Long-term monitoring of leaf phenology for two forest tree species located at their hot and dry, southern margin

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Fig.1: Decline of silver fir (Abies alba Mill.) stands on Mount Ventoux

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Introduction

The effect of climate change on European temperate tree species is characterized by a significant advance in budbreak dates[1] and contrasting responses regarding leaf senescence dates[2]. These phenological responses are under the control of several environmental determinants some of which seem to play an increasingly important role, such as the need for cold to lift the dormancy necessary for budburst[3] or the water stress causing early leaf senescence[4].

The dataset presented here shows the interest of long-term monitoring for two species located at the southern margin of their distribution area where environmental constraints are particularly pronounced (**Fig.1**).

Sites

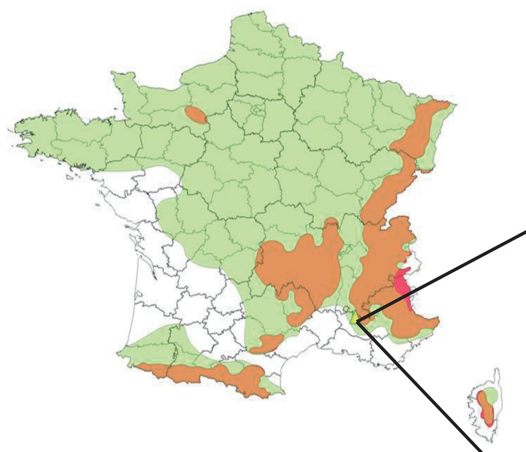

Fig.2: Beech and silver fir in France. Area of presence of beech alone in green, silver fir alone in red and both species in brown.

Fig.3: Transects studied on Mount Ventoux. One transect is located on the north side of the mountain (from 968 m to 1522 m) and includes both species (picture A), and the other transect is located on the south side (from 875 m to 1537 m) and includes only beech (picture B)

Phenological observations

Leaf phenology observations at the individual scale were conducted for two major European forest tree species, European beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill.). Observations were carried out over 14 consecutive years on 772 trees (**Table 1**) distributed along two altitudinal transects located on Mount Ventoux (**Fig.3**), a mountain in French south-eastern Alps (**Fig.2**).

SPECIES	PHENOPHASE	EXPOSURE	TREE NUMBER	OBSERVATIONS NUMBER
ABIES ALBA	budburst	north	169	8261
ABIES ALBA	leafing	north	163	741
FAGUS SYLVATICA	budburst	north	497	16157
FAGUS SYLVATICA	budburst	south	90	1713
FAGUS SYLVATICA	leaf_senescence	north	228	10224
FAGUS SYLVATICA	leafing	north	497	2041
FAGUS SYLVATICA	leafing	south	72	143
TOTAL			772	39280

Table 1: Total number of trees observed and total number of observations over the period (2006-2019) by species, phenophase and exposure.

Results

Silver fir: Over the observation period (2006 to 2019; **Fig.5**), the linear regression analyze allow to detect a significant (p-value <2e-16) year effect on the budburst dates (budburst date = 1.382*Year -2.645e+03) which explains 25 % of the budburst date variation (R^2 = 0.2474). The positive slope indicates a significant increasingly late budburst trend (β = +1.382). When we include the classes of altitude in the analyze, the results of the linear ANCOVA model indicate a significant difference in the equality of the slopes (p-value <4.238e-14) : **the altitude*year interaction is significant (p-value = 1.355e-05) and means that the influence of altitude on budburst dates varies from year to year**.

European beech: Over the observation period (2012 to 2019), the linear regression of the year on the senescence dates gives a significant negative slope (β = -0.9841; p-value = 2.11e-09) , indicating an increasingly early senescence trend. Also, we observed a larger within-population variability at low than at high altitude (**Fig.6**). Finally, the linear mixed model considering two fixed effects (altitude and year) and one random effect (observed trees) gives no significant effect of the altitude on the senescence dates (p-value = 0.1503). However, we observed a significant interaction between altitude*year (p-value = 1.026e-06), **which means that depending on the year, the rank of the senescence date varies according to altitude. Indeed, some years the senescence begins at 1100 and others at 1350m.**

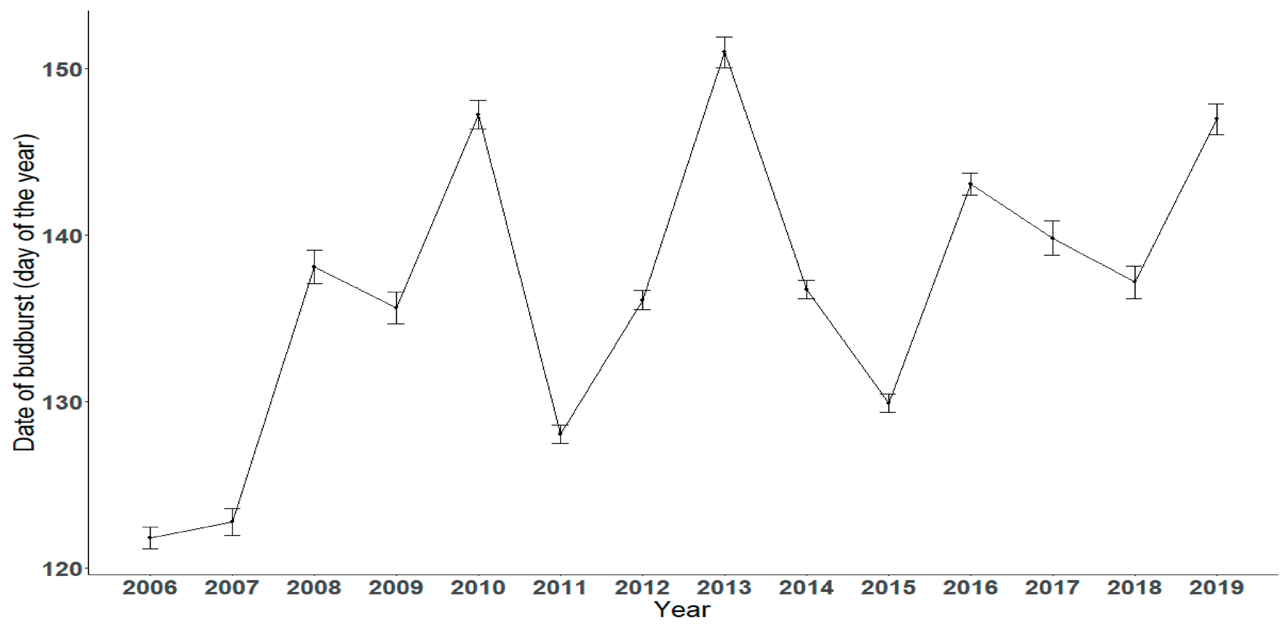

Fig.5: Variation of the date of budburst (Day of the Year when a stage BBCH7 is observed) between 2006 and 2019 period for silver fir. The vertical bars represent standard errors.

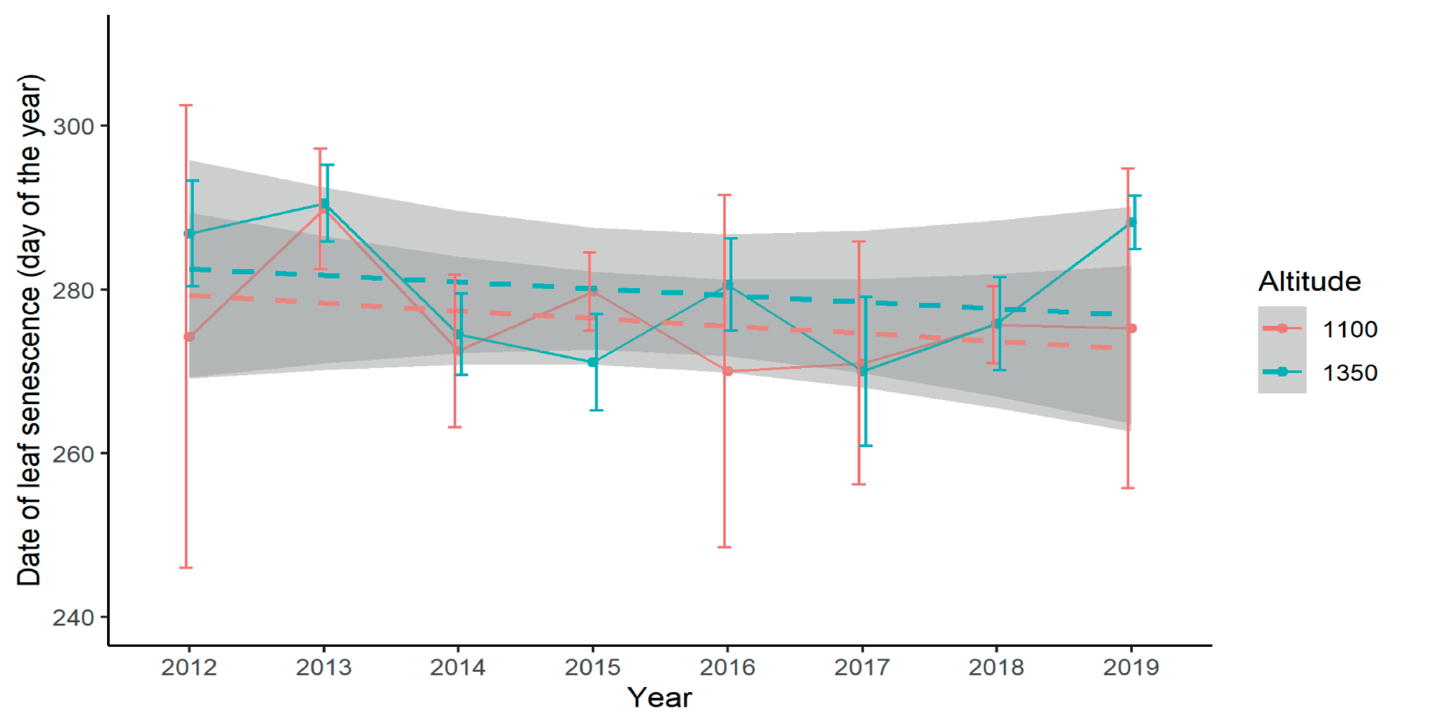

Fig.6: Variation of the date of the leaf senescence (Day of the year when a stage BBCH95 is observed) between 2012 and 2019 at two elevations for European beech. The linear regression dashed lines for 1100m and 1350m are respectively in red and blue. The vertical bars represent standard deviation.

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