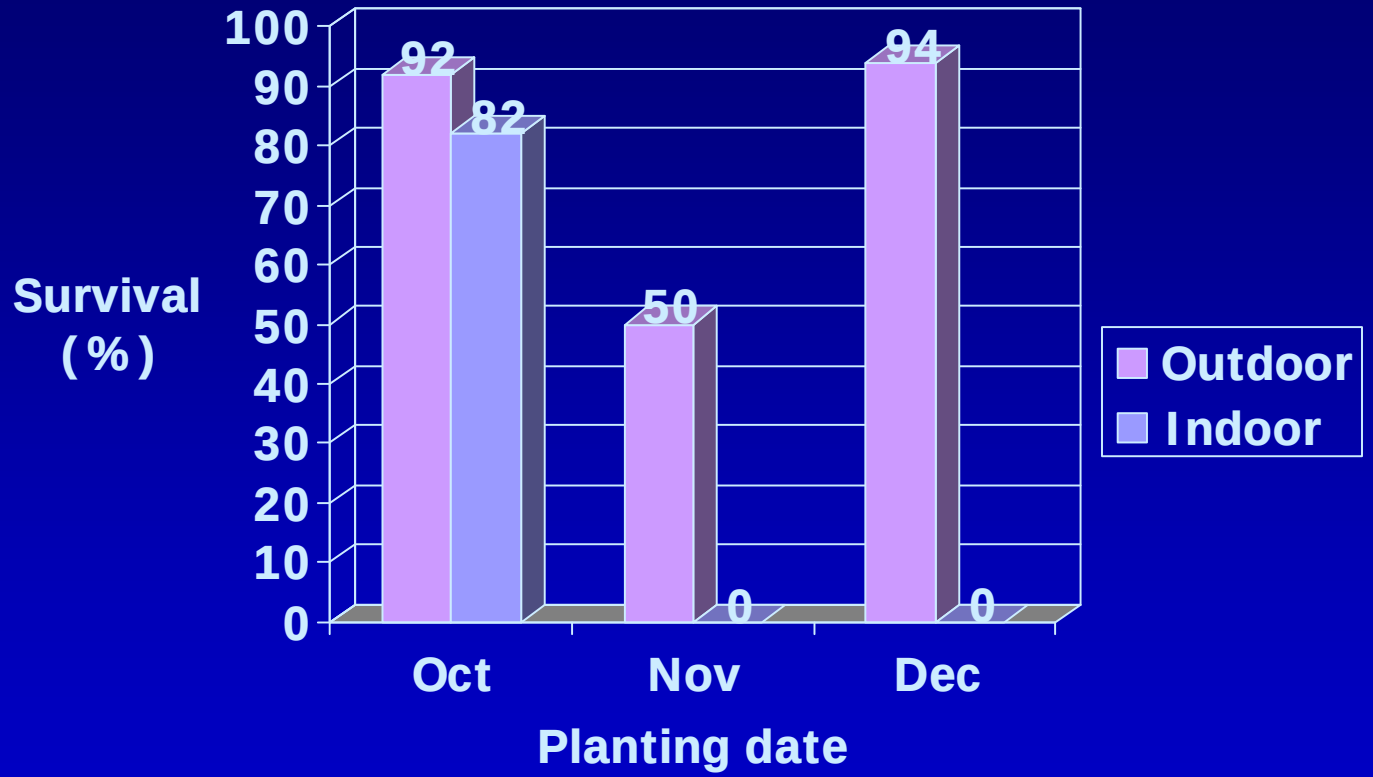
Chilling is affected by genotype

Seed stratification



Freeze tolerance

Container-grown loblolly pine



Mexal, Timmis and Morris 1979

Freeze tolerance

PREVENTION OF COLD DAMAGE TO CONTAINER-GROWN LONGLEAF PINE ROOTS

Richard W. Tinus[1], Mary A. Sword[2], and James P. Barnett[3]

Table 1--Cold hardiness of longleaf pine roots from a warm greenhouse and after hardening in a growth chamber.

greenhouse **chamber**

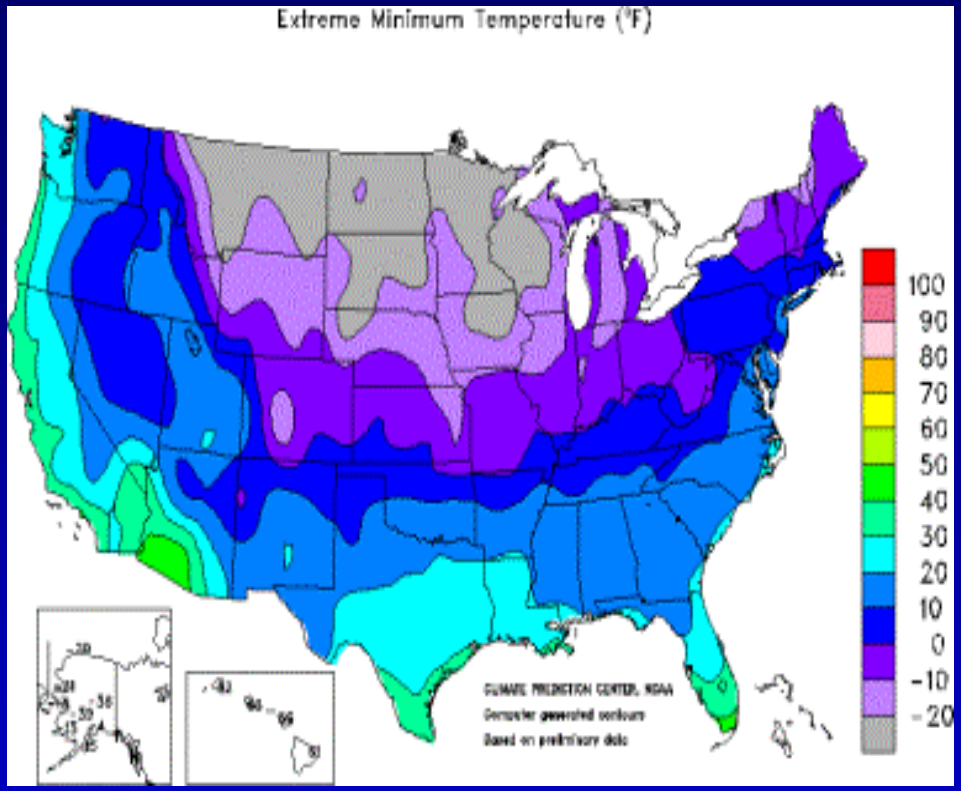
Index of Injury (Percent)	Corresponding temperatures (°F)		Expected Damaged
10	26aA	25aA	Not significant will recover
30	25aA	22aA	Heavy damage not shippable
50	24aA	18bB	Dead

* Values with the same letter are not significantly different at p = .05. Lowercase is for columns, uppercase for rows

Christmas 1983 Freeze

No freeze injury in north Alabama

Injury in south Alabama



Freeze tolerance

Tinus….Tree Planters' Notes 47(2):62-67; 1996.

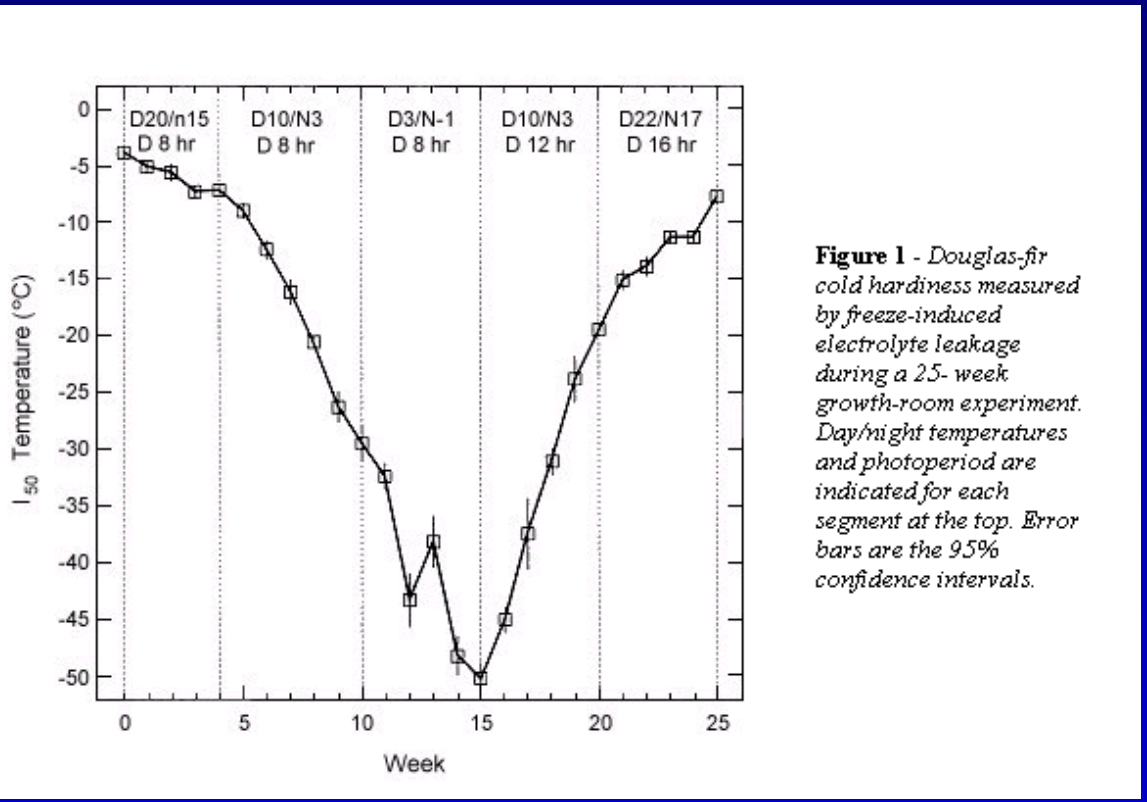


Figure 1 - *Douglas-fir cold hardiness measured by freeze-induced electrolyte leakage during a 25- week growth-room experiment. Day/night temperatures and photoperiod are indicated for each segment at the top. Error bars are the 95% confidence intervals.*

Cool temperatures are important
For improving freeze tolerance

But if seedlings are outplanted early
They can acclimate in the field.

Bud dormancy

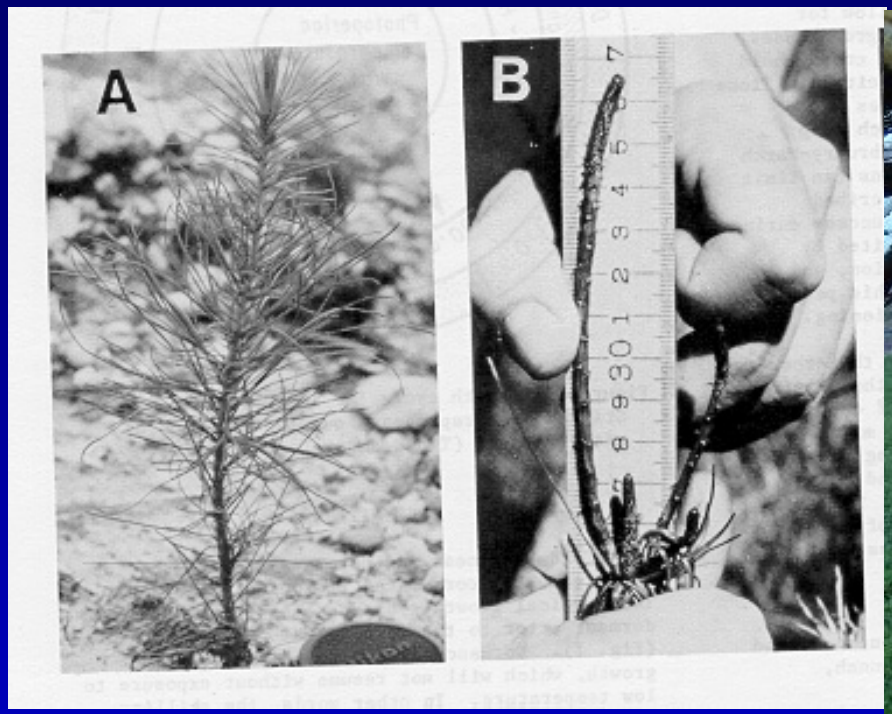
The seedling moves from dormancy to quiescence after accumulation of several hundred hours of low (0-10 °C) temperatures. This chilling is required before buds can break in response to warmer temperatures. If not totally fulfilled at the time of lifting, the chilling requirement may also be fulfilled by cold storage [4, 11], although temperatures in freezer storage at -2° C are considered below the optimum range to accumulate chilling [13].

Bud dormancy

Seedlings of silver maple require 2,000 to 2,500 hours of chilling to break dormancy. No differences were found in the time of first budbreak between cold-stored and nursery-lifted stock; there is a strong correlation between time of first budburst and root regeneration after the seedlings are transformed to environmental conditions suitable for growth.

Webb, P. D. 1978. Root regeneration and bud dormancy of sugar maple, silver maple, and white ash seedlings. Forest Science 23:474-483.

Bud dormancy



Normal container Greenhouse container

Mexal and Carlson 1981

Effects of chilling and photoperiod on dormancy release of container-grown loblolly pine seedlings. Garber,-MP Canadian-Journal-of-Forest-Research. 1983., 13: 6, 1265-1270;

Chilling temperatures apparently were involved both in ameliorating bud dormancy and in promoting vegetative growth.

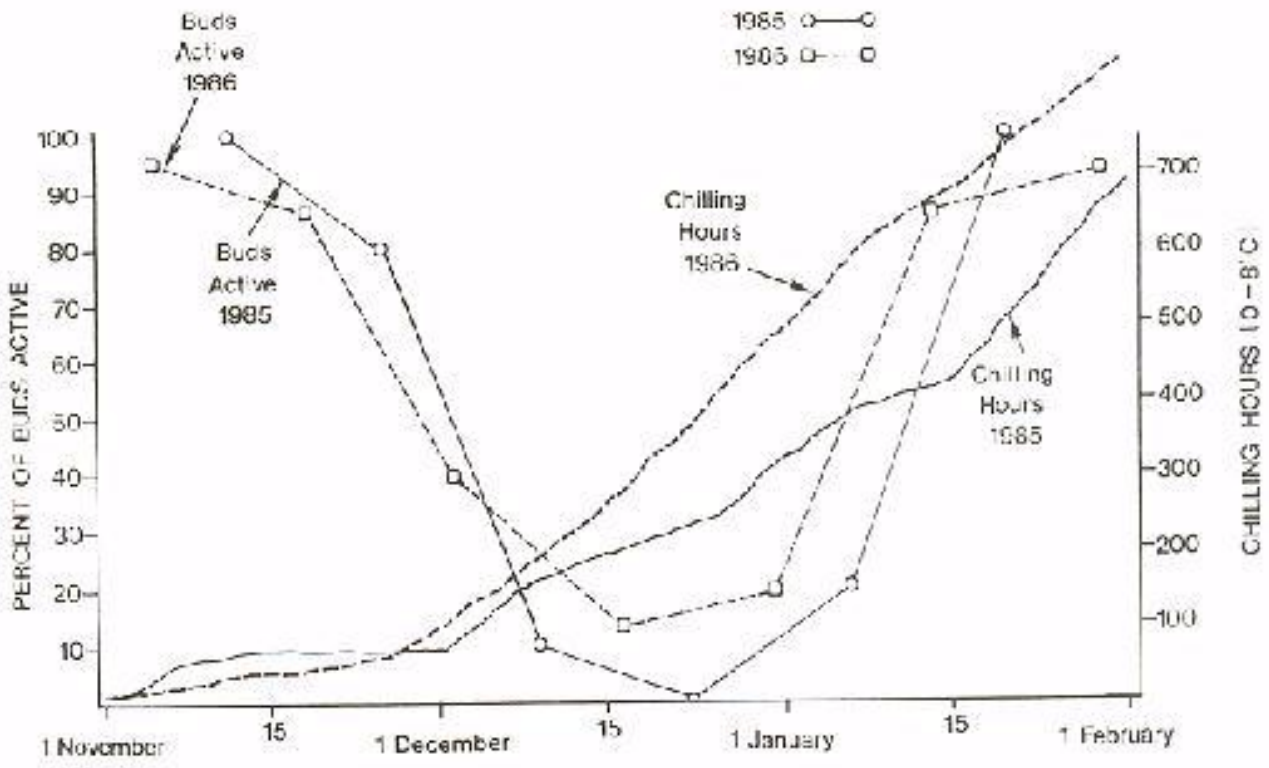
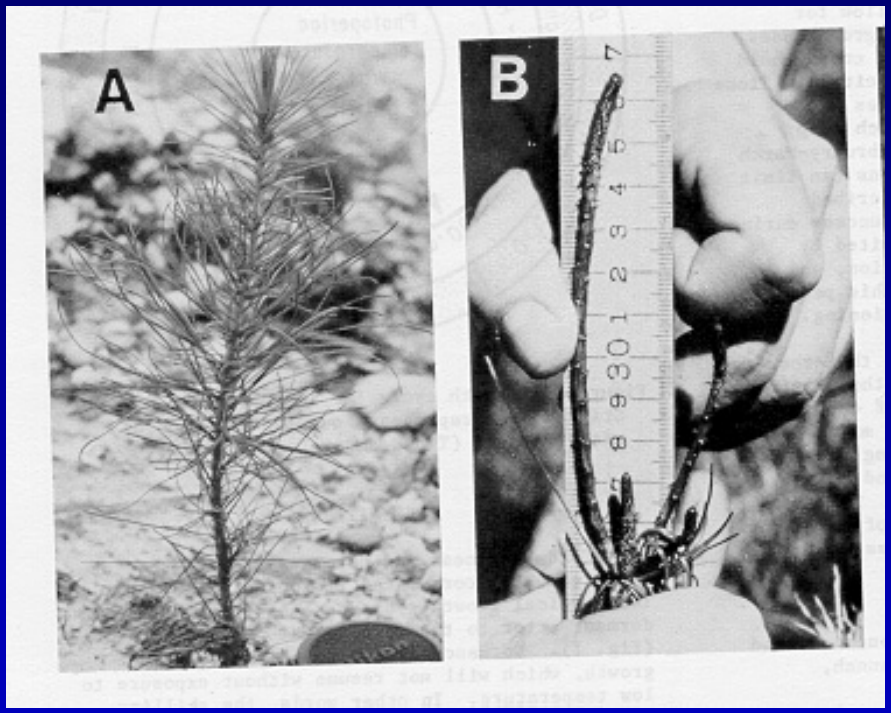


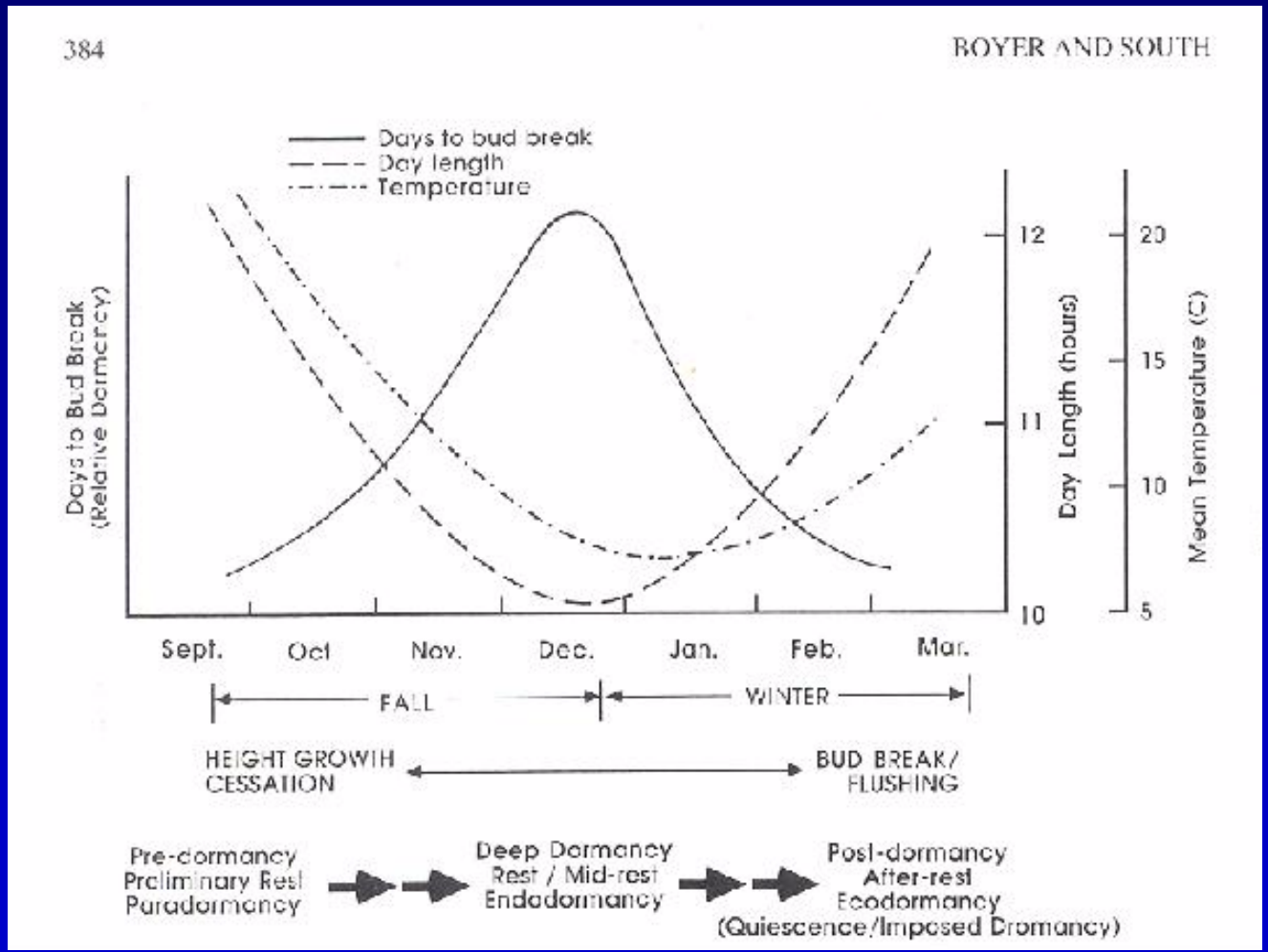
Figure 1. Accumulated chilling hours (0–8 °C) and the percentage of buds active after 28 days for bare-root seedlings grown outdoors and sampled from November to January. Each point represents 20 seedlings.

Chilling does affect bud dormancy



Chilling, lifting date and storage?

In most storage studies...
chilling is confounded with day-length



Changes in loblolly pine seedling root growth potential, dry weight, and dormancy during cold storage.
DeWald,-LE; Feret,-PP Forest-Science. 1988. 34: 41-54

Apparently between 400 and 500 chilling hours are necessary for satisfactory cold storage of loblolly pine seedlings at the New Kent Nursery.

However, chilling was confounded with photoperiod.

Planting Southern Pines

A Guide to Species Selection and Planting Techniques

http://msucares.com/pubs/pub1776.htm

Some nurseries use chilling hours (temperatures between 33 °F and 40 °F) as an indication of dormancy. Chilling hours are monitored in the nursery, and seedlings are lifted after 200 or more chilling hours have accumulated. This allows seedlings to be planted immediately or stored for no more than two or three days. When 400 chilling hours have accumulated, seedlings reach peak dormancy and can be cold-stored for up to 8 weeks. When you order seedlings, ask how the nursery determines that seedlings are properly hardened-off and are ready to lift.

Chilling hours (0-8C) were not intended to determine when to lift for “hot” planting of pines!!!!

Production and Marketing of Field-Grown Trees in Georgia

http://www.ces.uga.edu/pubcd/B1115-w.htmtm

The third physiological attribute important to seedling performance is the stage of dormancy at time of lifting. The stage of dormancy can be described as the hours of chilling temperatures (32° to **54°F**) the seedling is exposed to prior to lifting. Research with loblolly pine demonstrated a relationship between hours of chilling temperature prior to lift, duration of storage, and the out-plant performance. Quantitative guidelines do not exist at this time for hardwood seedlings. **Based on loblolly pine research, hardwood seedlings should have 200 to 400 hours of chilling temperatures before lifting and storage.** These seedlings will generally have better survival and early growth. The seedlings can be stored for at least 12 weeks at about 40°F in Kraft-polyethelene bags.

Chilling hours have not been tested to determine when to lift for planting of hardwoods!!!!

Seedling storage?

So far, there have been no published scientific studies that prove chilling increases loblolly pine seedling tolerance to cool storage!!

Seedling storage?

The idea that chilling was related to storage may have started in Oregon with a paper by Dennis Lavender and F.P Wareing (New Phtologist 1972: 71, 1055-1067).

Lavender, D.P., and P.F. Wareing. 1972. Effects of daylength and chilling on the responses of Douglas fir (*Pseudotsuga menziesii* (Mirb) Franco) seedlings to root damage and storage. New Phytol. 71:1055-1067.

Seedling storage?

They said...

“A period of chilling, following short-day pretreatment, greatly increases the seedlings’ resistance to the adverse effects of root damage and dark storage.”

Seedling storage?

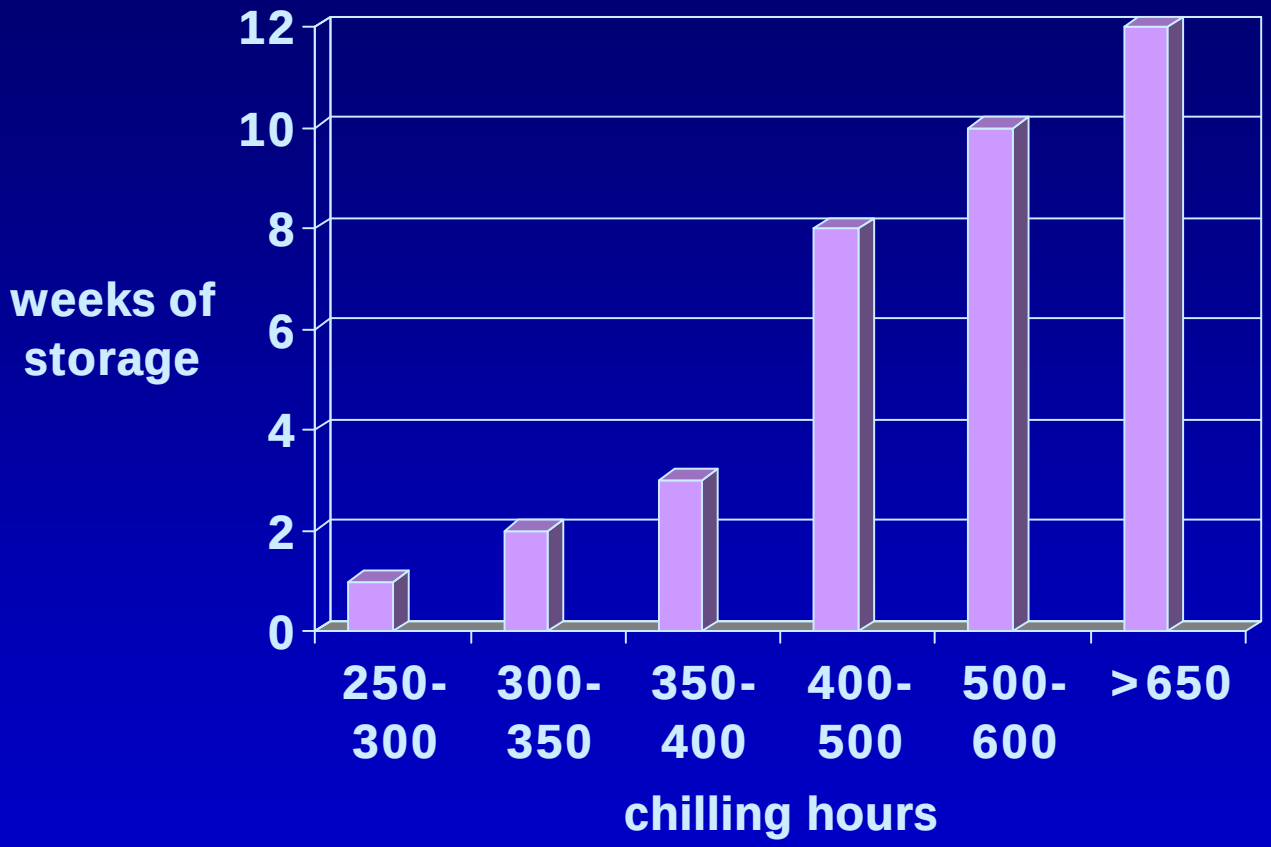
They said...
“A period of chilling, following short-day pretreatment, greatly increases the seedlings’ resistance to the adverse effects of root damage and dark storage.”

However, in their study # 3, survival was good in all treatments so they based their conclusions on percentage change in seedling fresh weights! In fact, the mean fresh weights for the seedlings were: 9.8 g for the short day+ chill vs. 12.1 g for the short + warm treatment!

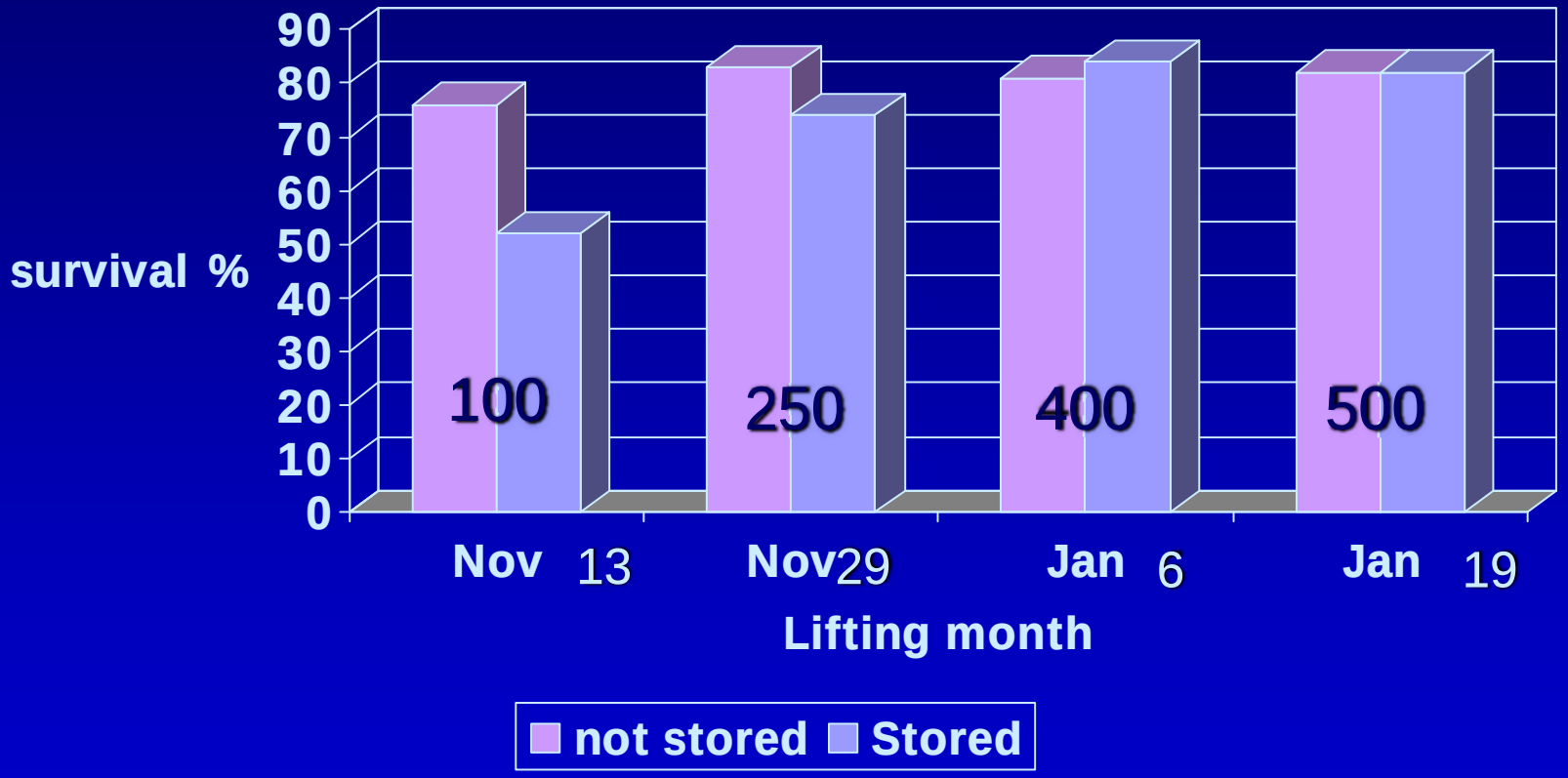
Seedling storage?

The idea that chilling influences the storability of loblolly pine was proposed in 1980 (Mexal and Garber: NZJF 10:72-82). In two separate studies, they noticed what *appeared* to be a relationship between bud dormancy and storability. IF bud dormancy and storability were related, then it would be logical for managers to record chilling hours. As a result, Weyerhaeuser adopted a policy of counting chilling hours (0-8° C) and varying the length of storage with the number of chilling hours.

Seedling storage?



Effects of 10-wk of storage by lifting data (Williams 1989)



However, chilling was confounded with photoperiod.

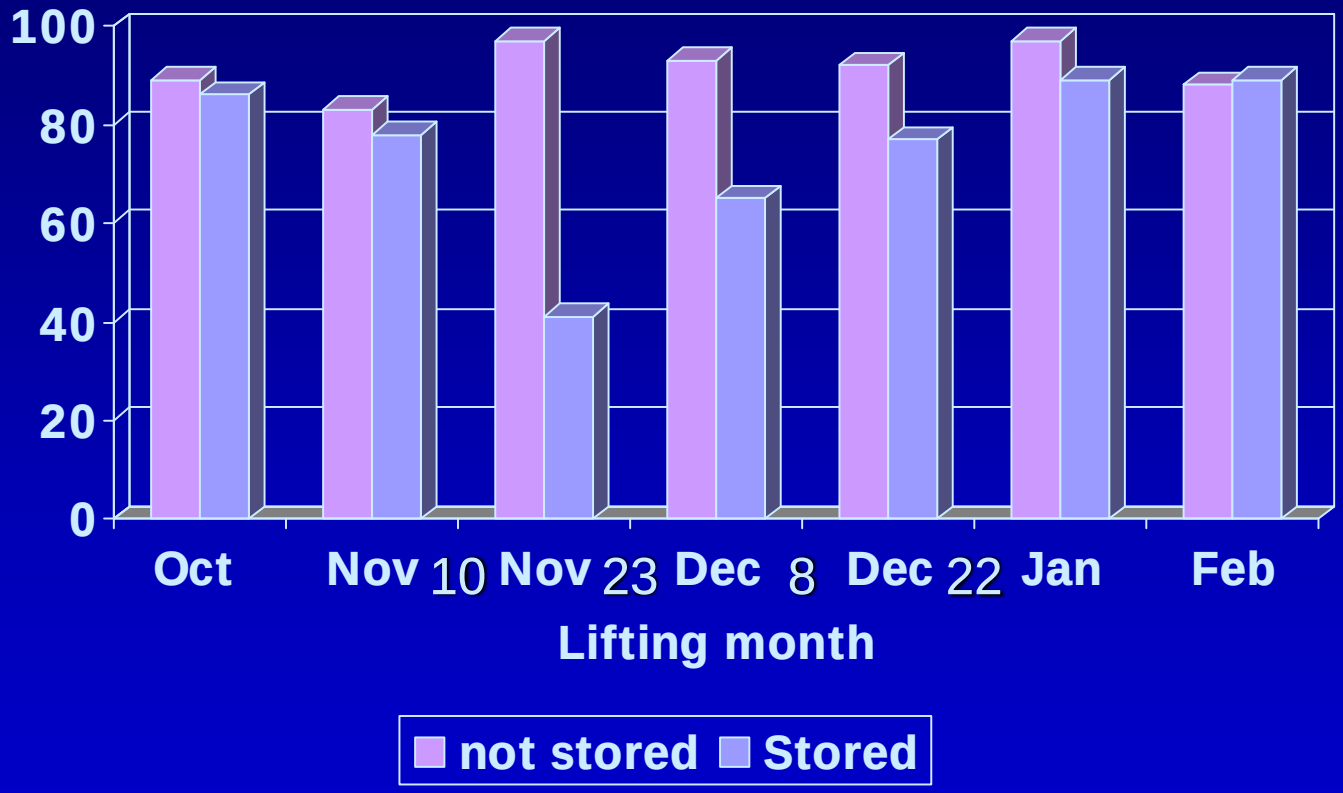
Seedling storage?

However, we soon quickly realized that storability could be achieved with a low level of chilling. At first, we thought this was related to using different seed sources. However, we no longer believe there is a cause and effect relationship between bud dormancy (chilling hours) and storability. In some years, 8 weeks of storage was OK with as little as 75 hours of chilling. If there was a direct relationship between chilling and storability, then the amount of chilling required (to store seedlings successfully for 8 weeks) should be about the same from year to year (but it is not).

Seedling storage?

One paper deals with loblolly pine and storage (Stumpff and South 1991). When lifted on Oct. 27, 1988 seedlings could be stored for 1 month with no decline in survival. However, survival of seedlings lifted on Nov. 22 and stored for 1 month declined by 44%. Since seedlings stored well will little chilling but did not store well in late November, this suggests that some other factor is more important than chilling for determining the ability of seedlings to withstand cool storage.

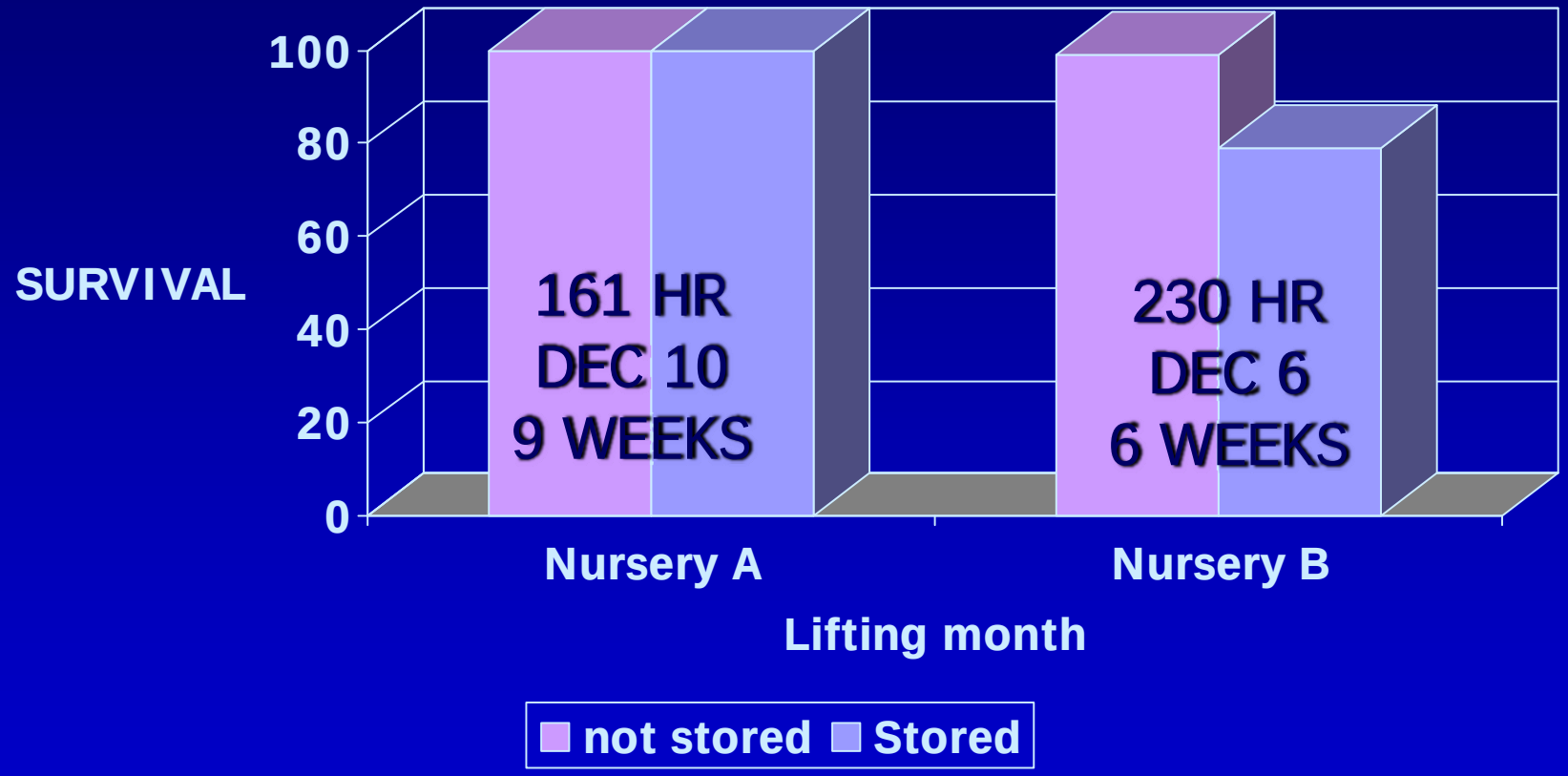
Effect of 4-wk of storage by lifting data



Seedling storage?

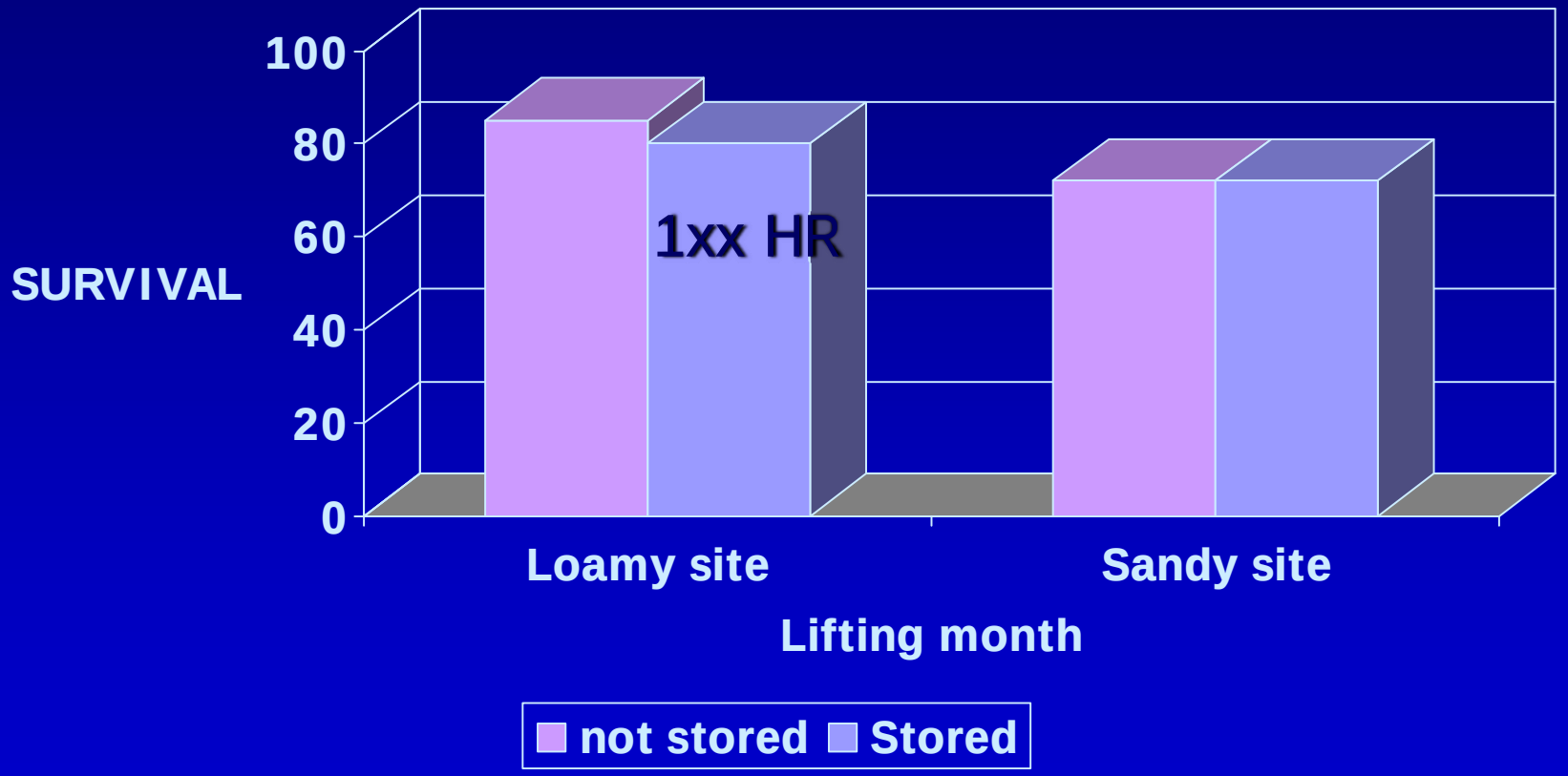
One paper deals with shortleaf pine and chilling (Hallgren Tauer and Weeks: Forest Science 39:478-498). When lifted on Dec. 1, 1986 (314 chilling hours) seedlings could be stored for 1 month with no decline in RGP. However, the next year seedlings were lifted with 459 chilling hours (Nov. 30, 1987) and RGP declined by 60%. Since seedlings the 1987 seedlings were lifted were lifted with 148 more hours of chilling, this suggests that some other factor is more important for determining the ability of seedlings to maintain good RGP during storage (not photoperiod… not chilling).

Effects of 6-9-wk of storage December 2001

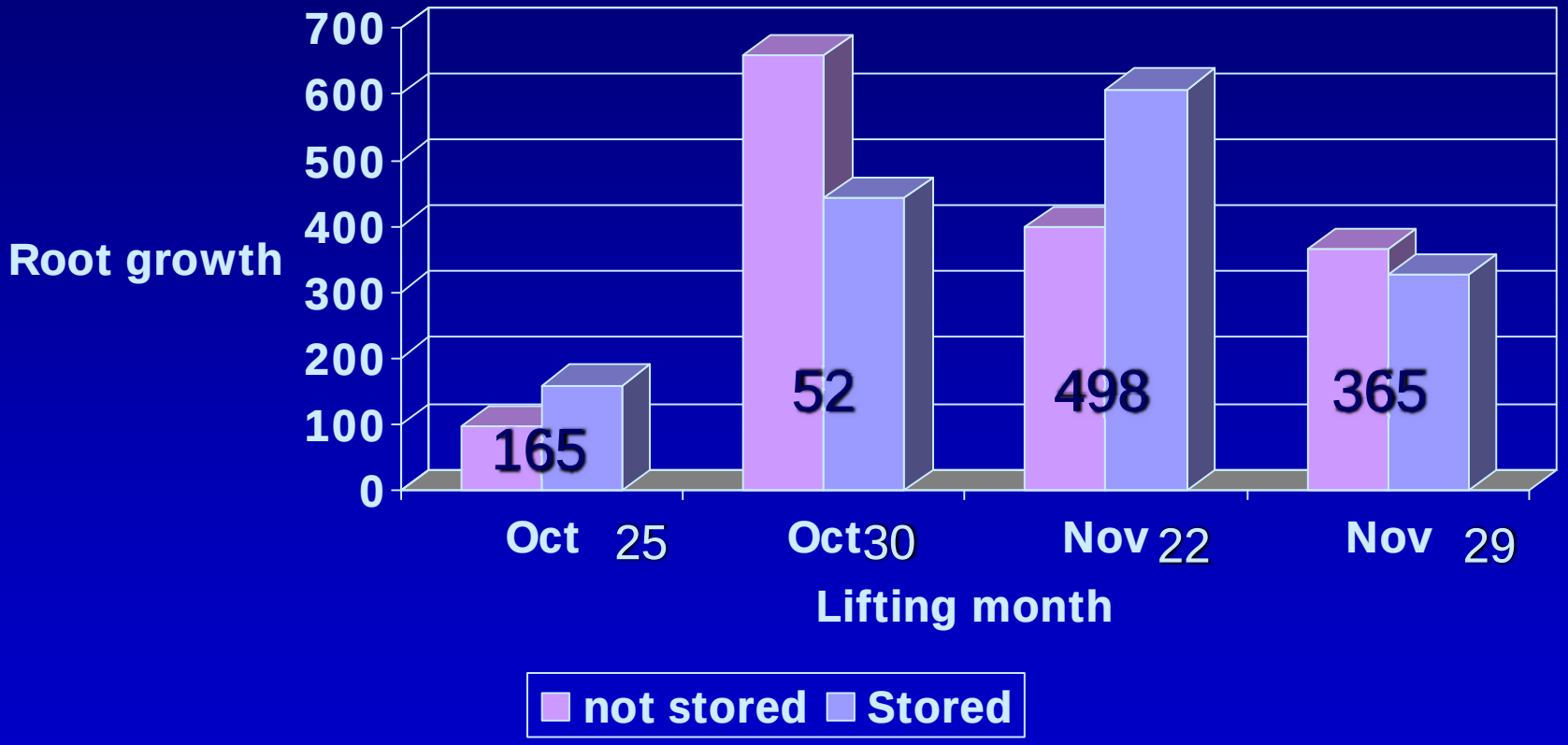


Effects of 6-wk of storage November 5, 1990

(South and Donald 2002)



Effects of 6-wk of storage in VA (DeWald and Ferret 1988)



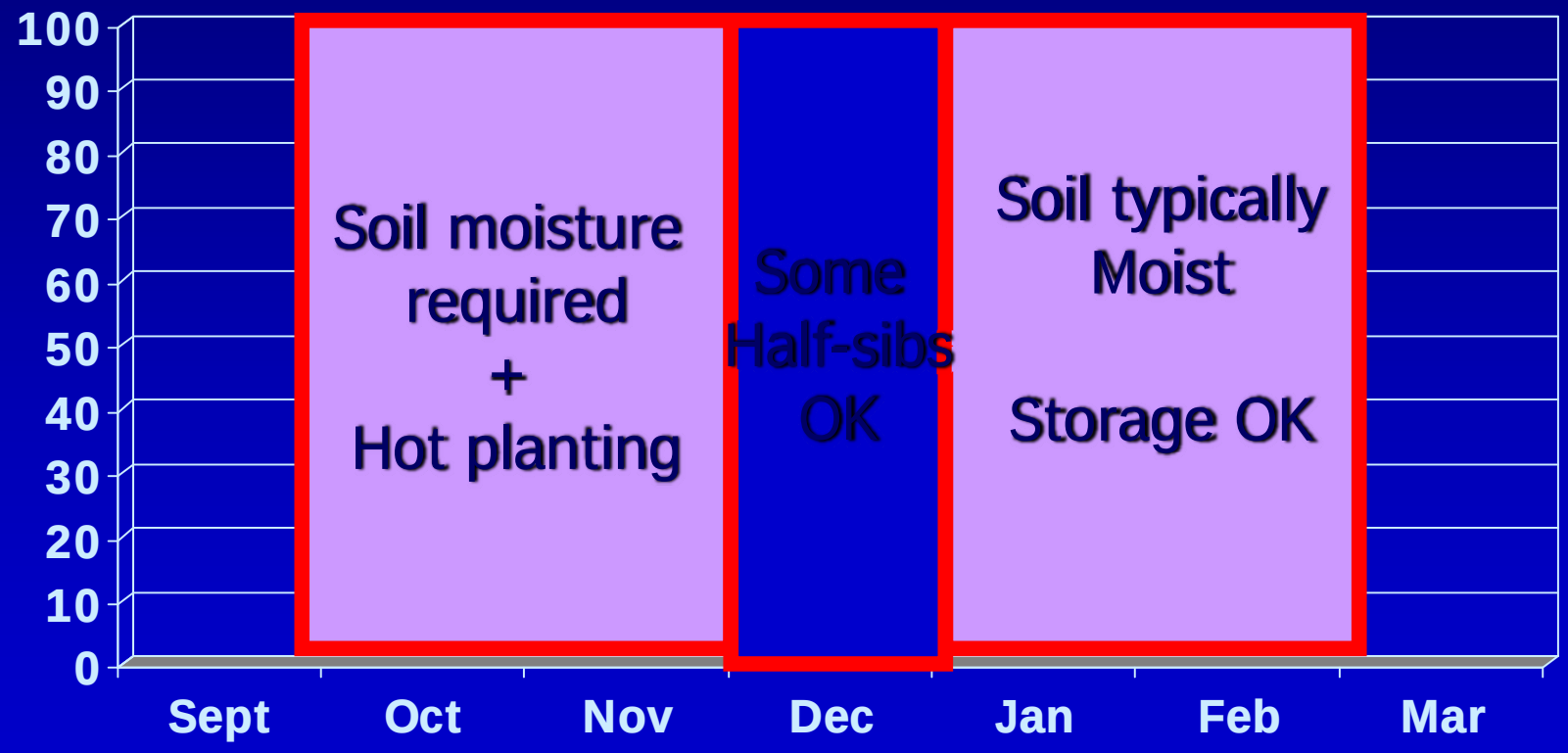
Operational considerations

By Dec. 15, 1998 there were 73 chilling hours at Auburn (compared with 443 by the same date in 1997). If chilling really determined storability, then 2-month storage could not begin until the 7th of January. With the warm weather in January, some terminal buds were breaking in the nursery (with 500 chilling hours). In other words, if a nursery waited till January 7th to begin lifting, they might find a lifting window only 3 weeks long! That is a mighty short lifting window!

Operational considerations

Before 1980, nursery managers used to start lifting by the calendar. For example, for the Ashe Nursery in Mississippi, the date was Dec. 15. The idea of varying lifting date (for "cool" planting) seemed attractive to some. But if storage is affected more by other factors (i.e. photoperiod) then it makes more since to lift (for "cool" planting), by calendar date. Other factors (such as seedling size, wet soil, frozen ground, pathogens, lignification, wet foliage, fungicide dips, root injury), likely affect storability more than chilling.

Lift date and storage



Outside chilling improves seedling quality

- Improves freeze resistance
- Affects bud dormancy
- Reduces maintenance respiration – and therefore results in heavier seedlings (Since chilling occurs in the fall, this Improves root:weight ratio)

Nursery managers can:

- Before December, encourage customers to “hot plant” in moist soil
- Tell customers chilling is important for freeze tolerance... but seedlings “hot” planted early will acclimate naturally before a freeze.
- Keep water off foliage in storage
- Produce lignified seedlings that can better withstand lifting and storage
- In warm falls, do not lift seedlings right after a hard freeze or when beds have been saturated
- Use data from “local” genotypes to determine

Questions?

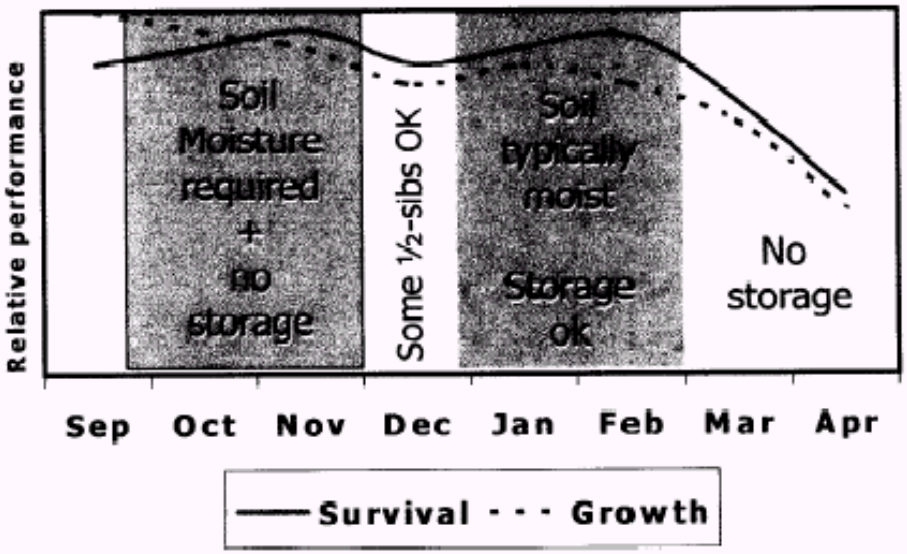
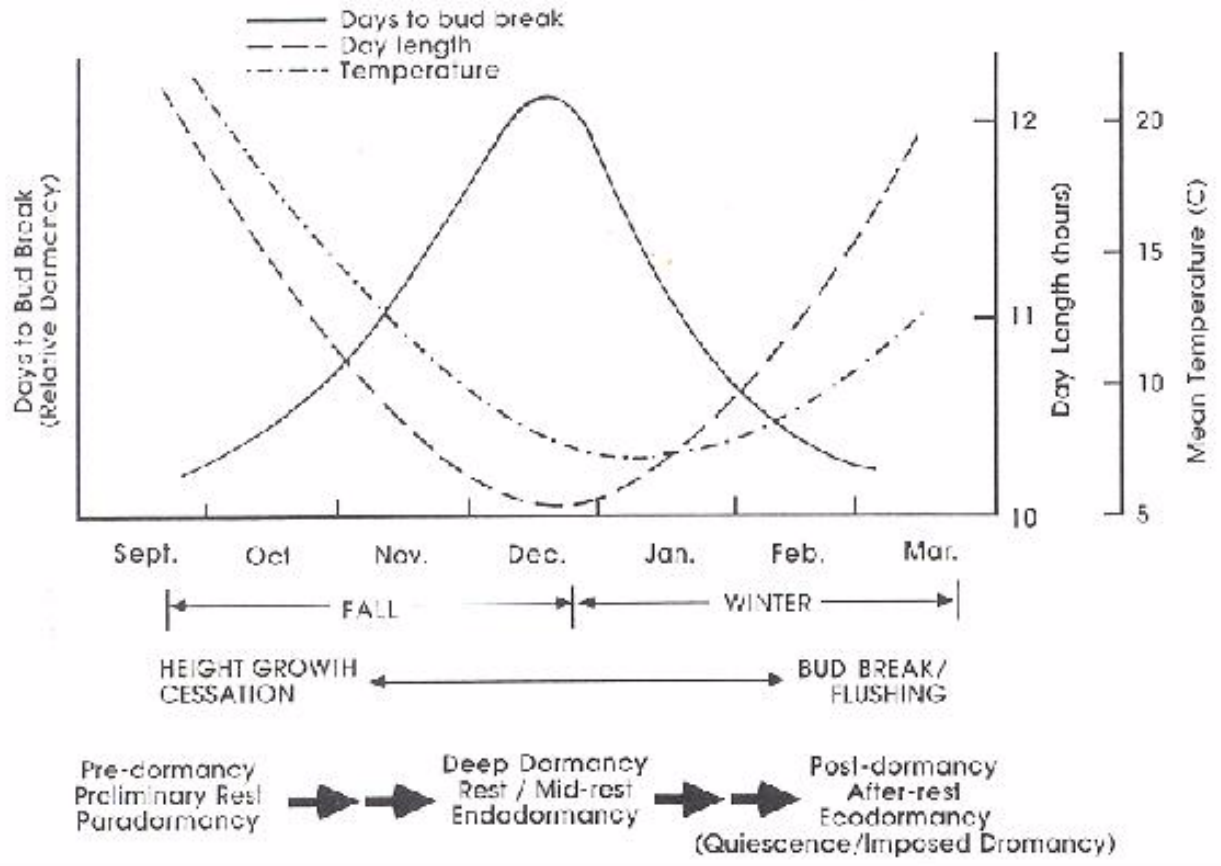
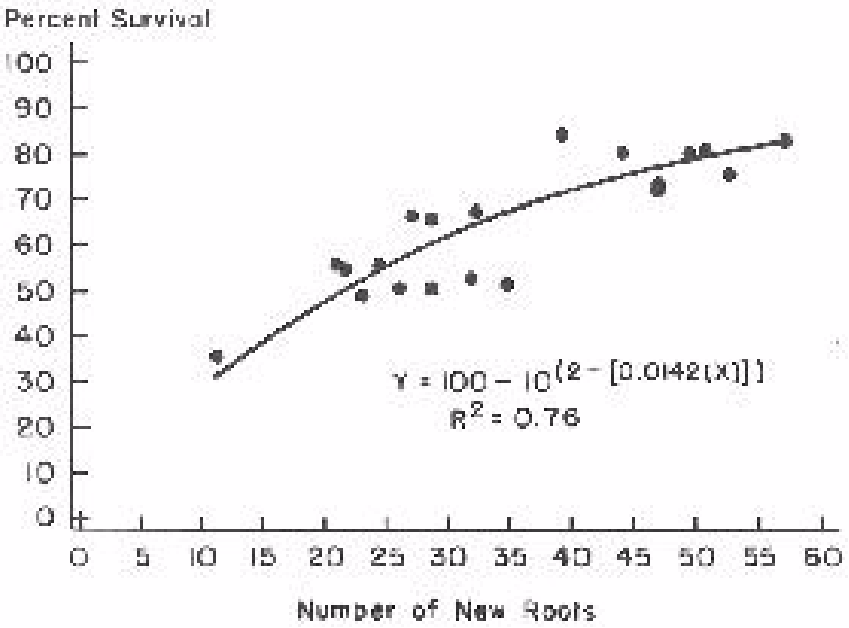
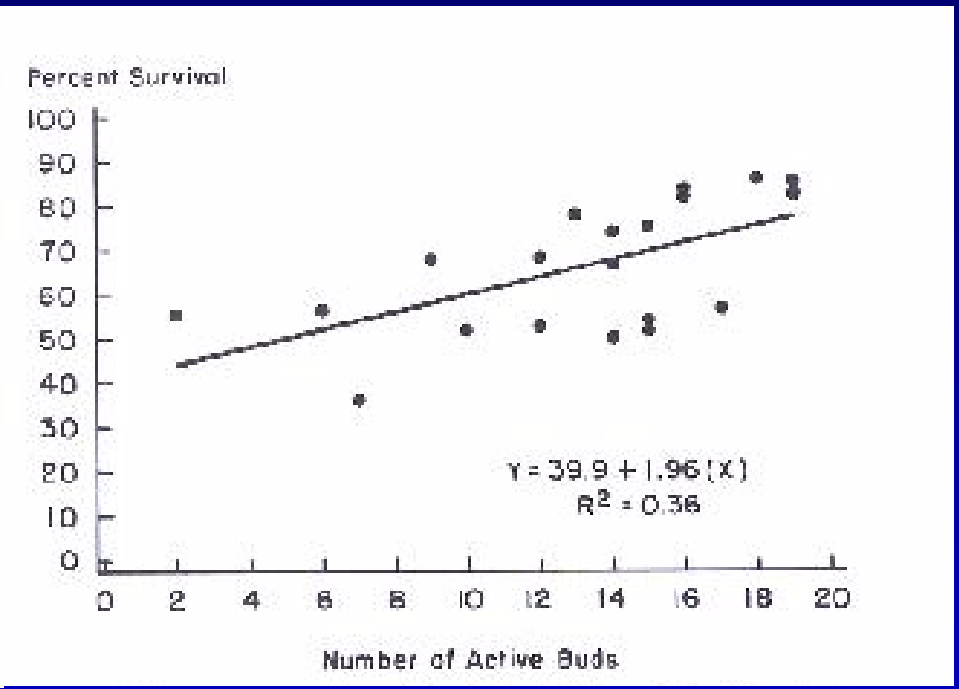


Figure 10. Relative performance of bare-root loblolly pine seedlings when planted during the fall planting season (October and November) and in the traditional planting season (January and February) in the southern United States. Some genotypes may perform well when planted soon after lifting during the month of December.


Days to bud break
Day length
Temperature
Days to Bud Break (Relative Dormancy)
Day Length (hours)
Mean Temperature (C)
12
11
10
20
15
10
5
Sept.
Oct
Nov.
Dec.
Jan.
Feb.
Mar.
FALL
WINTER
HEIGHT GROWTH CESSATION
BUD BREAK/ FLUSHING
Pre-dormancy
Preliminary Rest
Paradormancy
Deep Dormancy
Rest / Mid-rest
Endodormancy
Post-dormancy
After-rest
Ecodormancy
(Quiescence/Imposed Dormancy)

Loblolly pine

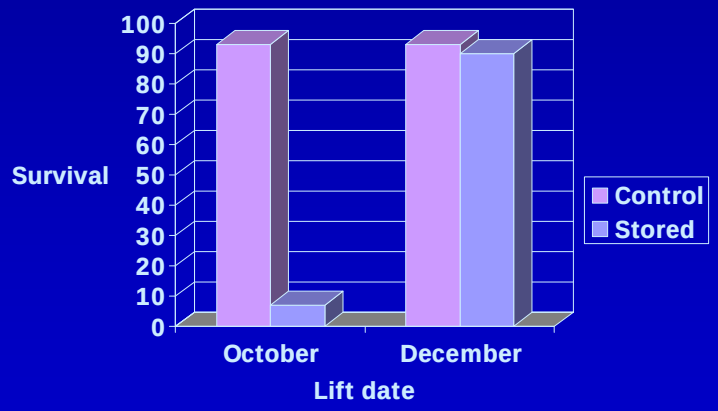




Seedling storage?

They also said…
“The [negative] effect of dark storage at low temperatures is still evident in chilled seedlings, but is much reduced.”

However, in their study # 2 natural chilling was confounded with lifting date!



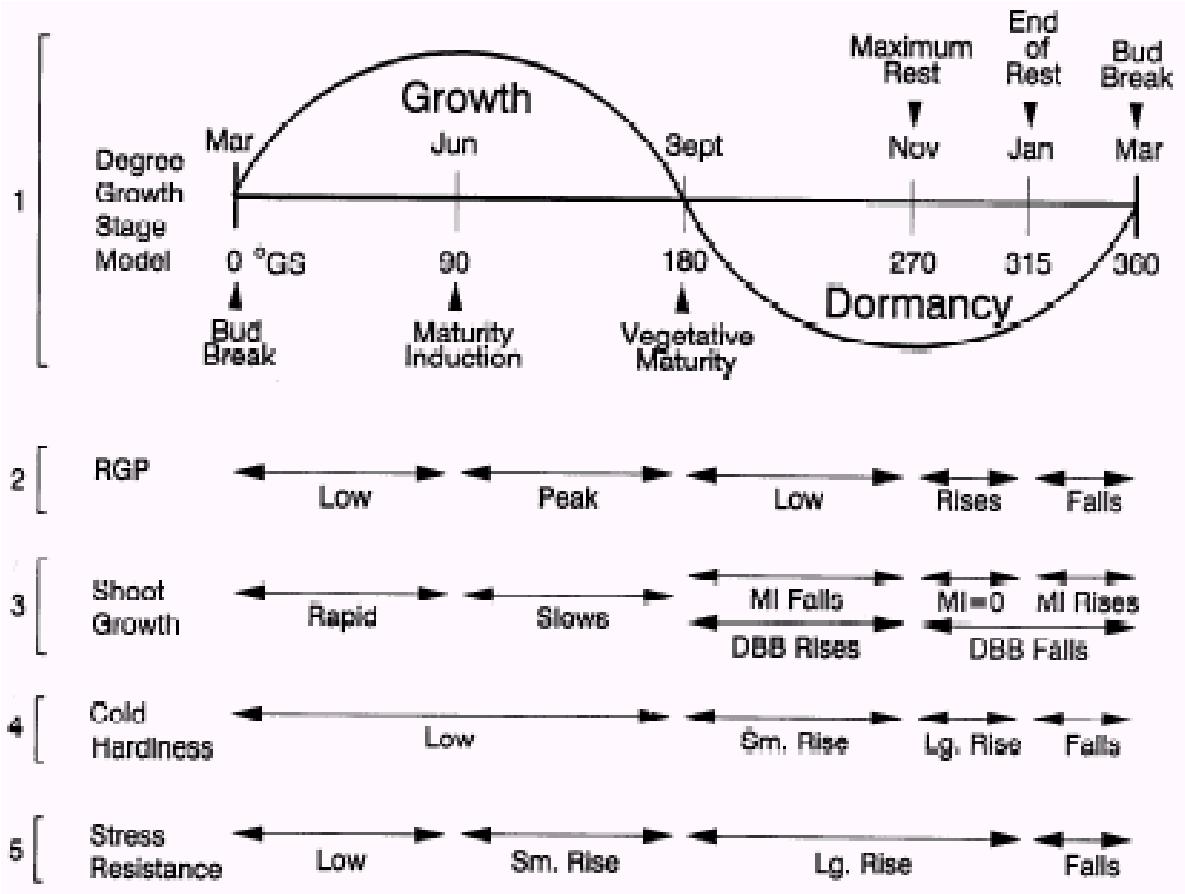


Figure 7.1—*A Degree Growth Stage model (Fuchigami and Nee 1987, Fuchigami et al. 1982) representing one complete annual cycle, with changes in root growth potential (RGP), shoot growth (MI = mitotic index, DBB = days to bud break), cold-hardiness, and stress resistance during the cycle.*

Root growth potential and bud dormancy of 2+0 eastern white pine grown in a Virginia nursery.
Johnsen,-KH; Feret,-PP; Seiler,-JR
Canadian-Journal-of-Forest-Research. 1989. 19:1598-1602;.

It is concluded that if the relation between RGP (expressed as a percentage of annual maximum RGP) and DRI is consistent between years, chilling sums could be used to predict RGP peaks and therefore to choose appropriate lifting dates.

Bigras F (1996) Conifer bud dormancy and stress resistance: A forestry perspective. In: Lang GA (ed) Plant Dormancy. Physiology, biochemistry and molecular biology. CAB International, Oxon, p 171-192.

Seedling storage?

So far, there have been no published scientific studies that prove chilling increases loblolly pine seedling tolerance to cool storage!!

Seedling storage?

But we kept finding cases that did not agree with the chilling-storage hypothesis. By 1991, we said "The relatively good survival of seedlings lifted in late October and early November and stored for 4 weeks supports the conclusion that successful cool storage of loblolly pine seedlings may not be as directly related to chilling as once believed."

Effects of natural chilling and cold storage on budbreak and root growth potential of loblolly pine (Pinus taeda L.).
Carlson,-WC
Canadian-Journal-of-Forest-Research. 1985., 15: 4, 651-

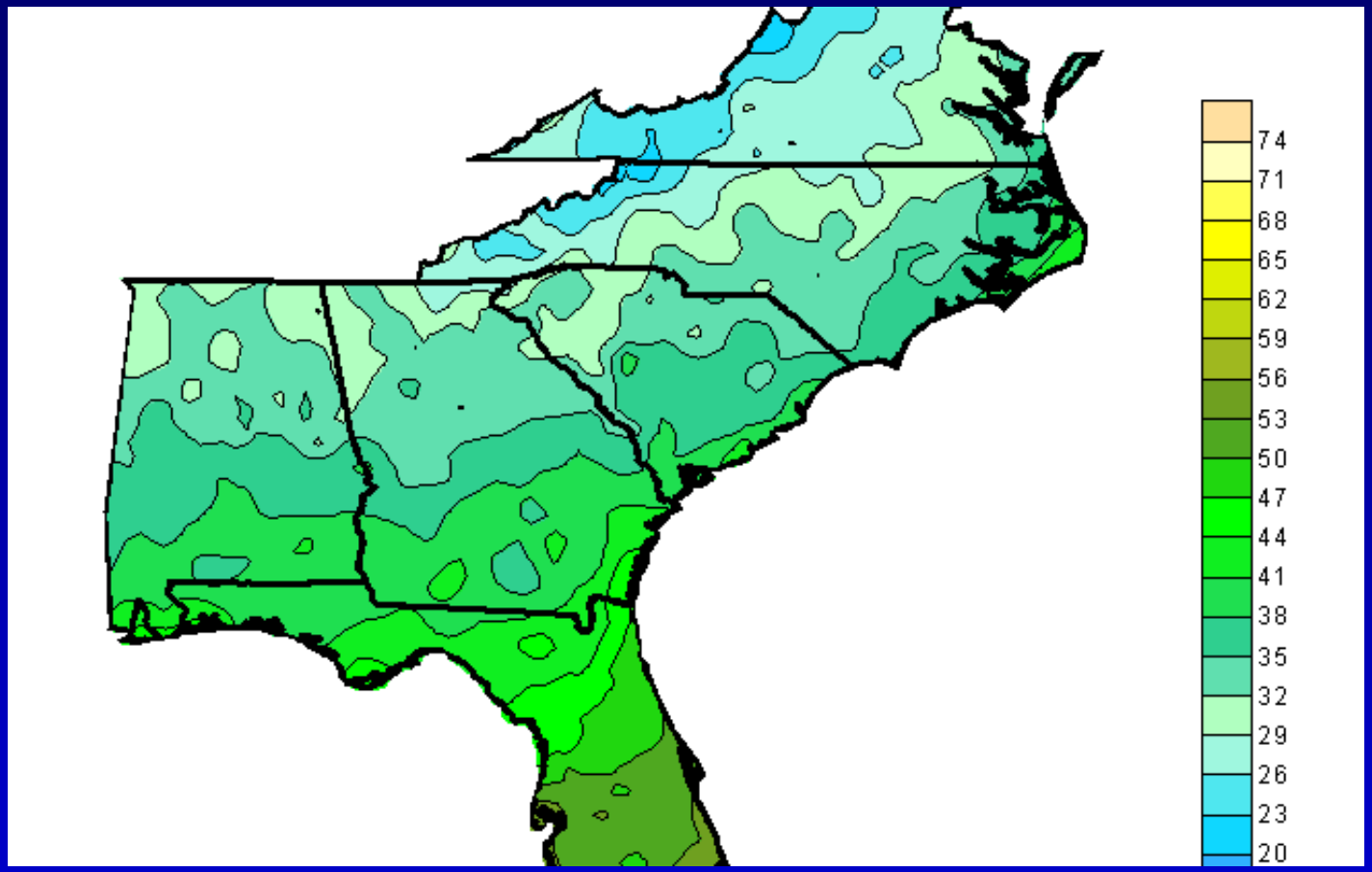
Effect of extended storage of longleaf pine container stock or outplanting survival and growth. (Claridge Nursery)

Study conducted three consecutive years (plantings in December 1996-98)

Seedlings in cold storage from 0 to 8 weeks have been outplanted and are being compared for survival after 1 growing season and for commencement of height growth initiation.

Results show no significant differences in survival due to length of storage time indicating that longleaf container stock can be stored for several weeks without lowering the survival rate.

Mean average temperature in December



Irrigate after application

Auburn, AL - 400 chilling hour dates

- 1984-5 January 6
- 1985-6 January 11
- 1986-7 December 31
- 1997-8 December 9
- 1998-9 January 7
- 1999-0 January 2