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Historical phenological responses in apple tree to contrasting warming contexts may clarify future crucial responses in Europe

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Objectives and Methods
This study aims to provide a comprehensive overview of historical flowering responses recorded in apple in contrasting warming contexts. To examine this issue, a dataset was collected from flowering dates collected for two main BBCH stages and several cultivars in both temperate regions of western Europe suitable for apple cropping and in unsuitable mild regions of northern Morocco and southern Brazil, where insufficient fruit bearing is mainly due to inadequate flowering phenology and intensity (Legave et al. 2013). Two forcing tests (one-bud cuttings and Tabuenca’s test) were used to analyse the dormancy and growth dynamics (Malagi et al. 2015).

RESULTS and DISCUSSION 1. Differentiated responses of flowering date and blooming duration
A new overview in space and time of flowering date changes was provided in apple tree highlighting not only flowering date advances, as in previous studies (Guédon and Legave 2008), but also stationary flowering date series (Fig. 2). At global scale, differentiated flowering time patterns resulted from interactions between regional differences in the thermal determinisms of flowering date and in the impacts of warming context. This may explain flowering date advances in most of European regions (change-point instant at the end of the 1980s, Fig.3) and in Morocco (later instant in 1994) vs. stationary flowering date series in the Brazilian regions. A notable exception in Europe was found in the French Mediterranean region (Nîmes) where the flowering date series became stationary from 1974 to 2013 due to both marked winter and spring warming (Legave et al. 2015). This was related to relatively low “winter” temperatures in France (min. temperature clearly below 10°C from Nov. to Feb.) vs. high “winter” temperatures from May to August in Brazil, as no mean temperature below 12°C up to mid-July in some years. In addition, the eco-dormancy durations of flower buds were clearly longer in France than in Brazil (Table 2). This was also related to relatively low “spring” mean temperatures in France (10.5°C vs. high “spring” mean temperatures in Brazil (15.5°C). Such contrasting dynamics of both bud dormancy and growth between France and Brazil might explained adequate flowering at the blooming phase in France (Fig. 5) vs. inadequate flowering in Brazil (Fig. 6) (Malagi et al. 2015).

2. Differentiated dynamics of bud dormancy and growth

Table 1 – Flowering and temperate data collected in climate-contrasting regions for three apple cultivars.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Southern France</th>
<th>Southern Brazil</th>
<th>Morocco</th>
</tr>
</thead>
</table>

Figure 1 – Geographical distribution of locations in both Hemispheres.

Figure 2 – Segmentation of BBCH61 stage date series using optimal piecewise constant and linear models in the case of Golden Delicious (Legave et al. 2015):

Flowering advance in Bonn (1962-2013) linked to “spring” warming
Flowering advance in Aïn Toudjade (1984-2013) linked to “spring” warming
Flowering stationary in Nîmes (1974-2013) linked to “winter” warming and “spring” warming
Flowering stationary in Sao Joaquim (1974-2013) no significant warming

Figure 3 – Change-point distribution for two-segment constant models (BBCH61 series)

Figure 4 – Dormancy dynamics of vegetative buds (cutting test).

Figure 5 – Intense flowering and short blooming duration in southern France.

Figure 6 – Weak flowering and extended blooming duration in southern Brazil.

Table 2 – Duration (days) of flower bud growth from en-dormancy release (Tabuenca’s test) to BBCH61 stage.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>southern France</th>
<th>southern Brazil</th>
<th>Morocco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gala</td>
<td>2011-2012</td>
<td>2012-2013</td>
<td>2013-2014</td>
</tr>
<tr>
<td>GS</td>
<td>2011-2012</td>
<td>2012-2013</td>
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<td>GS</td>
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<td>2012-2013</td>
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</tbody>
</table>

WHICH FUTURE CRUCIAL IMPACTS ON PHENOLOGICAL CONSEQUENCES?
European Mediterranean regions of apple cropping might be gradually affected in near future by excessive delays of dormancy release linked to declines in “winter” chilling accumulation. This would be especially crucial in the French Mediterranean region (Nîmes) where stationarities of flowering stage dates were found for forty years. In fact, this apparent stationarity was the result of both marked chill declines and heat increases (Legave et al., 2013). At tree and orchard scales, this could cause future phenological disorders similar to those observed in mild regions. Continuous warming from autumn to spring in the French Mediterranean region (as in 2015-2016) could excessively increase bud competitions, firstly during the fulfillment of chilling requirements in endo-dormancy and later during the fulfillment of heat requirements in eco-dormancy, finally leading to periods very intense and short blooming phase (Fig. 6).

References