

Dormancy, Chilling evaluation and means to control poor bud break in peaches

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CONTENT

- What is dormancy and its significance for the deciduous tree
- Chilling requirements
- Measuring chilling accumulation
- Chemicals to break dormancy

CLIMATIC ADAPTATION OF TEMPERATE FRUIT CROPS

- These fruit trees were selectively adapted to grow in areas where sharp seasonal climate exist and the winters are cold to very cold.
- Trees were adapted to grow in spring and summer and stop growing and prepare for survival in the coming winter.
- The summers are typically with long days and mild to warm temperatures. The daylength changes markedly in spring (increasing) and in autumn (Decreasing)

DORMANCY

- For that purpose, dormancy was developed.
- Basically, dormant organs develop the capacity to stand at very low temperatures without harming the dormant tissues.
- Specific tissues had to be developed for survival not for growth.
- Definition: **Dormancy is the sum of processes that constitute a programmed inability for growth in various types of plant meristems in spite of suitable environmental conditions**

CLIMATIC ADAPTATION OF TEMPERATE FRUIT CROPS

The critical elements for these plants were:

- How to know that winter is approaching
- How to prepare for survival during the cold period.
- How to know that winter is over and growth and development can be resumed.

DORMANCY

Three processes develop generally in a simultaneous way:

1. Developing of dormancy
 2. Stop of terminal growth
 3. Induction in the dormant organs of cold resistance
- In temperate zones, leaf drop occur in parallel

DORMANCY

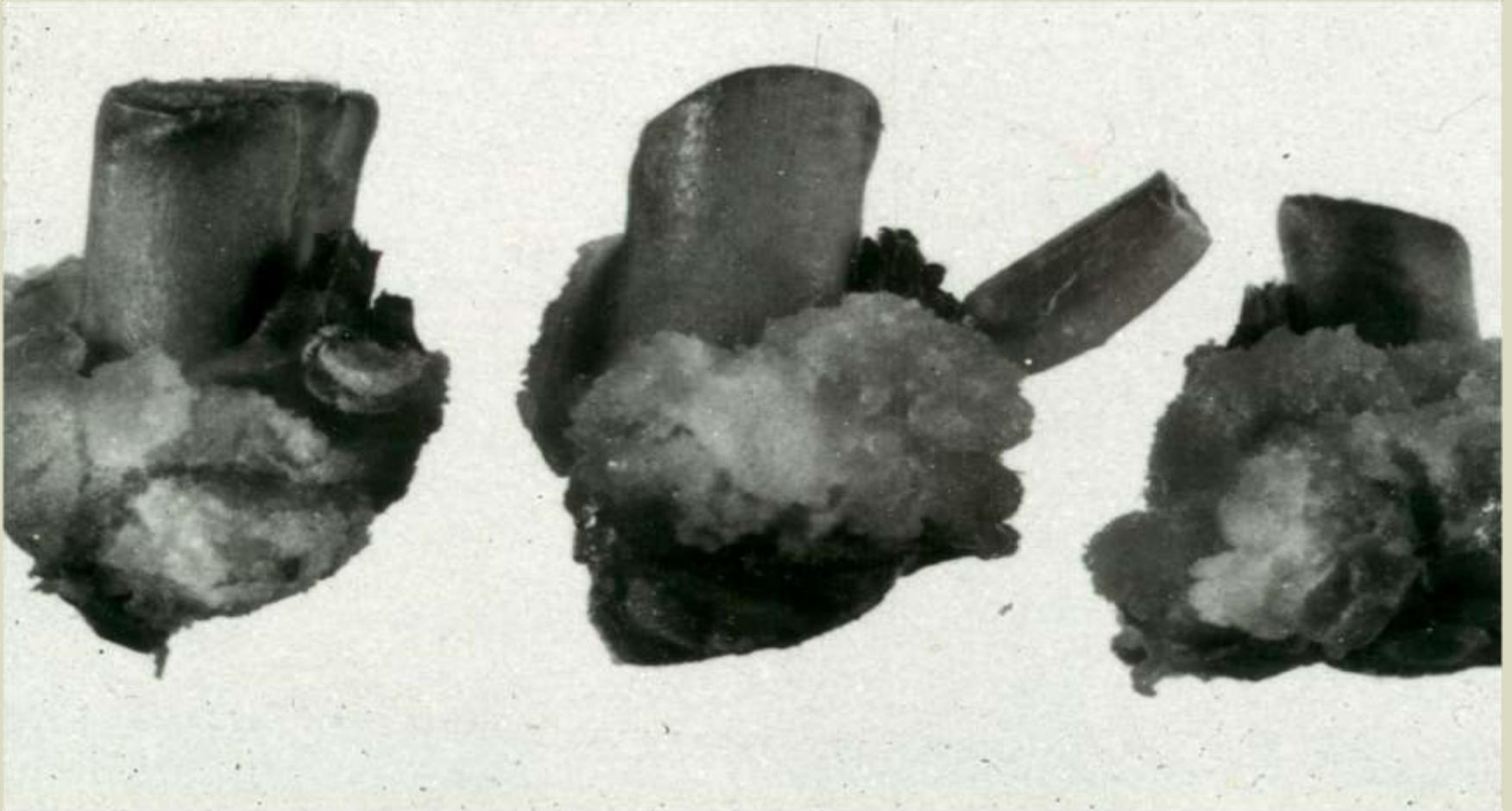
- Dormancy is induced endogenously so it will develop at all environments but its induction is enhanced by short days and low temperatures.
- Also stop of growth, leaf drop and cold resistance are enhanced by these 2 factors

Who enter into dormancy? Not roots



Rooting dormant peach cuttings

Who enter into dormancy?
Buds but not cambium



The winter dilemma

- While dormant buds having a meristem can survive very low temperatures, once buds start to develop and grow – cold resistance is lost. This process can not be reversed. So if premature bud break occurs – all buds may die. So nature selected a mechanism to overcome this problem and decides when it is safe to start growing. This mechanism is chilling requirement

Chilling requirement

- Every species of the temperate fruit crops and every cultivar has a specific chilling requirement. Only after this chilling is reached will the buds respond to favorable conditions and break and will grow. There are adaptations between the cultivars growing in a certain place and the chilling normally available there.
- Chilling is a special combination of temperature level and duration as will be described

Definition of dormancy stages

Paradormancy - buds that won't grow due to an internal (physiological) influence by another part of the plant, such as “apical dominance”

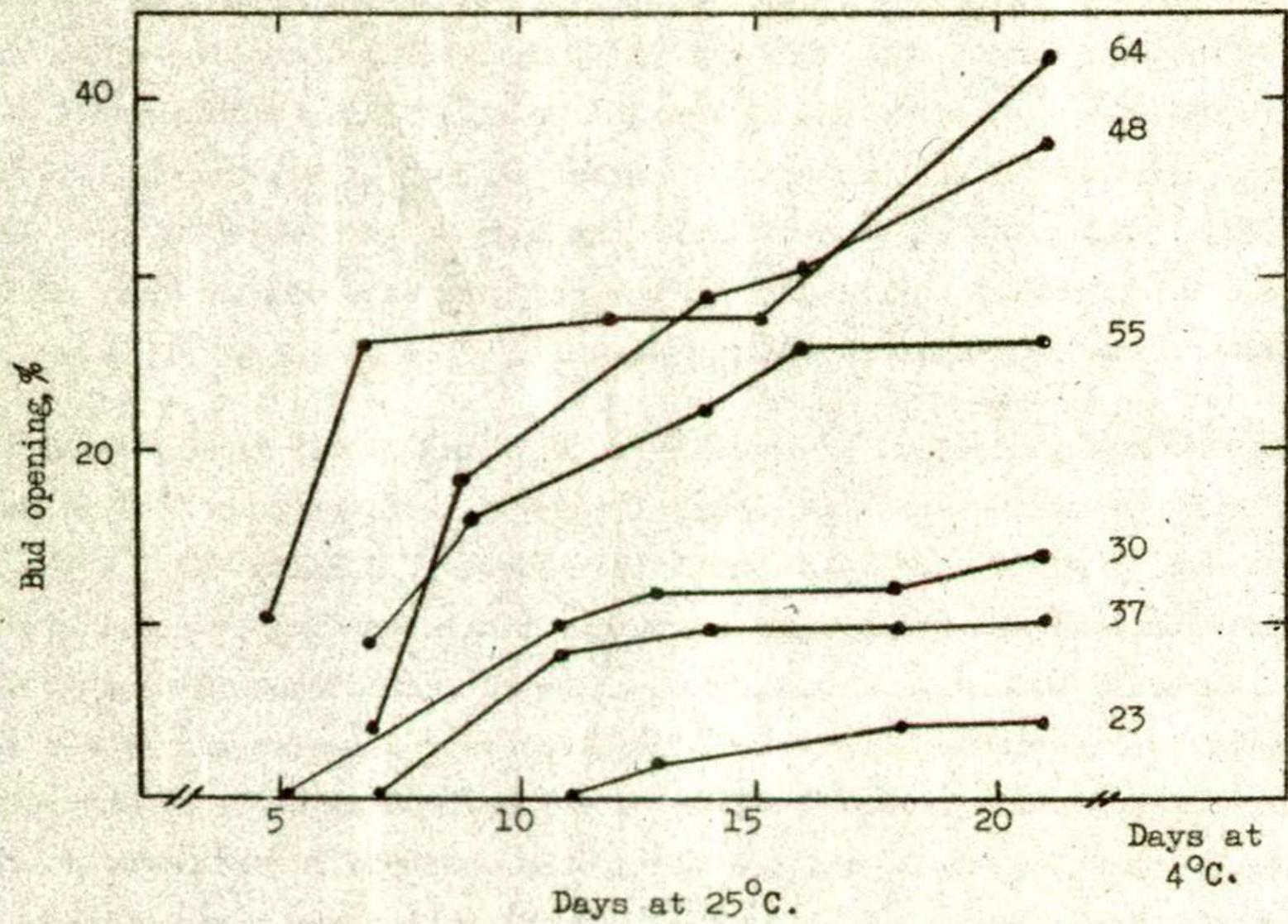
Endodormancy - buds that won't grow due to an internal (physiological) condition within the bud, also known as “rest ” or “winter dormancy”

Ecodormancy - buds that will grow if given suitable external (environmental) conditions (warm temps, water, nutrients)

EFFECTS OF PROPER ALLEVIATION OF DORMANCY AND BUDBREAK

THREE ASPECTS OF GOOD ALLEVIATION OF DORMANCY ARE APPARENT:

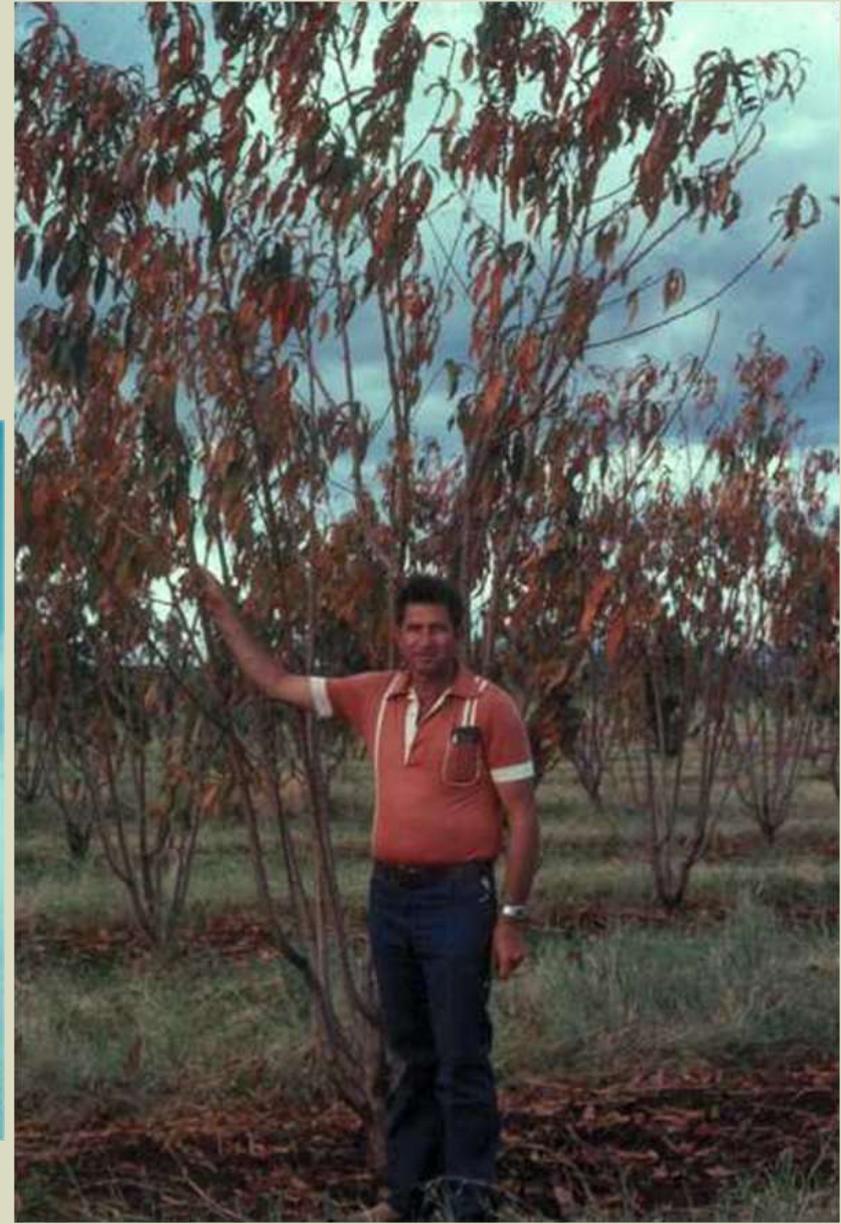
- A HIGH LEVEL OF BUDBREAK
- UNIFORM BUDBREAK
- EARLY BUDBREAK



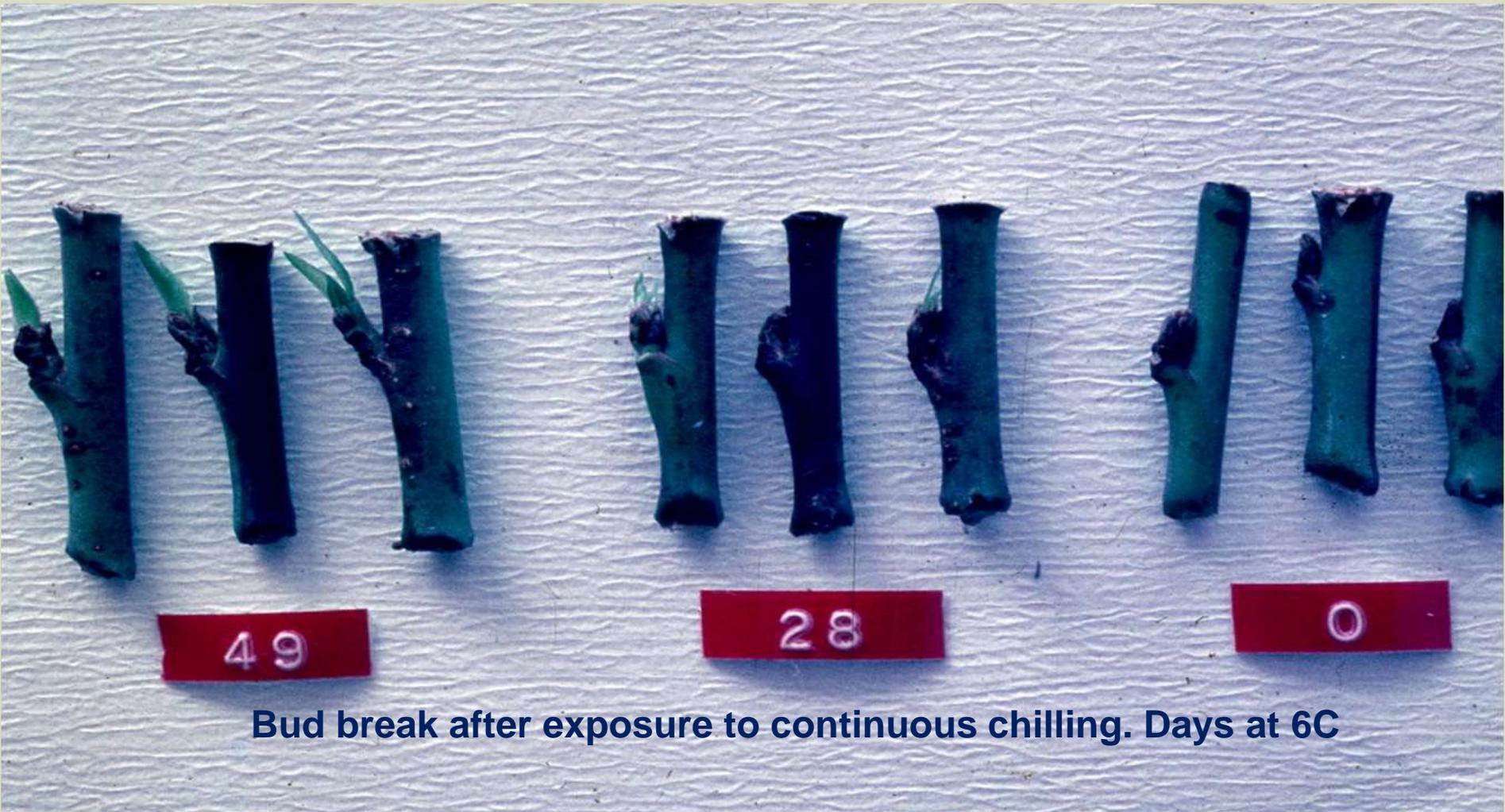
Factors that Enhance Chilling Requirements

Requirements

- Vertical growth and resulting apical dominance
- Excessive vegetative growth increases markedly the chilling requirements of the buds



Dormancy of the individual bud (no transfer of chilling)



Bud break after exposure to continuous chilling. Days at 6C

POOR LEAFING DUE TO LACK OF CHILLING

APPLE



APRICOT



PEACH



Dormancy completion- a dual response

- Most of the works evaluating dormancy completion, rely on measuring the level of bud breaking or the time needed for buds to break under forcing conditions.
- Climatic models present quantitative values regarding chilling requirements. But it is clear that dormancy completion has many qualitative values that are not considered by the models. In most cases, the evaluation of bud break is limited to the initial stages of bud opening in both vegetative and floral buds.

The idea of “chilling requirement” means that once the dormant state has been completed, normal development will be attained. This regards completion of dormancy as a **yes or no effect** rather than a gradual response. This reasoning led to evaluate only the initial stages of bud breaking as the measure of dormancy breaking.

In practice, the effect of breaking bud dormancy is far reaching and has an impact on the development after bud breaking. Growth vigor is tied to the rate of dormancy completion in a quantitative manner.

Vegetative buds

- After exposure to sufficient chilling, growth is rapid and vigorous. When buds are exposed to warm winters growth is sluggish and poor. Under certain conditions, budbreak may be high but all vegetative buds will form rosettes.
- The following abnormal development symptoms connected to dormancy were noted:
 - Low vigor rosette formation
 - Chlorotic growth
 - Increase in sucker production

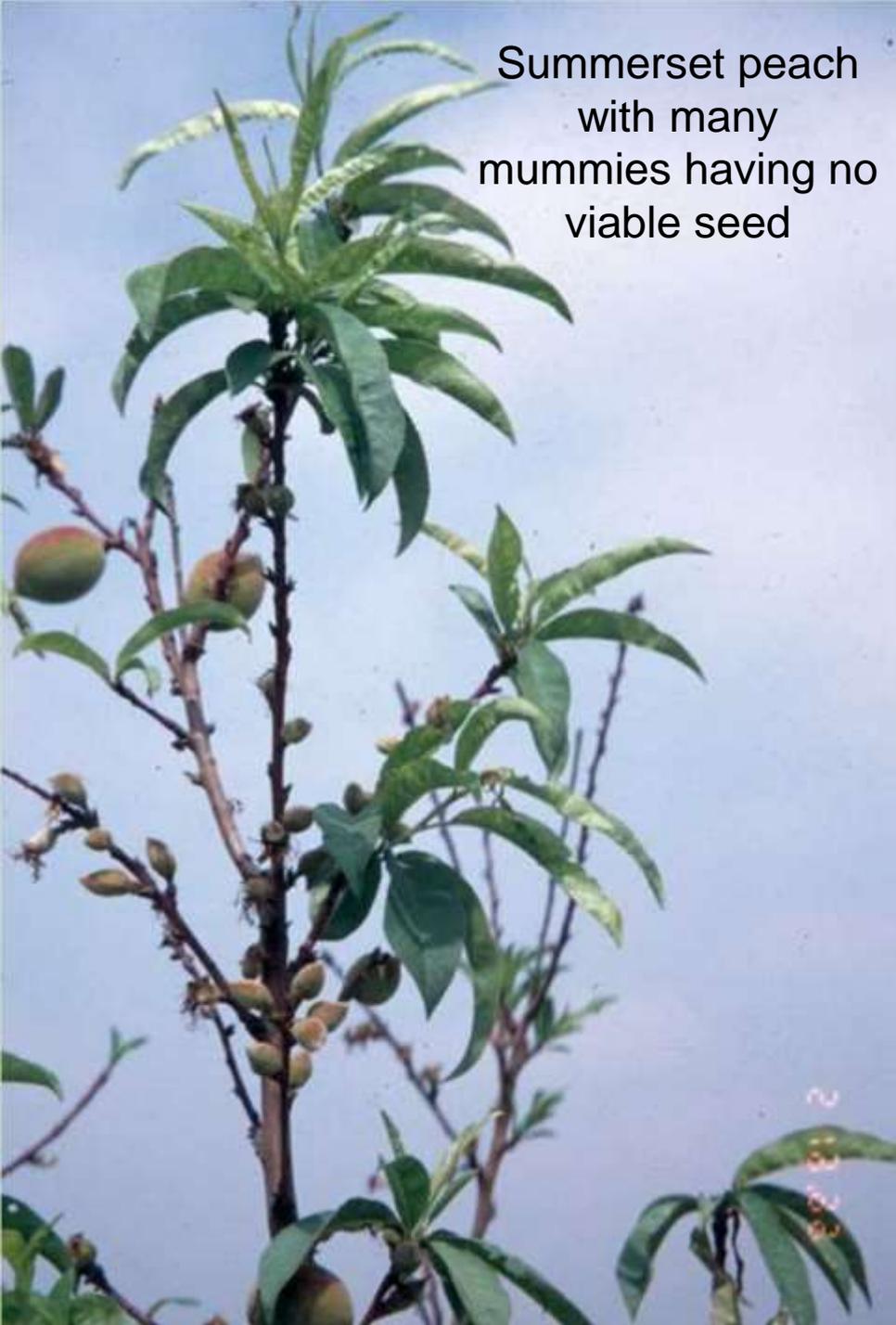
Floral Buds

- Floral buds, especially in stonefruit species, may break satisfactorily but will not set normal fruit. It seems that specific climatic conditions may affect normal development of the flower bud.
- Clearly heat spells during winter may have a non-reversible effect on the development of the flower bud leading to non functional ovaries.
- The following abnormality on stonefruit species was noted:
 - Double pistiles -double fruits
 - Small styles
 - Lack of styles
 - Lack of the whole female part
 - Poor pollen production
 - Poor nectar production, no attraction for bees
 - Small petals
 - Early aging of flowers

Specific temperature effects on floral buds

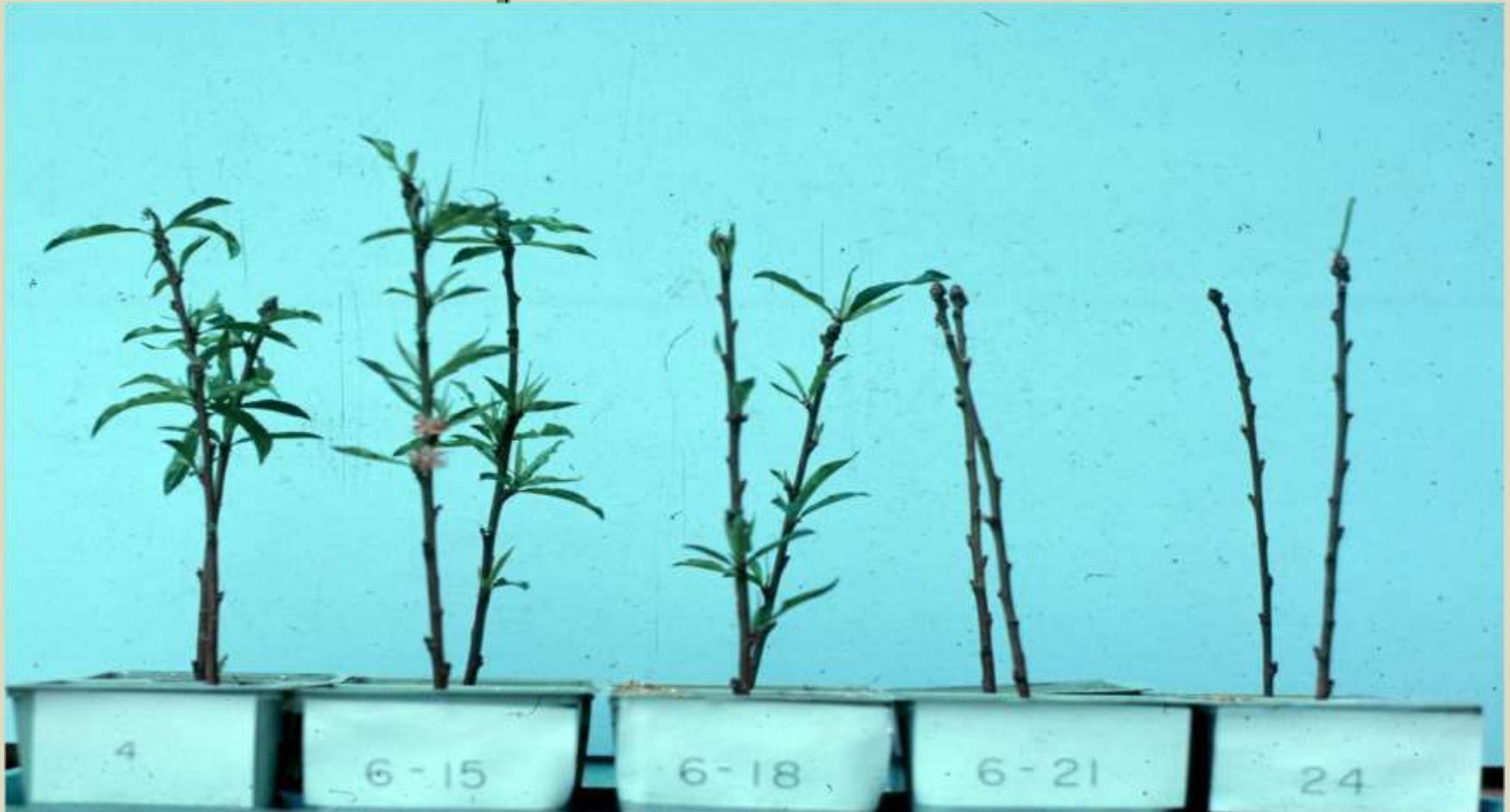
- Floral buds of stonefruit species are very sensitive to climatic conditions and to chemicals, more than other organs. Extreme conditions will damage the bud and may cause death.
- The floral bud completes its development only after complete chilling accumulation.
- Specific climatic conditions, especially heat spells even in winter, will interfere with normal flower bud development. Under such conditions, completion of chilling requirements will not improve fruit set and yield.
- Promotion of vegetative buds at the time of bud break will affect the competitive power of the floral bud and will reduce the potential fruit set.

Summerset peach
with many
mummies having no
viable seed



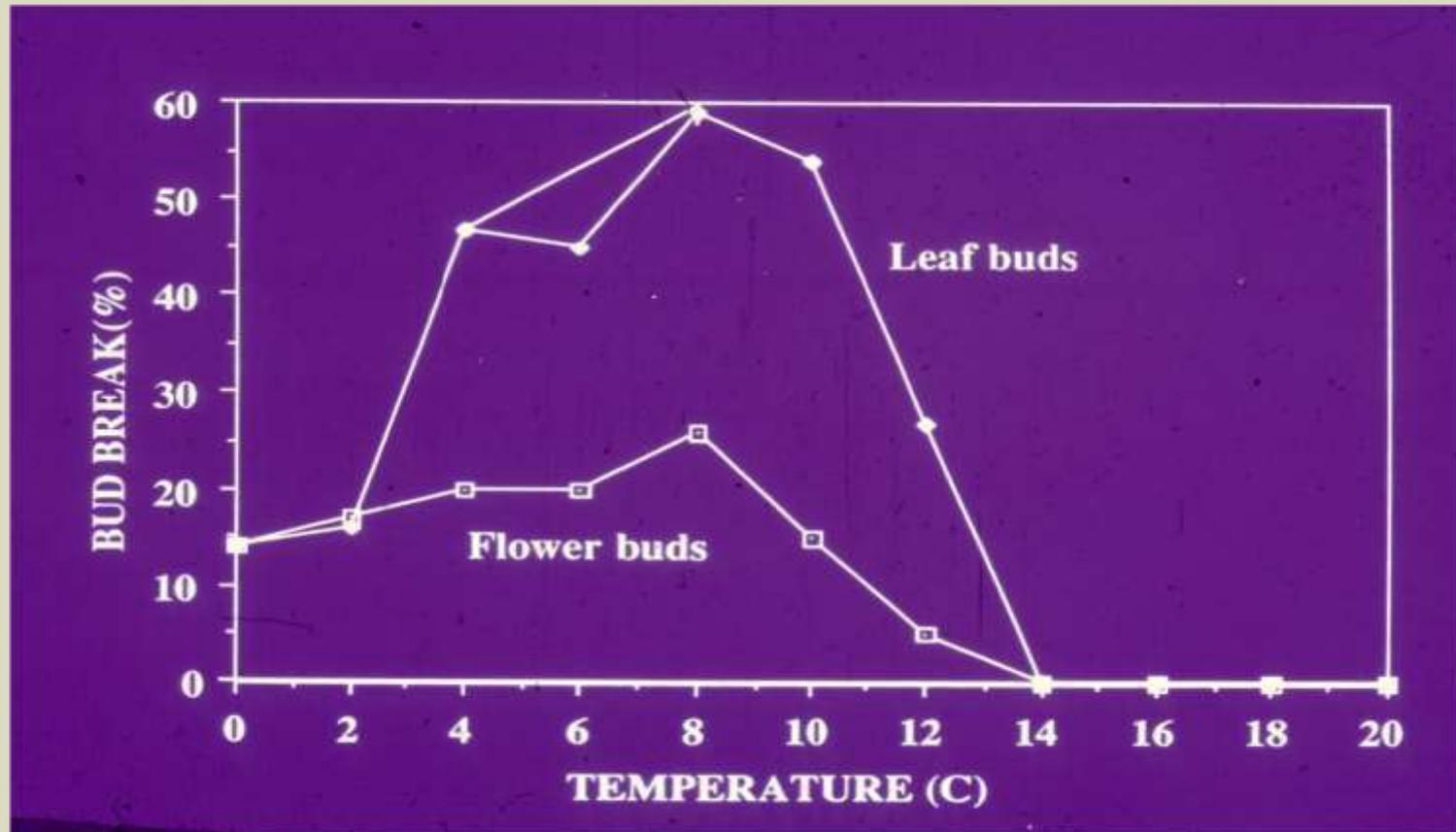
- Small abnormal nectarine fruit after a heat spell had occurred in winter

Examining chilling requirements in peach buds



Testing the effect of high temperature on chilling in a daily cycle.
6C for 16 hrs, high temperature for 8 hrs.

Low temperature effects: Effect of the same duration of exposure to different temperatures on the level of bud break in Redhaven



1. THE LOW TEMPERATURE EFFECTS IN THE PEACH

A. optimal effect at 6-8C

B. No effect at 14C or higher

C. Low effect at 0C and no effect at
negative temperatures

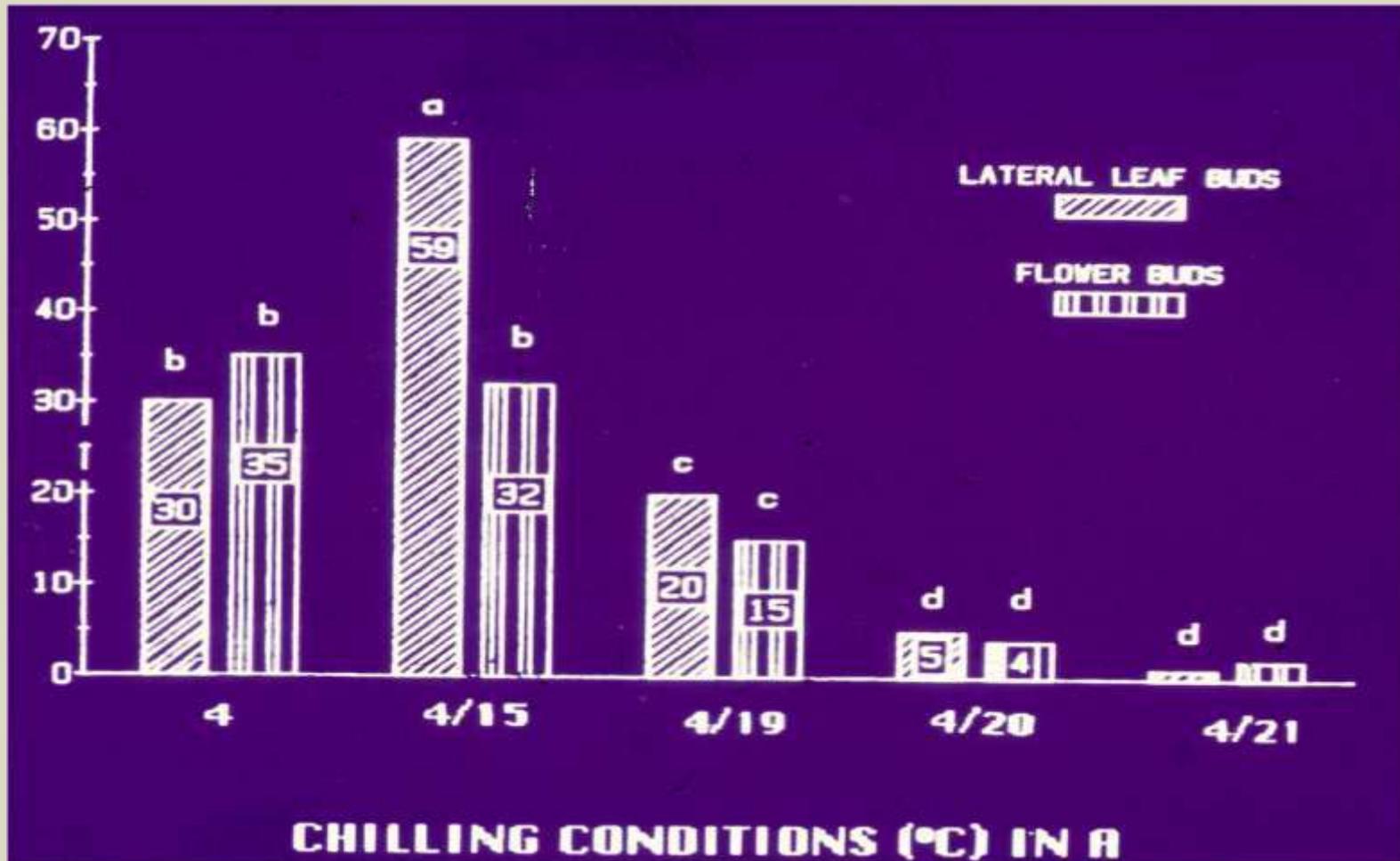
2. THE HIGH TEMPERATURE ANTAGONIZING EFFECT

A. THE TEMPERATURE LEVEL

**B. THE LENGTH OF THE CYCLE
OF LOW - HIGH TEMPERATURES**

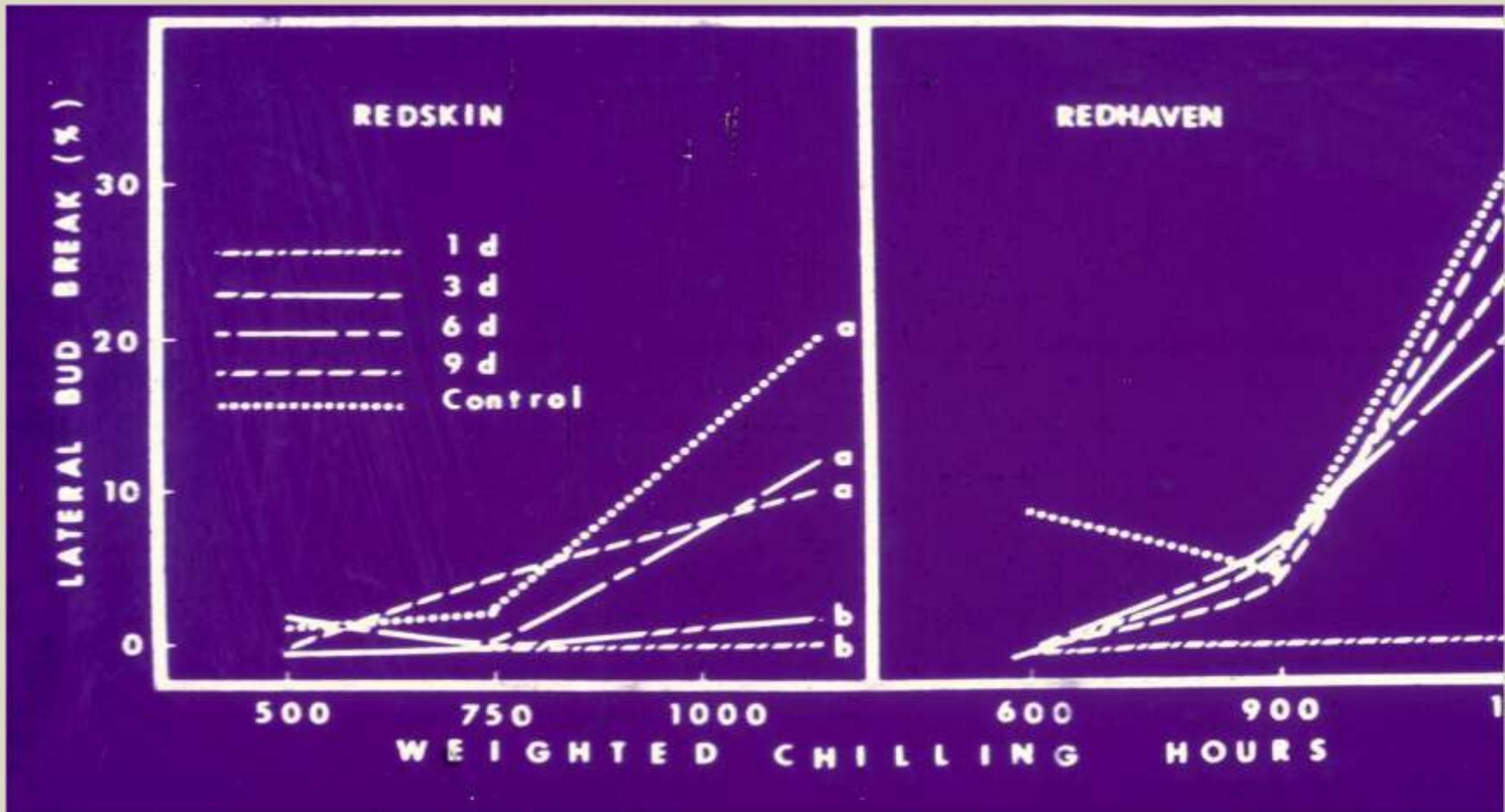
**C. THE HIGH TEMPERATURE
DURATION IN THE DAILY CYCLE**

a. TEMPERATURE LEVEL: Effect of high temperature on chilling negation in the peach. [Exposure to low (16 hours) and high (8 hours) temperatures in a diurnal cycle compared to continuous 4C. Equal chilling in all treatments. Bud break after 21 days at 25C.]



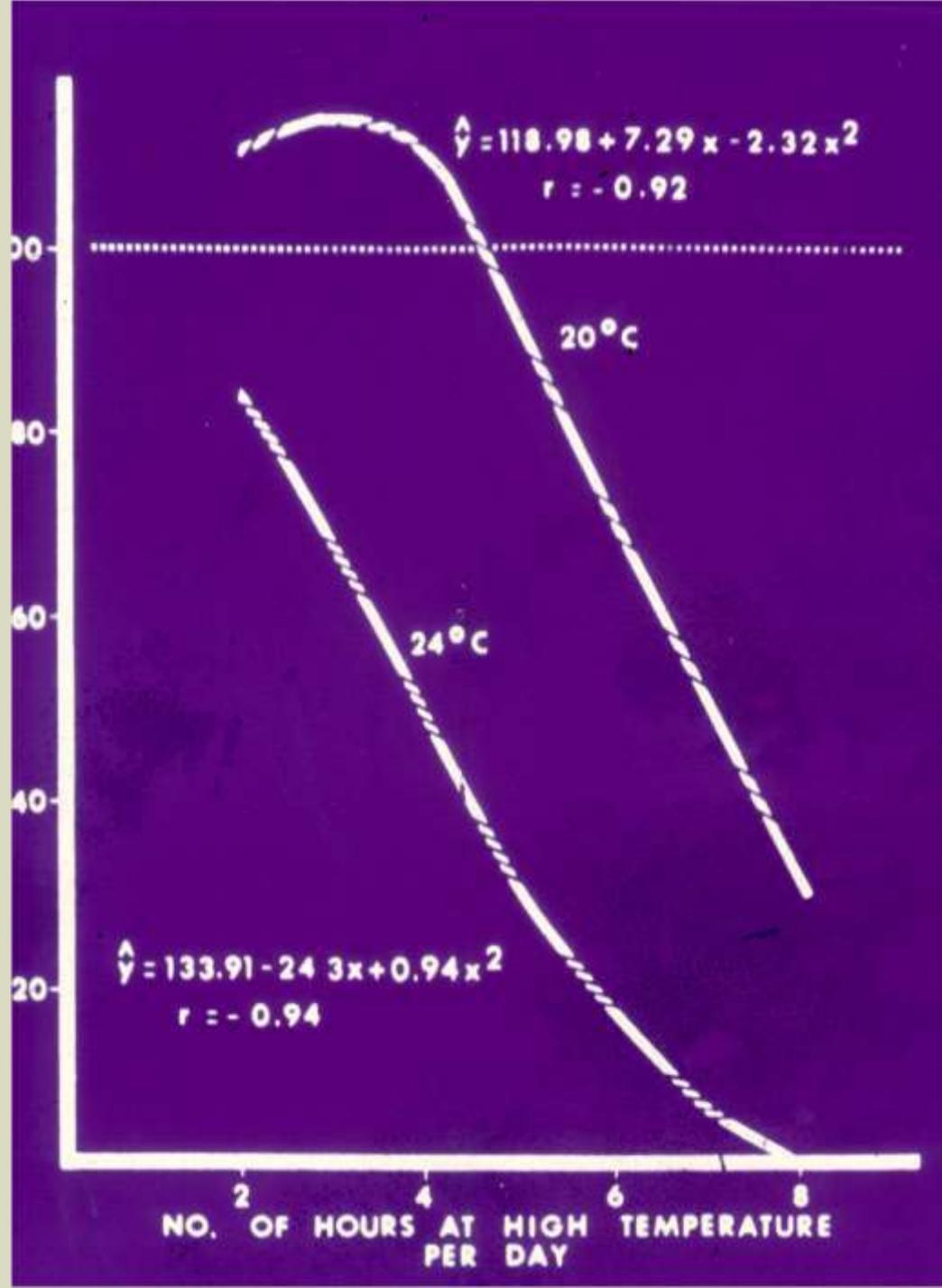
b. THE EFFECT OF CYCLE LENGTH

on chilling negation by high temperature. All chilling at 6C and heating at 24C where identical [Level of negation is rapidly reduced with increase in cycle length]



c. HIGH TEMPERATURE DURATION IN A DAILY CYCLE

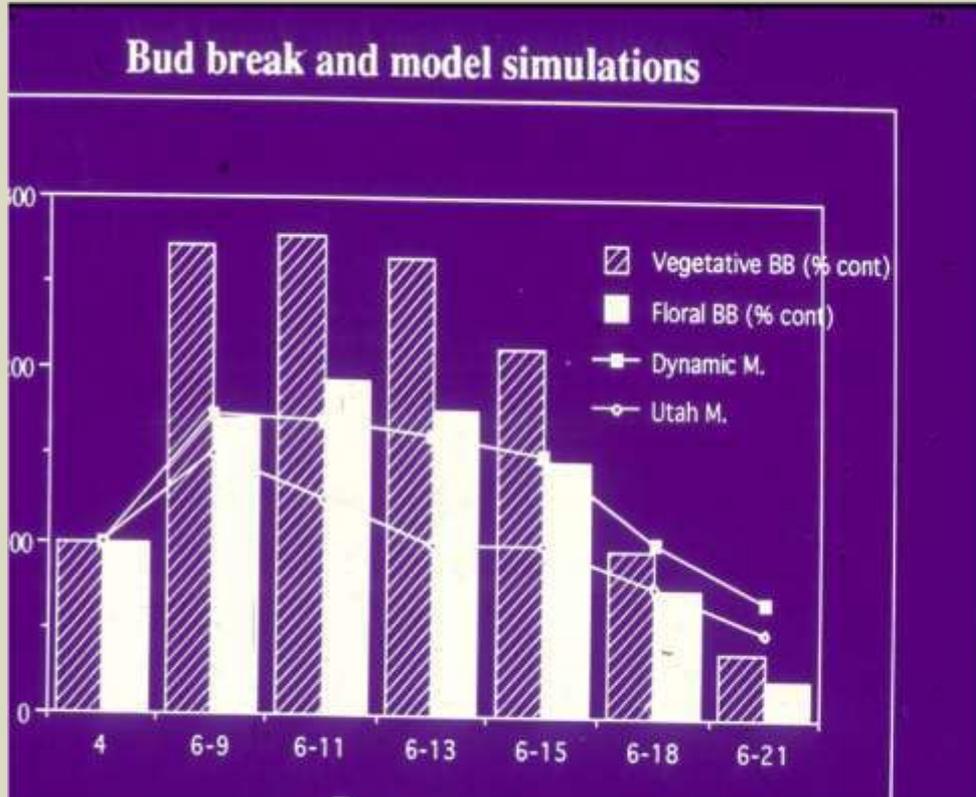
The effect of different durations of exposure of small peach trees to 20 or 24C in a daily cycle. Total chilling exposure was the same for all treatments at 6C.



3. The moderate temperature effect

- Moderate temperatures (12-16C) enhance the chilling effect when cycle with lower temperatures

THE MODERATE TEMPERATURE PROMOTIVE EFFECT



- DEPENDS ON FORMER EXPOSURE TO LOW TEMPERATURE
- 13-15C HAVING NO DORMANCY BREAKING EFFECT ENHANCE BUD BREAK WHEN CYCLED WITH LOW TEMPERATURE

Chilling applied to all treatments was the same

Chilling Requirements - Summary

Based on work under controlled conditions with peaches, the following 3 temperature effects have been defined:

1. The favorable effect of chilling occurs maximally at 6C and declines to no effect below 0C and above 13C.
2. Negation of prior chilling can occur at temperatures higher than 18C in short (daily) cycles with the negation effect increasing with duration of heating in the day cycle and with the level of temperature.
3. A moderate temperature effect at 12 to 15C has shown a synergistic effect when alternated with chilling temperatures.

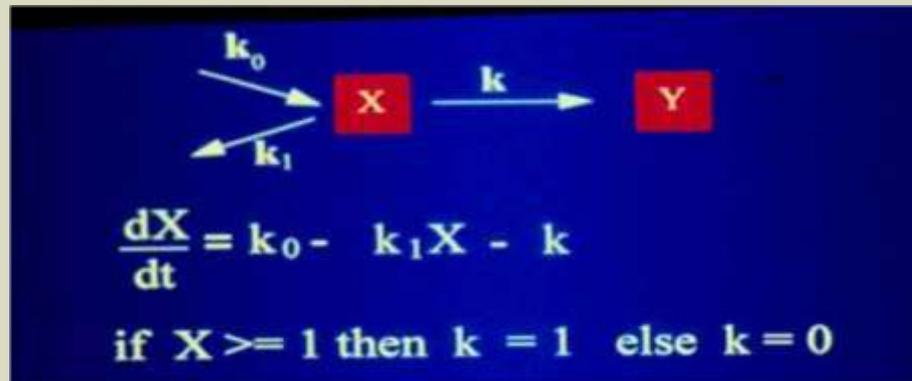
The Dynamic model was developed on the basis of the data presented

THE BASIC FUNCTIONS OF THE DYNAMIC MODE

X IS THE REVERSIBLE INTERMEDIATE, Y THE FINAL PRODUCT

X INCREASES TO HIGHER LEVELS AT LOW TEMPERATURES BECAUSE THEN $k_0 > k_1$

WHEN X REACHES LEVEL 1 THERE IS A TRANSITION OF X TO Y



The Temperature Dependence of Dormancy Breaking in Plants: Mathematical Analysis of a Two-Step Model Involving a Cooperative Transition

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A two-step model describing the thermal dependence of the dormancy breaking phenomenon is developed. The model assumes that the level of dormancy completion is proportional to the amount of a certain dormancy breaking factor which accumulates in plants by a two-step process. The first step represents a reversible process of formation of a precursor for the dormancy breaking factor at low temperatures and its destruction at high temperatures. The rate constants of this process are assumed to be dependent upon the temperature according to the Arrhenius law. The second step is an irreversible cooperative transition from the unstable precursor to a stable dormancy breaking factor. The transition is assumed to occur when a critical level of the precursor is accumulated. The two-step scheme is analysed mathematically. This model explains qualitatively the main observations on dormancy completion made under controlled temperature conditions and relates the parameters of the theory to the measurable characteristics of the system.

Dynamic Model

Reversible process

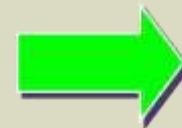
*Chilling
Temperatures*



Precursor



Intermediate



*Chill
Portion*

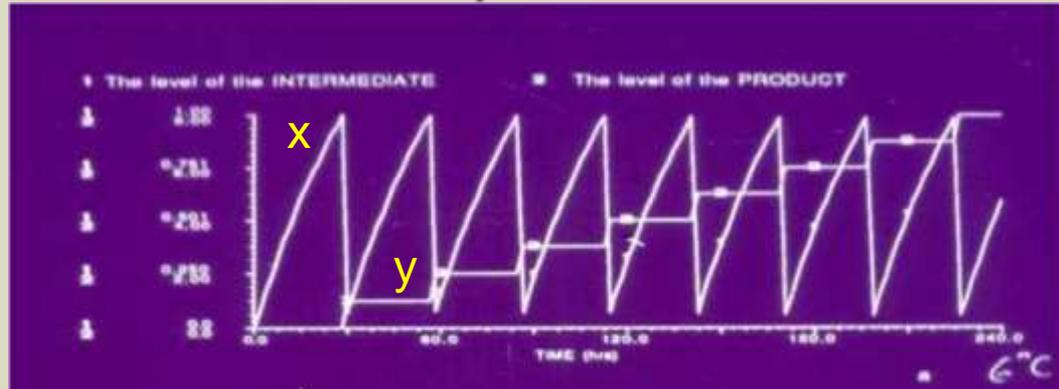


Irreversibly fixed

*High temperatures
negate chilling*

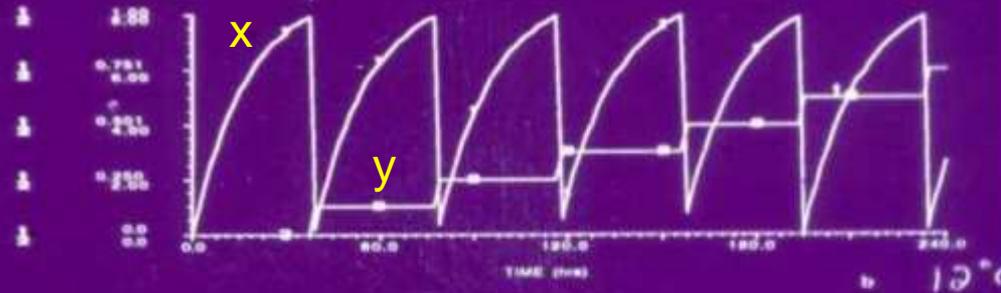
Simulation of chilling portions accumulation during 240 hours at 6, 12 and 14°C

Continuous normal accumulation of Y



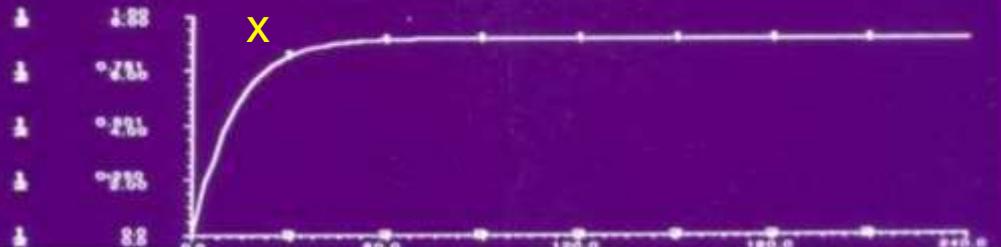
6C

Slower accumulation of Y because of longer time to build up X



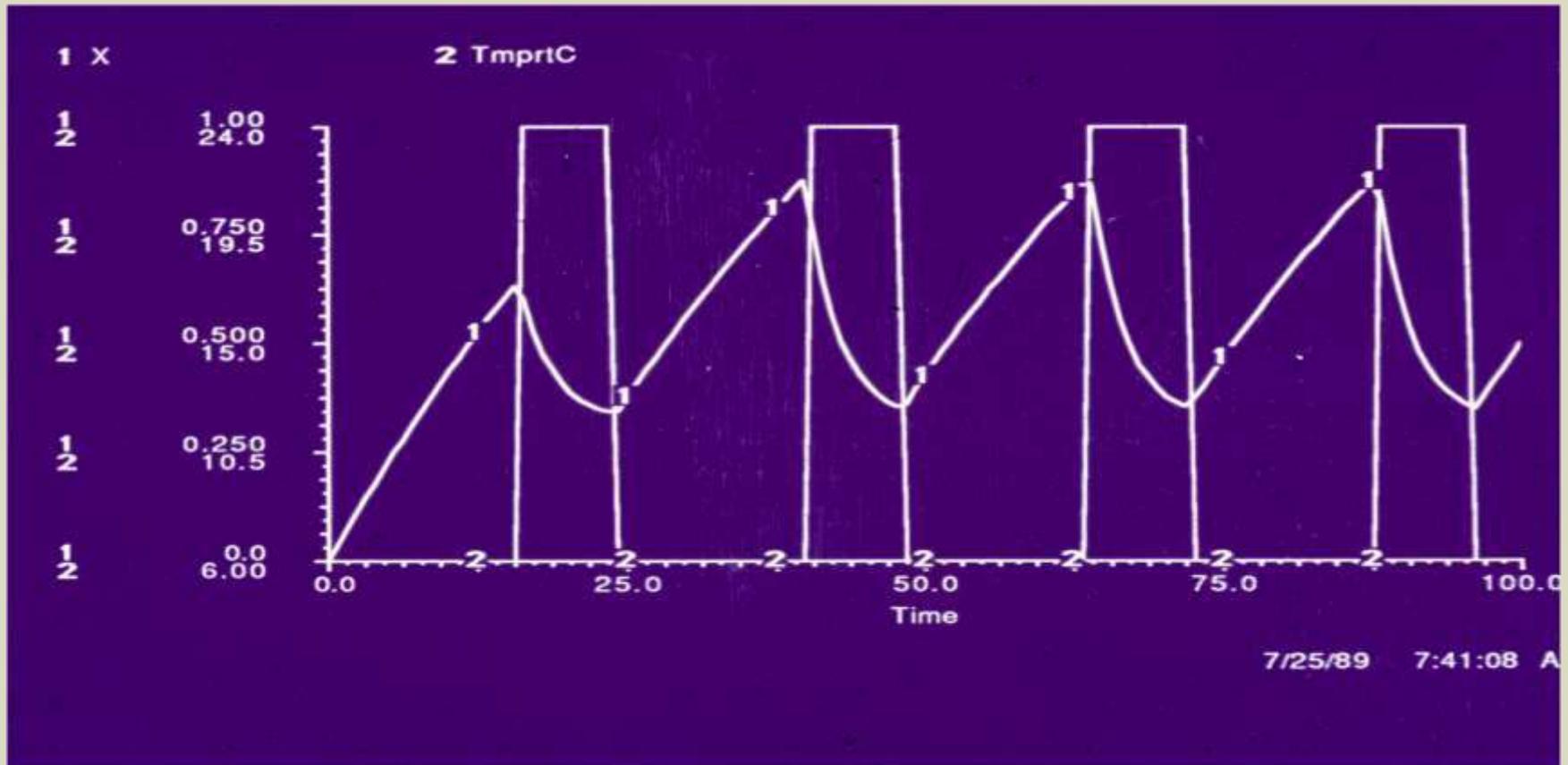
12C

No accumulation of Y since X never reaches its critical level

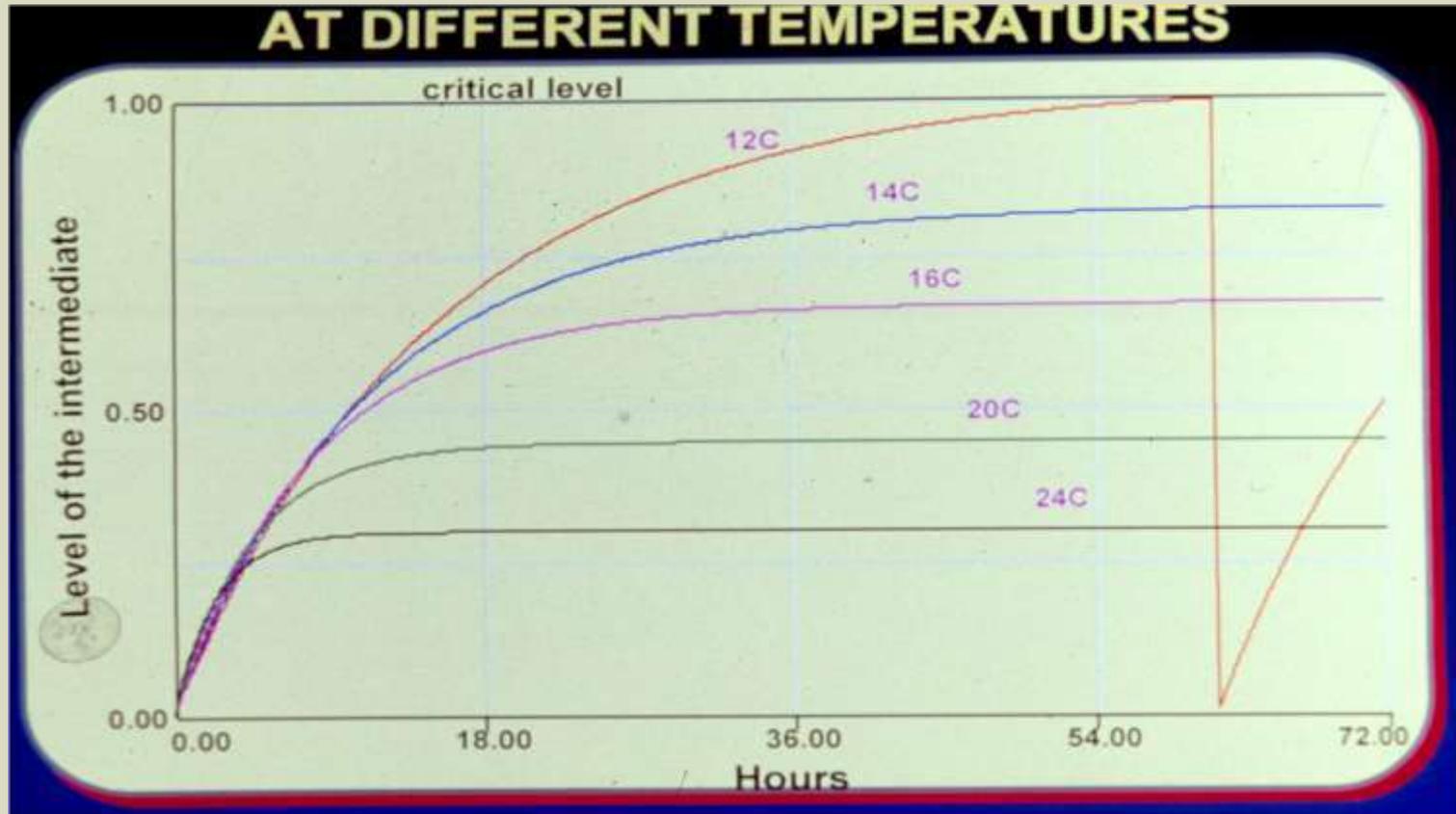


14C

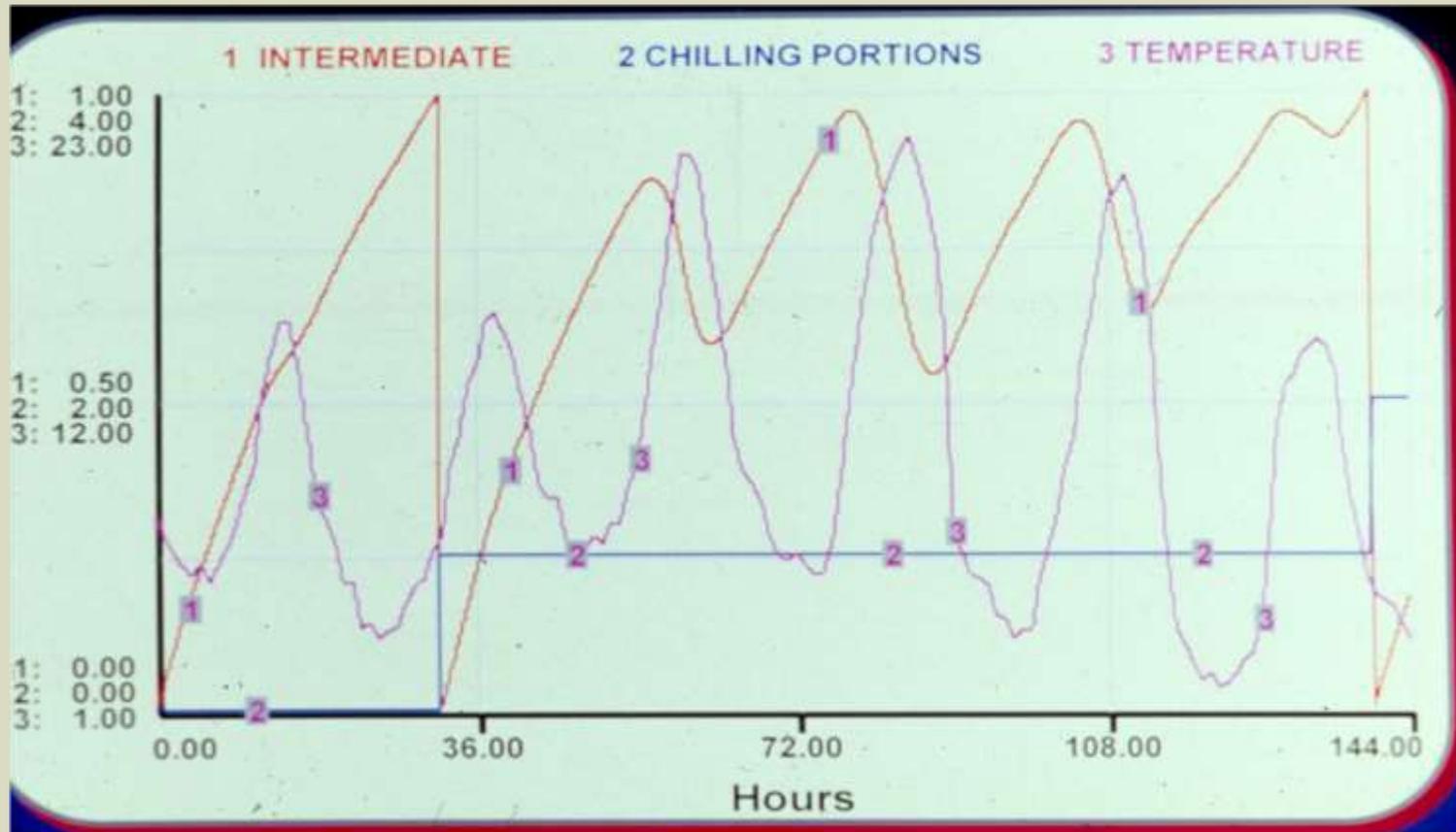
Changing level of the intermediate at a 6-24 C in a 16 h -8h cycle



Accumulation of the intermediate



Changing intermediate and accumulation of chilling portions with natural temperatures



Estimation of chilling portions of flower buds

Chilling portions (+ leaf buds)

PEACH

Flordaprince	12
Maravilha	18+22
Earligrande	18
83-4W	18+25
Flordaglo	18+22
Rhodes	30
Summerset	40

NECTARINE

Aprilglo	12
Fiestared	18
Redglo	18
Sunsnow	18
9-11N	18
9-6N	18+22
84-16N	18
85-6N	18
Sunblaze	20
Mayglo	22
Rhodes	30
Flavortop	35
Fantasia	42

Chilling portions (+ leaf buds)

APRICOT

Canino	30+35
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APPLE

Golden Delicious	48+52
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SWEET CHERRY

Lapins	36
Rainier	46
Bing	49
Burlat	52
Chinook	52
Sam	70

Possible effects of global warming for deciduous fruit trees

From prediction of increase in minimum as well as in maximum temperatures far reaching consequences can be deducted:

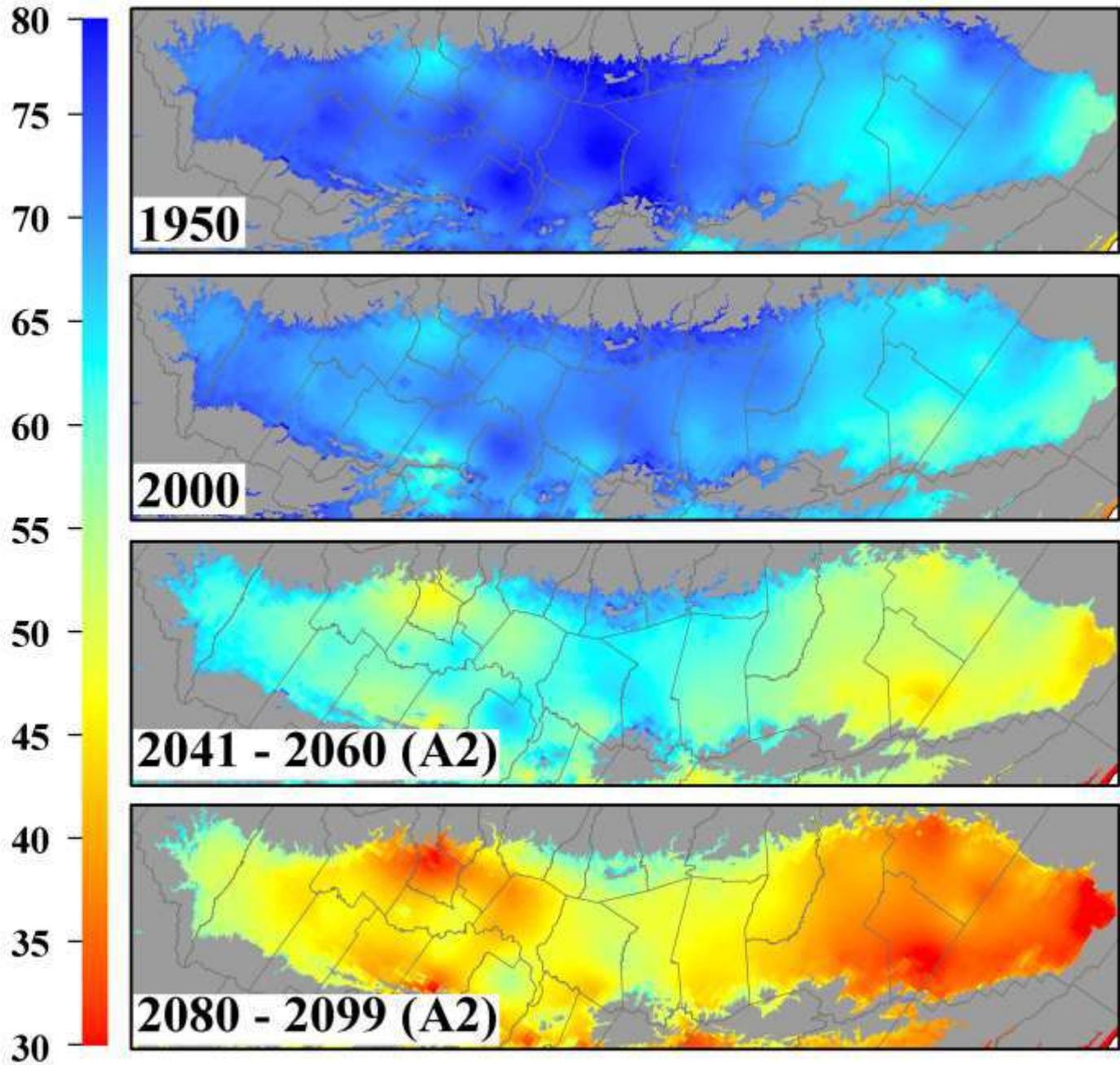
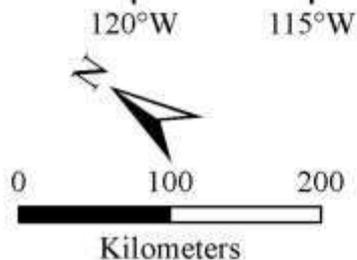
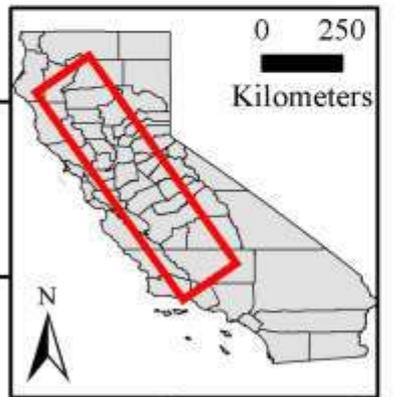
- Increase in minimum temperatures under marginal conditions will reduce chilling portion accumulation. In addition increase in maximal temperatures will result in a higher level of chilling negation.
- The combined effect will result in smaller accumulation of chill portions and increase difficulty in getting good bud break
- In addition, for stone fruit species, damage to normal development of flower buds is expected

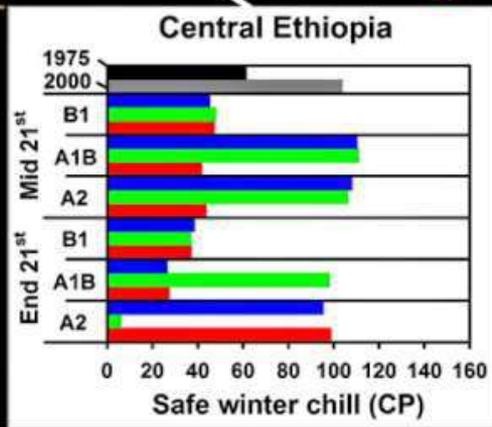
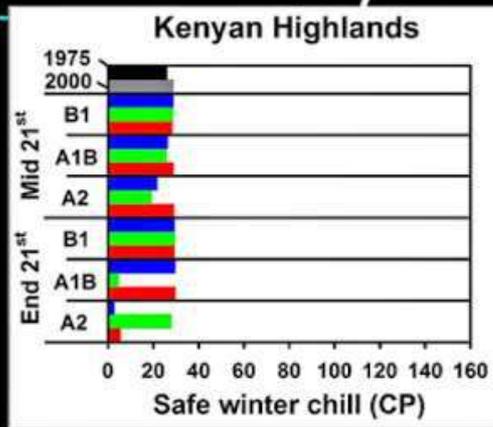
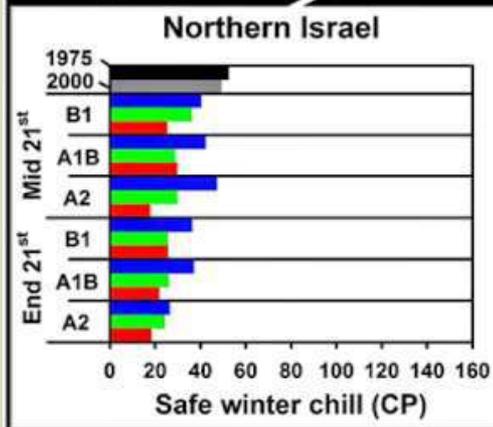
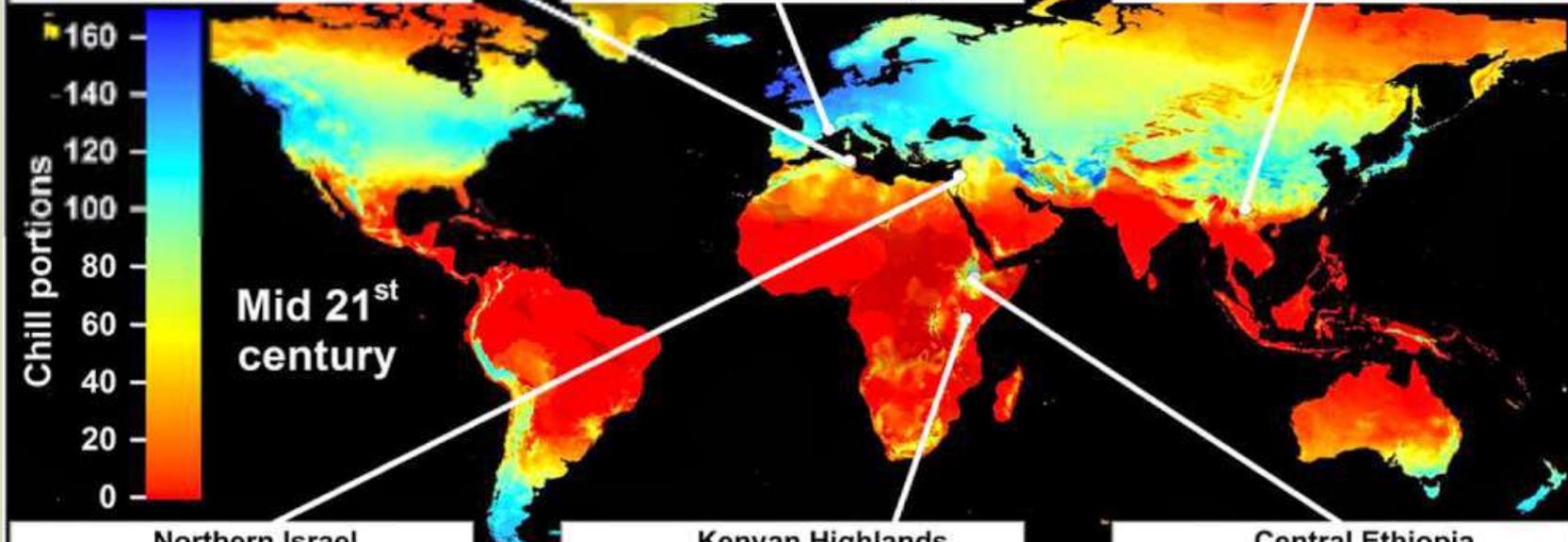
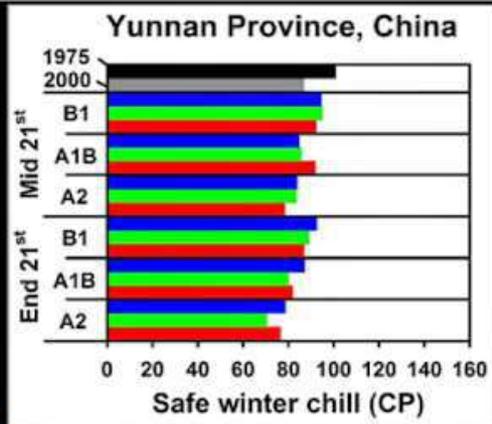
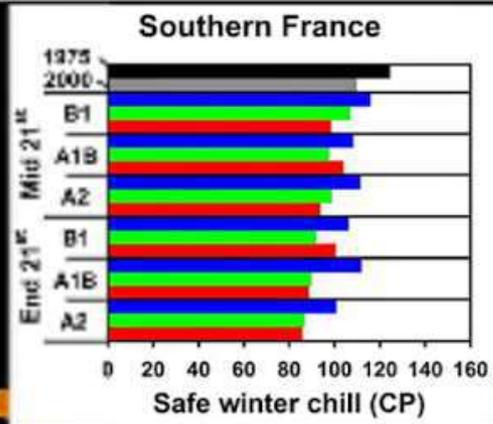
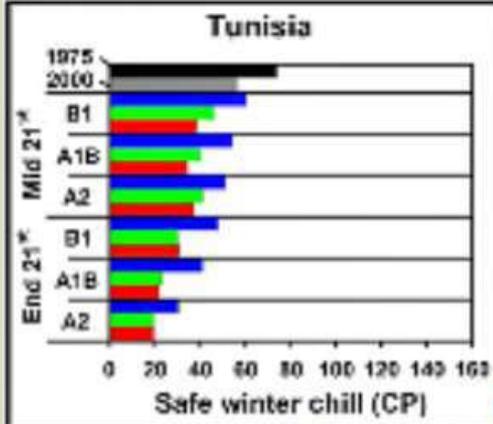
Prediction of temperature increase in California central valley

Declining winter chill for fruit and nut trees in California

Eike Luedeling
Minghua hang, Evan Girvetz

Safe winter chill (Chill Portions)





This map was produced by Luedeling et al.*

It is based on three scenarios of world activity to reduce output of greenhouse gases:

B1 which considers a very strong activity.

A1B which considers strong activity but a late start.

A2 which considers no activity at all.

It takes into consideration 3 climatic models:

1.HADCM3 (blue)

2.CSIRO (green)

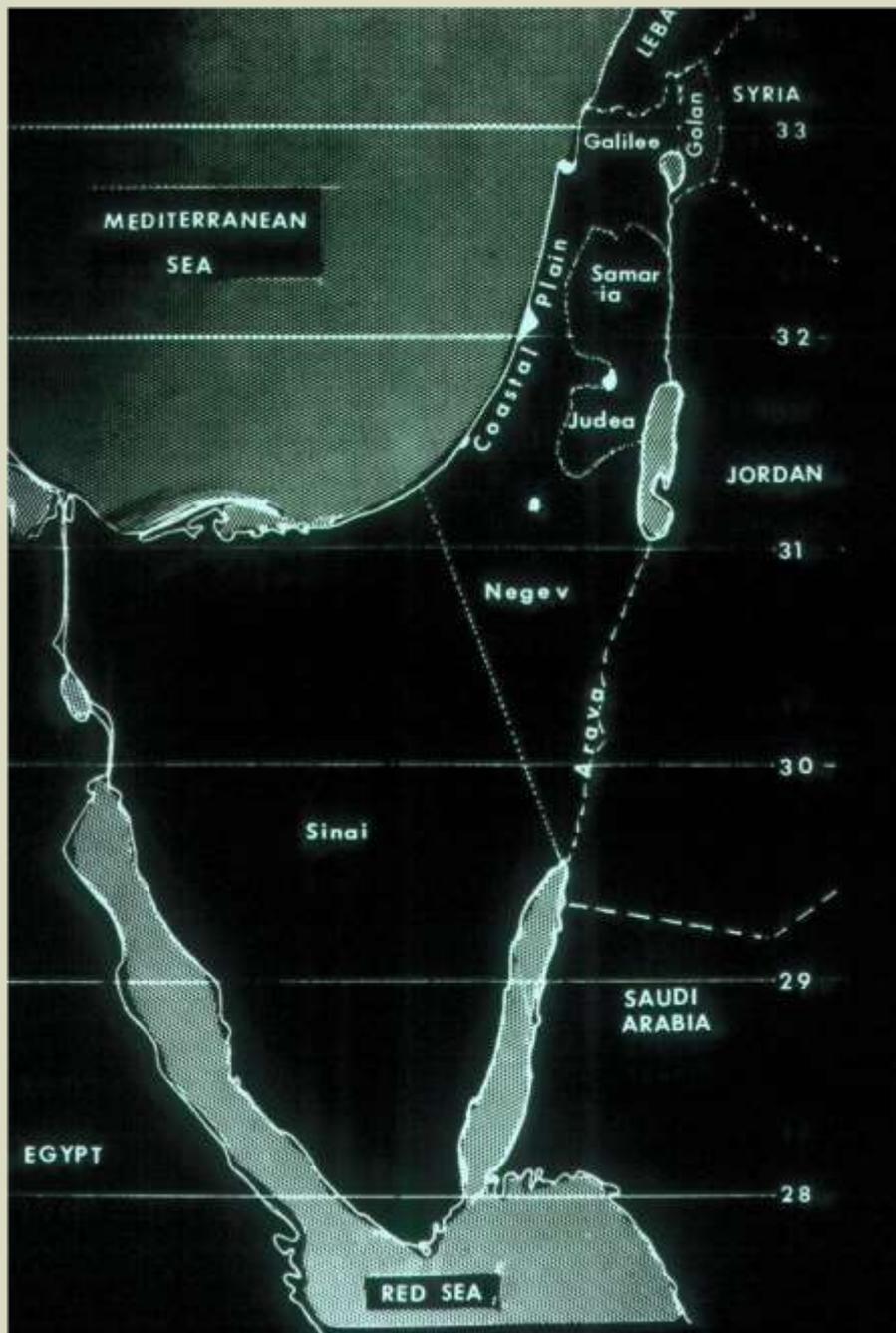
3.MIROC (red)

The calculations are based on chill portions of the dynamic model.

1 chill portion equals 28 hrs of exposure to 6C.

Safe winter chill means at least 90% probability of having the designated chilling portions.

*Luedeling E., Girvetz E.H., Semenov M.A., Brown P.H. (2011): Climate Change Affects Winter Chill for Temperate Fruit and Nut Trees. Plos One 6: e20155

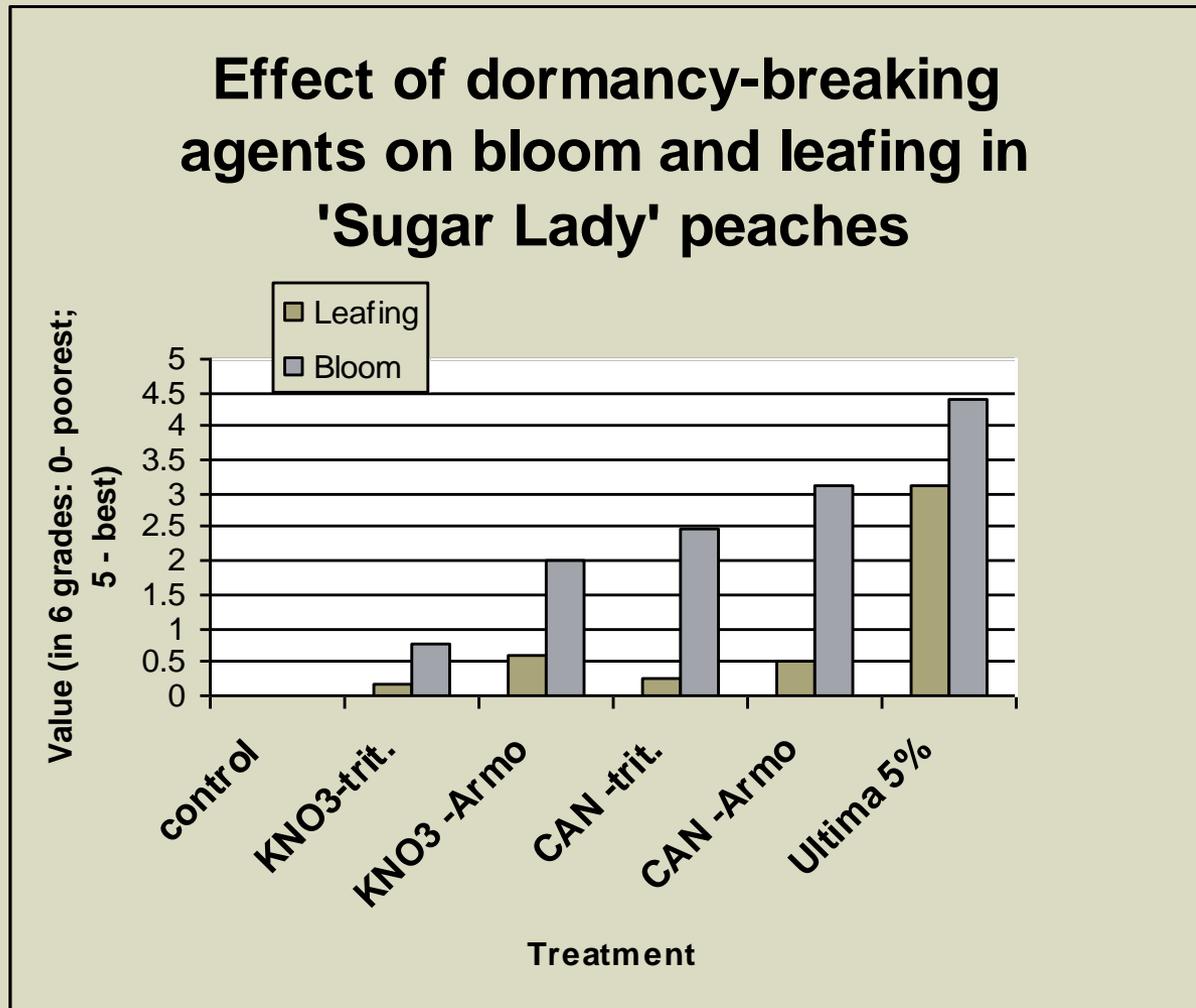


MAP OF ISRAEL AND NEIGHBORING COUNTRIES

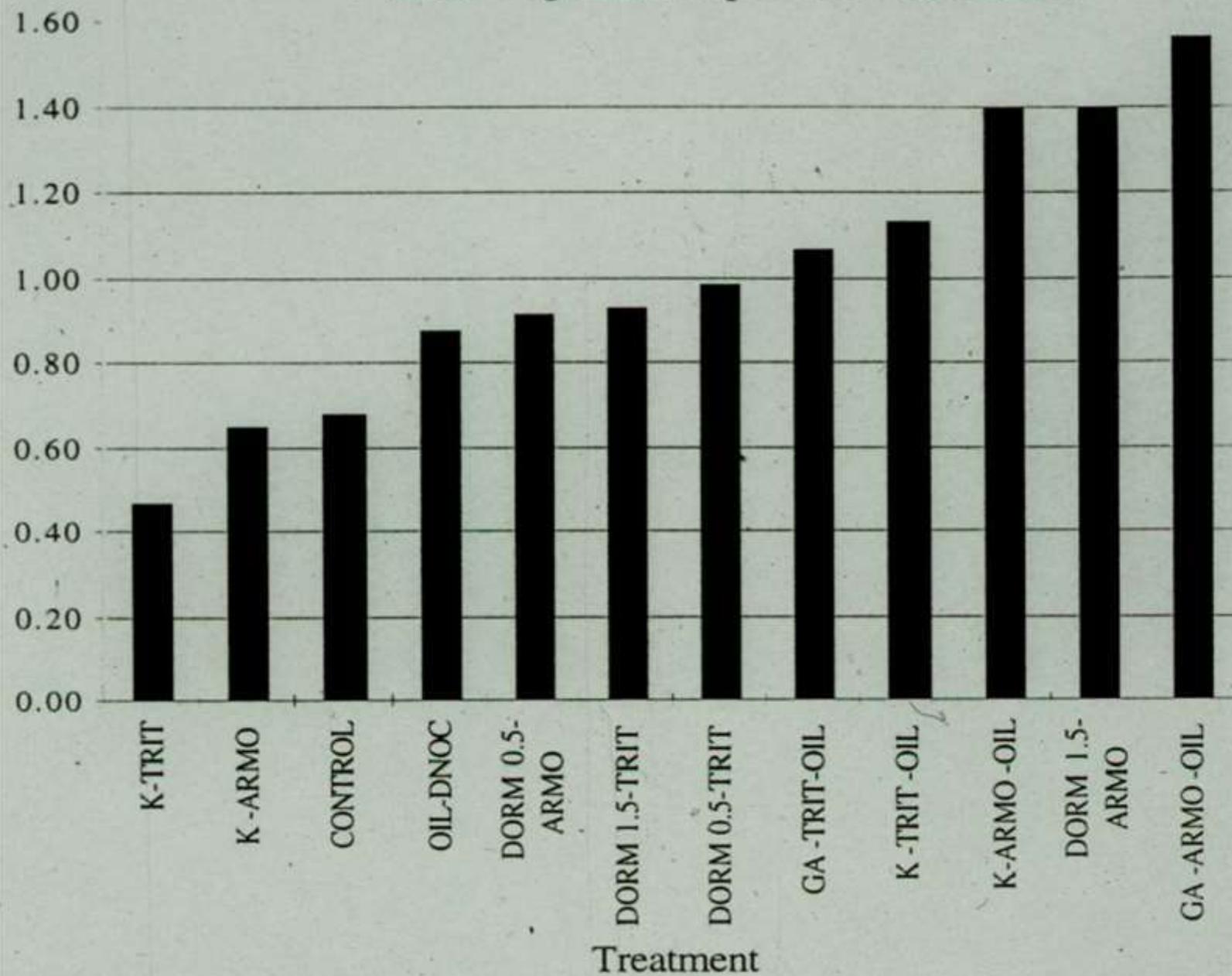
Problems with dormancy breaking chemicals

- Two drawbacks of using dormancy-breaking agents are apparent: Their possible human toxicity and their possible phytotoxicity.
- Many potent dormancy-breaking agents were taken off the market notably oil-DNOC because of human and environmental toxicity.
- Oils, dinitro compounds, Dormex and other chemicals were found to cause damage to the tree especially to flower buds leading to drop in yield. Especially susceptible were found stone fruit species having simple, less protected, flower buds. While other chemicals having a mild effect (like KNO_3) not enough to compensate for the lack of chilling in various locations.

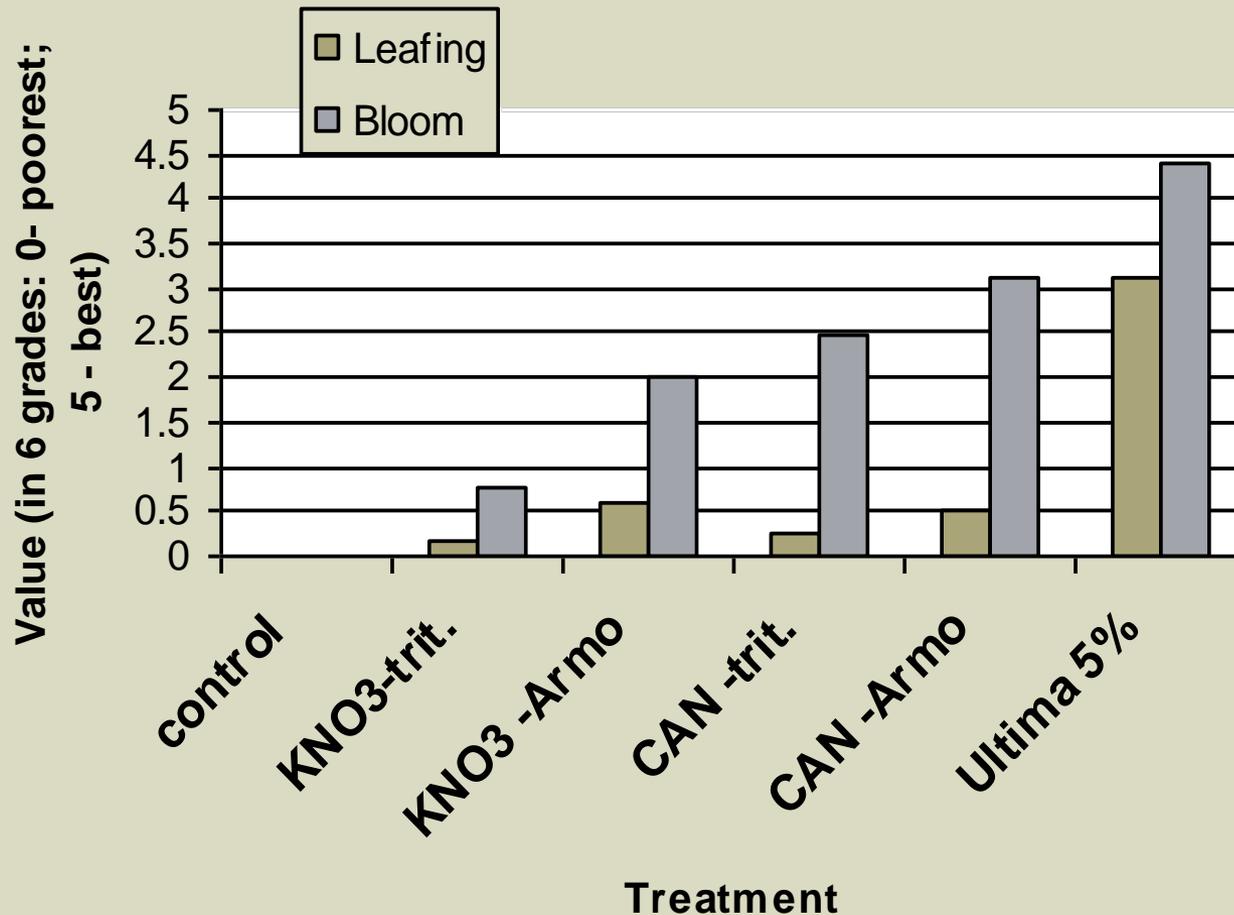
New chemicals to break dormancy



Ratio Vegetative/ reproductive bud break



Effect of dormancy-breaking agents on bloom and leafing in 'Sugar Lady' peaches



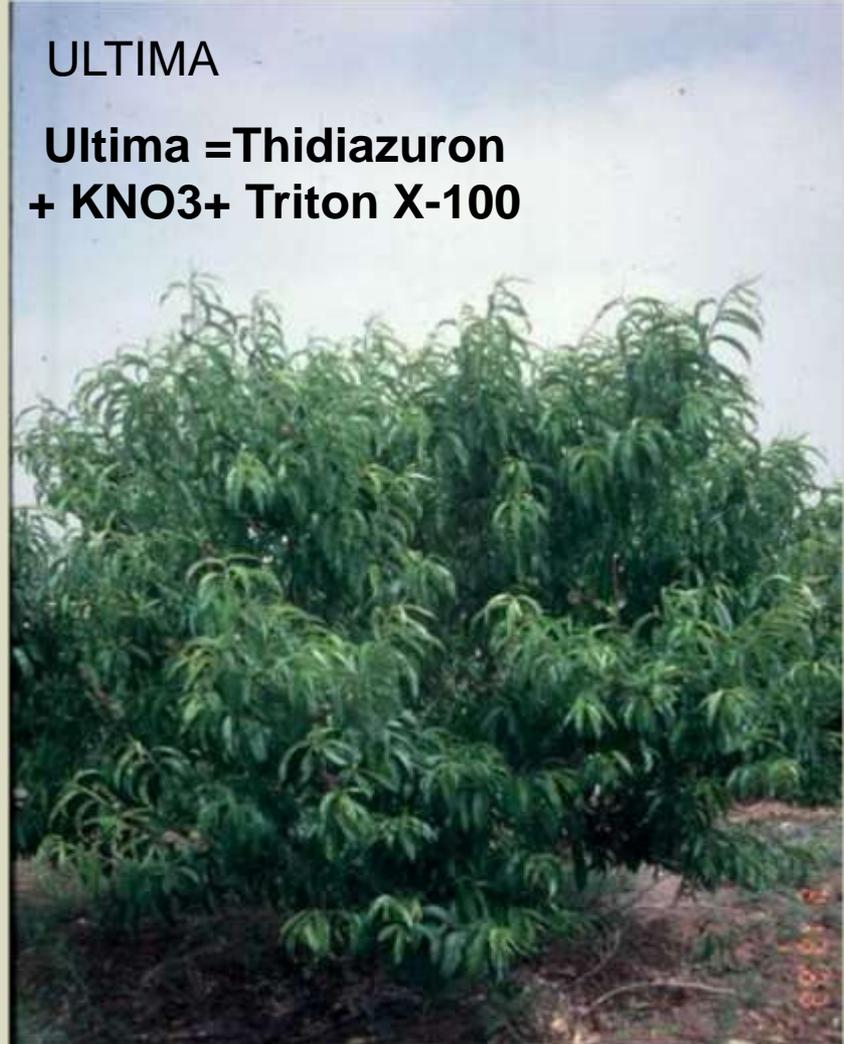
EFFECT OF ULTIMA ON BREAKING BUD DORMANCY IN THE 'WHITE LADY' PEACH

CONTROL



ULTIMA

**Ultima =Thidiazuron
+ KNO₃+ Triton X-100**





**Yield on Ultima* -
treated 'White Lady'
tree.**

**No yield on the
control tree**

***Ultima = Thidiazuron
+ KNO_3 + Triton X-100**

Advancement of fruit maturation

Effect of Ultima
(Thidiazuron and KNO_3) on
the 'White Lady' Peach and
the Wickson plum in
Comparison to oil-DNOC

By replacing missing cold,
early bud break occurred
and early fruit development
will lead to early fruit
ripening.



Effect of oil-Thidiazuron and oil on bud break and fruiting in the 'Maravillia' peach in comparison to other dormancy-breaking agents

Treatment	Evaluation bloom (1-10) 14/1/02	Evaluation leafing (1-5) 14/1/02	Total harvest kg/ ha In 2 pickings till 22.4.02
Control	0.13c	0c	500b
Oil-DNOC	1.00c	0c	1130b
Oil-DNOC Dormex 0.5%	2.25b	0.3c	3510b
Oil 75 ppm TDZ EC	4.88a	1.8b	13910a
Oil 100 ppm TDZ EC	5.63a	2.4a	14540a

Comparing the effect of Armobreak with a few dormancy-breaking agents on 'Rhodes' peach (opening buds on a standard 30 cm shoot)

Treatment*	Flowers/shoot	Veg. buds Breaking/shoot	Ratio floral/ veg. budbreak
Control	4.84	3.28	1.47
Oil+DNOC	5.94	5.18	1.15
GA+Trit+Oil	4.03	4.29	0.93
GA+Armo+Oil	3.48	5.43	0.64
K+Trit	5.50	2.58	2.13
K+Armo	6.75	4.36	1.54
K+Trit+Oil	4.09	4.64	0.88
K+Armo+Oil	3.59	5.02	0.71
Dorm 0.5+Trit	4.48	4.40	1.02
Dorm 0.5 +Armo	4.95	4.53	1.10
Dorm 1.5+Trit	4.60	4.26	1.07
Dorm 1.5+Armo	3.59	5.02	0.71

In all pairs Armobreak had a stronger effect on Vegetative bud break. On Floral buds it depends on the added chemical.

Ratio Floral/vegetative Bud break equaled or surpassed control only in KNO₃ treatment

*DNOC - Dinitro-ortho-cresol applied at 0.075% with oil

Armo - Armobreak at 1%

Oil - White superior oil at 5%

GA - Gibberellic acid at 50 ppm

Trit - Triton X-100 at 0.025%

K - KNO₃ at 5%

Dorm - Dormex at either 0.5 or 1.5%

- Dormancy breaking chemicals can also improve lateral bud break and branching by reducing apical dominance effect and thus be of help in tree training and in improving lateral bud break.
- Timing of the treatment is critical to get the specific response.
- Terminal buds always have lower chilling requirements than lateral buds. Late application of a dormancy breaking agent may inhibit advancing terminal buds.