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THE CLIMATIC DETERMINISM OF VEGETATIVE BUD BREAK ON PEACH TREES WITH NO EXPOSURE TO CHILLING : SOME EXPERIMENTAL RESULTS

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Abstract

The influence of the climatic factors on bud break in trees deprived from chilling is still poorly documented, due mainly to lack of experiments under well controlled conditions. Using a greenhouse (the temperature was maintained above 15°C) and chambers with well controlled temperature and photoperiod, we applied 5 treatments to peach trees : they all included the same chilling deprivation from October onwards. From the end of March onwards the treatments differed in the temperature, photoperiod and light intensity conditions. Outdoor conditions were a supplementary treatment. The data confirmed some previous results (break of endodormant buds can be induced without any chilling) and gave much additional information. Candidate conditions for triggering off bud burst included the following :

1- temperature rising above a critical value (of 27°C to 35°C)
2- heat units accumulated from October 11 exceeding 3650 degree-days
3- photoperiod becoming longer than a critical value (of 12 to 16 hours)
4- light intensity becoming higher than a critical value (of 250 to 600 $\mu mol.m^{-2}.s^{-1}$),

None of them proved necessary individually. Only certain combinations of conditions (1+3, 1+4, 2+4, 3+4) proved effective; the other combinations by pairs and the conditions considered alone proved insufficient (2+3, 2, 3, 4) or could not be achieved through the treatments (1+2, 1).

However, further experiments under controlled conditions are needed for improving knowledge on the determinism of bud burst without chilling (precise quantification of the effects of temperature and light, other factors being taken into account).

Résumé

Peu d'informations existent concernant les effets des facteurs climatiques sur le débourrement des bourgeons chez des arbres privés de froid, essentiellement en raison du manque d'expériences en conditions contrôlées. A l'aide d'une serre (la température était maintenue au dessus de 15°C) et de chambres à température et photopériode contrôlées, nous avons appliqué à des pêchers 5 traitements : tous ont comporté une privation de froid commençant en octobre . A partir de la fin mars, ils ont été différenciés par la *température, la photopériode et l'intensité de la lumière. Les conditions naturelles ont constitué un traitement supplémentaire. Les données ont confirmé certains résultats antérieurs (le débourrement de bourgeons endodormants peut être induit sans intervention de froid) et ont donné plusieurs autres informations. Parmi les conditions susceptibles de jouer un rôle dans le déclenchement du débourrement figurent:*

1. *la température lorsqu'elle s'élève au-dessus d'une valeur critique (située entre 27°C et 35°C)*
2. *l'accumulation d'unités de chaleur supérieure à 3650 degrés-jours comptés à partir du 11 octobre*
3. *la durée de la photopériode lorsqu'elle dépasse une valeur critique (située entre 12 et 16 heures)*
4. *l'intensité de la lumière au delà d'un seuil situé entre 250 et 600 µmol.m^{-2}.s^{-1}).*

Aucune de ces conditions ne s'est révélée nécessaire individuellement. Seules des combinaisons (1+3, 1+4, 2+4, 3+4) sont suffisantes; les autres, associées par 2 ou prises isolément, se sont avérées insuffisantes (2+3, 2, 3, 4) ou n'ont pas été testées (1+2, 1). Toutefois, l'amélioration des connaissances sur le déterminisme du débourrement en l'absence de froid (quantification précise des effets de la température et de la lumière, autres facteurs à prendre en compte) nécessite d'autres expériences sous conditions contrôlées.

1. Introduction

Once the deep dormancy state (endodormancy) is established in trees, a prolonged exposure to cold temperatures allowing their buds to meet the so-called chilling requirements is the condition under temperate climates that generally determines the recovery of their physiological capacity to ensure a satisfactory bud break. Among the factors known to modulate or partially replace the action of cold are chemical agents, mild or high temperature and light. Many of the reports about temperature as a factor able to break dormancy could not specify which of mild or high (heat shock) temperatures actually operated in the observed conditions. However, heat shock effects were underscored by Chandler (1960) on apple trees ; Erez and Lavee (1971) showed the positive effect of long periods of mild temperature interrupting chilling on peach trees. Heide (1993b) showed that day length plays a role in bud break in beech confirming former results, and also in other deciduous species (1993 a). In peach, the absolute need of some light for breaking of vegetative buds was demonstrated by Lavee and Erez (1969) ; Erez *et al.* (1966, 1968) showed the role of day length.

Some recent results indicated that partial completion of the chilling requirements may not even be an absolute requisite. Herter *et al.* (1993) induced the buds of completely cold deprived apple trees to break at a good rate with brief high temperature (45°C) treatment. Sparks (1993) studying data obtained on pecan, concluded that accumulation of mild temperature treatments could totally replace the chilling. However, his conclusion is questionable in consideration of some unclear points of the report.

Knowledge about the determinism of burst of deep dormant buds without chilling is still uncertain. To increase this knowledge, we investigated the effects of temperature and light on bud break of peach trees with complete chilling deprivation through experiments with conditions allowing some combinations between various parameters.

2. Materials and methods

2. 1. Treatments

'Redhaven' peach trees were grown outdoors in 100 l containers ; they were 4 years old in October 1994.

Treatment 'O' : 2 trees were left outdoors ; data were collected on them in the year 1995. In all the other treatments, the trees were moved into a greenhouse at the beginning of October ; this time of the year was found at the laboratory to be the period of deepest dormancy for peach under the natural conditions in Clermont-Ferrand.

Treatment 'G 95' : on October 6, 1994, 4 trees were moved into the greenhouse ; 15°C and 27°C were the assigned limits for air temperature ; a heating system could prevent the temperature from dropping below 15°C ; provided a screen was displayed each day from 8 am to 6 pm (true solar time) from March 25, 1995, onwards, a cooling system maintained the temperature below 27°C, with the exception hereafter mentioned : due to uncommon hot weather, on each of the days July 8, 9 and 10, the temperature reached 35°C and remained above 30°C during a mean period of 6 hours. The PAR absorbance of the screen was 90% of the incident light ; thus, in the greenhouse the value of incident radiation above the trees, until March 25 was nearly the same as that outdoors, then it was only about the one-fifth when integrated per day ; before March 25, the PAR radiation value, calculated as mean during the photophase, was between 300 and 700 $\mu mol.m^2.s^{-1}$; after March 25 it was between 150 and 250 $\mu mol.m^2.s^{-1}$. The trees were moved outdoors on July 20.

Treatment 'G 96' was almost identical with treatment 'G 95' , with the following differences : on October 11, 1995, 2 trees were moved into the greenhouse. The mean air temperature during fall and winter was slightly lower than in 'G 95', as shown by the heat unit sum values in Fig. 1. A hot spell occurred one month earlier than in 'G 95' : between June 4 and 12, 1996, the temperature remained above 30°C for 2 to 10 hours per day and reached 38°C during 3 days. The trees were moved outdoors on July 16.

The first part of the other treatments was the same as the beginning of treatment 'G 96' : on October 11, 1995, 5 trees were moved into the aforementionned greenhouse.

Treatment 'Tp' : on March 26, 1996, 2 trees were moved to a controlled chamber of : 35/25°C, day/night, 10/14h (hot temperature T, short photoperiod p). On April 29, the trees were moved outdoors.

Treatment 'tP' : on March 26, 1996, 2 trees were moved to a controlled chamber of 25/15°C, day/night, 16/8h (mild temperature t, long photoperiod P). On May 5, the trees were moved outdoors.

Treatment 'tp' : on May 15, 1996, one tree was moved to a controlled chamber of 25/15°C, day/night, 10/14h (mild temperature t, short photoperiod p). On July 16, the tree was moved outdoors.

In each of the chambers used for these treatments, the air temperature was controlled within 0.5°C and Osram HQITS lamps gave around 600 $\mu mol.m^{-2}.s^{-1}$ of PAR at the level of the mid part of the main branches.

2. 2. Observations

As heat units accumulation was thought to be a possible factor of budburst control, heat unit sums according to time and to the different treatments were computed ; we chose the conventional model of degree-days accumulation, with 4.5°C as base temperature commonly used in peach ; accumulation was started on October 11 (Fig. 1).

At the beginning of each treatment, one of the main branches of each tree was selected (as an exception, 4 branches were selected on the only tree under treatment 'tp'). All the vegetative buds borne by the one year shoots longer than 1cm on these branches constituted a sample of buds for successive observations ; on average it involved 50 one-year-shoots, including 50 terminal buds and 300 axillary buds. From the first signs of bud swelling the sample was examined at various intervals depending on the rate of burst and the burst buds were registered (a bud was scored as burst when green tips of leaves were visible between the scales).

3. Results

The dynamics of bud burst at the tree level corresponding to the different treatments are shown in Fig. 2. A first group of treatments ('O', 'Tp' and 'tP') were very similar (final percentage of bud burst between 83% and 100% for the terminal buds and between 64% and 93% for the axillary ones). In a second group, the treatments 'G95' and 'G96' were characterized by responses of the terminal buds of similar scale to those of first group treatments (final percentages of burst 96% and 84% respectively), while the responses of axillary buds were weaker (final percentages 47% and 40% respectively). Treatment 'tp' resulted in much weaker responses of both terminal and axillary buds (final percentages : 44% and 7%). The lower the level of bud break, the more staggered the dates of break of different buds on a tree : the time between the date of first break and the date corresponding to 95% broken buds among those destined to development varied between 20 and 45 days, depending on the treatment.

We determined, instantaneously or later in time, integrated values of different characteristics of the climatic factors at the time of bud burst (or some days before) under each of the treatments. We chose to locate the bud burst period as the date when the cumulated percentage of burst buds was 10 (percentage taking into account all the buds, terminal and axillary). Corresponding to the treatments, the dates were : 'G95' : July 11 ; 'G96' : June 16 ; 'Tp' : April 7 ; 'tP' : April 12 ; 'tp' : July 15.

We could point at four temperature or light characteristics as candidate conditions for triggering bud burst :
-condition 1 : temperature rising above a critical value (heat shock effect)
-condition 2 : heat units accumulation from the time when deep dormancy has been reached exceeding a critical value
-condition 3 : photoperiod becoming longer than a critical value
-condition 4 : light intensity becoming higher than a critical value.

The results allowed to define the critical value only for condition 2 : the critical accumulation of heat units is that obtained under 'tp' at the time of bud burst : 3650 degree-days accumulated since October 11, on July 15.

Concerning the other conditions the results only allowed to determine range limits of critical values :

-**condition 1** : the critical temperature is between 27°C and 35°C. At values below 27°C, earlier bud burst would have been observed under 'tp' and 'G95' . The conditions triggering bud burst under 'Tp' (1 and 4 combined) were met as early as the beginning of May under 'tp' (observed bud burst time was not before July 15) and the conditions triggering bud burst under 'G96' (1 and 3 combined) were met as early as the beginning of June under 'G95' (observed bud burst time was not before July 11). At values above 35°C, no bud burst occured under 'Tp'

-**condition 3** : the critical photoperiod is between 12 and 16 hours. At values below 12 hours, earlier bud burst would have been observed in every treatment, as each of them occured as early as the beginning of March the conditions triggering bud burst under 'tP' (3 and 4 combined). At values above 16 hours, no bud burst occured under 'tP'

-**condition 4** : the critical light intensity is between 250 and 600 $\mu mol.m^{-2}.s^{-1}$. At values below 250 $\mu mol.m^{-2}.s^{-1}$, earlier bud burst would have been obtained under 'G95', as it fulfilled the conditions for triggering bud burst under 'tP' (3 and 4 combined) as early as the beginning of June (observed bud burst time was not before July 11). For values above 600 $\mu mol.m^{-2}.s^{-1}$, no bud burst could have occured under 'tp'.

We looked for the conditions fulfilled at the time of bud break under the different treatments (Fig. 3); it allowed us to specify for each of the conditions or their various combinations whether they were necessary and/or sufficient for triggering bud break.

None of the conditions considered alone was necessary : among the treatments (all of them induced bud burst), there was at least one under which a given condition was not met at the time of bud burst (treatments 'tP' and 'tp' did not meet condition 1 ; treatments 'Tp', 'tP' and 'G96' did not meet condition 2 ; treatments 'Tp' and 'tp' did not meet condition 3 ; treatments 'G95' and 'G96' did not meet condition 4). *A fortiori*, no combination of the conditions would be necessary.

The conditions considered alone were sufficient ?

For some period, conditions 3 under treatment 'G95' and 4 under all the treatments were met alone ; as long as one of them was the only condition satisfied no bud burst occurred. So, conditions 3 and 4 appear to be insufficient. Nor did condition 2 in addition to condition 3 under treatment 'G95' result in bud burst. Condition 2 also appears to be insufficient. In all the cases when condition 1 was met, it resulted very soon in bud burst (treatments 'Tp', 'G95' and 'G96'), but in none of these cases the condition was met alone. So, we cannot decide whether condition 1 is sufficient or not.

The combinations of conditions were sufficient ?

The combination of conditions 1 and 2 was not met under any treatment ; so, it cannot be said whether this combination is sufficient or not. Under treatment 'G95' the combination of conditions 2 and 3 was met and did not result in bud burst ; so, this combination appears to be insufficient. The combinations 1+3, 1+4, 2+4, and 3+4, were sufficient as they induced bud burst under treatments 'G96', 'Tp', 'tp' and 'tP'respectively. It follows that any combination of conditions by threes and, of course, the combination of the four conditions should be sufficient. This was confirmed in the case of the combination 1+2+3, the only one achieved in the experiment (treatment 'G95').

4. Discussion

As a conclusion of his study, Sparks (1993) stated that bud break may occur with no chilling once sufficient heat accumulated. This appeared uncertain on account of the methods of estimating the heat and chilling accumulations : the choices of the calendar periods of chilling and heat accumulation and of the chilling model with accumulation only at temperature below 7.2°C are rather questionable. It is widely accepted that the upper temperature limit for chilling action is close to 15°C (Cannell, 1989) ; so, our results undoubtedly showed that bud burst may occur without any chilling. Previously, to our knowledge, only from the experiments of Herter *et al.* (1993) could such a conclusion be clearly inferred.

In each of the mentioned studies the relation of only one signal with bud burst was examined (respectively, heat accumulation and heat shock) ; implicitly, the authors considered them as sufficient signals and so they usually are by the readers. This is not justified, because others factors (particularly, photoperiod and light intensity) might have had an influence, either alone or combined with the signal taken into account. With regards to that, our results give much additional and original information. They considered 4 different signals (2 temperature signals and 2 light signals) and, in many of the possible cases of signals considered alone and of their different combinations, they allowed to specify whether they were necessary and/or sufficient. Interaction seems to be an important feature of the determinism of bud burst without chilling, since it can be triggered by combinations of signals each of which is not sufficient alone (for example, signals 3 and 4). Signal 2 has indeed an effect on triggering bud burst, but it seems much weaker than that of signal 1 : considering combinations by pairs, associated with signal 3 or 4, signal 1 has a strong effect in both cases, while signal 2 has no effect and a weak effect respectively. Bud burst could be triggered by light signals only (combination of signals 3 and 4)

Of course, much is still to be known about the climatic determinism of bud burst without chilling. With regards to the factors taken into account in this study, precise determination of the critical temperature and light values needs further experiments under controlled conditions. Other factors not considered in this study may affect bud burst, and among them, the water tree content is probably important.

In our experiment the trees were maintained under chilling deprivation for different given periods (6 to 8 months) since they had reached the state of deep dormancy, when the signals took place ; the observed responses are not necessarily independent of these periods and of the chilling deprivation conditions of, this should be investigated.

Effective bud burst can be seen as the result of two distinct phenomenons : first the bud recovers from unability to grow, then it actually grows until it bursts. They possibly have different determinisms. No information could be obtained from our results about this point, as our observations did not distinguish these phenomenons. Methods exist that could allow the separate approach of the growth ability and the actual bud growth, they could be used with advantage.

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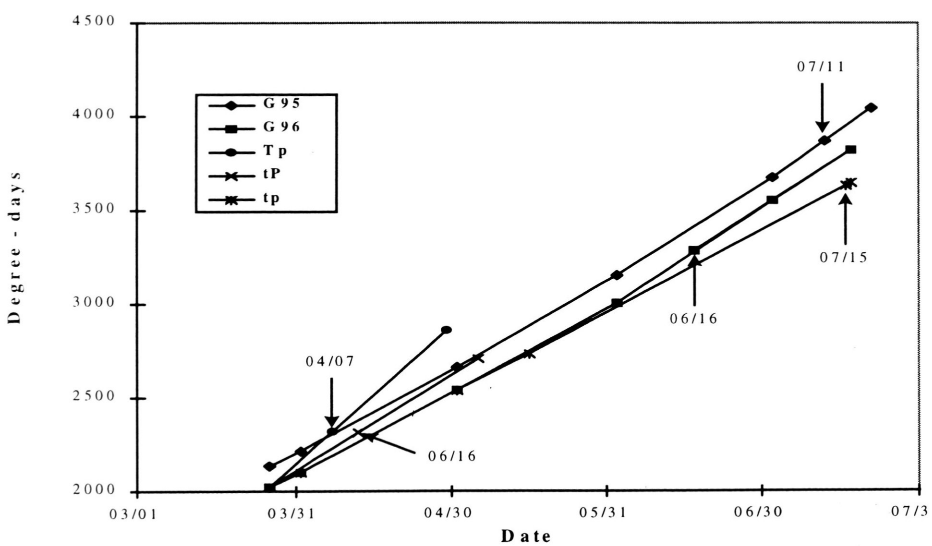
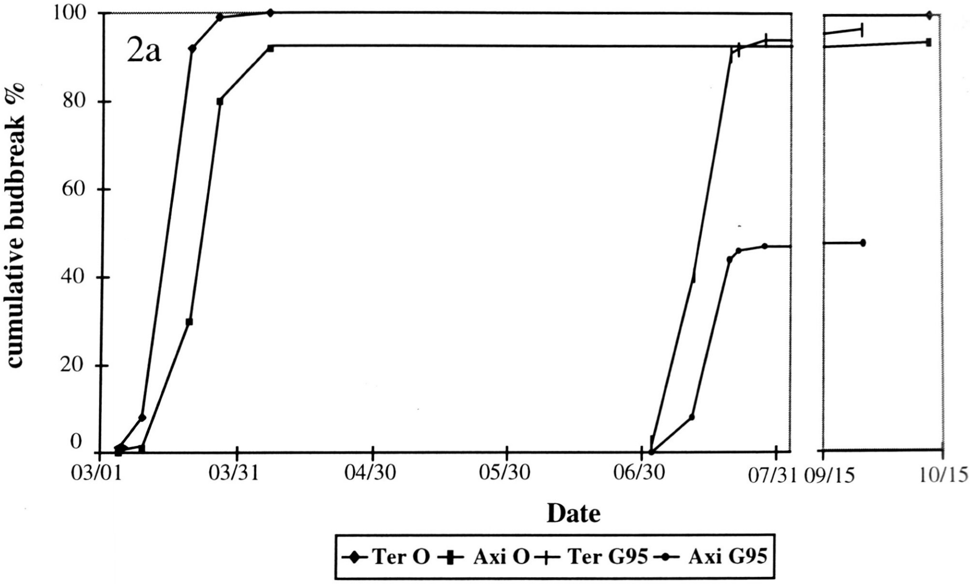


Figure 1 - Heat units accumulation under the different treatments : degree- days summed since October 11, base temperature : 4.5°C. The arrows show the dates corresponding to 10% burst buds (terminal and axillary buds as a whole).



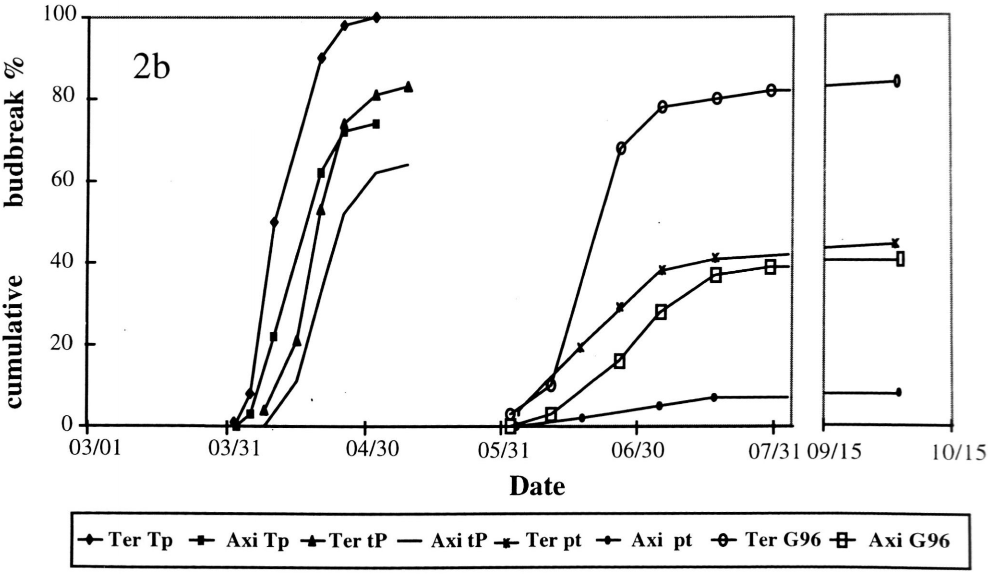


Figure 2 - Time course of burst of terminal and axillary buds (cumulative percentages) under the different treatments ; a : treatments 'O', 'G 95', 'G 96' ; b : treatments 'Tp', 'tP', 'tp'.

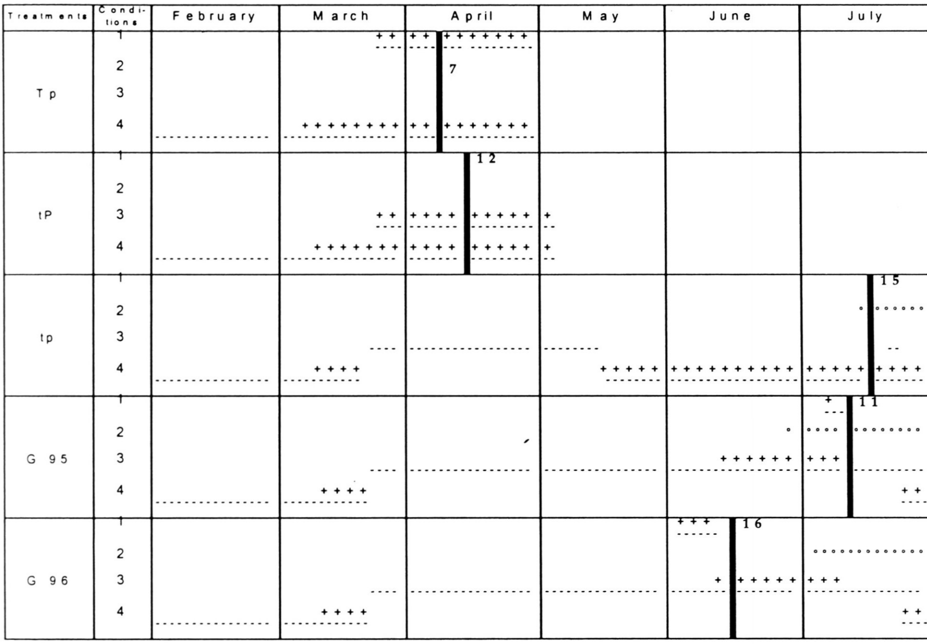


Figure 3 - Periods during which the 4 candidate conditions for triggering off bud burst were fulfilled under the different treatments. For each parameter the periods corresponding to the extreme values (upper values +++++ ; lower values -----) of the possible ranges of the critical values are shown : upper / lower values : 1 (temperature) 35 / 27°C ; 3 (photoperiod) 16 / 12 hours ; 4 (light intensity) 600 / 250 $\mu mol.m^{-2}.s^{-1}$. ; critical value of the parameter 2 (heat accumulation) : 3650 degree-days (ooooo). For each treatment, the vertical line shows the date corresponding to 10% burst buds (terminal and axillary buds as a whole).