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## Impacts of climatic changes on the vegetative development of olive cultivars

Gabriel W. L. Florêncio<sup>1</sup>, Fabrina B. Martins<sup>1</sup>, Mábele de C. Ferreira<sup>1</sup> & Rodolfo A. de A. Pereira<sup>2</sup>

<sup>1</sup> Universidade Federal de Itajubá/Natural Resources Institute. Itajubá, MG, Brasil. E-mail: gabrielflorenco1797@gmail.com - ORCID: 0000-0003-3510-884X; fabrinabm@gmail.com (Corresponding author) - ORCID: 0000-0003-0401-6168; mabeleferreira@yahoo.com.br - ORCID: 0000-0001-6724-7217

<sup>2</sup> Universidade de São Paulo/Escola Superior de Agricultura Luiz de Queiroz. Piracicaba, SP, Brasil. E-mail: rodolfopereira@usp.br - ORCID: 0000-0002-3240-4611

**ABSTRACT:** The aim of this study was to simulate the vegetative development of the olive cultivars Arbequina and MGS ASC315 cultivated in Maria da Fé, MG, Brazil (22° 18' 29" S, 45° 22' 31" W, 1.276 m of altitude). The development of these cultivars was simulated in nine transplanting dates, considering three distinct scenarios for three periods (2011-2040, 2041-2070 and 2071-2100). Climate changes influence the olive crop management. The increase in air temperature modifies the development rate and the duration of the seedling phase of the cultivars Arbequina and MGSASC315. In colder months, there is accelerated vegetative development and shorter seedling phase duration. Conversely, in warmer months, there is delayed development with longer seedling phase duration.

**Key words:** *Olea europaea* L., phenology, air temperature

## Impactos de mudanças climáticas no desenvolvimento vegetativo de cultivares de oliveira

**RESUMO:** Este estudo teve como objetivo simular o desenvolvimento vegetativo das cultivares de oliveira Arbequina e MGS ASC315 cultivadas em Maria da Fé, MG, Brasil (22° 18' 29" S, 45° 22' 31" W, 1.276 m de altitude). O desenvolvimento destas cultivares foi simulado em nove épocas de transplântio, considerando três cenários distintos para três períodos (2011-2040, 2041-2070 e 2071-2100). As mudanças climáticas influenciaram o manejo da cultura da oliveira. O aumento na temperatura modifica a taxa de desenvolvimento e a duração da fase de muda das cultivares de oliveira Arbequina e MGS ASC315. Em meses mais frios, existe o desenvolvimento vegetativo acelerado e redução da duração da fase de muda, enquanto em meses mais quentes, existe um desenvolvimento retardado com aumento da duração da fase de muda.

**Palavras-chave:** *Olea europaea* L., fenologia, temperatura do ar



**INTRODUCTION**

The Intergovernmental Panel on Climate Change (IPCC, 2013) has projected increases in atmospheric CO<sub>2</sub> and air temperature up to 5.0 °C in the state of Minas Gerais, Brazil, in the 21<sup>st</sup> century (Santos et al., 2017b). In theory, C3 plants, which represent most terrestrial species, should be favored by the increase of CO<sub>2</sub> since they are highly dependent on atmospheric CO<sub>2</sub> to have the enzyme Rubisco, which is solely responsible for the metabolic process that governs photosynthesis in C3 plants (Fagundes et al., 2010; Taiz et al., 2018). Conversely, the Warburg effect occurs under high temperature conditions, in which O<sub>2</sub> inhibits the fixation of CO<sub>2</sub> by the Rubisco enzyme, thus reducing photosynthesis and increasing photorespiration (Marenco & Lopes, 2009). This impact hinders development because it shortens the cycle duration and reduces yield, due to the reduction of photosynthesis and the accumulation of photoassimilates (Fagundes et al., 2010). Thus, studies examining the potential impacts of climatic changes on the development of annual and perennial species are important in scenarios with promising economic potential (IPCC, 2013; Walter et al., 2014), such as olive trees that are cultivated in the southern and southeastern regions of Brazil (Martins et al., 2012; Wrege et al., 2015; Santos et al., 2017b).

The impact of climate change on olive crops can be analyzed through the development of simulation models which are commonly used for annual crops (Streck et al., 2011) and scarce for perennial crops (Costa & Streck, 2018). These models simulate the development through leaf appearance rate (LAR), using air temperature response functions, differing basically between linear or additive and non-linear or multiplicative categories (Martins et al., 2014). The aim of the present study was to simulate the vegetative development of the cultivars Arbequina and MGS ASC315 in nine transplanting dates, considering different climate projections.

**MATERIAL AND METHODS**

Due to the expansion of olive crops cultivation in Minas Gerais, Brazil (Garcia et al., 2018), a numerical study was performed in Maria da Fé, MG, Brazil (22° 18' 29" S, 45° 22' 31" W, 1.276 m of altitude). According to Köppen classification, the region presents Cwb climate, characterized by dry winters and rainy summers (Souza & Martins, 2014). The cultivars Arbequina and MGS ASC315 were chosen because both have been used with the objective of producing olive oil in the region (Martins et al., 2012).

The vegetative development models (VD) used in this study were differentiated for each cultivar, with the Wang and Engel model (WE) for Arbequina and the Phyllochron model (PHYL) for MGS ASC315, based on the results obtained by Martins et al. (2014). In both models, VD is given by the number of accumulated leaves in the main stem (NL) which integrated in time provides the duration of the seedling phase (DSS), which refers to the number of days between the transplanting date and the threshold of NL = 20 (Martins et al., 2012, 2014).

In the WE model, NL is given by Martins et al. (2014) Eq. 1:

$$NL_{estimated} = \sum_{i=1}^n (LAR_{max} f(T)) \quad (1)$$

where:

NL<sub>estimated</sub> - number of accumulated leaves in the main stem;  
 LAR<sub>max</sub> - maximum daily leaf appearance rate (0.270390 leaves d<sup>-1</sup>); and,

f(T) - beta function of air temperature (Eqs. 2 and 3):

$$f(T) = \frac{[2(Tm - Tb)^\alpha (Tot - Tb)^\alpha - (Tm - Tb)^{2\alpha}]}{(Tot - Tb)^{2\alpha}}, \text{ when } Tb \leq Tm \leq TB \quad (2)$$

$$f(T) = 0, \text{ when } Tm < Tb \text{ or } Tm > TB \quad (3)$$

where:

Tm - daily mean air temperature;  
 Tb, Tot and TB - cardinal temperatures for Arbequina (10.5, 16.1 and 37.8 °C, respectively) (Lisboa et al., 2012; Martins et al., 2012, 2014); and,  
 α - calibration coefficient (Eq. 4):

$$\alpha = \frac{\ln 2}{\ln [(TB - Tb) / (Tot - Tb)]} \quad (4)$$

where:

i - date of the beginning of simulation (Table 1); and,  
 n - date that the cultivar Arbequina reaches NL = 20.

In the PHYL model, NL is given by Martins et al. (2014) (Eq. 5):

$$NL_{estimated} = STac_{i=1}^n / \overline{PHYL} \quad (5)$$

where:

STac - air temperature function, given by the sum of the daily thermal time (Std) (Eqs. 6 to 8):

$$Std = (Tm - Tb) \text{ 1 day, when } Tb < Tm \leq Tot \quad (6)$$

$$Std = (Tot - Tb) \left[ \frac{Tm - TB}{Tot - Tb} \right] \text{ 1 day, when } Tot < Tm \leq TB \quad (7)$$

$$Std = 0, \text{ when } Tm \leq Tb \text{ or } Tm \geq TB \quad (8)$$

where:

Tb, Tot and TB - cardinal temperatures for MGSASC315 (11.0, 14.7 and 37.8 °C respectively) (Lisboa et al., 2012; Martins et al., 2012, 2014);

n - when the cultivar MGSASC315 reaches NL = 20; and,  
 PHYL - average phyllochron values (17.05 °C d leaf<sup>-1</sup>).

Tm data from three General Circulation Models (GCMs) - MIROC5 (M1), IPSL-CM5 (M2) and MRI-CGC (M3) (MCGs) members of the Coupled Models Intercomparison Project Phase 5 (CMIP5) were used in the air temperature functions of the VD models (f(T) of the WE and STac models in the PHYL model). GCMs were chosen due to the unavailability of up-to-date results from regional models, which are highly computationally costly. Besides, the new generation of GCMs

**Table 1.** Beginning of the simulations based on transplanting date (TT) and duration of the seedling phase, in calendar days, in both olive cultivars

Transplanting date (i)	Duration of the seedling phase (days) <sup>a</sup>	
	Arbequina	MGS ASC315
TT1 - 20/05/2010	69	84
TT2 - 20/06/2010	100	170
TT3 - 20/07/2010	76	132
TT4 - 20/08/2010	64	126
TT5 - 29/09/2010	91	110
TT6 - 27/10/2010	69	110
TT7 - 20/11/2010	72	100
TT8 - 21/12/2010	70	98
TT9 - 15/01/2011	89	108

<sup>a</sup>Extracted from Martins et al. (2014)

represents the state of the art in climate system modeling (Santos et al., 2017b).

Future climate simulations of CMIP5 use the new generation of radiative forcing scenarios called Representative Concentration Pathways (RCPs) -2.6, 4.5 and 8.5, which correspond to approximate radiative forcing of 2.6, 4.5 and 8.5 W m<sup>-2</sup>, associated with CO<sub>2</sub> equivalent concentrations of 490, 650 and 1.370 ppm, respectively at the end of the 21<sup>st</sup> century (Moss et al., 2010; Vuuren et al., 2011).

The T<sub>m</sub> used in the VD models was obtained by Eq. 9:

$$T_m = (T_{max} + T_{min}) / 2 \quad (9)$$

where:

T<sub>max</sub> - obtained by the average daily maximum air temperatures of the three GCMs (°C); and,

T<sub>min</sub> - obtained by the average daily minimum air temperatures of the three GCMs (°C).

It was necessary to make T<sub>m</sub> corrections in the three GCMs. Therefore, the methodology proposed by Lenderink et al. (2007) was used. It is based on the monthly bias between the climatic means (NP) obtained with the meteorological station data and the climatic means of the historical period of the GCMs, both for 1971 to 2000. Subsequently, the bias was applied to the daily values of T<sub>m</sub> for the month in question (January: 3.4; February: 2.8; March: 3.1; April: 3.2; May: 4.7;

June: 4.8; July: 4.5; August: 4.5; September: 3.8; October: 3.5; November: 3.9; December: 3.2 (°C)).

Finally, to evaluate the impact of climate change on the DSS variable, the analysis of variance (ANOVA) was applied in a tri-factorial scheme (9 x 3 x 3) to evaluate the effect of the sources of variation: transplanting dates (nine periods), representative concentration pathways (RCPs 2.6, 4.5 and 8.5) and projections (PR1 = 2011-2040, PR2 = 2041-2070 and PR3 = 2071-2100), as recommended by Streck et al. (2013). The DSS values were submitted to the Shapiro-Wilk normality test ( $p \leq 0.05$ ) and the means were compared by the Scott-Knott test ( $p \leq 0.05$ ) using the software SISVAR 5.3 (Ferreira, 2011).

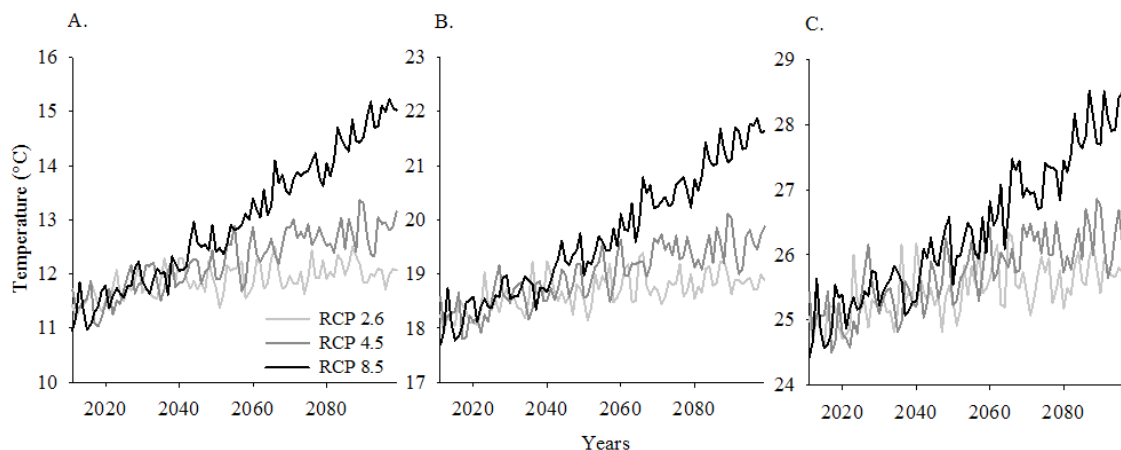
## RESULTS AND DISCUSSION

The air temperature projections for each RCP demonstrate a gradual increase in mean, maximum and minimum air temperatures throughout the 21<sup>st</sup> century, especially for RCP 8.5. This is expected because it presents the greatest radiative forcing (8.5 W m<sup>-2</sup>) and concentration of emitted CO<sub>2</sub> (1.370 ppm) (Riahi et al., 2011) (Figure 1).

This increase can reach 1.5 °C in the short term (PR1), 3.0 °C in the medium term (PR2) and up to 4.0 °C in the long term (PR3) for Maria da Fé, MG, Brazil (Table 2). This corroborates the values recorded by Santos et al. (2017b) for the state of Minas Gerais, Brazil.

Such increases in air temperature (Figure 1) will result in direct damage to the physiological processes of plants, influencing the duration of the vegetative and reproductive stages in olive crops (Tanasijevic et al., 2014) and, consequently, in the DSS. This occurs because the reactions of photosynthesis and photorespiration, enzymatic activities, rate of transport and translocation of solutes (Freitas et al., 2017) are intensified or reduced based on the temperature (Taiz et al., 2018).

Generally, in the current and future climates (PR1, PR2 and PR3), the DSS in Arbequina is lower than in MGS ASC315. In addition, except for TT5 (i = 29/09) and TT9 (i = 15/01), there is a similar behavior of DSS between the two cultivars, radiative forcing and projections. The rise in temperature will increase the DSS in TT1 (20/05), TT4 (20/08), TT6 (27/10), TT7 (20/11) and TT8 (21/12) and reduce DSS in TT2 (20/06)



Due to their values, the axes of the air temperature variables have different scales

**Figure 1.** Minimum (A), mean (B) and maximum (C) temperature projections obtained by the average of three general circulation models (GCMs) for three representative concentration pathways (RCP 2.6, 4.5, 8.5)

**Table 2.** Characterization of medium air temperature (°C) for simulations based on transplanting dates (TT) for the cultivars Arbequina and MGSASC315 for short (PR1 = 2011-2040), medium (PR2 = 2041-2070) and long term projections (PR3 = 2071-2099) in three representative concentration pathways - RCP (2.6, 4.5 and 8.5) for Maria da Fé, MG, Brazil

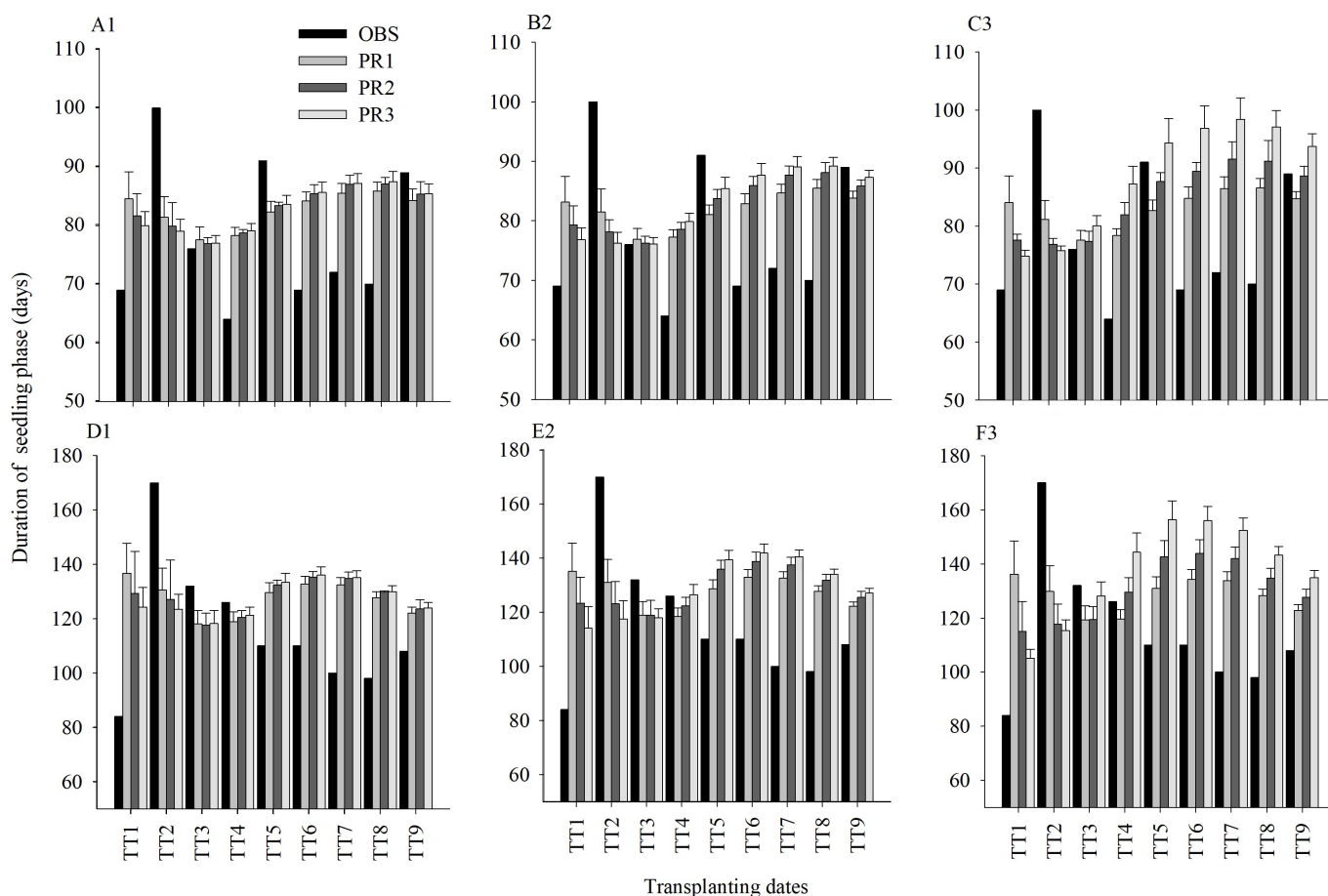
Transplanting date*	RCP 2.6			RCP 4.5			RCP 8.5		
	PR1	PR2	PR3	PR1	PR2	PR3	PR1	PR2	PR3
Arbequina									
TT1	13.2	13.5	13.7	13.2	13.7	14.2	13.2	14.2	15.5
TT2	14.2	14.4	14.6	14.0	14.5	14.9	14.1	15.2	16.6
TT3	16.4	16.5	16.6	16.2	16.6	17.2	16.2	17.8	19.5
TT4	19.1	19.2	19.4	18.8	19.5	20.0	18.9	20.6	22.2
TT5	21.0	21.3	21.4	20.8	21.7	22.1	21.1	22.5	23.9
TT6	21.7	22.0	22.1	21.4	22.2	22.6	21.7	22.9	24.4
TT7	22.0	22.3	22.4	22.0	22.7	23.1	22.2	23.4	24.7
TT8	22.1	22.4	22.5	22.2	22.8	23.1	22.3	23.3	24.5
TT9	21.6	21.9	21.9	21.7	22.2	22.6	21.7	22.6	23.7
MGS ASC315									
TT1	14.8	14.7	14.9	14.7	14.8	15.1	14.7	15.3	16.3
TT2	16.3	16.3	16.3	16.1	16.4	16.7	16.2	17.2	18.1
TT3	17.9	18.0	18.2	17.7	18.3	18.8	17.8	19.3	21.0
TT4	19.8	20.1	20.2	19.6	20.4	20.9	19.8	21.4	23.1
TT5	21.4	21.8	21.9	21.3	22.2	22.6	21.6	22.9	24.2
TT6	21.8	22.2	22.2	21.8	22.5	22.9	22.0	23.1	24.2
TT7	21.8	22.1	22.2	21.8	22.4	22.8	22.0	22.9	24.0
TT8	21.3	21.6	21.6	21.3	21.9	22.2	21.4	22.2	23.1
TT9	20.2	20.4	20.5	20.3	20.7	21.1	20.2	21.0	22.0

\* For transplanting dates consult Table 1

and TT3 (20/07) in both cultivars. Except for TT1, the increase in DSS occurred in simulations performed in periods with the highest air temperatures (Table 2). On the contrary, the reduction of DSS (about 20 days for Arbequina and 50 for

MGS ASC315) occurred in periods with the lowest values of air temperature, especially in TT3 and in RCP 8.5 (Figure 2).

The increase in DSS occurred mainly in the spring and summer (MGS ASC 315) (TT6, TT7, TT8 and TT9) (Figure 2), in



For transplanting dates consult Table 1. The vertical lines refer to the standard deviation

**Figure 2.** Duration of the seedling phase (DSS) for the cultivars Arbequina (A, B and C) and MGSASC315 (D, E and F) observed (OBS) and simulated for short (PR1 = 2011-2040), medium (PR2 = 2041-2070) and long term projection (PR3 = 2071-2099) in representative concentration pathways - RCPs 2.6 (1), 4.5 (2) and 8.5 (3)



which the highest values of  $T_m$  were projected; this is similar to what was observed for the VD of red rice (Streck et al., 2013) and potato (Streck et al., 2006). This occurs because at higher temperatures, especially above  $T_{ot}$  (Arbequina = 16.1 °C and MGS ASC315 = 14.7 °C) (Lisboa et al., 2012), there is a reduction in the development rate, thus increasing the DSS. Reduced development occurs due to higher breath maintenance rate, energy-consuming process (ATP and NADPH) or carbon skeletons from photosynthesis (Taiz et al., 2018), which raise maintenance costs by increasing protein turnover and maintaining ionic balance (Marenco & Lopes, 2009; Ruelland & Zachowski, 2010).

Significant effect of triple interaction was verified among transplanting dates, radiative forcing and projections for both cultivars ( $p \leq 0.05$ ) on the DSS. Among the main effects, the highest values of the *f*-test were for the transplanting date (1061.51: Arbequina and 506.53: MGSASC315), RCP (420.57: Arbequina and 161.84: MGSASC315) and projection (225.81: Arbequina and 84.67: MGS ASC315). This indicates that the transplanting date has a greater effect on VD and DSS for both olive cultivars (Table 3), similar to what was observed by Streck et al. (2013) in different rice genotypes.

There is a tendency of increase in DSS, except for TT2 and TT5 for Arbequina and TT2 and TT3 for MGSASC315, intensified toward PR3, especially in RCP 8.5 in both cultivars. More specifically, TT7 and TT8 of the Arbequina cultivar presented higher DSS in the three radiative forcing and in the three periods, around 86 days ( $\pm 0.311$ ) for PR1 and RCP 2.6 and 97 days ( $\pm 0.919$ ) for PR3 in RCP 8.5. Conversely, TT3 and TT4 will have the lowest DSS in radiative forcing in the short and medium term (PR1 and PR2, respectively). In addition, long-term TT1 and TT2 (PR3), especially in RCP 8.5, simulated in May and June,

will cause a reduction in DSS. In the cultivar MGS ASC 315 in TT2 there was also a reduction of DSS (around 47 days) in the three RCPs throughout the projections. From TT5 to TT9, especially those simulated in September (TT5), October (TT6) and November (TT7), presented an increase in DSS throughout the projections. For both olive cultivars, the VD through DSS was shortened or elongated depending on the simulated transplanting date, like that observed by Streck et al. (2006) with potato cv. Asterix, Streck et al. (2012) with corn, Liu & Tao (2013) with wheat, and Streck et al. (2013) with different rice genotypes.

Late growing seasons in autumn and early winter will increase VD and reduce DSS; and those cultivated in spring and summer will delay VD and increase DSS. This is mainly due to the fact that  $T_m$  is higher than the  $T_{ot}$  of the cultivars equal to 14.7 °C for MGSASC315 and 16.1 °C for Arbequina (Lisboa et al., 2012) and close to a cardinal temperature ( $T_B$ ) of 37.8 °C (Denney et al., 1985). The development rate increased when  $T_m$  was between  $T_b$  and  $T_{ot}$  but decreased when it moved away from  $T_{ot}$  and approached  $T_B$  (Streck et al., 2006; Ruelland & Zachowski, 2010; Martins et al., 2014). This occurs because in olive crops, Rubisco is the sole enzyme controlling photosynthesis in the metabolic process (Taiz et al., 2018). In conditions with high  $T_m$ , the Warburg effect occurs and  $O_2$  inhibits  $CO_2$  fixation by Rubisco, thereby reducing photosynthesis, increasing photorespiration (Marenco & Lopes, 2009) and DSS. In practice, it is necessary to reduce the negative impact of increasing  $T_m$  in warmer seasons in nurseries where olive seedlings are cultivated. For this, two options can be used namely: shading screens and sprinkler irrigation (Costa & Streck, 2018).

Considering climate change projections, studies by García-Mozo et al. (2010), Tanasijevic et al. (2014) and Moriondo

**Table 3.** Comparison of means for the duration of seedling phase (DSS, days) for both olive cultivars (Arbequina and MGS ASC315) considering three radiative forcing (RCP 2.6, RCP 4.5 and RCP 8.5) and three projections (PR1 = 2011-2040, PR2 = 2041-2070, PR3 = 2071-2100) in Maria da Fé, MG, Brazil

Transplanting date	RCP 2.6			RCP 4.5			RCP 8.5		
	PR1	PR2	PR3	PR1	PR2	PR3	PR1	PR2	PR3
Arbequina									
TT1	84.8 Cb3	81.6 Dc2	79.9 Bc1	83.1 Ca3	79.3 Bb2	76.8 Ab1	84.1 Db3	78.1 Aa2	74.8 Aa1
TT2	81.6 Ba2	79.9 Cb1	78.9 Bb1	81.3 Ba3	78.3 Ba2	76.3 Aa1	81.1 Ba3	77.2 Aa2	75.7 Aa1
TT3	77.6 Aa1	76.9 Aa1	76.9 Aa1	76.8 Aa1	76.3 Aa1	76.1 Aa1	77.5 Aa1	77.5 Aa1	80.0 Bb2
TT4	78.1 Aa1	78.9 Ba1	79.0 Ba1	77.2 Aa1	78.5 Ba2	79.9 Ba3	78.3 Aa1	81.8 Bb2	87.2 Cb3
TT5	82.1 Bb1	83.6 Ea2	83.5 Ca2	81.0 Ba1	83.5 Ca2	85.4 Cb3	82.5 Cb1	87.5 Cb2	94.2 Dc3
TT6	84.0 Cb1	85.5 Fa2	85.5 Da2	82.9 Ca1	85.7 Da2	87.6 Db3	84.6 Db1	89.3 Db2	96.7 Ec3
TT7	85.4 Da1	87.0 Ga2	87.1 Ea2	84.7 Ea1	87.6 Ea2	89.0 Eb3	86.4 Eb1	91.2 Eb2	98.2 Ec3
TT8	85.8 Da1	87.1 Ga2	87.4 Ea2	85.5 Ea1	87.9 Ea2	89.2 Eb3	86.5 Ea1	90.9 Eb2	96.9 Fc3
TT9	84.2 Ca1	85.4 Fa1	85.4 Da2	83.8 Da1	85.7 Da2	87.3 Db3	84.6 Da1	88.4 Db2	93.6 Dc3
MGS ASC315									
TT1	137.4 Ea3	129.4 Dc2	124.1 Cc1	134.6 Da3	123.8 Bb2	114.4 Ab1	136.1 Da3	116.8 Aa2	105.1 Aa1
TT2	131.0 Da3	127.3 Dc2	123.3 Cb1	130.4 Ca3	123.6 Bb2	117.6 Ba1	129.7 Ca3	118.9 Aa2	115.1 Ba1
TT3	118.0 Aa1	117.8 Aa1	118.0 Aa1	118.4 Aa1	118.9 Aa1	118.0 Ba1	119.2 Aa1	119.7 Aa1	127.8 Cb2
TT4	118.4 Aa1	120.9 Ba1	121.0 Ba1	118.3 Aa1	122.1 Ba2	126.5 Cb3	119.2 Aa1	129.1 Bb2	143.9 Ec3
TT5	129.2 Ca1	132.9 Ea2	133.2 Ea2	128.7 Ca1	135.5 Da2	139.4 Eb3	130.7 Ca1	142.1 Db2	156.1 Gc3
TT6	132.5 Da1	135.5 Ea2	135.8 Ea2	132.9 Da1	138.5 Db2	141.8 Eb3	133.9 Da1	143.5 Dc2	155.6 Gc3
TT7	132.2 Da1	134.9 Ea2	135.0 Ea2	132.6 Da1	137.2 Da2	140.4 Eb3	133.5 Da1	141.5 Db2	152.2 Fc3
TT8	127.6 Ca1	129.8 Da1	129.9 Da1	127.8 Ca1	131.5 Ca2	134.0 Db2	128.2 Ca1	134.4 Cb2	143.0 Ec3
TT9	121.9 Ba1	123.8 Ca1	123.9 Ca1	122.2 Ba1	125.3 Ba2	127.0 Cb2	122.6 Ba1	127.5 Bb2	134.8 Dc3

TT - Transplanting date. For transplanting dates consult Table 1. Means followed by the same capital letter in the column (radiative forcing), and lowercase letter in the line (transplanting date) and number (projection), do not differ among themselves by the Scott-Knott test at 0.05 probability. Original data is presented in the table above. However, transformation [Ln (DSS)] was necessary, due to the non-presupposition of normality

et al. (2015) demonstrated changes in the vegetative and reproductive development of olive crops in different regions of Europe. It has been verified that high temperatures (> 30 °C) at the beginning of flowering cause floral abortion (García-Mozo et al., 2010; Tanasijevic et al., 2014), while during pollination and flowering affects stigma receptivity, ovule longevity and pollen tube growth, impairing fertilization and fruit formation (Garcia et al., 2018). Concurrently, the duration of flowering and fruiting is shortened (Tanasijevic et al., 2014), indicating that olive crops are vulnerable to climatic changes. In addition, the increase in temperature will reduce the accumulation of chilling hours, which is required by the olive tree to interrupt dormancy, start differentiation of flower buds and have normal flowering (Santos et al., 2017a; Garcia et al., 2018). The insufficiency of chilling accumulation causes a series of physiological anomalies, generating irregularities in sprouting and flowering, which adversely affect the development (Santos et al., 2017a) of the olive tree.

Thus, both the vegetative development, represented by the DSS, and the reproductive development of the olive tree are vulnerable to the projected climatic changes throughout the 21<sup>st</sup> century. This corroborates the results presented by Santos et al. (2017b) for climatic zoning in MG, Brazil. Such information will affect the choice of the best dates for transplanting and the techniques for seedling production, development of the seedlings in projections of climatic changes, affecting the olive tree management and the success of seedlings establishment in the field.

## CONCLUSIONS

1. The increase in air temperature, reaching 3 °C at the end of the century, will probably modify the development rate and duration of the seedling phase in the cultivars Arbequina and MGSASC315 cultivated in Maria da Fé, MG, Brazil.

2. In colder months, there is increased vegetative development in olive crops and reduced seedling phase duration. Conversely, in warmer months, there is delayed development and longer seedling phase duration.

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