Physiological and biochemical evolution of peach leaf buds during dormancy course under two contrasted temperature patterns

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Summary: Budbreak anomalies in temperate fruit trees grown under mild conditions have often been described. However, only few authors approached the physiological evolution of leaf buds all along the dormancy period according to the temperature pattern. The aim of this study was to characterize the evolution of peach leaf bud dormancy through some physiological and biochemical parameters under temperate winter conditions and under total cold deprivation after the endodormancy onset. Two treatments were applied in peach trees cv. Redhaven: (i) Regular Chilling Amounts – RCA and (ii) Total Chilling Deprivation – TCD. Buds were sampled periodically from different parts of the stem (terminal, medium and basal ones). We recorded the evolution of: carbohydrate concentrations (glucose, fructose, sucrose, sorbitol and starch), respiration rate, water contents and energy metabolism (ATP and ADP ratio). The dynamics of these parameters were compared and correlated with dormancy evolution ("one node cuttings" test) and budbreak patterns *in planta*. The endodormancy intensity of terminal buds was significantly lower than those of median and basal buds in early October. Under RCA treatment, this gradient faded and the bud endodormancy release was completed at the same time in all positions along the stem. Thereafter, the "cuttings" test indicated that terminal buds grew slightly faster than median and basal buds, and, consistently, budbreak *in planta* started with the terminals buds, followed by the medians and then by the basal ones. The carbohydrate contents showed a transitory change only when the buds began to grow after the endodormancy was released under RCA. Respiration, water content and ATP/ADP changed dynamics only under RCA and only after the end of the endodormancy (their respective changes were very parallel). The dynamics of none of the tested parameters could be related with the endodormancy dynamics, but respiration, water content and ATP/ADP could be consistent markers of the actual bud growth before bud break (in this respect, ATP/ADP could not show differences between the terminal and axillary buds while respiration and water content could).
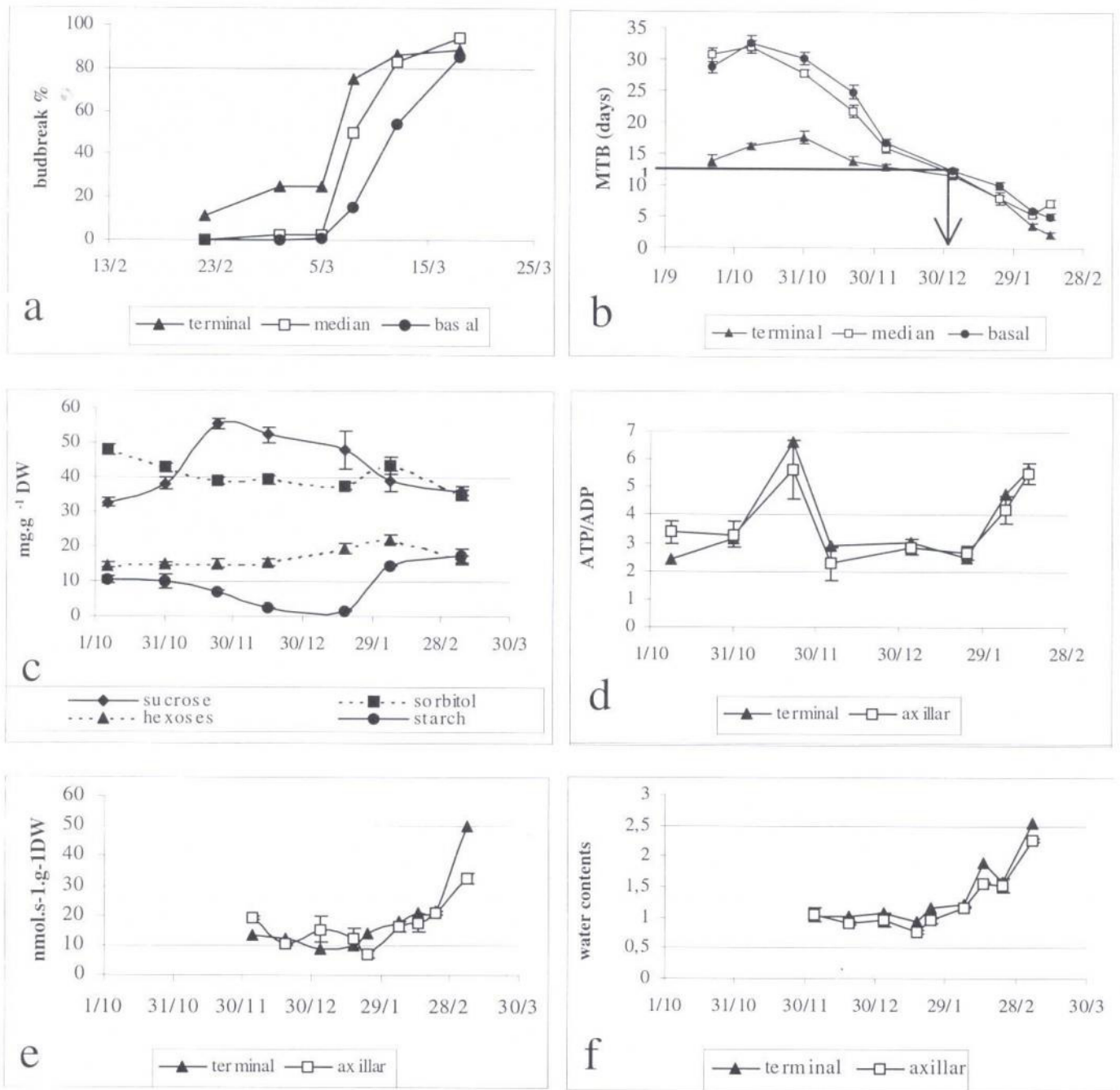
Key words: endodormancy, carbohydrate concentration, respiration intensity, water contents, budbreak anomalies.

Introduction

Low percentage and heterogeneity along the stem in budbreak and flowering and other anomalies occur in temperate fruit trees grown in subtropical conditions, when chilling requirement is not satisfied (*Dennis*, 1987; *Mauget & Rageau*, 1988; *Petri & Leite*, 2003; *Leite*, 2004, *Holb*, 2006). The characteristics of budbreak and flowering depend on the dynamics of bud dormancy and especially endodormancy. However, few studies have investigated the actual evolution of bud dormancy along the rest period, according to the temperature conditions. The aim of this study was to characterize the evolution of leaf buds dormancy during different phases under two contrasted temperature patterns: temperate winter conditions and total cold deprivation after the endodormancy onset. We could compare data of a biological reference test and some of other approaches during rest.

Materials and methods

The experiment was carried out in Clermont-Ferrand, France, in 2000/2001 and 2001/2002. Two treatments were applied in peach trees cv. Redhaven: (i) Regular Chilling Amounts – RCA (plants in natural conditions) and (ii) Total Chilling Deprivation – TCD (plants were in containers transferred in early October from outside into a heated greenhouse with temperature between 15 °C and 25 °C, before any action of chilling accumulation). Vegetative buds were sampled periodically (twice and once a month in RCA and TCD, respectively), from different parts of the stem (terminal, medium and basal ones). We recorded in the leaf primordial the evolution of: carbohydrate concentrations (glucose, fructose, sucrose, sorbitol and starch) in 2000/2001. They were measured as described in *Maurel & Leite* et al. (2004). In 2001/2002 we recorded in buds the respiration rate measured by differential microcalorimetry as described in *Hansen & Criddle* (1990), the water contents

Figure 1. (a) phenology of vegetative budbreak (basal, median and terminal buds); (b) mean time to budbreak, MTB, along the stem (basal, median and terminal buds); (c) dynamics of hexoses, sucrose, sorbitol and starch specific contents; (d) ATP/ADP ratio in terminal and axillaries buds; (e) respiration rate; and (f) water contents; under RCA treatment.

and approached energy metabolism status by the ATP/ADP ratio measured as described in *Bonhomme* et al. (2000a). The dynamics of the different parameters were compared and correlated with dormancy evolution characterized by the Mean Time to Budbreak (MTB) obtained from the "one node cuttings" test and budbreak patterns *in planta*.

Results and Discussion

Endodormancy, growth before budbreak and budbreak

Under the natural conditions of Clermont-Ferrand, the maximum level of endodormancy intensity was already observed in early October (beginning of autumn). Under

RCA, the mean time of budbreak (MTB) constantly decreased until the end of endodormancy (MTB = 12 days, Bonhomme et al, 2000b) that occurred in early January (*Figure 1b*). This general dynamics of endodormancy intensity in vegetative buds has been already described for several species in temperate conditions (*Crabbé*, 1987; *Mauget & Rageau*, 1988, *Herter*, 1992; *Brunel*, 2001). Our data also showed the difference between the peach trees and others species: in peach trees the difference of endodormancy intensity between the median and basal buds
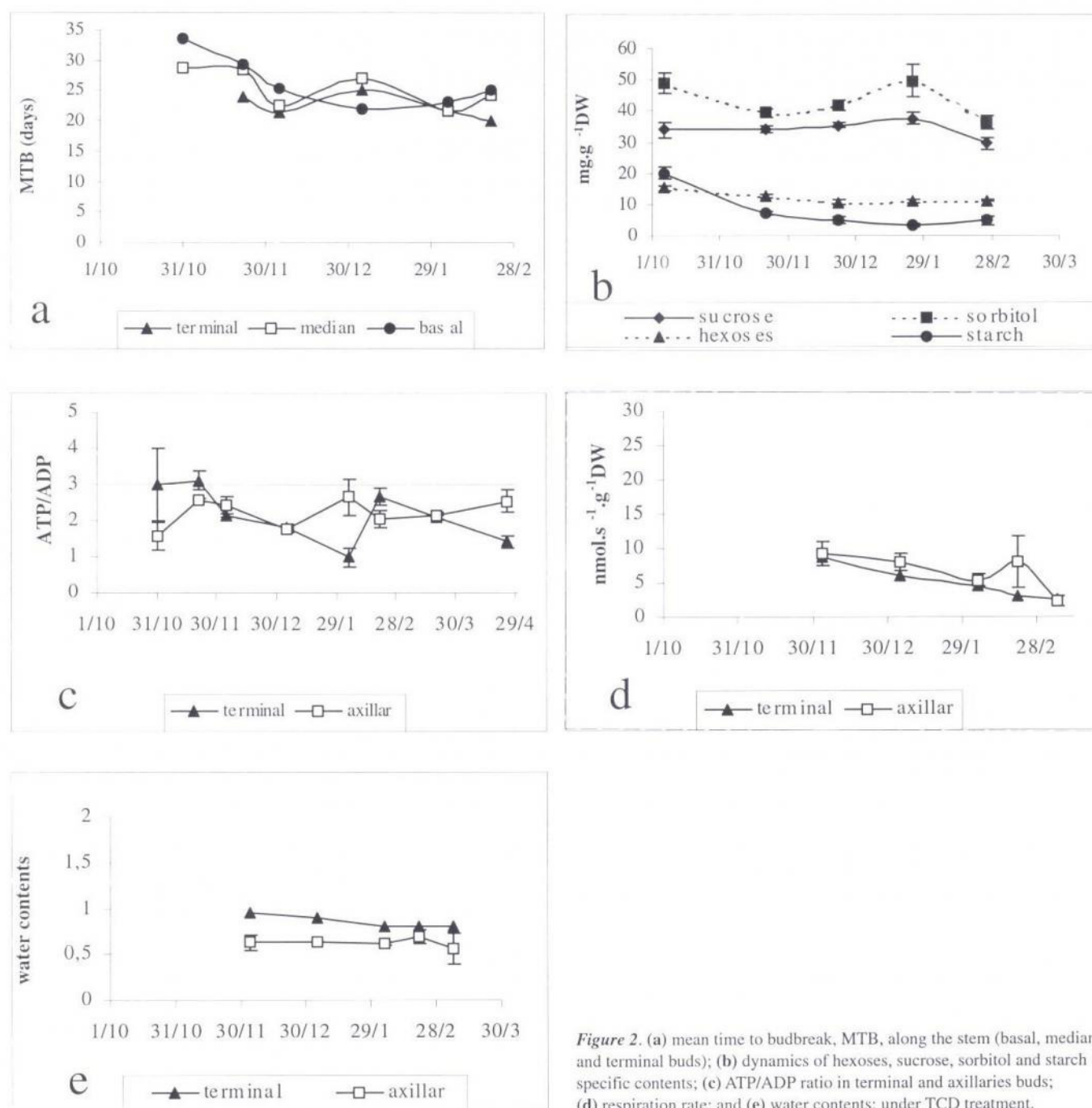
a

b

c

d

e

Figure 2. (a) mean time to budbreak, MTB, along the stem (basal, median and terminal buds); (b) dynamics of hexoses, sucrose, sorbitol and starch specific contents; (c) ATP/ADP ratio in terminal and axillaries buds; (d) respiration rate; and (e) water contents; under TCD treatment.

of the branch was rather weak, but the terminal buds were significantly less endodormant than the other ones, resulting in acrotonic potential of growth. However, as for the species of basitonic potential, the gradient was eliminated in proportion as the endodormancy was released. After the end of endodormancy, around 20 days before the beginning of budbreak of the terminal buds, their MTB value became lower than the MTB values of the other buds, showing that they had took the lead in growth (*Figure 1b*).

These data correspond to the budbreak order observed along the branch, beginning by the terminal buds and following by the median buds and then by the basal buds (*Figure 1a*).

Under TCD, the MTB values decreased during the first months of the treatment, then stabilized around 20 days, indicating the persistence of the endodormancy (*Figure 2a*). No clear differences between terminal, median and basal buds could be observed. Consistently, there was no budbreak.

Carbohydrate concentrations

Under both treatments, the concentration values were not significantly different between the primordial of the buds in different positions along the branch, so, in the figures, the values were shown pooled at the stem level. Under RCA (*Figure 1c*) the concentration of starch, already low in

October, decreased until almost the exhaustion in January, then increasing until March. The increasing concentration in sucrose in November could be the result of the degradation of the starch in the buds or the importations from the stem. The concentration of sorbitol decreased. These differences of dynamics between sucrose and sorbitol were also observed by *Moing* et al (1994), in plum trees, and by *Marquat* (1996), in peach trees. According to *Marquat* et al. (1999) this could be explained by the increase, in the case of the sucrose, and for the decrease, in the case of the sorbitol, of the absorption potentiality between October and December. The increase of the hexose's concentrations (glucose + fructose) observed after the endodormancy release could be linked to the increase of the activity of the enzymes sorbitol oxidase (SOX) and parietal invertase (IP) that act respectively in the degradation of the sorbitol and of the sucrose (*Maurel*, 2003). The hexoses seem to carry out an important action in the budbreak, as *Maurel & Leite* et al (2004) observed a preference for the glucose absorption on the sucrose and sorbitol starting from December and glucose predominance in the xylem sap in March.

Under TCD, contrary to under RCA, the concentrations of the various carbohydrate were rather stable until late February, end of the experiment (*Figure 2b*). We showed through other results in leaf primordial under TCD (*Maurel & Leite* et al 2004) a strongly reduced activity of the enzymes SOX, NAD-SDH and IP starting from January. The stability of concentration levels of sucrose and sorbitol could be due to an incapacity of use these substrates in TCD. No correlation could be observed between carbohydrate levels and budbreak capacity,

The carbohydrate specific contents showed no much changes during the endodormancy release (October-December) under RCA; only the actual growth prior the budbreak (January-February) could transitory changes be seen (*Figure 1c*).

Respiration, water contents and ATP/ADP ratio

Under RCA, the evolutions of the respiration intensity (Figure 1e) and of the water contents of buds (*Figure 1f*) were almost parallel, with a strong correlation (r2> 0,90) between their values (*Figure 3*). The levels of the two parameters began to increase at mid-January, after the end of the endodormancy and around 3 weeks before budbreak, in agreement with the results of *Tamura* et al (1992) and *McPherson* et al (1997a and 1997b), among others. The values were slightly higher for the terminal buds than for the axillary buds from this date onwards.

The peaks in the dynamics of ATP/ADP ratio observed in November were probably artefacts and by consequence, the levels were constant from October to the end of January, and then increased (*Figure 1d*). This results similar to those obtained by *Bonhomme* et al. (1998). No differences between the values for the terminal buds and the values for the axillary ones could be seen.

Under TCD, the respiration intensity (*Figure 2d*), water contents (*Figure 2e*) and the ATP/ADP ratio (*Figure 2c*) did not change (oscillations in values for the terminal buds probably originated in measure uncertainty).

These results suggest that the respiration intensity, water content and ATP/ADP ratio are parameters not linked to the endodormancy dynamics but could be consistent markers of the actual bud growth after the end of their endodormancy. In this way, respiration intensity and water content should be more accurate than ATP/ADP ratio, as they showed differences between terminal and axillary buds under RCA (consistently with the difference in budbreak time), while ATP/ADP could not (*Figure 3*).
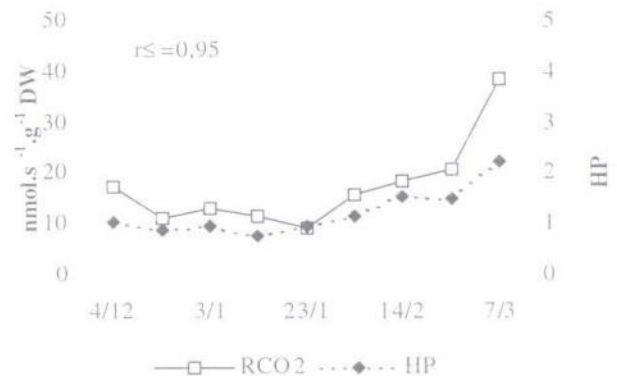
Figure 3. Dynamics of respiration rate and water content under RCA treatment and coefficient of correlation (r2) between the parameters.

Conclusions

All of the parameters (carbohydrate concentrations, respiration intensity, water content and ATP/ADP ratio) expressed different dynamics under RCA and TCD treatments, but none of them could be clearly related with the corresponding endodormancy dynamics. The significant differences were to be seen only when endodormancy had been released (under RCA). ATP/ADP and mainly respiration intensity, water content, seem good candidate markers of the actual growth before budbreak. Water content would especially interesting because measurement method is simple and not expensive.

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