

**Univerzita Karlova**

**Přírodovědecká fakulta**

**Katedra botaniky**

Studijní program: Biologie

Studijní obor: Botanika



**Role fenotypové plasticity, genetické a epigenetické diferenciace u  
ekofyziologických znaků druhu *Festuca rubra* L. v reakci na klimatické  
změny**

**Role of phenotypic plasticity, genetic and epigenetic differentiation in  
ecophysiological traits of *Festuca rubra* L. in response to climate change**

**Bc. Veronika Koláříková**

**Diplomová práce**

Školitel: doc. RNDr. Zuzana Münzbergová, Ph.D.

Praha 2017



**Prohlášení:**

Prohlašuji, že jsem závěrečnou práci zpracovala samostatně a že jsem uvedla všechny použité informační zdroje a literaturu. Tato práce ani její podstatná část nebyla předložena k získání jiného nebo stejného akademického titulu.

V Praze dne 15.8. 2017

---

Bc. Veronika Kolářiková



## **Poděkování:**

Na tomto místě bych chtěla poděkovat své školitelce Zuzce Münzbergové za několik důležitých věcí. Za vedení práce, za spoustu cenných rad a připomínek, za přátelský přístup. Za to, že mě vedla k podání GAUKu, který bych bez jejího nápadu a pomoci nezískala. Za to, že mě nikdy nenechala ve štychu před všemožnými hořícími termíny pro odevzdání prací. A také za to, že mě ‘donutila’ napsat tuto práci v angličtině, i když se mi moc nechtělo, neb to pro mě byla velmi cenná zkušenost. Též děkuji Tomášovi Hájkovi za odborné rady s měřením fyziologických záležitostí a mnohé konzultace. Dále bych chtěla poděkovat rodině a přátelům za velkou podporu při celém studiu. A nakonec, velký dík patří Pavlovi Kosovi. Za to, že to se mnou vydržel, za rady, válečné porady a za pomoc s technickými počítačovými záležitostmi, které se třeba někdy naučím provádět sama.

Práce vznikla za finanční podpory GAČR 15-07795S a GAUK 925516.

## Abstrakt:

Pochopení schopnosti druhů reagovat na změnu klimatu je nezbytné pro předpověď jejich budoucího rozšíření. Pokud migrace není dostačující, je nutná reakce prostřednictvím fenotypové plasticity a/nebo genetické/epigenetické adaptace. Hlavním cílem této práce bylo zjistit, jaké mechanismy využívá v reakci na změnu klimatu dominantní druh *Festuca rubra*. Bylo zde využito recipročního přesazovacího pokusu s klimaboxy simulujícími různé klimatické podmínky na původních lokalitách v západním Norsku, které disponují faktoriálně zkříženými gradienty teplot a srážek, tedy zde bylo možné studovat vliv teploty a vlhkosti samostatně, ale i kombinovaně.

V první části experimentu byla oddělena plastická odpověď od genetické diferenciace tak, že rostliny s různými genotypy z původních lokalit byly přesazeny do klimaboxů nastavených na kombinace teplot a srážek z původních čtyř extrémních lokalit (nejvlhčí a nejsušší kombinované s nejteplejší a nejchladnějšími). Po pěti měsících byly měřeny ekofyziologické znaky, které jsou klíčové pro adaptivitu a fitness a jsou tak zásadní pro fungování rostlin. Mezi měřené znaky patří čistá fotosyntetická rychlost ( $P_N$ ), fluorescence chlorofylu (parametr  $\phi P_0$ ), osmotický potenciál, denzita průduchů, velikost průduchů a specifická listová plocha (SLA).

V druhé části experimentu bylo zjišťováno, zda součástí genetické diferenciace může být i epigenetická diferenciace. K tomu bylo využito stejných genotypů jako v prvním experimentu. Polovina rostlin byla ošetřena demetylačním činidlem 5-azacytidinem a polovina byla použita jako kontrola. Nově vytvořené ramety z těchto rostlin rostly ve dvou klimaboxech nastavených na studené-suché a teplé-vlhké původní podmínky. Byly měřeny znaky, u kterých byla detekována genetická diferenciace.

Studie prokázala, že relativní význam fenotypové plasticity a genetické diferenciace se výrazně liší mezi znaky. Fenotypová plasticita i genetická diferenciace jsou ovlivněny teplotou, vlhkostí a jejich interakcemi původu rostlin i kultivace a vliv těchto faktorů se liší mezi jednotlivými znaky. Epigenetická diferenciace nebyla zjištěna. Výsledkem tedy je, že reakce druhu *Festuca rubra* na změnu klimatu v rámci ekofyziologických znaků je řízena fenotypovou plasticitou a genetickou diferenciací, avšak bez epigenetické diferenciace.

**Klíčová slova:** Klimatické změny, ekofyziologické znaky, epigenetická diferenciace, genetická diferenciace, lokální adaptace, fenotypová plasticita, reciproční přesazovací pokusy

## Abstract:

Understanding the ability of species to respond to climate change is essential for prediction of their future distribution. When migration is not adequate, reaction via phenotypic plasticity and/or genetic/epigenetic adaptation is necessary. The main aim of this study is to determine mechanisms of response to climate change in dominant grass species *Festuca rubra*. The study used reciprocal transplant experiment with growth chambers simulating different climatic conditions. Original localities in western Norway represent factorially crossed gradients of temperatures and precipitations, thus it was possible to study the effect of temperature and moisture separately as well as combined.

In first part of the experiment, plastic responses were separated from genetic differentiation. To do this, plants with different genotypes from original localities were transplanted to growth chambers set to simulating temperature and moisture course in the four extreme localities (wettest and driest combined with warmest and coldest). After five months, ecophysiological photosynthetic-related traits were measured. These traits are important for species ability to adapt and maintain high fitness and thus they are essential for plants function. Specifically, it was net photosynthetic rate ( $P_N$ ), fluorescence of chlorophyll (parameter  $\phi P0$ ), osmotic potential, stomatal density, stomatal size and specific leaf area (SLA).

In the second part of the experiment I determined whether epigenetic differentiation could be part of the genetic differentiation using the same genotypes as in the first experiment. Half of the plants were treated by demethylation agent 5-azacytidine and half was used as a control. Newly grown ramets from these plants grew in two growth chambers set up to cold-dry and warm-wet original conditions. Traits, where genetic differentiation was detected in the first experiment, were measured.

The study demonstrated that relative effect of phenotypic plasticity and genetic differentiations strongly differs between traits and these effects are influenced by temperature, moisture and their interactions of origin as well as of cultivation and the effects of these factors differs between traits. Epigenetic differentiation was not detected. Therefore, it was suggested that the response of *Festuca rubra* to climate change within ecophysiological traits is driven by phenotypic plasticity as well as by genetic differentiation, but not epigenetic differentiation.

**Key words:** climate change, ecophysiological traits, epigenetic differentiation, genetic differentiation, local adaptation, phenotypic plasticity, reciprocal transplant experiment



# Contents

|                                                                                 |           |
|---------------------------------------------------------------------------------|-----------|
| <b>1 INTRODUCTION .....</b>                                                     | <b>11</b> |
| 1.1 First part – phenotypic plasticity and genetic differentiation.....         | 12        |
| 1.2 Second part – epigenetic differentiation.....                               | 13        |
| 1.3 Description of traits and measurement methods .....                         | 15        |
| 1.3.1 Net photosynthetic rate .....                                             | 15        |
| 1.3.2 Chlorophyll fluorescence.....                                             | 16        |
| 1.3.3 Osmotic potential.....                                                    | 18        |
| 1.3.4 Specific leaf area .....                                                  | 19        |
| 1.3.5 Stomatal density and size .....                                           | 19        |
| 1.4 Study species <i>Festuca rubra</i> L.....                                   | 19        |
| 1.5 Aims of the thesis.....                                                     | 20        |
| <b>2 METHODS .....</b>                                                          | <b>21</b> |
| 2.1 Localities .....                                                            | 21        |
| 2.2 First experiment .....                                                      | 22        |
| 2.2.1 Plant material.....                                                       | 22        |
| 2.2.2 Measurements.....                                                         | 24        |
| 2.2.3 Data processing and statistical analysis.....                             | 27        |
| 2.3 Second experiment .....                                                     | 28        |
| 2.3.1 Plant material.....                                                       | 28        |
| 2.3.2 Pilot experiment.....                                                     | 29        |
| 2.3.3 Measurements.....                                                         | 29        |
| 2.3.4 Data processing and statistical analysis.....                             | 30        |
| <b>3 RESULTS .....</b>                                                          | <b>31</b> |
| 3.1 First experiment .....                                                      | 31        |
| 3.1.1 Target and original climate and their interactions .....                  | 31        |
| 3.1.2 Signs of local adaptation.....                                            | 38        |
| 3.1.3 Directionality in environmental change responses .....                    | 39        |
| 3.1.4 Relationship between data from the first experiment and growth data ..... | 42        |
| 3.2 Second experiment .....                                                     | 44        |

|                                                                                                              |    |
|--------------------------------------------------------------------------------------------------------------|----|
| 3.2.1 Pilot experiment .....                                                                                 | 44 |
| 3.2.2 Effect of azacytidine, target and original conditions and their interactions for main experiment ..... | 45 |
| 3.2.3 Comparison of pilot and main experiment.....                                                           | 48 |
| 3.3 Comparison of result from the first and second experiment.....                                           | 49 |
| <b>4 DISCUSSION</b> .....                                                                                    | 51 |
| 4.1 Discussion of methods.....                                                                               | 51 |
| 4.1.1 First experiment .....                                                                                 | 51 |
| 4.1.2 Second experiment.....                                                                                 | 55 |
| 4.2 Discussion of results.....                                                                               | 56 |
| 4.2.1 First experiment .....                                                                                 | 56 |
| 4.2.2 Second experiment.....                                                                                 | 62 |
| <b>5 CONCLUSION</b> .....                                                                                    | 65 |
| <b>6 REFERENCES</b> .....                                                                                    | 66 |
| <b>7 APPENDIX</b> .....                                                                                      | 77 |
| 7.1 Primary data.....                                                                                        | 78 |

### List of shortcuts, figures and tables:

|           |                                                                            |
|-----------|----------------------------------------------------------------------------|
| dev       | Deviance                                                                   |
| $\phi P0$ | Parameter of chlorophyll fluorescence describing photosystem II efficiency |
| PCA       | Principal component analysis                                               |
| $P_N$     | Net photosynthetic rate                                                    |
| PSII      | Photosystem II                                                             |
| SLA       | Specific leaf area                                                         |

| Figures   | Page | Tables   | Page |
|-----------|------|----------|------|
| Figure 1  | 15   | Table 1  | 17   |
| Figure 2  | 17   | Table 2  | 23   |
| Figure 3  | 18   | Table 3  | 31   |
| Figure 4  | 19   | Table 4  | 38   |
| Figure 5  | 21   | Table 5  | 39   |
| Figure 6  | 33   | Table 6  | 42   |
| Figure 7  | 34   | Table 7  | 44   |
| Figure 8  | 36   | Table 8  | 45   |
| Figure 9  | 37   | Table 9  | 48   |
| Figure 10 | 38   | Table 10 | 49   |
| Figure 11 | 40   |          |      |
| Figure 12 | 43   |          |      |
| Figure 13 | 44   |          |      |
| Figure 14 | 46   |          |      |
| Figure 15 | 46   |          |      |
| Figure 16 | 48   |          |      |



# 1 Introduction

Global climate change is a problem that affects the entire Earth. Flora and fauna worldwide must cope with it, otherwise they risk extinction. One of the biggest problem is increasing temperature and changing precipitation regime (Walther et al., 2002), which represents selective pressure on natural populations. Many species will thus face novel conditions. They must respond to them adequately, if they want to survive. For understanding species future fitness and distribution, it is necessary to detect the mechanisms of reaction to climate which is underway now (Jump and Penuelas, 2005).

The plants can react to changing climate via migration, phenotypic plasticity, genetic adaptation or via combination of these strategies (Anderson et al., 2012b). Migration is well known and documented strategy (Ackerly, 2003; Davis and Shaw, 2001; Shaw and Etterson, 2012). However, recent studies suggest that only migration is not an adequate response to contemporary rate of climate change (Gienapp et al., 2008). In this case, plastic responses and/or genetic adaptations should be more important (Gienapp et al., 2008; Nicotra et al., 2010). Moreover, other recent studies showed that epigenetic modifications (e.g. DNA methylation) also should play role in adaptation to novel conditions (Bossdorf et al., 2008; Johannes et al., 2009). The question is, to what extent are the plants able to cope with climate change only via phenotypic plasticity, and when genetic differentiation (or/and epigenetic modification) is necessary (Ghalambor et al., 2007; Gienapp et al., 2008; vanTienderen, 1997). The importance of phenotypic plasticity versus genetic differentiation or epigenetic modifications for species response to changing climate is, however, still largely unknown (Hoffmann and Sgro, 2011).

Long-term changes in climate conditions can represent a stress for the species, especially in combination with thermal and rainfall extremes (Ciais et al., 2005). The reactions of species to the stress conditions depend on physiological adjustment which lead to changes in growth (Chaves et al., 2002; Penuelas et al., 2013). Physiological adjustments can be rapid and effective (Nicotra et al., 2010). For example, increase photosynthetic rate or decrease water loss via osmotic adjustment and changes in stomatal characteristic can lead to better prosperity in different climate. Changes in physiological traits should be thus crucial for general response of plants to climate change (Benomar et al., 2016; Yeh et al., 2012).

This study is focused on ecophysiological traits of the dominant grass species of temperate grasslands in Europe, *Festuca rubra*, under climate change. The study is divided into two parts. First part is concerned with role of phenotypic plasticity and genetic adaptation and second part considers a possibility of epigenetic differentiation.

## 1.1 First part – phenotypic plasticity and genetic differentiation

The plants can react to climate change via phenotypic plasticity and/or genetic adaptation. Phenotypic plasticity is the ability of a genotype to produce different phenotypes under different environmental conditions, e.g. (Valladares et al., 2014). Higher plasticity can provide to plants a better chance to adjust rapid environmental fluctuations and give them a time to further genetic adaptation to novel conditions, e.g. (Ghalambor et al., 2007; Jump and Penuelas, 2005; Nicotra et al., 2010). Although the phenotypic plasticity could protect the plants in long term, it can operate only within the historical extend of genetic variability of the species (Anderson et al., 2012a). The adaptation could be thus crucial in long term climate change. The adaptation to novel conditions occurs when the species dispose of sufficient genetic variability which enables to select genotypes capable to cope well with novel climate (Franks et al., 2014; Nicotra et al., 2010). If different genotypes from different environments do not respond to the certain climate change in the same way, we can say they are genetically differentiated. Moreover, if they prosper in their own environment better than in the others, we can talk about local adaptation (Kawecki and Ebert, 2004). Independent existence of genetic differentiation or local adaptation does not mean that plants are able to adapt to rapid climate change (De Frenne et al., 2011), but it provides information about ability of the population to adapt to their home climate in the past. Thus, it could be expected that, especially in combination with adaptive phenotypic plasticity, the plants will have a potential to adapt to climate change (Gonzalo-Turpin and Hazard, 2009).

To find out, what mechanisms the species use to respond to climate, it is necessary to separate the importance of genetic differentiation from plastic responses. One of the possibilities is to expose plants collected on the localities with different climatic conditions to climate change and study the differences between individual genotypes in different environments in selected traits. Reciprocal transplant experiment is an appropriate method to achieve this. This method is usually applied in controlled field experiment (Franks et al., 2014), but it is also possible to use growth chambers for simulating climate conditions at original localities (Gibson et al., 2016).

Most reciprocal transplant experiments have been done by transplanting species upwards or downwards along altitudinal or latitudinal gradients, e.g. (Etterson, 2004; Kim and Donohue, 2013; Zhou et al., 2013). For this study, the SeedClim project of University of Bergen (unique natural climatic grid with 12 grassland localities). It which dispose of factorial crossed gradients of average temperatures of three warmest months and average annual precipitations.

It is a unique system because at most localities is not possible to study temperature and precipitation conditions independently. The SeedClim system was used in several previous studies, e.g. (Klanderud et al., 2015; Meineri et al., 2014; Meineri et al., 2013).

For my experiment, plants were collected in the original Norwegian localities. Identical clones from the populations were transplanted into growth chambers simulating four extreme conditions from the original sites. By measuring ecophysiological traits, it was assessed whether plants respond to climate change by phenotypic plasticity (target effect), i.e. when all plants within each growth chamber react to change identically regardless of their origin or the reaction differs between populations (effect of origin), i.e. when plant populations within each growth chamber react to change differently. It was also possible to look at the local adaptation via comparison of prosperity in home and foreign conditions.

This system also provides a possibility to find out whether the plants respond to change in temperature together with precipitation by improving or worsening their fitness and how extensive this change will be (Butof et al., 2012; Lu et al., 2016; Wu et al., 2016). For Norway, the climate change forecast is rising temperature (by about 1.5°C to 2.2°C) and precipitation (by about 18%) over the next century (Hanssen-Bauer et al., 2005). The climate change simulated in this study is in maximum by 4°C and by 2100mm of precipitations. By transplanting the plants to warmer and wetter conditions it is thus possible to assess how plants will respond to this predicted climate change just through phenotypic plasticity.

## **1.2 Second part – epigenetic differentiation**

First part of the thesis shows if the species react to climate change via phenotypic plasticity or if the plants are also genetically differentiated which could lead to local adaptation. Indeed, the genetic differentiation could not be driven just by differences in genetic information but also could be driven by epigenetic modifications (Cortijo et al., 2014; Latzel et al., 2012; Zhang et al., 2013).

Epigenetic modifications are changes in genes expressions without changing the DNA sequence. The best-known and explored modification is DNA methylation (Ashapkin et al., 2016). DNA methylation is a biological process by which a methyl group is added to the cytosine bases of DNA to form 5-methylcytosine (Liu et al., 2015). Change in DNA methylation or change in other epigenetic modifications could be expressed by phenotype change (Nicotra et al., 2010). It was found that the epigenetic modifications determining phenotypic expression can differ in identical genotypes under different conditions (Ashapkin et al., 2016). Moreover,

the studies show that the plants can “memorize” the conditions where they grow and pass this experience to their offspring (Akimoto et al., 2007; Latzel et al., 2014; Verhoeven et al., 2010). It means that a considerable proportion of epigenetic modifications could be stably transmitted from parents to offspring (Johannes et al., 2009; Vaughn et al., 2007). It indicates that these modifications can be heritable and may provide an adaptive advantage to offspring (Boyko and Kovalchuk, 2011; Liu et al., 2015). Moreover, it was suggested that transgenerational effect driven by epigenetic modifications are stronger in stressful condition such as heat stress (Iwasaki and Paszkowski, 2014; Zhong et al., 2013). The inheritance of epigenetic modifications also depends on the mode of reproduction. In the case of sexually growing plants, these environmentally induced epigenetic changes may not be transferred to offspring because they are deleted during meiosis (Jullien and Berger, 2010). However, some studies demonstrate the existence of epigenetic modifications in sexually reproducing plants, such as the study of flower mutants of *Linaria vulgaris* where the flower symmetry is probably epigenetically inherited for at least 250 years (Cubas et al., 1999). Even environmentally-induced epigenetic changes can be heritable leading to transgenerational maternal effects (Boyko and Kovalchuk, 2011). Through this effect, heritable epigenetic modifications are often studied in sexually reproducing plants by exposing maternal plants to some stress factor and observing whether the experience with the stress environment is transferred to offspring, e.g. (Latzel et al., 2014; Yang et al., 2015). However, vegetatively reproducing plants produce offspring with identical genetic information as their parents. Thus, it is possible to directly study changes in methylation between parents and offspring and show the role of epigenetic inheritance in transgenerational effect. Moreover, clonal plants do not realize meiosis so the epigenetic inheritance can play more prominent role in clonal plants than in sexually reproducing plants (Duhovnikoff and Dodd, 2015).

One of the relatively simple ways how to indirectly test whether the epigenetic modification could play some role in adaption to climate change is to compare genetically identical plants treated with demethylation agent with control plants under different climatic conditions (Gonzalez et al., 2016). To do this, identical genotypes of plants as in the first part of experiment were used. Using the same system as in the first part allows to find out, whether the differences between genotypes from different populations could be caused by epigenetic differentiation and if epigenetic modification can contribute to adaptation to climate change.

As demethylation agent was used 5-azacytidine (Sigma-Aldrich, Praha, Czech Republic). It is agent which inhibit methylation of emerging DNA (Jones et al., 1983). The plants treated with this agent should clonally produce new ramets without inherited methylation

marks. 5-azacytidine was successfully used in some previous studies (e.g. (Gonzalez et al., 2016)).

### 1.3 Description of traits and measurement methods

Within this study, selected traits described below were measured: net photosynthetic rate ( $P_N$ ), chlorophyll fluorescence parameter expressing photosystem II efficiency (parameter  $\phi P0$  – PSII efficiency), specific leaf area (SLA), osmotic potential, stomatal density and stomatal size. Previous studies focused on phenotypic plasticity and genetic differentiation under climate change mostly study growth-related traits (e.g. the studies reviewed in (Franks et al., 2014). This study is focused on ecophysiological traits. These traits are important for species ability to adapt and maintain high fitness and thus they are essential for plant function (Benomar et al., 2016). However, they are very rarely used in these types of studies. Thus, the diploma thesis provides important novel information about functionality of these traits under climate change.

#### 1.3.1 Net photosynthetic rate

Net photosynthetic rate ( $P_N$ ) is the total rate of photosynthetic  $CO_2$  fixation after subtraction of the rate of  $CO_2$  release during respiration per second. Photosynthetic rate is influenced by many external factors such as temperature and water regime and also the structure of assimilating organs such as leaves thickness or stomata density (Procházka, 1998). Net photosynthetic rate is closely related with the activity and assimilation capacity of Rubisco. This capacity changes with temperature (Yamori et al., 2014) and also is affected by soil moisture (Azhar et al., 2014). It is known that photosynthesis rate disposes high plasticity mainly in changing temperatures (Yamori et al., 2014) but also shows certain genetic differentiation between populations, e.g. (Azhar et al., 2014; Robakowski et al., 2012).

One of the most common methods of net photosynthesis rate measurement is gasometric method (Procházka, 1998). The method principle is the exact measurement of the loss of  $CO_2$  that pass-through measuring chamber with leaves of life plant. The loss of  $CO_2$  thus represents the amount of  $CO_2$  taken by the plant for photosynthetic



**Figure 1:** Li-Cor 6400, illustration of measurement

processes. Li-Cor 6400 (Lincoln, Nebraska, USA) (Fig. 1) was used for the measurements in this study.

### 1.3.2 Chlorophyll fluorescence

Chlorophyll fluorescence is energy absorbed by chlorophyll molecules re-emitted as light. Approximately 90% of fluorescence at room temperature is emitted by photosystem II (PSII) (Maxwell and Johnson, 2000). The quantity of this emitted light depends on the ability of PSII to utilize absorbed light energy. By measuring chlorophyll fluorescence is thus possible to detect the degree of damage of photosystem II in chloroplasts. It shows a quality of metabolism of chloroplasts, through which it is possible to document various kinds of stresses in reaction to different environmental conditions, e.g. drought or temperature stress (Maricle and Adler, 2011). Fluorescence of chlorophyll could change among sites with different climatic conditions within species (Reinhardt et al., 2011; Song et al., 2016) but also could be influenced by origin of the plants when grown in common conditions (Psidova et al., 2015).

The most common method how to obtain the values of chlorophyll fluorescence is to measure dark adapted plants by fluorometer. Dark adaptation is important to obtain a reference point in which all plants will be photosynthetically inactive before the measurement (Maxwell and Johnson, 2000). Here, the chlorophyll fluorescence at dark adapted plants was measured using Fluorpen FP-100 MAX/USB (Photon System Instruments, Czech) (Fig. 2). The principle of the measurement with Fluorpen is in plant expository to saturated light and measurement of emitted fluorescence which proceeds as follows. All electron transmitters and reaction centers in PSII are reoxidated in dark adapted state. In this state, fluorometer illuminates the plant with weak radiation and detect minimal level of chlorophyll fluorescence ( $F_0$  or O (origin)). Then the plant is illuminated by saturated pulse of light, which cause fast closure of all active reaction centers of PSII because all electron acceptors are reduced. This point occurs one second after illumination and is called maximum yield of fluorescence ( $F_M$  or P (peak)). Between these two points 2 intermediate points ( $F_J$  and  $F_I$ ) are also measured. All these parameters are called OJIP or so called Kautsky effect. From these four measured numbers, it is possible to calculate parameters which represent photochemical quantum yield of PSII and photochemistry and electron transport activity (Stirbet and Govindjee, 2011). Table of shortcuts of values and their formulas are shown in Table 1.

One parameter was used for subsequent analyses: Maximum quantum yield of primary PS II photochemistry ( $\phi P0$ ). This parameter is considered to be a good indicator of metabolic perturbations in leaves of many species (Baker and Rosenqvist, 2004).  $\phi P0$  provides an estimate maximum quantum efficiency of PSII photochemistry (Butler, 1978). This parameter is widely used to detect stress-induced changes in the photosynthetic apparatus. Decrease in the parameter can be caused by slowly relaxing quenching processes and photodamage to PSII reaction centers which reduce the maximum quantum efficiency of PSII (Baker and Rosenqvist, 2004). Thus, decreasing  $\phi P0$  means degradation of photosynthetic apparatus and higher values of this parameter show better prosperity of the plant in given growth conditions.



**Figure 2:** Fluorpen FP-100 MAX/USB

**Table 1:** Table of shortcuts of OJIP parameters and their meanings.

| shortcut  | meaning                                                                                                                                     | Formula     |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| $F_0$     | Minimum fluorescence (all PSII reaction centers open, $t = 0$ , O-step) first reliable fluorescence after the onset of actinic illumination |             |
| $F_M$     | Maximum fluorescence (all PSII reaction centers closed, P-step) maximum value under saturating illumination                                 |             |
| $F_J$     | Fluorescence at the J-step ( $t = 2$ ms)                                                                                                    |             |
| $F_I$     | Fluorescence at the I-step ( $t = 30$ ms)                                                                                                   |             |
| $F_V$     | Maximum variable fluorescence                                                                                                               | $F_M - F_0$ |
| $\phi P0$ | Maximum quantum yield of primary PSII photochemistry (PSII efficiency)                                                                      | $F_V / F_M$ |

### 1.3.3 Osmotic potential

Water potential describes water content in the soil, plants and atmosphere. The contrast in the water potential between two different sites in one system (for example root and leaf) determines the direction of water transport in the system. Water potential ( $\Psi_w$ ) is composed of osmotic potential ( $\Psi_\pi$ ), matrix potential ( $\Psi_m$ ), turgor potential ( $\Psi_p$ ) and gravitational potential ( $\Psi_g$ ) (Procházka, 1998).

$$\Psi_w = \Psi_\pi + \Psi_m + \Psi_p + \Psi_g \text{ [MPa]}$$

In this study, osmotic component of water potential was measured. The osmotic potential is the chemical potential of water in a solution due to the presence of dissolved substances (solutes). The osmotic potential always takes negative values because water moves from lower concentration of solutes to higher concentrations (pure water at atmospheric pressure and at a temperature of 25°C corresponds to zero MPa) (Chavarria and Pessoa dos Santos, 2012). The plant with lower value of osmotic potential has more solutes in its cells. The values of osmotic potential produced by the cell solute concentration at full hydration correspond with values of turgor loss point (Bartlett et al., 2014). Turgor loss point is negative water potential at which leaf cells lose turgor and the leaf wilts (Cheung et al., 1975). In this point, the plant is closing stomata, ceasing gas exchange and growth. Also, the turgor loss point represents the soil water potential below which the plant cannot take up sufficient water to recover from wilting (Bartlett et al., 2012b). When the plant is osmotically adjusted (the osmotic potential acquires lower values – symplastic solute concentration is higher), it causes delay of turgor loss point, and therefore better osmotic adjustment to drought. Osmotic potential is thus key drought tolerance trait with high level of plasticity (Bartlett et al., 2014).

The osmotic potential was measured using Wescor HR-33T (Wescor, Inc., USA) (Fig. 3) with dew point method. The method is based on measuring the dew point temperature of the air above a sample closed in measuring chamber using a thermocouple. The temperature is compared with temperature measured at the reference sample at which the osmotic potential is known.



**Figure 3:** Wescor HR-33T

### 1.3.4 Specific leaf area

Specific leaf area (SLA) is defined as leaf area per unit dry mass [ $\text{mm}^2/\text{mg}$ ] (Wilson et al., 1999). SLA is often positively correlated with plant growth (Garnier et al., 2001) and amount of nitrogen (Wright et al., 2004) and may be indicative of trade-off between rapid biomass production (high SLA) and efficient conservation of nutrients (low SLA) (Giuliani et al., 2014). Changes in SLA could be driven by phenotypic plasticity (Agrawal et al., 2008) but also by genetic adaptation (De Frenne et al., 2011).

### 1.3.5 Stomatal density and size

Stomatal density and size are related to the ability to regulate gaseous exchange (Bussotti et al., 2005). Carbon dioxide acquisition is crucial for photosynthetic procession but it leads to water loss. Trade-off between stomatal density and size is hence important for plant's prosperity (Beerling and Chaloner, 1993). The presence of numerous small stomata is considered an adaptation to dry environments (Bussotti et al., 2005) which means that stomata size and density change with different precipitation regimes (Taylor et al., 2012). Small stomata also increases capacity for transpirational cooling (Hetherington and Woodward, 2003) and thus could be advantageous in adaptation to higher temperatures (Carlson et al., 2016). These characteristics could be also plastic in response to different temperature and precipitation regimes (Montoro and Sadras, 2014; Xu et al., 2014).

To obtain epidermal impression of the abaxial leaf surface, the clear nail polish was used, as e.g. (Anderson and Gezon, 2015).

## 1.4 Study species *Festuca rubra* L.

*Festuca rubra* L. (Fig. 4) is a common perennial grass species of temperate grasslands in Europe. The species grows across a wide climatic gradient in different density in grasslands, both as a dominant with only few other species and also as a minor component of species rich stands. It reproduces by seeds as well as vegetatively producing both intravaginal and extravaginal tillers on rhizomes (Münzbergová et al., 2017). Clones of *F. rubra* are characterized by considerable genetic variability and plasticity in response to environmental factors (Herben et al., 2001; Skalova et al., 1997).



**Figure 4:** *Festuca rubra* L., plant from experiment

## 1.5 Aims of the thesis

The main aim of the thesis was to understand the importance of genetic and epigenetic differentiation along gradients of temperature and moisture and the degree of plastic response to temperature and moisture on ecophysiological traits of a wide-spread clonal grass, *Festuca rubra*.

This study provides new information about the mechanisms of adaptation to climate change in the species which dominates in many grassland systems. Norwegian system of localities allows to study changes in temperature and moisture independently but also combined without other factors, for instance a length of a day. The study is divided into two parts. Each part provides new knowledge and will help to answer the following questions:

### 1) First part

- a) Is the response within ecophysiological traits of *Festuca rubra* to the climate change driven primarily by phenotypic plasticity or genetic differentiation? Respectively, what is a relative importance of phenotypic plasticity, genetic differentiations and their interactions in measured traits?
- b) Can a local adaptation be considered? Respectively, do plants perform better in their home conditions?
- c) How will the plants respond to predicted climate change? Respectively, how do the plants respond to different degree and direction of climate change?
- d) How will these patterns differ between the traits?

### 2) Second part

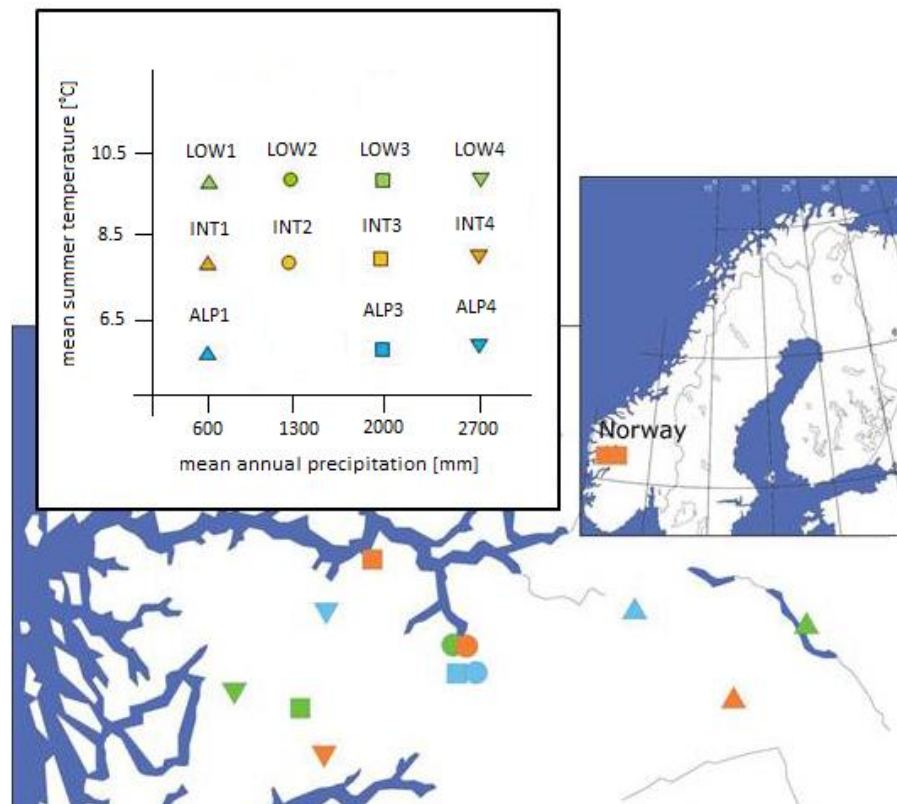
- e) Is the genetic differentiation detected in the first part caused by epigenetic differentiation? Respectively, will the demethylation of cytosine affect the expression in the plant traits?

## 2 Methods

### 2.1 Localities

For this thesis localities established within SeedClim project of University of Bergen was used. Seedclim project is natural climate grid in western Norway, which combines 12 sites representing four levels of mean annual precipitation (ca. 600 (1), 1300 (2), 2000 (3), and 2700 (4) mm, Fig. 5) and three levels of summer temperature (means of the four warmest months (6.5 - LOW, 8.5 - INT and 10.5 - ALP °C, Fig. 5). The target communities are grazed intermediate-rich meadows (*Potentillo-Festucetum ovinae*; G8 sensu Fremstad 1997) occurring on south-facing (except for one site (LOW 3), which is exposed to the east, shallow slopes (5–20°C) with relatively rich bedrock terms of nutrient availability. Sites were selected specifically to keep grazing regime and history, bedrock, slope, aspect, and vegetation types as constant as possible. Geographical distance between sites is on average 15 km and ranges from 175 km (LOW1 and LOW4) to 650 m. The two geographically closest localities, LOW2 and INT2, which are only 650 m apart are also 400 m a.s.l. apart (Meineri et al., 2014; Münzbergová et al., 2017).

**Figure 5:** Position of each site within the SEEDCLIM climate grid. Missing point shows the locality where *Festuca rubra* does not occur. The figure was taken from University of Bergen website.



## 2.2 First experiment

### 2.2.1 Plant material

For this thesis, the plant material, which was collected and prepared for experiments within a project of my supervisor, was used. The method of collecting and preparation of the experiment is thus taken from the publication of Zuzana Münzbergová (Münzbergová et al., 2017).

In July 2014, at least 40 clones of *F. rubra* were collected at each locality, except one (ALP2), where *F. rubra* does not occur. Therefore, the collection was realized only in 11 localities. The collected plants were located at least 1 m apart from each other. The living plants were transported to the experimental garden of the Institute of Botany in Průhonice and planted into pots (16 x 16 x 16 cm, filled with a mixture of common garden soil and sand in 1:2 ratio). After the plants recovered from the transport at the end of August 2014, the plants were extracted from the pots and reduced to a single ramet. This was done to ensure that they have only one clone per pot avoiding the possibility that they originally collected multiple intermingled clones.

At this stage, the identity of plants was also confirmed using flow cytometry (see (Castro et al., 2011) for methods) and only those with a genome size ranging between 9.29 and 10.41 pg were selected. This corresponds to the most widespread hexaploid cytotype of *F. rubra* (Sampoux and Huyghe, 2009). From each locality, 25 viable genotypes fulfilling this condition were selected.

Cultivating the plants continued in the garden until November 2014. Then the clones were transferred to the greenhouse. The temperature in the greenhouse was set to keep between 5°C and 10°C. At the beginning of February 2015, about 10 single ramets of similar size with three leaves and without flower buds were cut off from the tussocks and placed into small plastic cups filled with water to set roots. At the end of February 2015, a single ramet with developed roots was planted into pots 5 × 5 × 8.5 cm into a mixture of common garden soil and sand in 1:2 ratio. For each clone (25 clones from each population), 4 ramets were planted. The pots were kept in the greenhouse and dead ramets were replaced if necessary within the next two weeks.

The pots were divided into 4 groups so that one clone from each population was represented in each group. Thus, in each group were 11 populations x 25 clones, i.e. 275 ramets in each growth chamber, i.e. 1100 ramets in total. Pots within each group were fully randomized, placed into three metal trays and moved to a growth chamber. The position of the pots in the growth chamber were randomized monthly.

The plants were cultivated in climatic chambers (Vötsch 1014) under conditions simulating the field situation in the spring (second half of April - second half of June). The regimes were derived from temperature course in the four extreme localities (wettest and driest combined with warmest and coldest), but respecting technical possibilities of the climatic chambers and avoiding night frosts. The temperature in the growth chamber differed between the cold and warm treatments and changed over the growing season following the course of temperature at the natural localities (Table 2). To set the correct moisture level in the growth chambers, TMS5 data-loggers were used to continuously measure soil moisture in the pots (TOMST Co., (Hemrova et al., 2016)) and identified the correct level of watering to achieve soil moisture comparable to that at the localities. As a result of this calibration, the dry regime plants were watered with about 20 ml of tap water per plant applied to the trays if the soil moisture was lower than 15%. In the wet regime, plants were cultivated under full soil saturation with about 1.5 cm of water in the bottom of the tray. Soil moisture was monitored continuously during the whole experiment and watering was modified to ensure constant moisture throughout the experiment. Three data-loggers were placed in each growth chamber. Each data-logger was placed in a pot with a growing *Festuca* plant, which was intermixed among the experimental plants and was of the same size as the experimental plants, but was not a part of the experiment. For all the regimes, the same day length and radiation were used, i.e. 16 hours of full light (6 am – 10 pm) and 4 hours of full dark with a gradual change of light availability in the transition between the light and dark period over 2 hours. Over the full light period, the radiation was  $360 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ , red radiation (R,  $\lambda=660 \text{ nm}$ ) of  $26 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ , and far-red radiation (FR,  $\lambda=730 \text{ nm}$ ) of  $15 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ ,  $R/FR = 1.73$  (the radiation measured using a SPh 2020 photometer from Optické dílny Turnov, Czech Republic).

**Table 2:** The table shows temperature regimes set in growth chambers during experiment. The table was taken from (Münzbergová et al., 2017).

| COLD REGIME     | Time (day) | Min | Max    | Av    | WARM REGIME     | Time (day) | Min   | Max    | Av     |
|-----------------|------------|-----|--------|-------|-----------------|------------|-------|--------|--------|
| acclimatization | 1-4        | 5°C | 15°C   | 9.8°C | acclimatization | 1-4        | 5°C   | 16°C   | 10.1°C |
| Cold 1          | 5-67       | 3°C | 12.5°C | 7.5°C | Warm1           | 5-25       | 3°C   | 16°C   | 9.2°C  |
|                 |            |     |        |       | Warm2           | 26-46      | 3°C   | 18.5°C | 10.2°C |
|                 |            |     |        |       | Warm3           | 47-67      | 3°C   | 24.3°C | 12.5°C |
| Cold4           | 68-88      | 3°C | 14.5°C | 8.4°C | Warm4           | 68-88      | 3.4°C | 25°C   | 12.9°C |
| Cold5           | 89-176     | 3°C | 14.7°C | 8.5°C | Warm5           | 89-176     | 5°C   | 23.8°C | 14.8°C |

### 2.2.2 Measurements

The measurement started when acclimatization in growth chambers terminates. Beside the ecophysiological traits described below, other growth traits were measured on the plants – plant height, number of ramets, proportion of extravaginal ramets, rhizome weight, belowground biomass, aboveground biomass and belowground and aboveground biomass ratio. The measurements and results from this part are presented in (Münzbergová et al., 2017). Here, these growth-related traits were used for illustration of the relationships between all traits.

#### 2.2.2.1 Net photosynthetic rate ( $P_N$ )

Photosynthesis was determined by measurement of light-saturated net photosynthetic rate ( $P_N$ ) by Li-Cor 6400.

This measurement was done only on the plants from four most extreme localities: warm-dry (LOW 1), warm-wet (LOW 4), cold-dry (ALP 1) and cold-wet (ALP 4) (Fig. 5). It was not possible to measure all plants from the experiment, because each measurement was too time-consuming. Therefore, only 10 plants were randomly selected from each locality, i.e. 40 plants in each growth chamber, i.e. 160 plants in total (total number of all plants is 1100).

Plants were moved from growth chamber into the room of measurements at least half an hour before the measurement. As plants usually close stomata after moving in response to environmental change, it was necessary to give them enough time to re-open them. Before measuring, leaves were prepared so that they fit exactly into measuring area of the Li-Cor chamber (chamber has a size of 2 x 3 cm). Leaves were aligned side-by-side to total width of 2 cm and fixed by two tapes. The tapes were 3 cm apart. The result was area filled with leaves of size 2 x 3 cm bordered by two tapes, which corresponded to measuring area of Li-Cor chamber.

Measurement: The measurements were done at 25° C  $\pm$  2° C and minimum 55% of relative humidity. Li-Cor was set at light intensity of 1600  $\mu\text{mol m}^{-2} \text{s}^{-1}$  and CO<sub>2</sub> flow rate 300  $\mu\text{mol s}^{-1}$ . Each plant was measured at least 25 minutes to ensure that the stomatal conductance is stabilized, which usually occurred in 15-20 minutes. The leaves were cut after each measurement. Then the measured leaves were scanned and put in a paper bag. The measurements were done daily from 8 am to 5 pm. To verify that this day time had no effect on measurement, the several plants were pre-experimentally measured three times during a day - at the morning, midday and later afternoon. All measurements lasted for four weeks.

For the calculation of  $P_N$  it is necessary to know the exact area of the measured leaves. The area of the scanned leaves was measured in program NIS-elements (Laboratory Imaging, spol. s r. o.). Almost all leaves were naturally folded and their area was measured in the folded state. Area of leaves which were non-folded was divided by two to correspond to the area of the folded leaves.

#### **2.2.2.2 Specific leaf area (SLA)**

For the calculation of specific leaf area (SLA), scanned parts of leaves after measurement with Li – Cor were used. The samples were placed in paper bags, dried at 60 °C and weighed. For calculation of the leaf area, area of folded leaves was multiplied by two to acquire real area of the leaves. SLA was calculated as a ratio of leaf area (mm<sup>2</sup>) to dry mass (mg).

#### **2.2.2.3 Chlorophyll fluorescence**

Chlorophyll fluorescence was measured using FluorPen FP-100 MAX/USB set to measurement of OJIP parameters (Stirbet and Govindjee, 2011).

To obtain the required parameters, it was necessary to keep the plants to adapt to darkness before measuring. Therefore, growth chambers were set to switch off light earlier – at 8 pm. Usually, they switch off at 12 midnight. The plants were transferred in fully-dark plastic bags to a dark room, where the temperature was about 25 °C. Headlamp, which was covered by green plastic film, was used to navigate in the darkness (green light has no effect on the fluorescence, it was confirmed experimentally during preparation of the experiment). All samples were measured 3 times. Different plant parts were measured in each measurement to ensure that the same place on the plant was not exposed to radiation by light pulses of FluorPen twice. The measurements started at 9 pm and ended at 10:30 pm. All the measurements lasted 14 days.

#### **2.2.2.4 Osmotic potential**

Osmotic potential was measured with dew point micro voltmeter Wescor HR-33T using dew point method (e.g. (Bartlett et al., 2012b)).

For samples preparation, it was necessary to have all plants fully saturated with water. Therefore, sampling was timed just before terminating the growth chamber experiment. All plants were watered one day before sampling so that they stand in water. The next morning,

two or three well-grown leaves were cut off from each plant. These leaves were placed into a syringe. The syringe was closed with piston and its needle was sealed up by a rubber stopper. All prepared samples were placed in a freezer set to -20°C and were left there for several weeks until the measurement began.

The samples were taken out of the freezer half an hour before the measurements. The needle was removed from the syringe. By pressure of the piston, leaf cytoplasm was squeezed out and pipetted (pipette was set to 10 microliters). The leaf cytoplasm from pipette was placed into the measuring chamber on a filter paper. All samples were measured until equilibrium has been stabilized – it occurred usually after three minutes. Values were read twice, after three minutes and after six minutes for a control. Values measured with Wecor are not real values of osmotic potential. The real values must be calculated using standardized solution with known value of osmotic potential. 0.3 mol solution of NaCl with osmotic potential 1.34 MPa was used.

#### **2.2.2.5 Stomatal density and stomatal size**

Stomatal density and stomatal size was measured on samples of all localities, but from each locality only 10 plants were selected.

For studying stomatal density and size, stomatal imprints were used (for example (Gitz and Baker, 2009)). Two opened leaves were placed on a microscope slide with abaxial side up and fixed by a tape. They were covered by transparent nail polish and let dry for about an hour. A transparent adhesive tape was then placed over the polish and used to remove the imprint from the leaves. The imprint with the tape was placed on another microscopic slide. The tape was carefully removed so that the imprint stayed on the slide.

Stomatal density and stomatal size was assessed from the imprint using microscope Nikon with camera for live projection. NIS – elements software was used for calculation of stomatal density and stomatal size. Stomatal density was calculated using a grid with a square edge of 500 µm. The number of stomata was calculated in certain area. Edge of the leaf and edge of the grid delimited the area. Exact dimension of the selected area was determined and number of the stomata per unit area was calculated. Stomata density was counted on three parts of each sample. From each of these three parts, three stomata were randomly chosen and their length was measured, resulting in 9 measured stomata of each sample.

### 2.2.3 Data processing and statistical analysis

Complete dataset consisted of six traits. Correlation among all the traits was explored by Pearson correlation. The correlation was done on 160 plants, for which all the traits were measured, see above. The correlation also included other traits presented in (Münzbergová et al., 2017). This correlation was also done on the same 160 plants. To create correlation matrix and assess its significance, the Hmisc package (Harrell, 2016) in R (version 3.3.2) was used. To visualize the correlation, principal component analysis (PCA) with standardization across traits was done using the vegan package (Oksanen, 2016) in R.

All other tests were done using mixed effect models with clone identity as a random factor. If it was necessary, data were transformed to fit the assumptions of normality and homogeneity of variance. For all dependent variables, the tests assume Gaussian distribution of the dependent variable, except for PSII efficiency assuming Gamma distribution. Also, relative importance of local and target conditions expressed as the proportion of total deviance explained in the data was counted. For net photosynthetic rate, additional analysis with time of measurement as covariate was done to check the influence of measuring time on the results. Mixed effect models were processed with R (version 3.3.2) using lme4 package (Bates et al., 2015).

Several hypotheses in the first experiment were tested. For each, different system of data preparation was used.

#### 1) Effect of origin, target, and their interactions:

To study the effect of origin, target, and their interactions on all the dependent variables, different temperatures and precipitations of the original localities and target conditions were coded. They were coded with numbers 1-4 for precipitations (1 representing the lowest and 4 the highest value for precipitation), and 1-3 for temperatures (1 for the lowest and 3 for the highest value for temperature). Conditions in the growth chambers were coded in the same way (using 1 and 3 for low and high values of temperature and as 1 and 4 for low and high values of precipitation). The effects of temperature and precipitation of origin as well as target and their two-way interactions on performance of the plants were tested.

Because all the traits were not measured within all plants, an analysis with the same number of samples, i.e. sub-selection according to the traits with the smallest number of measurements, was also made.

## 2) Sign of local adaptation:

To study a possibility of local adaptation, local vs. foreign criterion was used (Kawecki and Ebert, 2004). This criterion presumes that the plants prosper better in their home conditions. For this test, the plants shifted to the same temperature or moisture as they had in original localities, were marked by 1. Plants that grew in foreign condition, were marked by 0. The effect of local versus foreign temperature, moisture and their interaction was tested.

## 3) Impact of directionality of the climate change:

To describe how the plants respond to the directionality of climate change between the original localities and the growth chambers, the same system of codes was used as described in no.1. The codes for original localities were subtracted from codes for target conditions. It resulted new codes (-3 to 3 for temperature and -4 to 4 for moisture). The negative values indicate transplantation to colder or drier conditions and positive values indicate transplantation to warmer or wetter conditions. Zero indicates plants grown in their home conditions. The effect of differences in temperature, moisture, and their two-way interactions on all the dependent variables were tested.

Data and graphs were processed in program Microsoft Excel 2017.

## 2.3 Second experiment

### 2.3.1 Plant material

For this experiment, the same plant material collected for the first experiment described above was utilized. This plant material was also used in (Münzbergová et al., in prep.) and thus the methodology of preparing plants is taken from this text.

Plants from four most extreme original climates (driest coldest, driest warmest, wettest coldest and wettest warmest) were used. In October 2015, six genotypes per population were chosen and planted in 10x10x10 cm pots in a glass greenhouse to multiply. A random half of the plants (six per genotype) was chosen as a demethylating treatment. These plants were sprayed three times in a week with 100  $\mu\text{mol}$  solution of 5-azacytidine with added surfactant for ten months. Other plants were sprayed with water containing surfactant to account for possible confounding effects of the surfactant. The use of surfactant was crucial for lowering water tension, which ensured an even layer of the dissolved 5-azacytidine on the leaves' surface. To ensure that all plants received comparable amount of the demethylation agent, each plant was sprayed with five pulses of a mechanical sprayer.

In September 2016, several ramets, each with three leaves and without visible signs of initiating flower buds, were cut from each tussock and placed into small plastic cups filled with water, to set roots. After two weeks, two ramets with developed roots were individually planted into  $5 \times 5 \times 8.5$  cm pots filled with a mixture of common garden soil and sand in 1:2 ratio, just as in first experiment.

Finally, 6 genotypes in 12 replications from 4 populations, where half of the plants were treated with azacytidine and all these plants were in 2 replications, were prepared.

In this experiment, just two growth chambers were used, simulating the two strongest climatic extremes along the climatic grid – warmest and wettest and coldest and driest. The setting of the growth chambers was the same as in first experiment described above. The plants were let to grow in the chambers for 24 weeks and then started the measurements.

### **2.3.2 Pilot experiment**

In order to determine, if the experiment had a potential to show the effect of azacytidine, pilot experiment was made. Before transfer of the plants to growth chambers, stomatal density was counted on one individual of each genotype, i.e. six individuals per population (24 plants) with demethylation treatment and the same without demethylation treatment, i.e. 48 plants in total.

### **2.3.3 Measurements**

The measurements started when acclimatization in growth chambers terminated, as in the first experiment. For this thesis, the physiological traits were measured. Also, as in the first experiment, data of growth traits were collected – plant height, number of ramets, rhizome weight, belowground biomass, aboveground biomass and belowground and aboveground biomass ratio. These measurements and results are unpublished so far (Münzbergová et al., in prep.).

The physiological traits in this experiment were selected based on the results of the first experiment analysis. Traits for which there was evidence of genetic differentiation among populations were chosen. Based on the results, fluorescence of chlorophyll, osmotic potential and stomatal density and size was selected.

All measurements were done the same as in the first experiment described above. All traits were measured at all the plants in the experiment.

#### **2.3.4 Data processing and statistical analysis**

In the pilot experiment as well as in the full experiment, the effect of target conditions, original conditions, azacytidine and their interactions on measured dependent variables were tested. The same coding system for the original localities was used as described in the first experiment. For pilot experiment, pair-wise comparison between azacytidine and control within each population was made to visualize significant differences for each original locality.

All tests were done using mixed effect models with clone identity as a random factor. If it was necessary, data were transformed to fit the assumptions of data normality and homogeneity of variance. For all dependent variables, the tests assume Gaussian distribution of the dependent variable. Data and graphs were processed in program Microsoft Excel 2017. Mixed effect models were processed with R (version 3.3.2) using lme4 package (Bates et al., 2015).

### 3 Results

#### 3.1 First experiment

##### 3.1.1 Target and original climate and their interactions

The results of analysis concerning target and original conditions and their interaction are presented in Table 3.

**Table 3:** The effect of original (O) and target (T) temperature (temp) and moisture (mois) and their two-way interactions on plant performance in the growth chambers. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold and colored. Dev. indicates deviance explained by the given variable.

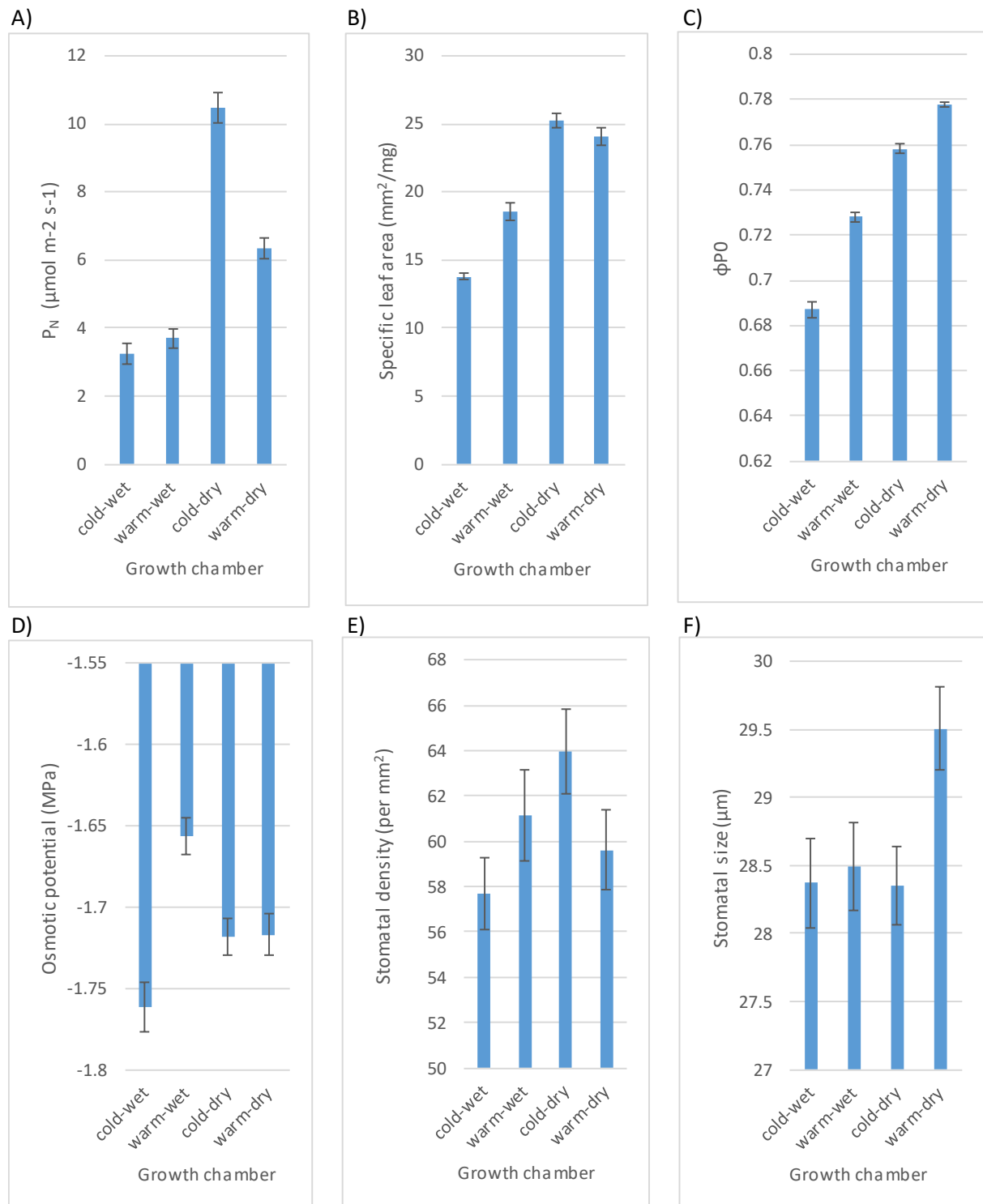
|                | P <sub>N</sub> |                  | φP0    |                  | SLA    |                  | o. potential |                  | s. density |               | s. size |               |
|----------------|----------------|------------------|--------|------------------|--------|------------------|--------------|------------------|------------|---------------|---------|---------------|
|                | dev.           | p                | dev.   | p                | dev.   | p                | dev.         | p                | dev.       | p             | dev.    | p             |
| Ttemp          | 13.5           | <b>&lt;0.001</b> | 299.36 | <b>&lt;0.001</b> | 7.8798 | <b>0.005</b>     | 21.255       | <b>&lt;0.001</b> | 0.0643     | 0.7999        | 5.7954  | <b>0.0161</b> |
| Tmois          | 118.56         | <b>&lt;0.001</b> | 867.37 | <b>&lt;0.001</b> | 47.321 | <b>&lt;0.001</b> | 0.7876       | 0.3748           | 2.1717     | 0.1406        | 4.5254  | <b>0.0334</b> |
| Otemp          | 0.2702         | 0.8103           | 0.3341 | 0.5632           | 2.9691 | 0.0849           | 3.1864       | 0.0743           | 7.9804     | <b>0.0047</b> | 4.6898  | <b>0.0303</b> |
| Omois          | 0.0121         | 0.7223           | 0      | 0.9958           | 0.3185 | 0.5725           | 1.73         | 0.1884           | 2.9625     | 0.0852        | 0.174   | 0.6766        |
| Otemp x Omois  | 0.7723         | 0.2913           | 4.5646 | <b>0.0326</b>    | 1.075  | 0.2998           | 0.0526       | 0.8186           | 10.333     | <b>0.0013</b> | 0.0113  | 0.9154        |
| Otemp x Ttemp  | 0.0078         | 0.8239           | 0.2859 | 0.5928           | 3.2964 | 0.0694           | 0.1653       | 0.6844           | 4.6597     | <b>0.0309</b> | 1.3922  | 0.238         |
| Otemp x Tmois  | 0.2947         | 0.8511           | 1.846  | 0.1742           | 0.8243 | 0.3639           | 1.0702       | 0.3009           | 0.4054     | 0.5243        | 0.2058  | 0.6501        |
| Omois x Ttemp  | 1.1841         | 0.4529           | 3.7196 | 0.0538           | 0.3617 | 0.5476           | 0.0476       | 0.8273           | 0.0506     | 0.8221        | 0.1641  | 0.6854        |
| Omois x Tmois  | 0.0967         | 0.9953           | 0.194  | 0.6596           | 0.0025 | 0.9605           | 6.7847       | <b>0.0092</b>    | 0.0355     | 0.8506        | 0.5449  | 0.4604        |
| Ttemp x Tmois  | 36.213         | <b>&lt;0.001</b> | 5.9349 | <b>0.0148</b>    | 18.55  | <b>&lt;0.001</b> | 19.477       | <b>&lt;0.001</b> | 6.3424     | <b>0.0118</b> | 3.8565  | <b>0.045</b>  |
| no. of observ. | 160            |                  | 1100   |                  | 160    |                  | 1100         |                  | 440        |               | 440     |               |

P<sub>N</sub> – net photosynthetic rate, φP0 – PSII efficiency, SLA – specific leaf area, o. potential – osmotic potential, s. density – stomatal density, s. size – stomatal size, no. of observ. – number of observations.

### 3.1.1.1 Target conditions

Target conditions significantly affected all traits. Specifically, all traits were affected by interaction between target temperature and moisture. All traits except stomatal density were affected by target temperature. And finally, target moisture affected photosynthetic traits ( $P_N$  and PSII efficiency), SLA, and stomatal size (Table 3). In general, the plants in dry growth chambers had higher values of net photosynthetic rate (Fig. 6, A), PSII efficiency (Fig. 6, C), SLA (Fig. 6, B), and stomatal size (Fig. 6, F). The plants in warm growth chambers had higher PSII efficiency (Fig. 6, C), SLA (Fig. 6, B), osmotic potential (Fig. 6, D), and stomatal size (Fig. 6, F). Only net photosynthetic rate was higher in cold growth chambers (Fig. 6, A). With regards to interactions, net photosynthetic rate and SLA increased in wet growth chambers with rising temperature, while decreased in dry growth chambers (Fig. 6, A, B). PSII efficiency also increased in wet growth chambers. It increased in cold growth chambers too, but with smaller difference (Fig. 6, C). Osmotic potential increased with rising temperature in wet growth chambers and did not change in dry growth chambers (Fig. 6, D). In case of stomata, density and size were constant in wet growth chambers, while in dry growth chambers stomatal density decrease with temperature and by contrast, stomatal size increased (Fig. 6, E, F).

**Figure 6:** The effect of target conditions on measured traits (A – net photosynthetic rate, B – specific leaf area, C – PSII efficiency characterized by parameter  $\phi P0$ , D – osmotic potential, E – stomatal density, F – stomatal size). Columns show mean and error bars  $\pm$  standard error.

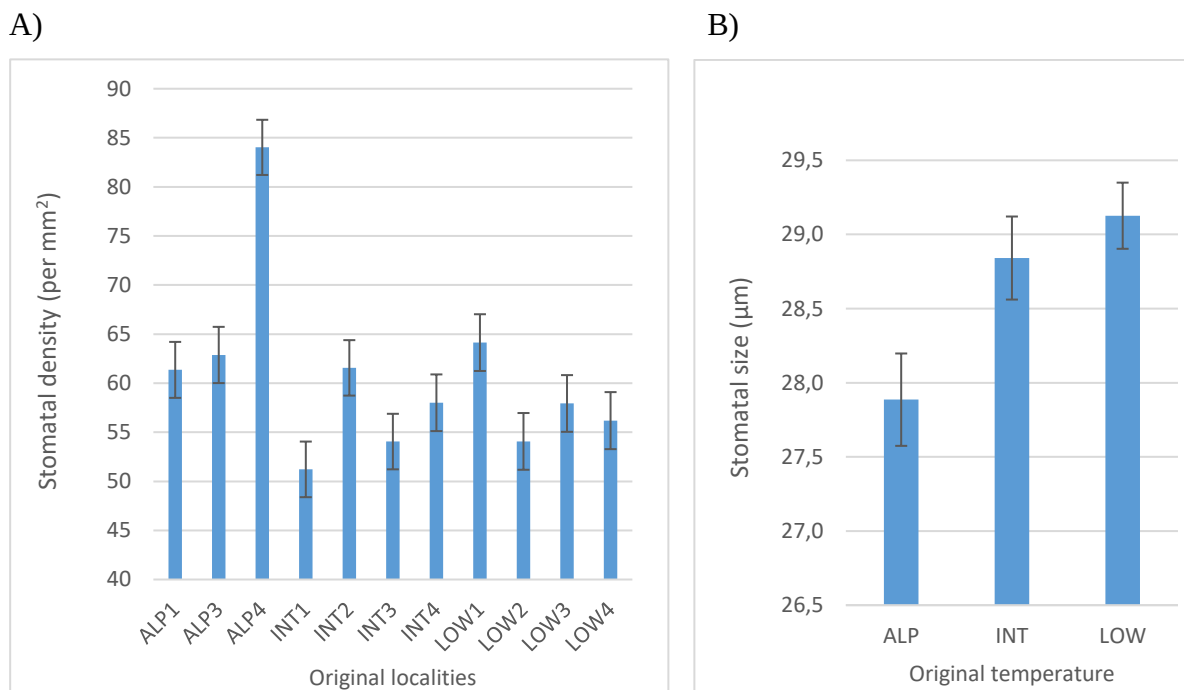


### 3.1.1.2 Original conditions

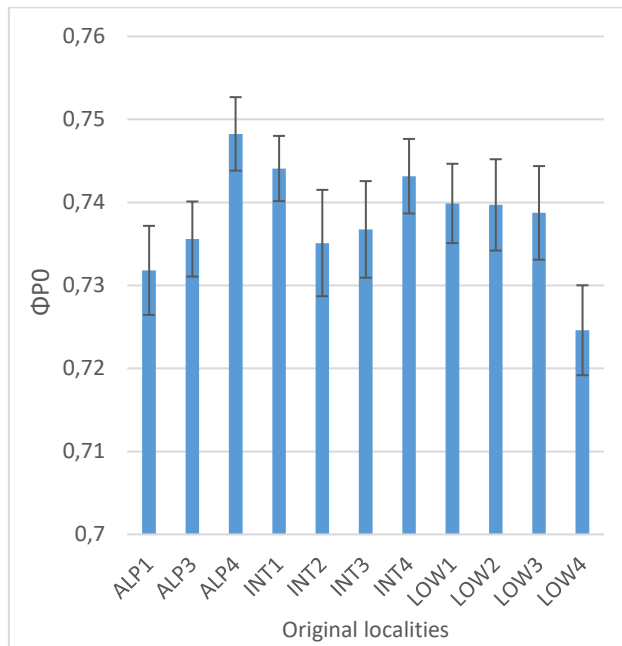
Original climate significantly affected PSII efficiency, stomatal density, and stomatal size. Specifically, original temperature affected stomatal density and size. Interaction between original temperature and moisture affected PSII efficiency and stomatal density (Table 3). Regarding the stomata, the plants originating from cold conditions had higher density and smaller size, while those originating from warm climate had lower density and bigger size (Fig. 7, A, B). In case of interactions, stomatal density as well as PSII efficiency increased with increasing moisture in cold conditions, while decreased in warm conditions (Fig. 7, A, C).

**Figure 7:** The effect of original conditions on measured traits. A) effect of original climate on stomatal density, B) effect of original temperature to stomatal size, C) effect of original climate to PSII efficiency.

ALP denotes the cold sites, INT denotes intermediate sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites. Columns show mean and error bars  $\pm$  standard error.



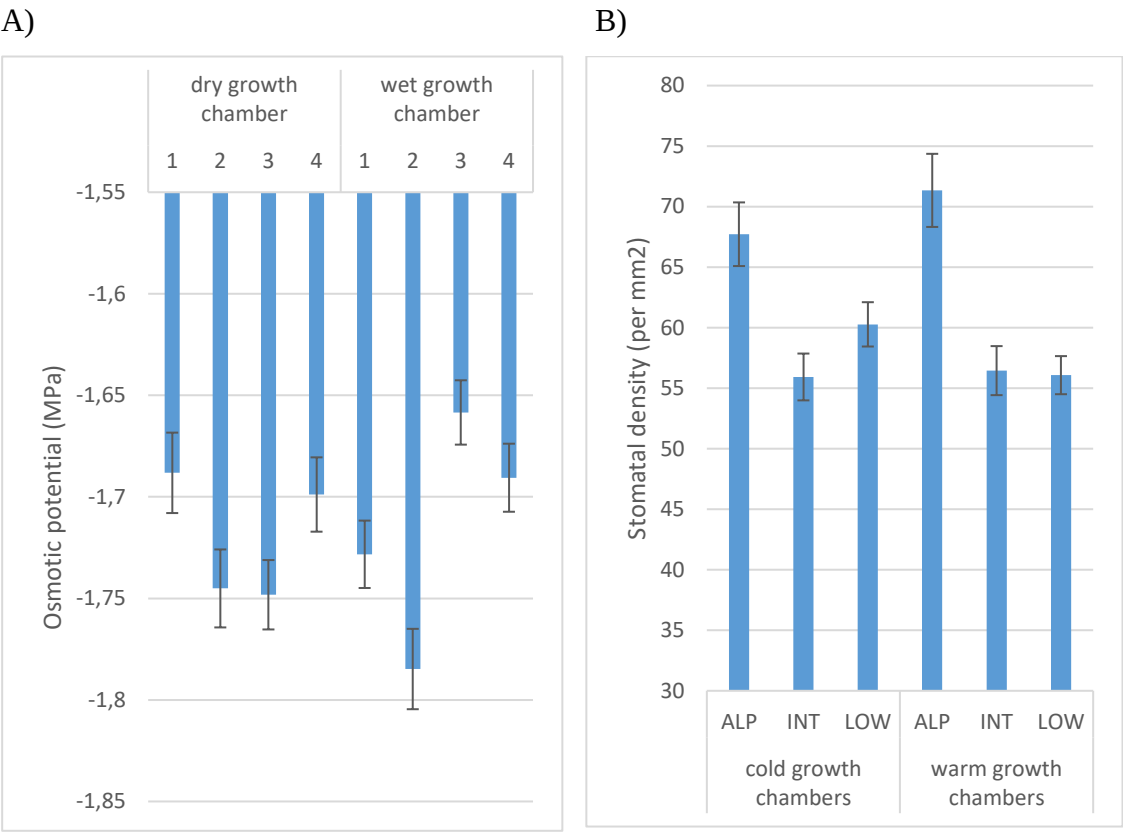
C)



### 3.1.1.3 Interaction between target and original conditions

Two significant interactions between original and target conditions were found. Specifically, osmotic potential was affected by interaction between original and target moisture, and stomatal size by interaction between original and target temperature (Table 3). Osmotic potential of plants originating from drier localities decreased with shifting to wet conditions; on the contrary, the plants coming from wetter localities decreased with shifting to drier conditions (Fig. 8, A). Stomatal density of plants coming from cold climate differed more from other plants in warm growth chambers than those in cold growth chambers (Fig. 8, B).

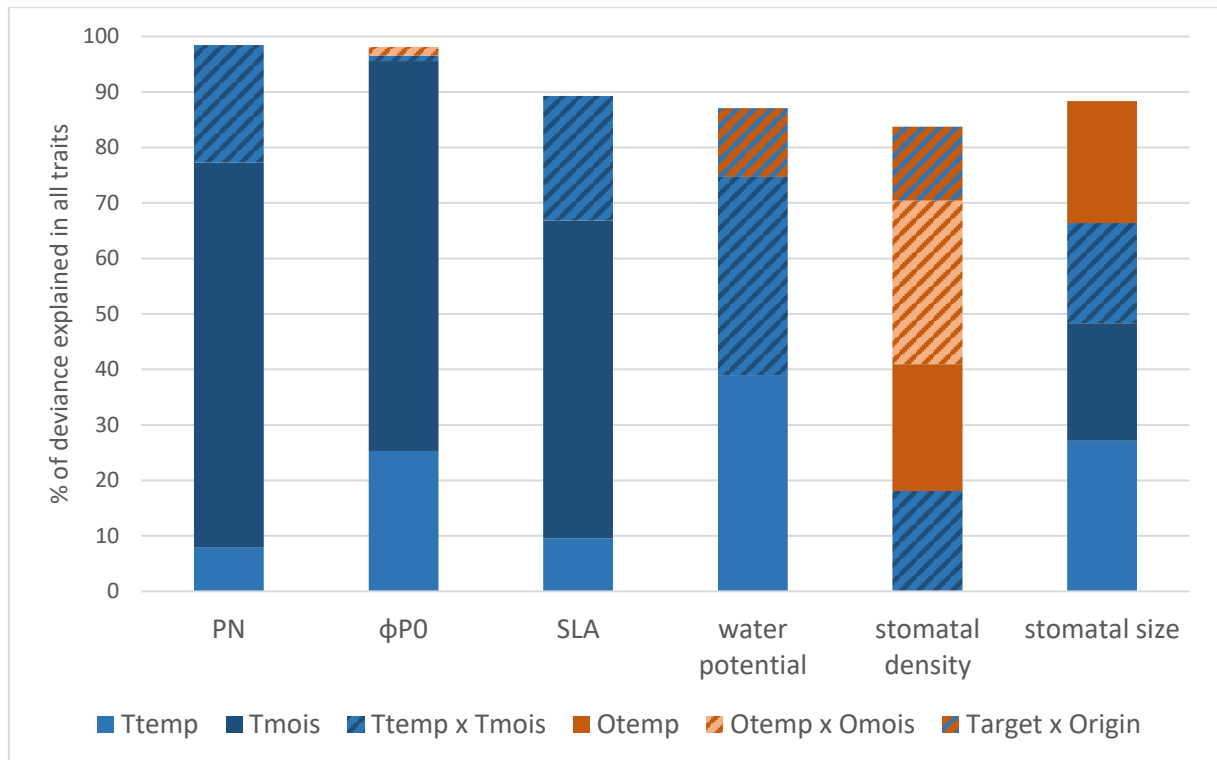
**Figure 8:** The effect of interaction between original and target conditions. A) the effect of interaction between original moisture and target moisture on osmotic potential, B) the effect of interaction between original and target temperature on stomatal density. ALP denotes the cold sites, INT denotes intermediate sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites. Columns show mean and error bars  $\pm$  standard error.



### 3.1.1.4 Relative importance of local and target conditions

Relative importance of local and target environment and their interaction in all measured parameters is shown in Figure 9.

**Figure 9:** Relative importance of local (orange) and target (blue) environment and their interaction (blue/orange) in all measured parameters. Percentage show explained deviance by the model for significant variables. T - target environment, O – original environment, temp – temperature, mois – moisture.



### 3.1.2 Signs of local adaptation

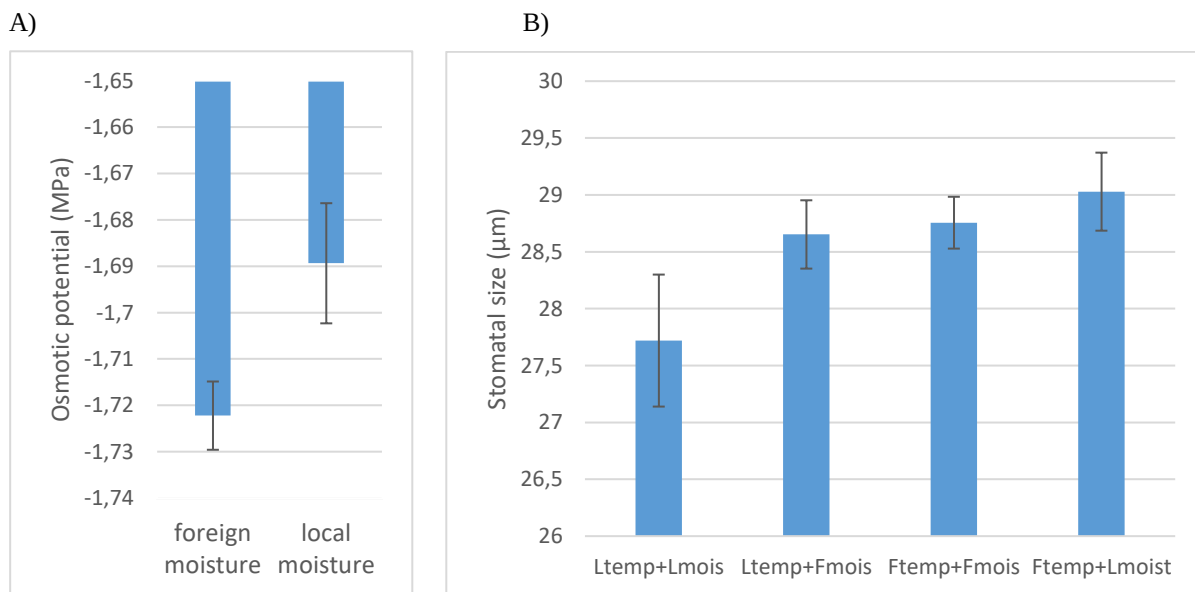
Difference between home and foreign conditions was significant for osmotic potential and for stomatal size. Osmotic potential was depended on local/ foreign moisture, and stomatal size was affected by interaction between local and foreign temperature and moisture (Table 4). Specifically, plants growing in foreign moisture had lower values of osmotic potential than plants growing in local moisture (Fig. 10, A). Plants growing in their own temperature and moisture had shorter stomata than in other combinations (Fig. 10, B).

**Table 4:** The effect of local vs. foreign temperature (temp) and moisture (mois) and their two-way interactions on plant performance in the growth chambers. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold and colored. Dev. indicates deviance explained by the given variable.

|             | $P_N$  |        | $\phi P0$ |        | SLA    |        | o. potential |              | s. density |        | s. size |              |
|-------------|--------|--------|-----------|--------|--------|--------|--------------|--------------|------------|--------|---------|--------------|
|             | dev.   | p      | dev.      | p      | dev.   | p      | dev.         | p            | dev.       | p      | dev.    | p            |
| temp        | 0.0149 | 0.903  | 0.1375    | 0.7108 | 1.2617 | 0.2613 | 3.16         | 0.0755       | 1.8944     | 0.1687 | 1.632   | 0.2014       |
| mois        | 0.0603 | 0.8061 | 0.4364    | 0.5089 | 0.7676 | 0.3809 | 4.6378       | <b>0.031</b> | 0.4439     | 0.5052 | 0.6082  | 0.4355       |
| temp x mois | 0.0601 | 0.8063 | 1.4437    | 0.2295 | 0.0985 | 0.7537 | 0.2866       | 0.5924       | 0.1237     | 0.7251 | 4.6602  | <b>0.031</b> |
| N           | 160    |        | 1100      |        | 160    |        | 1100         |              | 440        |        | 440     |              |

$P_N$  – net photosynthetic rate,  $\phi P0$  – PSII efficiency, SLA – specific leaf area, o. potential – osmotic potential, s. density – stomatal density, s. size – stomatal size, N – number of observations.

**Figure 10:** a) Effect of local vs. foreign moisture on osmotic potential. B) Effect of interaction between local (L) and foreign (F) temperature (temp) and moisture (mois) on stomatal size. Columns show mean and error bars  $\pm$  standard error.



### 3.1.3 Directionality in environmental change responses

In all traits except stomatal size, significant difference in directionality was detected. Specifically, directionality of temperature affected specific leaf area, net photosynthetic rate, PSII efficiency, and osmotic potential. Directionality of moisture affected net photosynthetic rate, PSII efficiency, specific leaf area and stomatal size (Table 5).

Shifting to drier condition affected all traits by increasing their values (i.e. higher values of net photosynthetic rate, specific leaf area, PSII efficiency and stomatal density) (Fig. 11, A, B, C, E). Warmer climate also caused increase of PSII efficiency, specific leaf area and osmotic potential, except net photosynthetic rate, which had higher values with shifting to colder climate (Fig. 11, A, B, C, D).

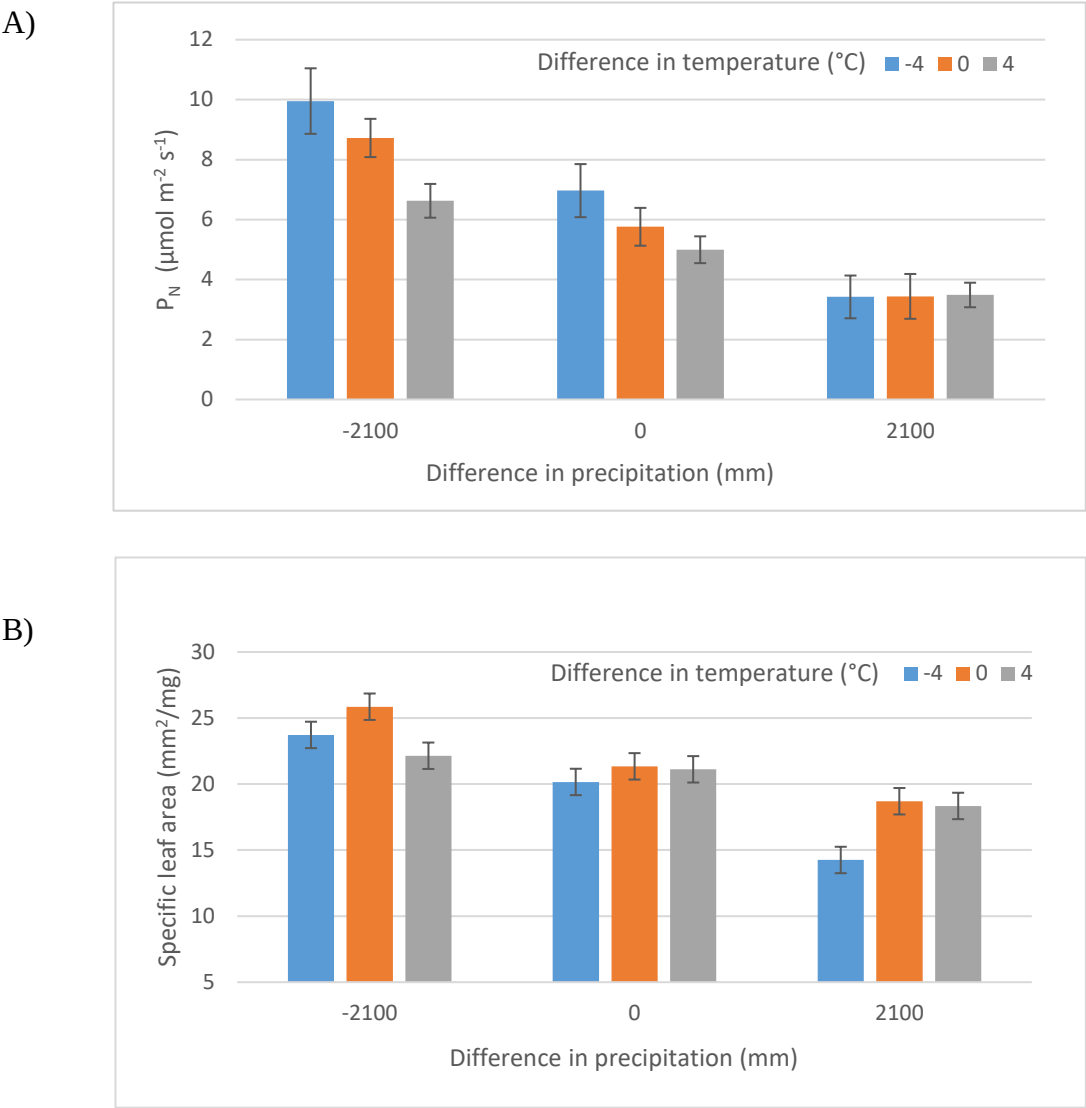
Interaction between differences of temperature and moisture for net photosynthetic rate, specific leaf area and osmotic potential was significant (Table 5). In case of net photosynthetic rate, with shifting to drier conditions the values were generally higher and decreased with increasing temperature, while with shifting to wetter conditions the values were generally lower and independent on temperature (Fig. 11, A). Regarding to specific leaf area, the values decreased with the temperature when moisture was reduced, while increased moisture caused higher values in increased temperature (Fig. 11, B). And finally, in case of osmotic potential, the temperature loses its effect with shifting to drier climate, on the contrary, with shifting to wetter climate osmotic potential increased with temperature (Fig. 11, D).

**Table 5:** The effect of difference in temperature (diftemp) and moisture (difmois) between localities of origin and target conditions and their two-way interactions on measured parameters. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are marked in bold and colored. Dev. indicates deviance explained by the given variable.

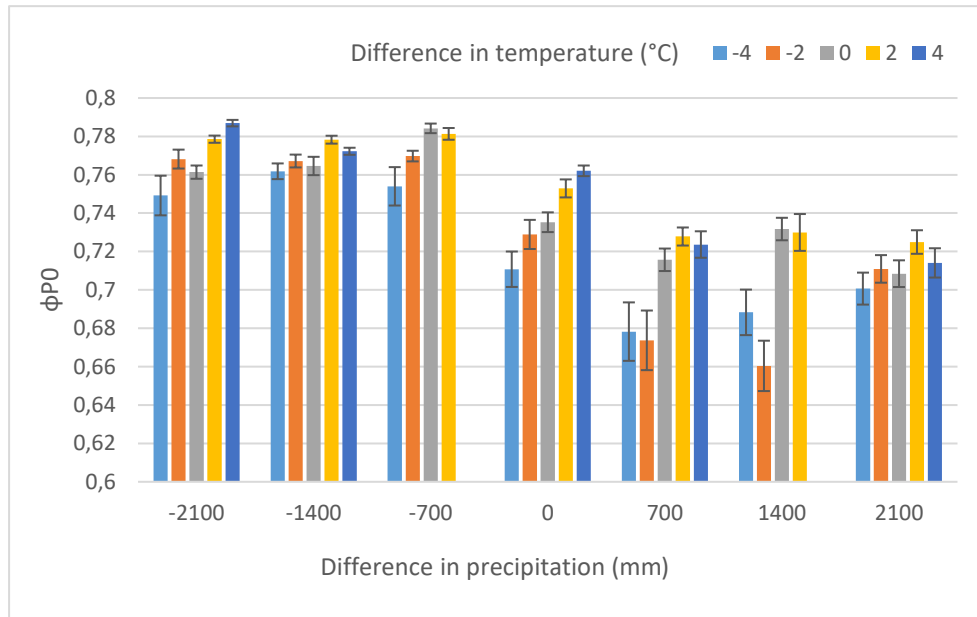
|                  | P <sub>N</sub> |                  | φP0    |                  | SLA    |                  | o. potential |                  | s. density |              | s. size |        |
|------------------|----------------|------------------|--------|------------------|--------|------------------|--------------|------------------|------------|--------------|---------|--------|
|                  | dev.           | p                | dev.   | p                | dev.   | p                | dev.         | p                | dev.       | p            | dev.    | p      |
| diftemp          | 9.2795         | <b>0.002</b>     | 279.55 | <b>&lt;0.001</b> | 6.3499 | <b>0.012</b>     | 23.924       | <b>&lt;0.001</b> | 0.6894     | 0.4064       | 1.7613  | 0.1845 |
| difmois          | 66.111         | <b>&lt;0.001</b> | 771.19 | <b>&lt;0.001</b> | 67.988 | <b>&lt;0.001</b> | 0.0128       | 0.9101           | 4.0804     | <b>0.491</b> | 3.0912  | 0.0787 |
| diftem x difmois | 7.4151         | <b>0.006</b>     | 1.6836 | 0.1945           | 8.1806 | <b>0.004</b>     | 23.924       | <b>&lt;0.001</b> | 0.1969     | 0.6573       | 1.4143  | 0.2343 |
| N                | 160            |                  | 1100   |                  | 160    |                  | 1100         |                  | 440        |              | 440     |        |

P<sub>N</sub> – net photosynthetic rate, φP0 – PSII efficiency, SLA – specific leaf area, o. potential – osmotic potential, s. density – stomatal density, s. size – stomatal size, N – number of observations.

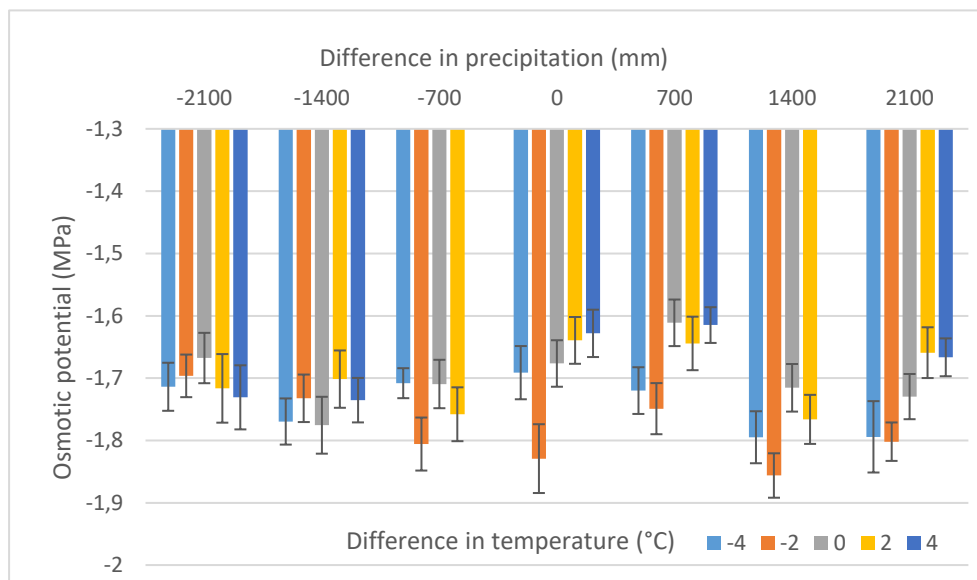
**Figure 11:** Effect of difference in temperature and moisture between target and original climate on A) net photosynthetic rate, B) specific leaf area, C) PSII efficiency, D) osmotic potential, E) stomatal density. Columns show mean and error bars  $\pm$  standard error.



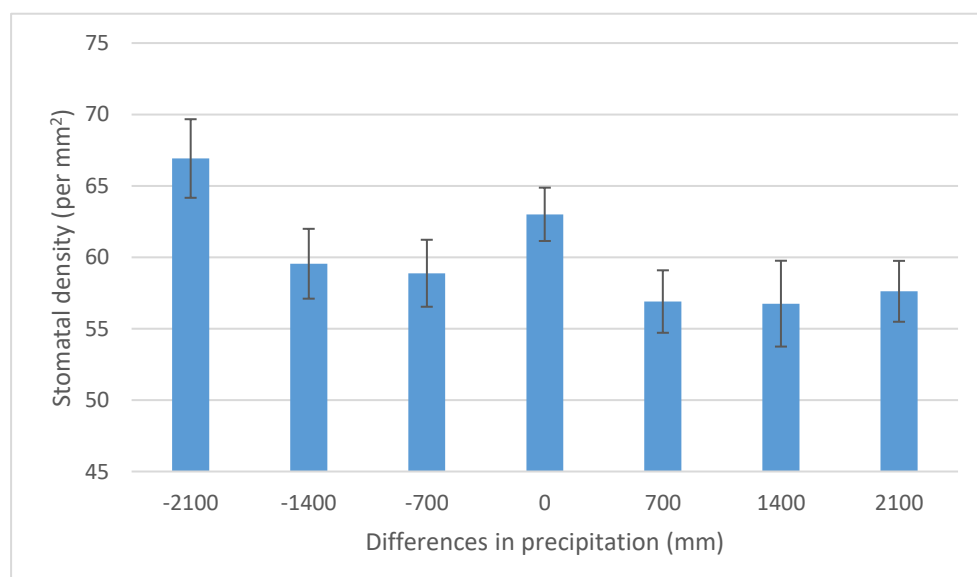
C)



D)



E)



### 3.1.4 Relationship between data from the first experiment and growth data

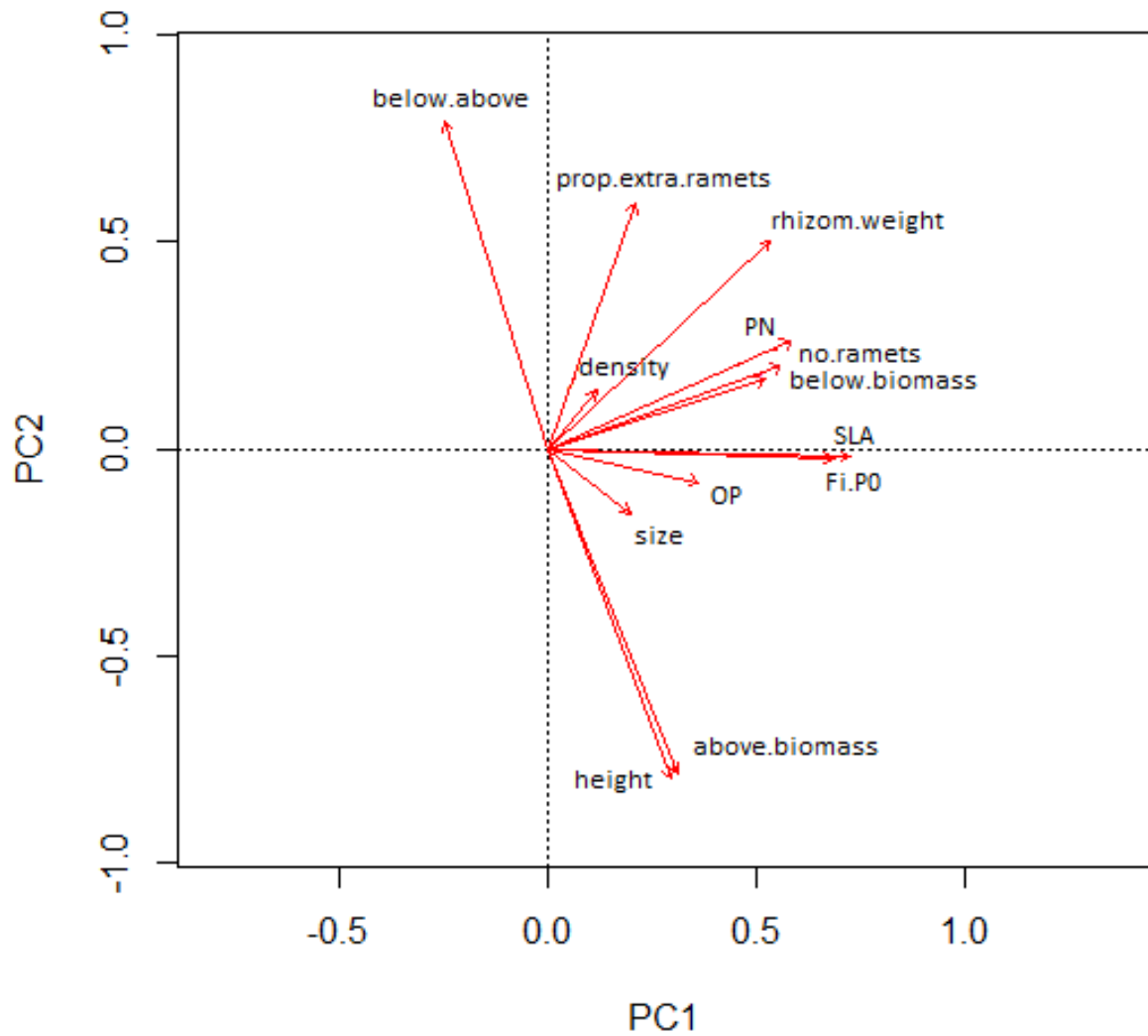
Significant correlation between net photosynthetic rate ( $P_N$ ), PSII efficiency ( $\phi P0$ ) and specific leaf area (SLA) was found. Also, osmotic potential showed significant correlation with photosynthetic traits ( $P_N$ ,  $\phi P0$ ), but  $r$  – values are quite low. Negative correlation was significant between stomatal density and size, but  $r$  – values are also low.

Physiological traits significantly correlated with all growth traits except proportion of extravaginal ramets and belowground and aboveground ratio (Table 6). In spite of many significant results, only few  $r$ - values showed stronger dependence between traits. Stronger positive correlation ( $r>0.5$ ) was shown for correlation between specific leaf area and number of ramets. Other correlations were weaker ( $p\leq 0.4$ ).

**Table 6:** Correlation matrix of physiological traits (blue) and growth traits (green) for the first experiment. Significant correlation coefficient with  $p<0.05$  are highlighted (orange). Explanatory note:  $P_N$  – net photosynthetic rate,  $\phi P0$  – PSII efficiency, SLA – specific leaf area, s. density – stomatal density, s. size – stomatal size, height – plant height, no.ram. – number of ramets, p.e.ram. – proportion of extravaginal ramets, rhiz. w. – rhizome weight, b.bio – belowground biomass, a.bio – aboveground biomass, bel:abo – belowground and aboveground biomass ratio.

|           | $P_N$ | $\phi P0$ | o.potent. | SLA   | s. density | s. size | height | no. ram. | p.e.ram. | rhiz. w. | b. bio | a. bio | bel:abo |
|-----------|-------|-----------|-----------|-------|------------|---------|--------|----------|----------|----------|--------|--------|---------|
| $P_N$     | 1     | 0.54      | 0.28      | 0.55  | 0.06       | 0.1     | 0.03   | 0.33     | 0.07     | 0.35     | 0.33   | -0.06  | -0.02   |
| $\phi P0$ | 0.54  | 1         | 0.38      | 0.62  | 0.12       | 0.06    | 0.3    | 0.33     | 0.05     | 0.4      | 0.36   | 0.15   | -0.17   |
| o.potent. | 0.28  | 0.38      | 1         | 0.28  | -0.12      | 0.15    | 0.21   | 0.06     | 0.03     | 0.14     | 0.14   | 0.05   | -0.03   |
| SLA       | 0.55  | 0.62      | 0.28      | 1     | 0.16       | 0.07    | 0.33   | 0.52     | 0.12     | 0.4      | 0.37   | 0.21   | -0.19   |
| s. densit | 0.06  | 0.12      | -0.12     | 0.16  | 1          | -0.36   | 0.06   | 0.02     | 0.15     | 0.25     | -0.08  | 0      | -0.1    |
| s. size   | 0.1   | 0.06      | 0.15      | 0.07  | -0.36      | 1       | 0.16   | 0.12     | 0.05     | 0.03     | 0.31   | 0.1    | -0.08   |
| height    | 0.03  | 0.3       | 0.21      | 0.33  | 0.06       | 0.16    | 1      | -0.08    | -0.13    | -0.02    | 0.04   | 0.5    | -0.45   |
| no. ram.  | 0.33  | 0.33      | 0.06      | 0.52  | 0.02       | 0.12    | -0.08  | 1        | 0.25     | 0.39     | 0.4    | 0.25   | -0.13   |
| p.e.ram.  | 0.07  | 0.05      | 0.03      | 0.12  | 0.15       | 0.05    | -0.13  | 0.25     | 1        | 0.48     | 0.08   | -0.15  | 0.15    |
| rhiz. w.  | 0.35  | 0.4       | 0.14      | 0.4   | 0.25       | 0.03    | -0.02  | 0.39     | 0.48     | 1        | 0.36   | -0.01  | 0.03    |
| b. bio    | 0.33  | 0.36      | 0.14      | 0.37  | -0.08      | 0.31    | 0.04   | 0.4      | 0.08     | 0.36     | 1      | 0.15   | 0.04    |
| a. bio    | -0.06 | 0.15      | 0.05      | 0.21  | 0          | 0.1     | 0.5    | 0.25     | -0.15    | -0.01    | 0.15   | 1      | -0.56   |
| bel:abo   | -0.02 | -0.17     | -0.03     | -0.19 | -0.1       | -0.08   | -0.45  | -0.13    | 0.15     | 0.03     | 0.04   | -0.56  | 1       |

**Figure 12:** Correlation of all traits (physiological and growth) within the first experiment – principal component analysis diagram (PCA). First axis explained 26.85% and second 16.4% of total variability. Standardization across traits was done. Explanatory note: below.above - belowground and aboveground biomass ratio, prop.extra.ramets – proportion of extravaginal ramets, rhizom.weight – rhizome weight, PN – net photosynthetic rate, no.ramets – number of ramets, below.biomass – belowground biomass, density – stomatal density, SLA – specific leaf area, Fi.P0 – PSII efficiency, OP – osmotic potential, size – stomatal size, height – plant height, above.biomass – aboveground biomass.



## 3.2 Second experiment

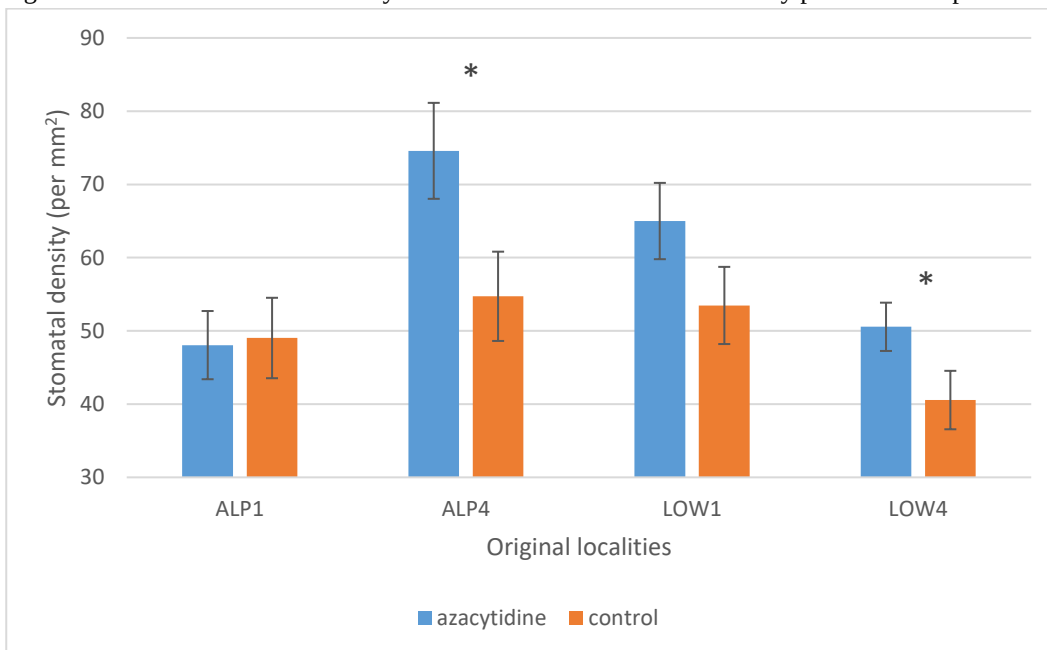
### 3.2.1 Pilot experiment

Analysis of pilot experiment showed significant effect of original temperature and effect of interaction between azacytidine and original moisture on stomatal density (Table 7). Demethylation caused increase of stomatal density in contrary to control in plants originating from wet localities, while demethylation had no effect in dry original localities. (Fig. 13).

**Table 7:** The effect of azacytidine (aza), original (O), temperature (temp) and moisture (mois) and their interactions on stomatal density before plants transferring to growth chambers. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold and colored.

|                        | dev.   | p-value        |
|------------------------|--------|----------------|
| azacytidine            | 0.6701 | 0.413          |
| Otemp                  | 7.4751 | <b>0.00626</b> |
| Omois                  | 0.0264 | 0.8708         |
| aza x Otemp            | 0.1506 | 0.698          |
| aza x Omois            | 12.087 | <b>0.00051</b> |
| Otemp x Omois          | 2.114  | 0.146          |
| aza x Otemp x Omois    | 2.3327 | 0.1267         |
| number of observations | 48     |                |

**Figure 13:** Effect of azacytidine, original temperature and moisture on stomatal density (pilot experiment). ALP denotes the cold sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites Columns show mean and error bars  $\pm$  standard error. Asterisk show significant difference between azacytidine and control treatment tested by pair-wise comparison.



### 3.2.2 Effect of azacytidine, target and original conditions and their interactions for main experiment

The results of analysis concerning effect of azacytidine, target and original conditions and their two-way interaction are presented in Table 8.

The effect of the target climate is neither presented nor discussed as these effects are discussed in detail in the first experiment.

**Table 8:** The effect of azacytidine (aza), original (O) and target (T) temperature (temp) and moisture (mois) and their two-way interactions on plant performance in the growth chambers. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold and colored. Dev. indicates deviance explained by the given variable.

|                   | $\phi P0$ |                  | osmotic potential |                  | stomatal density |               | stomatal size |                  |
|-------------------|-----------|------------------|-------------------|------------------|------------------|---------------|---------------|------------------|
|                   | dev.      | p                | dev.              | p                | dev.             | p             | dev.          | p                |
| target            | 13.189    | <b>0.00028</b>   | 732.33            | <b>&lt;0.001</b> | 1.5142           | 0.2185        | 81.51         | <b>&lt;0.001</b> |
| azacytidine       | 1.3327    | 0.2483           | 0.9898            | 0.3198           | 0.6151           | 0.4329        | 0.0107        | 0.9174           |
| Otemp             | 1.19      | 0.2753           | 0.9131            | 0.3393           | 3.0264           | 0.08192       | 27.175        | <b>&lt;0.001</b> |
| Omois             | 0.022     | 0.882            | 2.5592            | 0.1097           | 5.8194           | <b>0.0158</b> | 18.605        | <b>&lt;0.001</b> |
| target x aza      | 1.3105    | 0.2523           | 0.0647            | 0.7992           | 0.0319           | 0.8583        | 0.0057        | 0.9397           |
| target x Otemp    | 0.1392    | 0.7091           | 11.431            | <b>0.00072</b>   | 2.809            | 0.09374       | 8.4726        | <b>0.0036</b>    |
| target x Omois    | 20.651    | <b>&lt;0.001</b> | 7.7959            | <b>0.00523</b>   | 3.4878           | 0.06182       | 0.0031        | 0.9553           |
| aza x Otemp       | 0.5088    | 0.4756           | 0.9676            | 0.3253           | 1.5035           | 0.2201        | 0.8275        | 0.363            |
| aza x Omois       | 0.0933    | 0.76             | 1.1077            | 0.2926           | 0.2538           | 0.6144        | 1.0963        | 0.2951           |
| Otemp x Omois     | 18.195    | <b>&lt;0.001</b> | 23.917            | <b>&lt;0.001</b> | 5.0263           | <b>0.0249</b> | 0.6537        | 0.4188           |
| number of observ. | 576       |                  | 576               |                  | 576              |               | 576           |                  |

$\phi P0$  – PSII efficiency, SLA – specific leaf area, number of observ. – number of observations.

#### 3.2.2.1 Effect of azacytidine

Unfortunately, in spite of positive results in pilot experiment, no trait was significantly affected by azacytidine or by any interaction with azacytidine in the main experiment (Table 8).

#### 3.2.2.2 Original conditions

Original conditions affected all traits (Table 8). Stomatal density and size responded to original moisture (Fig. 14, A, B) and stomatal size also to original temperature (Fig. 14, C). Interaction between original temperature and moisture was significant for PSII efficiency, osmotic potential and stomatal density (Table 8). Specifically, the plants originating from dry climate had lower PSII efficiency and osmotic potential in combinations with cold climate, while those originating from wet climate showed higher values in combination with warm climate

(Fig. 15, A, B). In case of stomatal density, the plants originating from cold-dry conditions had higher stomatal density than the other (Fig. 15, C).

**Figure 14:** The effect of original conditions on measured traits. A) effect of original moisture on stomatal density, B) effect of original moisture and temperature on stomatal size.

ALP denotes the cold sites, INT denotes intermediate sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites. Columns show mean and error bars  $\pm$  standard error.

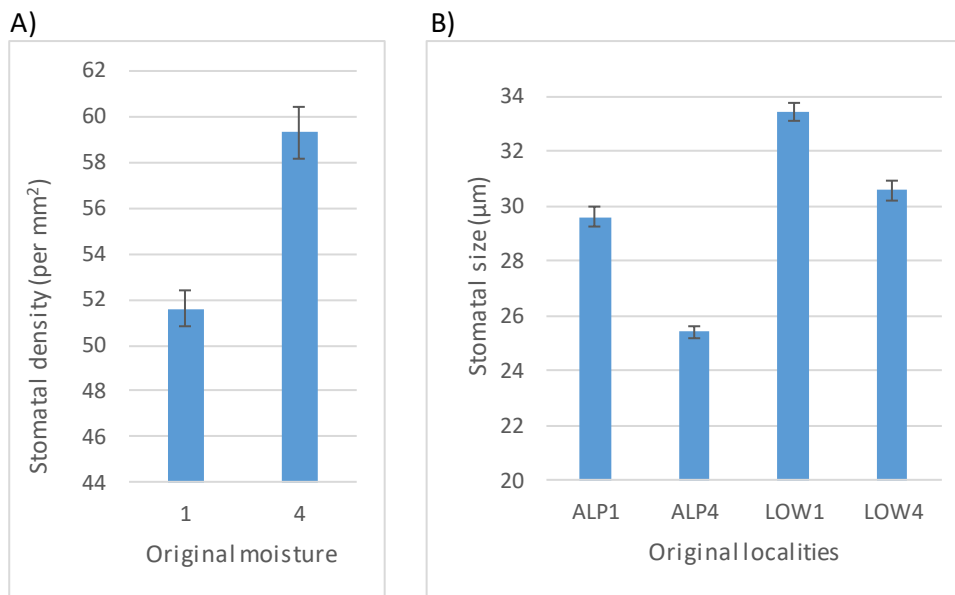
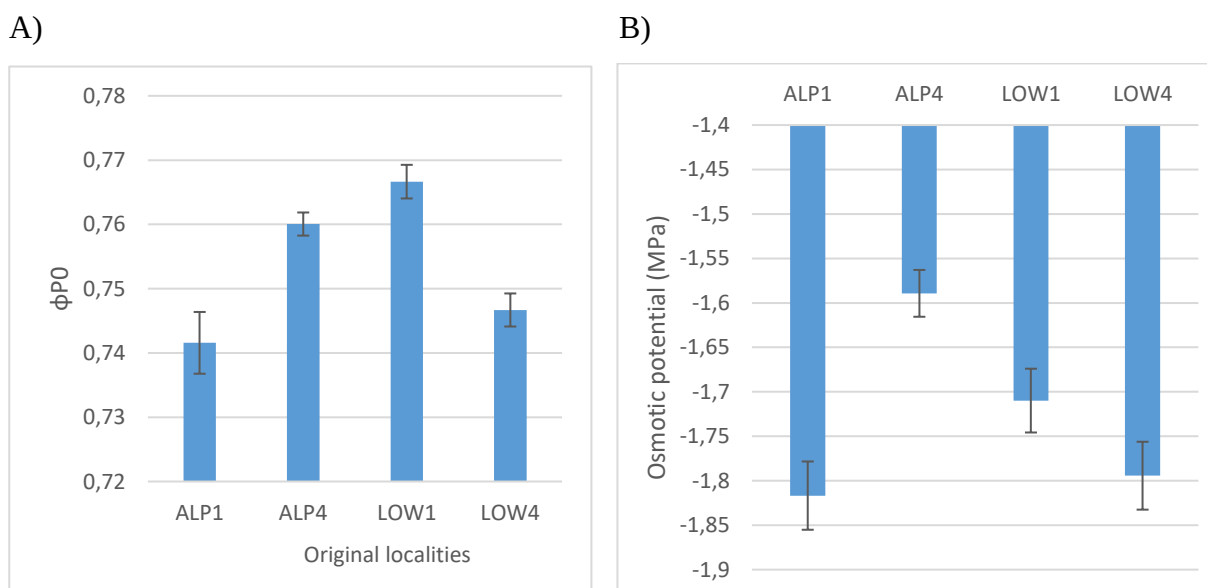
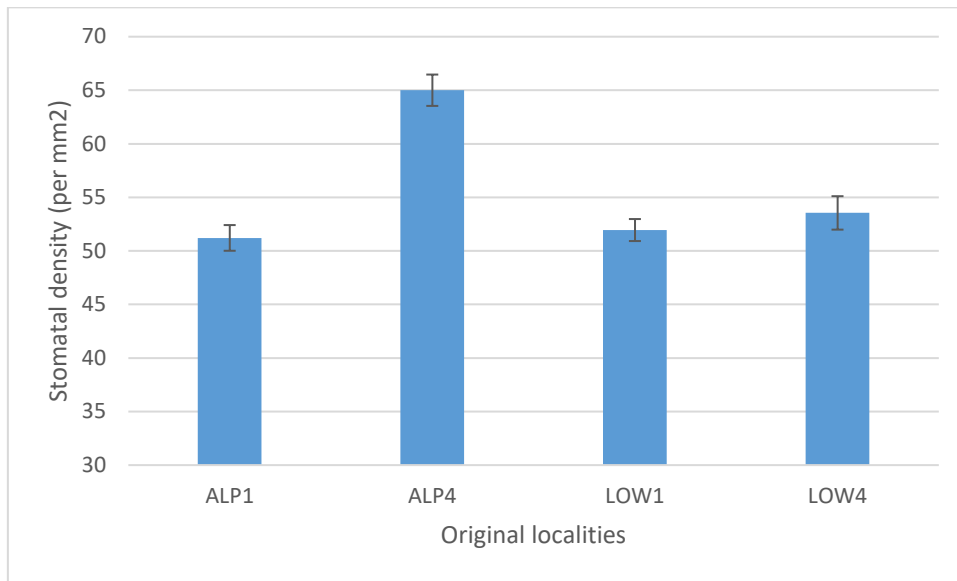


**Figure 15:** The effect of interaction between original temperature and moisture on measured traits for A) PSII efficiency B) osmotic potential C) stomatal density.

ALP denotes the cold sites, INT denotes intermediate sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites. Columns show mean and error bars  $\pm$  standard error.



C)



### 3.2.3 Comparison of pilot and main experiment

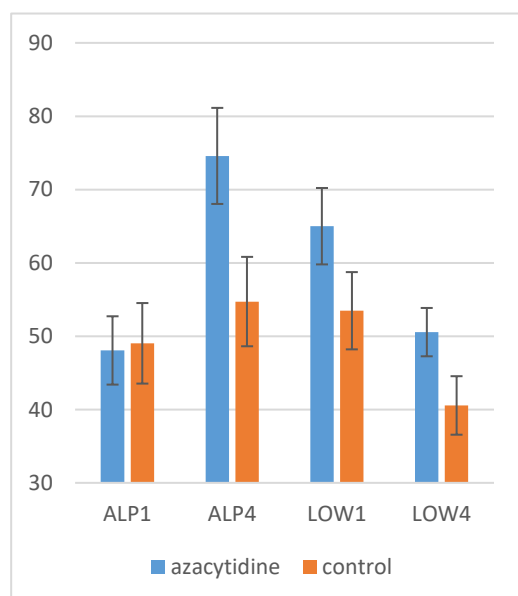
The results of stomatal density measurements within pilot and full-designed second experiment differ in response to demethylation treatment and original moisture (Table 9). The effect of azacytidine diminished in second experiment (Fig. 16, A, B) and the effect of original moisture was added.

|                        | pilot            | full           |
|------------------------|------------------|----------------|
|                        | p-value          | p-value        |
| azacytidine            | <b>0.00856</b>   | 0.4329         |
| Otemp                  | 0.256996         | 0.08192        |
| Omois                  | 0.741152         | <b>0.01585</b> |
| aza x Otemp            | 0.857617         | 0.2201         |
| aza x Omois            | 0.194006         | 0.6144         |
| Otemp x Omois          | <b>&lt;0.001</b> | <b>0.02497</b> |
| aza x Otemp x Omois    | 0.1267           | 0.5716         |
| number of observations | 48               | 576            |

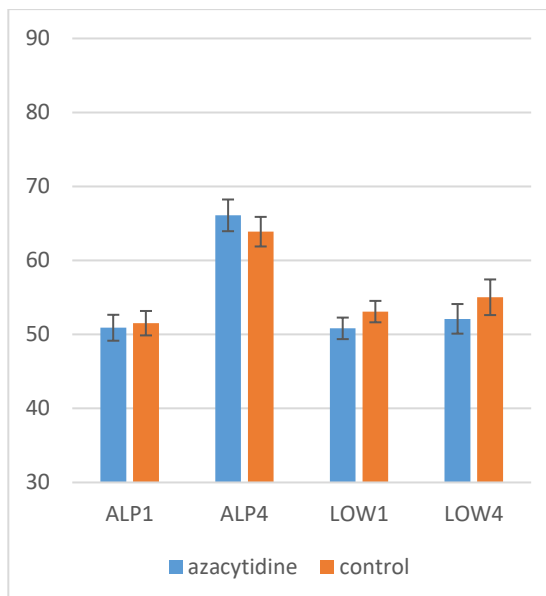
**Table 9:** Comparison of pilot and full experiment for stomatal density. Significant effects ( $p \leq 0.05$ ) are shown in bold. Complete results for each analysis are shown in Table 6 and Table 7.

**Figure 16:** Comparison of effect of demethylation treatment on plant origin in A) pilot experiment and B) full experiment. ALP denotes the cold sites and LOW denotes warm sites. 1 to 4 indicates moisture at the original localities with 1 indicating the driest and 4 the wettest sites. Columns show mean and error bars  $\pm$  standard error.

A) pilot experiment



B) full experiment



### 3.3 Comparison of result from the first and second experiment

The results of first and second experiment differ in some cases (Table 10). Both experiments coincided in reaction to target conditions, only. In general, in second experiment increased number of significant results. Just stomatal density was additionally affected by original temperature and interaction between original and target temperature within the first experiment. Stomatal density was also affected by original moisture in the second experiment in contrary to the first experiment, but the results are in fact quite similar as they are both close to the significance level.

**Table 10:** Illustrative differences between the first and second experiment. Significant effects ( $p < 0.05$ ) are shown in bold. Coincident results are marked by blue color, different results by orange color. Complete results are shown in Table 3 and Table 8.

| second experiment  |                  |                  |                |                  | first experiment |                  |                  |                 |                |
|--------------------|------------------|------------------|----------------|------------------|------------------|------------------|------------------|-----------------|----------------|
|                    | $\phi P0$        | o.p.             | s. density     | s. size          |                  | $\phi P0$        | o.p.             | s. density      | s. size        |
| target             | <b>&lt;0.001</b> | <b>&lt;0.001</b> | 0.2185         | <b>&lt;0.001</b> | Ttemp            | <b>&lt;0.001</b> | <b>&lt;0.001</b> | 0.7999          | <b>0.01607</b> |
|                    |                  |                  |                |                  | Tmois            | <b>&lt;0.001</b> | 0.3748           | 0.1406          | <b>0.03339</b> |
| Otemp              | 0.2753           | 0.3393           | 0.08192        | <b>&lt;0.001</b> | Otemp            | 0.5632           | 0.07425          | <b>0.004729</b> | <b>0.03034</b> |
| Omois              | 0.882            | 0.1097           | <b>0.01585</b> | <b>&lt;0.001</b> | Omois            | 0.9958           | 0.1884           | 0.08522         | 0.6766         |
| target x Otemp     | 0.7091           | <b>&lt;0.001</b> | 0.09374        | <b>0.00361</b>   | Otemp x Ttemp    | 0.5928           | 0.6844           | <b>0.03088</b>  | 0.238          |
|                    |                  |                  |                |                  | Otemp x Tmois    | 0.1742           | 0.3009           | 0.5243          | 0.6501         |
| target x Omois     | <b>&lt;0.001</b> | <b>0.005236</b>  | 0.06182        | 0.9553           | Omois x Ttemp    | 0.05378          | 0.8273           | 0.8221          | 0.6854         |
|                    |                  |                  |                |                  | Omois x Tmois    | 0.6596           | <b>0.00919</b>   | 0.8506          | 0.4604         |
| Otemp x Omois      | <b>&lt;0.001</b> | <b>&lt;0.001</b> | <b>0.02497</b> | 0.4188           | Otemp x Omois    | <b>0.03264</b>   | 0.8186           | <b>0.001306</b> | 0.9154         |
| no. of observation | 576              | 576              | 576            | 576              |                  | 1100             | 1100             | 440             | 440            |

T – target, O – original, temp – temperature, mois – moisture, no. of observation – number of observations



## 4 Discussion

### 4.1 Discussion of methods

#### 4.1.1 First experiment

##### 4.1.1.1 Experiment design

One of the best way how to study climate change is resurrection study – it provides direct evidence of evolutionary reaction to climate change over time but for that kind of study it is necessary to have samples from given locality collected in different time (Franks et al., 2014). Because such material was not available, a reciprocal transplant experiment was used. It is a method where space replaces time and provide the way how to study effect of climate change on the species *Festuca rubra*. Most reciprocal transplant studies transplant plants along elevation mimicking temperature or moisture gradients (e.g. (Frei et al., 2014; Torang et al., 2015; Wang et al., 2014), which means that they study just one factor separately. However, climate change consists from several factors which could interact. Here, factorially crossed gradients of temperature and moisture was used. This system enables to study effect of temperature and precipitation separately but also is possible to look at their interaction which can be important (Lu et al., 2016). Reciprocal experiments are generally considered to be a suitable method for studying climate change (Anderson et al., 2014). However, reciprocal transplants have several disadvantages which are rarely discussed. The common problem of reciprocal transplants is that the original sites are never exactly the same in all not studied abiotic conditions (despite effort to be as similar as possible). Also biotic conditions, such as the intensity of competition or herbivores may vary between localities. These factors may affect the resulting effects. Another problem with some reciprocal transplants is absence of replicates for each climate combinations (e.g. (Pratt and Mooney, 2013; Souther et al., 2012)). System of localities used in the present study also shows this deficiency. The problem of missing repeats is that the plant performance in a certain population may not be caused by original climate, but may be due to another unknown factor. Several repetitions of each site would considerably reduce this possibility. However, this large deficiency can be partially offset by the continuous character of the factors on the gradient. If the factors are continuous, it is possible to look at the trends of the measured traits along the gradient. If these trends exist, it is less likely that these populations differ for other reasons.

Reciprocal transplants are possible directly between original sites, or growth chambers can be used to simulate conditions in the native localities. In this study, the growth chambers were used. A disadvantage of growth chambers is that it is not possible to exactly simulate the original conditions. For example, light intensity of sunshine day or night frosts cannot be simulated. On the other hand, the great advantage of growth chambers is that they provide good accessibility and manipulation with the plants. Measurement of ecophysiological traits in the field would be very challenging, and some measurements, such as osmotic potential, would not be possible at all. The second big advantage of growth chambers is precisely controlled conditions that allow the elimination of other abiotic and biotic factors. They allow studying the effect of selected conditions without other effects.

The measurement of ecophysiological traits is not common for studies focused on phenotypic plasticity and/or genetic differentiation. Most of these studies investigate for example the flowering phenology (e.g. (Anderson et al., 2012a; Franks and Weis, 2008; Hanel and Tielborger, 2015)) or growth traits, such as plant height or biomass (e.g. (Etterson, 2004; Mimura and Aitken, 2010; Münzbergová et al., 2017)). The ecophysiological traits are usually neglected. The objection might be that ecophysiological traits are directly involved in the expression of growth traits or, for example, in the flowering phenology, and therefore the growth and phenology traits are sufficient to study the effects of climate change. However, according to my results, different ecophysiological traits can be manifested in a different way regardless of growth trait. In this context, I see the importance of using ecophysiological traits to study the effects of climate change on plants. Nevertheless, measuring ecophysiological traits may have also disadvantages. The experiment was designed to provide a representative number of samples. But some measurements were so time-consuming that it was not possible to measure all the samples. The numbers of measured samples are therefore unbalanced and in some cases (net photosynthetic rate and SLA) are low. Net photosynthetic rate and SLA showed neither genetic differentiation between populations nor interaction of origin and target conditions. It is possible that low number of measurements did not allow to detect the differences, because when all traits are reduced to the same set of samples as used to measure  $P_N$  and SLA, some interaction between origin and target conditions become non-significant (results of this analysis is shown in the Appendix 2).

#### 4.1.1.2 Comments on measurements

##### 1) Net photosynthetic rate – Li-Cor settings

When Li-Cor is used for net photosynthetic rate measurement, it is necessary to set the intensity of the light that irradiates the leaves in Li-Cor chamber and the amount of CO<sub>2</sub> that flows into the chamber. The light intensity was set at 1600  $\mu\text{mol m}^{-2} \text{s}^{-1}$ . This setting was used based on pre-experiment testing. At this intensity, the net photosynthesis rate was in its maximum and has not risen with adding more light. The intensity of the illumination in the Li-Cor chamber could have an effect if the plants were exposed to different light intensities in different growth chambers, because the plants exposed to different levels of light intensity should differ in their net photosynthetic rate maximum (Violet-Chabrand et al., 2017). In this case, all growth chambers were set to the same light intensity, therefore the same light irradiance in Li-Cor chambers was used for all plants. The CO<sub>2</sub> flow rate was set according to the producer's recommendations (Li-Cor, 1998-2012).

Measurements were made daily from 8 am to 5 pm. The length of measurement is necessary to be adjusted for each kind of species individually, because it depends on physiological changes during a day. The so-called midday or afternoon depression may occur in plants, indicating that the yield of photosynthesis decreases during a day without changes in light intensity. This can be caused, for example, by stomata closing due to the decrease of soil moisture (Koyama and Takemoto, 2014; Lange et al., 1971) or by the direct inhibitory effect of high light at the chloroplast level (Correia et al., 1990). In the case of this study, none of the effects occurred because the light intensity in growth chambers was never high enough to have an inhibitory effect on chloroplasts, also the fundamental lack of water in the plant not suffered, nor in the dry growth chambers (dry conditions – 600 mm / year). Thus, the plants had no reason to close the stomata. To confirm this, stomatal conductance was monitored during measurement. This theory has been verified by pre-experimental repeated measurements of the same plant at different times of the day. Also, I included time of measurement as a covariate in one version of my tests. This analysis had identical results to analysis without the covariate indicating the time of measurements did not affect the results. Analysis with time as covariate is shown in the Appendix 1.

##### 2) Chlorophyll fluorescence

Chlorophyll fluorescence measurement was made in the evening, each day during only 1.5 hour after dark adaptation. It is possible to measure samples during the whole day, but then

is necessary to let plants dark adapted at least 4-5 hours to ensure that plants are not influenced by different physiological statements during a day (Bacarin et al., 2016; Kalaji et al., 2014). However, the measurement is dependent on the damage of the PSII caused by, for example, light intensity or temperature. These damages are repaired during a night, and it is possible that after five hours of adaptation the measurements would not be indicative for damage of PSII, which accumulates during a day (Kalaji et al., 2014). It would be ideal to measure samples throughout the day due to a shorter time span between the first and the last measured sample, but for the above reason the measurement was done for only 1.5 hours per day.

Weak green light was used to navigate in dark during the measurement. This method is common for measuring fluorescence in the dark (Sun et al., 1998). However, it was suggested that green light is also absorbed and used for photosynthesis (Rappaport et al., 2007). Therefore, it is possible that despite the negative results of a pre-experimental green light test, this light could affect the exact chlorophyll fluorescence values. However, in the case of this study, I think that if green light affected the values, the results would not be affected, because all the plants were exposed to the same intensity of green light and therefore the values would be constantly changed for all plants.

### 3) Osmotic potential

The osmotic potential varies depending on the saturation of the leaves. Standardly, the osmotic potential is measured on the leaves collected at full saturation with water. Full saturation is ensured by sufficient plants watering and avoiding transpiration, for example, using a plastic bag (Bartlett et al., 2012a). Within this experiment, the leaves were not prevented from transpiration for time and manipulation reasons. Rates of transpiration certainly affected the values of osmotic potential because the plants were not fully turgid, so that the values were lower than they would be when the plants were measured in a fully turgid state. It could be argued that the rates of transpiration can differ between plants and thus measurement of osmotic potential can be influence by these differences. Nevertheless, the samples were collected at the same time each day, the light intensity as well as air humidity was identical for all plants among growth chambers and moreover, the stomatal traits, which can influence transpiration rate, were independent of osmotic potential, as suggested by absence of their correlation.

The disadvantage could be that the data are not comparable to other studies (Bartlett et al., 2012b), but it has been recently suggested that the method and the length of hydration affect the osmotic potential values differently for different species, so the comparison between osmotic potential measurement among species is probably not relevant (Arndt et al., 2015).

#### 4.1.2 Second experiment

Relationship between phenotype and epigenetic modifications is possible to study directly or indirectly. Direct way uses molecular methods, e.g. DNA screening with methylation-sensitive-AFLP so called MS-AFLP (ReynaLopez et al., 1997). This method provides direct evidence of epigenetic variation between individuals or populations (Schrey et al., 2013). However, this method requires specialized laboratory and funds. In contrary, method using demethylation agent is indirect, but in well-designed experiment provide similar information about changes in traits as molecular methods. Advantage of indirect method is that it provides direct evidence on functional changes in selected traits. Moreover, it is relatively easy to execute and inexpensive. However, disadvantage of using 5-azacytidine could be that this agent may sometimes induce classical mutation in sequence of DNA (Fieldes and Amyot, 1999), but it is highly unlikely that these mutations occur in all plants in population and moreover, such kind of problem can be detected by replicating each clone. Another potential disadvantage is that the demethylation induced by 5-azacytidine can be extensive (Amasino et al., 1990) and may not induce any clear phenotypic effect and thus the potentially existing epigenetic differentiation will not be detected. Despite these disadvantages, 5-azacytidine seems to be a suitable alternative to direct testing and it is often successfully used (Bossdorf et al., 2008).

Regarding to demethylation agent, another demethylating analogs as 5-azadeoxycytidine or zebularine can be used. Zebularine was not as commonly used and moreover, it was showed that 5-azacytidine can have greater demethylating effect across a genome (Griffin et al., 2016). The effect of 5-azacytidine and 5-azadeoxycytidine are similar (Haaf, 1995), but 5-azacytidine was successfully used on clonal plants (Gonzalez et al., 2016).

In case of experimental design, epigenetic differentiation was tested only on a limited selection of plant genotypes from the first experiment. Only some genotypes were selected originating from the most extreme sites, but in multiple replicates for each genotype. Maintaining the original number of genotypes from all localities would certainly support much more complex results, but in such a case it would not be possible to repeat the genotypes because of limited capacity of growth chambers. The missing replicates for each genotype would be incorrect, because it would not be possible to capture the variation induced by different effects of spraying by azacytidine on individual plants (Spens and Douhovnikoff, 2016). However, for detecting the occurrence of epigenetic differentiation in a model species, in my opinion a limited number of genotypes is sufficient, because if only the genotypes used for the second experiment were selected for another testing of results from the first experiment, the effect of origin was retained.

The results of this analysis are shown in the Appendix 3. Other changes in contrary to first experiment is number of growth chambers. In second experiment, just two growth chambers were used. In case of testing epigenetic differentiation, it is not important to have four combinations of target climate, because the only potentially interesting information united with target conditions is interaction between target conditions and azacytidine treatment, which can be detected already with two different combinations of target climate.

To find out whether epigenetic differentiation plays some role in what seems to be genetic differentiation, the treatment of 5-azacytidine which caused genome demethylation was used. However, epigenetic inheritance could be also caused by other epigenetic modifications such as histone modification or transposable elements (Saze, 2008). However, the methods and techniques for studying effect of these other epigenetic modifications are still very complicated and costly (Bossdorf et al., 2008; Herman et al., 2014). Therefore, just DNA methylation was used to represent epigenetic differentiation. Even though it is not yet possible to look at all possibilities of epigenetic inheritance, DNA methylation provides valuable information about epigenetic processes.

## **4.2 Discussion of results**

From a general point of view, the studied species *Festuca rubra* shows great phenotypic plasticity within the ecophysiological traits, resulting in a different response of plants between but not within each target environment. However, in some traits was also found a strong effect of origin. This effect demonstrates genetic differentiation, which, only in the case of stomata, gave a sign of local adaptation. Unfortunately, the results did not confirm any effect of epigenetic differentiation through the effect of azacytidine.

### **4.2.1 First experiment**

The main question of the first experiment was whether the species *Festuca rubra* reacts within the ecophysiological traits to climate change through phenotypic plasticity, and/or the populations from different climatic conditions are genetically differentiated. The results showed that the ecophysiological traits of *F. rubra* are very plastic, but some have demonstrated strong genetic differentiation. Thus, it is possible to suggest that *F. rubra* uses both strategies, plastic response as well as genetic differentiation and these responses strongly differ between traits. This suggestion is in line with (Münzbergová et al., 2017) and many others studying genetic

and plastic responses within various gradients of climate change, e.g. studies reviewed by (Franks et al., 2014) (38 studies until 2013), then e.g. (Brothers et al., 2016; Hamann et al., 2016; Preite et al., 2015; Sedlacek et al., 2015; Vitasse et al., 2014; Volis et al., 2015; Zhang et al., 2016). However, most of these studies are focused on phenological or growth-related traits. Just few studies show plastic vs. genetic responses in more than one ecophysiological trait (Anderson and Gezon, 2015; Benomar et al., 2016; Knutzen et al., 2015; Pratt and Mooney, 2013; Souther et al., 2012; Sultan et al., 2013; Zhang et al., 2012). Moreover, all the studies used only temperature or precipitation gradient, thus in contrary to this study, they lack the possibility to study interactions between these factors.

#### **4.2.1.1 Plastic response**

Phenotypic plasticity, determined by target conditions, was shown in all traits. However,  $P_N$ , SLA,  $\phi P0$  and osmotic potential were more plastic, than stomatal density and stomatal size. In comparison to other studies focused on phenotypic plasticity vs. genetic differentiation in ecophysiological traits mentioned below, importance of plasticity in each trait strongly differed between studies systems and between species. Just photosynthetic parameters mostly show high level of plasticity (Benomar et al., 2016; Souther et al., 2012; Yamori et al., 2014).

$P_N$ , SLA and PSII efficiency reflect plant stress (Ashraf and Harris, 2013; Shi et al., 2010). According to these traits, the plants prospered the worst in cold-wet target conditions, and the best in dry growth chambers particularly in combination with cold treatment. All these traits were affected by temperature, moisture and their interaction, but main driver of differences between growth chambers was the moisture, suggesting by the explained deviance. In many studies, where these traits were measured under dry and wet conditions, the values of these traits increased with moisture (e.g. (Pratt and Mooney, 2013; Ramirez-Valiente et al., 2010; Sultan et al., 2013). In case of this study, the reaction was opposite. However, wet conditions in this experiment mean high annual precipitation of 2700 mm. It is possible that plants under high and permanent soil moisture as in this experiment could face some level of hypoxia, suggested by low values of  $P_N$ , SLA and  $\phi P0$ , and visible red pigmentation of leaves, which could occur under stress from hypoxia, especially in combination with low temperature (Kawasaki et al., 2015; Ougham et al., 2005). Hypoxia would explain low values in  $P_N$ , SLA and  $\phi P0$  in wet growth chambers and the main effect of moisture on these traits, but this assumption is not based on direct testing.

Despite the main effect of moisture, temperature and interaction of temperature and moisture are not negligible in  $P_N$  and SLA. In case of PSII efficiency, although the effect of temperature and interaction between temperature and moisture was significant, the differences are very small. Nevertheless, the PSII efficiency increased with rising temperature, which indicates better prosperity in warmer conditions (Maricle and Adler, 2011). In  $P_N$  and SLA, the effect of interaction was stronger than effect of temperature, which is shown on resulting effect of temperature, mainly in case of  $P_N$ . SLA was higher in warmer conditions, which correspond with other studies transplanting plant along latitudinal gradients (Benomar et al., 2016; Gonzalo-Turpin and Hazard, 2009) and indicates higher growth rate, which correspond with positive correlation with number of ramets and plants height. In case of  $P_N$ , the reaction to warm conditions was negative, which was primarily driven by the highest values in cold-dry growth chamber. The effect of reducing photosynthetic rate with transplant to warmer climate is presented also in (Souther et al., 2012), where this effect is interpreted as the result of lower carbon uptake caused by half-closed stomata under warmer climate. However, the difference between study of Souther and present study is that they measured  $P_N$  directly in growth chambers under simulated temperature. In present experiment, all plants were measured under the same temperature, air humidity and after watering, thus the effect of half-opened stomata should not occur. Because the net photosynthetic rate could be influenced by many other factors, the reason for the highest values of  $P_N$  in cold-dry growth chamber remains unclear.

Low values of osmotic potential indicate plant acclimatization to dry conditions (Bartlett et al., 2014). Here, osmotic potential was not affected by target moisture at all. It corresponds with (Knutzen et al., 2015), but they used relatively short precipitation gradient. I suggest that target moisture here did not affect osmotic potential because, in fact, the plants never suffer from drought in the experiment. However, my results show that osmotic potential can be influenced by temperature. I am not aware of any phenotypic vs. genetic study using temperature gradient, where the osmotic potential was used, therefore a comparison is not possible. Nevertheless, despite significant effect of target temperature, the real difference of osmotic potential between growth chambers is maximum 0.1 MPa, which is too small difference to have any significant effect on plants physiology (Procházka, 1998).

Stomatal density and stomatal size show phenotypic plasticity, but especially in case of stomatal density the plasticity was very weak. The result presented here were different from the studies focused on stomatal density and size (Anderson and Gezon, 2015; Zhang et al., 2012). Both studies used temperature gradients and both presented plasticity in stomatal density, but not in stomatal size. Nevertheless, many studies, which were focused on only phenotypic

plasticity or genetic differentiation between populations differed in their results e.g. (Carlson et al., 2016; Montoro and Sadras, 2014). Thus I suggest that plastic reaction of stomatal traits is strongly species-specific.

All traits presented here were significantly affected by interaction between target temperature and moisture. None of the studies focused on plasticity vs. genetic differentiation in ecophysiological traits used combination of these factors. Here I demonstrate that this combination is important, because the explained deviance by this interaction reach up to 36%.

#### **4.2.1.2 Genetic differentiation**

PSII efficiency, stomatal density and stomatal size were significantly affected by climate of origin, which indicates genetic differentiation between populations.

Despite significant effect of interaction between original temperature and moisture in PSII efficiency, explained deviance was very low. Nevertheless, this result indicates that populations growing in different levels of temperature and moisture could be probably differently adjusted to their home conditions within photosynthesis efficiency.

Stomatal density and size showed strong dependence on climate of origin. These traits were negatively correlated, which is a common relationship existing probably for very long time (Hetherington and Woodward, 2003). Differences in stomatal density were significantly affected by temperature and interaction between temperature and moisture. The most distinct difference occurred in a cold-wet locality ALP4, where the density was much larger than in other localities. It did not correspond with expectation that plants in warmer and drier conditions have numerous but smaller stomata (Bussotti et al., 2005; Carlson et al., 2016). Also, in cold localities the stomatal density was higher than in lowland and stomatal size showed an opposite pattern. Just in warm localities stomatal density increased with drought. Generally, expected adaptation to drier conditions through numerous small stomatal was not detected. But in case of temperature, the effect could be influenced by different altitudes. Increase in stomatal density with elevation is presented e.g. in (Woodward et al., 2002). In this study, the stomatal density could increase with altitude because of higher irradiance. Thus, it is possible that despite lower mean seasonal temperature, the plants in high elevation are exposed to short-term higher irradiance and thus (mainly in case of locality ALP4) they could have adapted to it. Also, genetic differentiation as well as increasing or decreasing stomatal density and stomatal size along temperature gradient is probably species-specific, because in other studies these effects strongly differ between species. (Anderson and Gezon, 2015; Zhang et al., 2012).

#### **4.2.1.3 Target and origin interaction**

The interaction between target and origin represents genetic differences in plasticity between populations (e.g. (Hamann et al., 2016)). These differences were significant for osmotic potential and stomatal density. This interaction indicates that phenotypic plasticity in these traits is under selection (Thompson, 1991) and the population with stronger adaptive plasticity (i.e. positive reaction to changing climate (Ghalambor et al., 2007)) have better chance to adjust to novel conditions. For example, the plants originating from intermediate wet conditions demonstrate lower osmotic potential than others in dry target conditions indicating that these populations can better react to drought. The results presented are in line with (Münzbergová et al., 2017; Volis et al., 2015) and just partly agree with hypothesis that the plants originating from extreme and unpredictable conditions are more plastic (Schlichting, 1986).

The interaction in temperature and moisture in both traits explained about 10% of total deviance, which is not negligible. Usually, the genetic differentiation in plasticity is low or none across various traits (e.g.(Benomar et al., 2016; Franks, 2011; Knutzen et al., 2015; Münzbergová et al., 2017; Sultan et al., 2013; Zhang et al., 2012). Here I demonstrated that a magnitude of difference in plasticity differs between traits and could be influenced by moisture as well as temperature.

#### **4.2.1.4 Local adaptation**

Separating phenotypic plasticity and genetic differentiation proved that local adaptation can be considered for PSII efficiency, osmotic potential and stomatal density and size, because genetic differentiation could lead to local adaptation. Using home vs. foreign criteria (Kawecki and Ebert, 2004), this pattern was detected for osmotic potential and stomatal size.

In case of osmotic potential, the plants from home water regime had higher values. But similarly to response to target conditions, differences in values between home and foreign localities were negligible (approximately 0.03 MPa, which could not have any real effect on physiology of the plants (Procházka, 1998)) and cannot be considered as a local adaptation.

Plants in their home temperature and moisture had smaller stomata than in other combinations, but it is not clear why in interaction of local and foreign conditions the stomatal size should be greater. Nevertheless, stomatal density and size showed high level of genetic differentiation and evident differences between populations. It indicates that in spite of unclear

home vs. foreign analysis, the stomatal traits showed dependence on plant's origin and thus the potential of local adaptation through these traits exists.

Generally, the results do not confirm that the populations of *F. rubra* are locally adapted, but only selected traits indicate possibility of local adaptation. It is in line with (Münzbergová et al., 2017), where the local adaptation was significant just for selected traits.

#### **4.2.1.5 Directionality of climate change**

The main objective here was to determine how plants respond to the predicted direction of climate change, i.e. warmer and wetter climate. Only  $P_N$ , SLA and PSII efficiency have a predictive potential on the response to directionality of climate change, despite the direction of the change had a significant effect on all traits except stomatal size. In the case of osmotic potential, there was a certain tendency to decrease values towards the wet and cold conditions, but as in case of plasticity, the values are so similar that it is meaningless to interpret. The plasticity of stomatal density was also very low, thus the differences in the direction of the reaction are very low. It seems that the stomata density increased towards the wet conditions, but again, the change is very small.  $P_N$ , SLA and PSII efficiency were, as well as in the plastic reaction, mainly influenced by the effect of moisture change. In all cases, the trait values decreased towards the wet conditions. In the case of SLA and  $\phi P_0$ , this effect is mitigated by rising temperature, but the effect of precipitation was stronger. In the case of  $P_N$ , the temperature had an effect only with transplant towards drier conditions. The temperature did not play a role (the values were steadily decreasing) towards wet conditions. The results show that, although the rising temperature had rather positive effect on plants, the effect of rising precipitation was negative. So overall, within these photosynthetic-related traits, it seems that the plants will not benefit from climate change. However, (Münzbergová et al., 2017) suggested that plants have a beneficial effect on this direction of climate change. This inconsistency is probably caused by the fact that most plastic traits presented here were negatively influenced mainly by increasing precipitation. In Münzbergová study, the transplantation to wetter conditions caused decreasing for example plant height or number of ramets, but this effect was mitigated by rising temperature. Thus, general effect on plant performance towards predicted climate change is clearly positive with rising temperature, but it seems that rising precipitation will more or less inhibit this positive effect.

#### 4.2.2 Second experiment

The main aim of the second experiment was to find out, whether the genetic differentiation detected in the first experiment can be caused by epigenetic differentiation. This effect was not found within the main experiment, even though the pilot experiment was significant. This inconsistency in the results is probably due to an increase in the number of repeats in the main experiment, where each clone had 6 repetitions compared to the pilot experiment, where these repeats were missing. In addition, the pilot experiment was carried out before transferring the plants to growth chambers, so the time difference could also have played a role in this inconsistency.

The number of studies focused on differences in epigenetic variation between natural population from different environments is very low (e.g. (Bzdega et al., 2016; Cano et al., 2016; Herrera and Bazaga, 2010, 2011; Lira-Medeiros et al., 2010; Paun et al., 2010; Richards et al., 2012)), but all these studies show some level of epigenetic variation between different populations, which is in contrary to present study. However, none of these studies focused on link of epigenetic differentiation with specific climatic conditions, nor on its adaptiveness. Nevertheless, the results of (Münzbergová et al., in prep.) where the same plants but different traits were used, the epigenetic differentiation was proven. This inconsistency is probably caused by differences between traits. Most of ecophysiological traits measured here were highly plastic and showed none or weak genetic differentiation, except stomatal traits. Stomatal traits could be transgenerationally heritable under environmental stress, as shown at *Arabidopsis thaliana* in response to drought (Tricker et al., 2013), but stomata traits could be also genetically adapted to different levels of precipitation within one species (Muir et al., 2014). In this case it seems that the genetic differentiation shown for stomata traits is truly caused by genetic adaptation without any epigenetics.

It can be argued that the non-significance of the transgenerational effect could be due to a different beginning of the first and second experiment. The second experiment began about eight months after the first experiment. Over the course of these 8 months, the plants grew in the greenhouse and created many new ramets. Transgenerational effect in some cases lasts for many generations, but also can be unstable and disappear after few generations (Herman et al., 2014). It is possible, therefore, that the plants have 'adapted' to the greenhouse conditions, and thus eliminating the transgenerational effect. However, when comparing the results of the second experiment on genetic differentiation with the genetic differentiation observed in the first experiment, except few minor inconsistencies, the results are very similar. Especially in the

case of stomata, where the genetic differentiation was very significant, the effect of the original conditions was preserved, even the values of individual traits among populations are very similar (with respect to non-uniformity of experimental designs). Thus, if the transgenerational effect within the measured traits existed and was ‘deleted’ due to the wrong timing of the experiment, I assume that the effect of origin would also be ‘deleted’. However, the possibility that the discrepancy with experiment timing affected results could not be excluded.



## 5 Conclusion

The main aim of this diploma thesis was to demonstrate the mechanisms, which the target species *Festuca rubra* can use to react to climate change through ecophysiological traits. The study showed high level of phenotypic plasticity in all traits with the highest levels in photosynthetic-related traits. Populations originating from different climatic conditions are also genetically differentiated, especially in stomatal traits. Genetic differentiation together with some cases of better prosperity at home conditions provide signs of local adaptation, but only in selected traits. Epigenetic differentiation was not proven, thus differences between populations presented here seem to be driven only by genetic differentiation. The importance of plasticity and genetic differentiation strongly differs between traits. Also, specific reactions within measured traits were dependent on original as well as target temperature, precipitation and their combination. It demonstrates the importance of studying these factors simultaneously. Simulated directionality of climate change showed that the populations are able to cope with climate change only through plastic response, but for better prosperity they probably need genetic adaptation. Present genetic differentiation between population and possibility of local adaptation itself could reduce the chance of adaptation to novel conditions. However, together with high plasticity and with high genetic diversity of the species, there is a potential for selection of genotypes which will prosper better in changing climate or to selection of genotypes which will prosper better in novel local climate. Thus, it indicates that the species could have a potential to adapt to novel climate. Nevertheless, real situation in the field crucially depends on specific genotypes which occur within population as well as on gene flow between populations. Equally important are biotic factors such as interspecific competition or herbivory, which could also strongly change species ability to respond to climate change. The complex reaction to climate change can thus not be easily predicted.

## 6 References

- Ackerly, D. D., 2003, Community assembly, niche conservatism, and adaptive evolution in changing environments: *International Journal of Plant Sciences*, v. 164, p. S165-S184.
- Agrawal, A. A., A. C. Erwin, and S. C. Cook, 2008, Natural selection on and predicted responses of ecophysiological traits of swamp milkweed (*Asclepias incarnata*): *Journal of Ecology*, v. 96, p. 536-542.
- Akimoto, K., H. Katakami, H. J. Kim, E. Ogawa, C. M. Sano, Y. Wada, and H. Sano, 2007, Epigenetic inheritance in rice plants: *Annals of Botany*, v. 100, p. 205-217.
- Amasino, R. M., M. C. John, M. Klaas, and D. N. Crowell, 1990, Role of DNA methylation in the regulation of gene-expression in plants: *Nucleic Acid Methylation*, v. 128, p. 187-198.
- Anderson, J. T., and Z. J. Gezon, 2015, Plasticity in functional traits in the context of climate change: a case study of the subalpine forb *Boechera stricta* (Brassicaceae): *Global Change Biology*, v. 21, p. 1689-1703.
- Anderson, J. T., D. W. Inouye, A. M. McKinney, R. I. Colautti, and T. Mitchell-Olds, 2012a, Phenotypic plasticity and adaptive evolution contribute to advancing flowering phenology in response to climate change: *Proceedings of the Royal Society B-Biological Sciences*, v. 279, p. 3843-3852.
- Anderson, J. T., A. M. Panetta, and T. Mitchell-Olds, 2012b, Evolutionary and Ecological Responses to Anthropogenic Climate Change: *Plant Physiology*, v. 160, p. 1728-1740.
- Anderson, J. T., M. R. Wagner, C. A. Rushworth, K. Prasad, and T. Mitchell-Olds, 2014, The evolution of quantitative traits in complex environments: *Heredity*, v. 112, p. 4-12.
- Arndt, S. K., A. Irawan, and G. J. Sanders, 2015, Apoplastic water fraction and rehydration techniques introduce significant errors in measurements of relative water content and osmotic potential in plant leaves: *Physiologia Plantarum*, v. 155, p. 355-368.
- Ashapkin, V. V., L. I. Kutueva, and B. F. Vanyushin, 2016, Epigenetic variability in plants: Heritability, adaptability, evolutionary significance: *Russian Journal of Plant Physiology*, v. 63, p. 181-192.
- Ashraf, M., and P. J. C. Harris, 2013, Photosynthesis under stressful environments: An overview: *Photosynthetica*, v. 51, p. 163-190.
- Azhar, A., J. Sathornkich, R. Rattanawong, and P. Kasemsap, 2014, Responses of Chlorophyll Fluorescence, Stomatal Conductance, and Net Photosynthesis rates of Four Rubber (*Hevea brasiliensis*) Genotypes to Drought: *Advances in Rubber*, v. 844, p. 11-14.
- Bacarin, M. A., E. G. Martinazzo, D. Cassol, A. R. Falqueto, and D. M. Silva, 2016, Daytime variations of chlorophyll a fluorescence in pau d'alto seedlings: *Revista Arvore*, v. 40, p. 1023-1030.
- Baker, N. R., and E. Rosenqvist, 2004, Applications of chlorophyll fluorescence can improve crop production strategies: an examination of future possibilities: *Journal of Experimental Botany*, v. 55, p. 1607-1621.
- Bartlett, M. K., C. Scoffoni, R. Ardy, Y. Zhang, S. W. Sun, K. F. Cao, and L. Sack, 2012a, Rapid determination of comparative drought tolerance traits: using an osmometer to predict turgor loss point: *Methods in Ecology and Evolution*, v. 3, p. 880-888.

- Bartlett, M. K., C. Scoffoni, and L. Sack, 2012b, The determinants of leaf turgor loss point and prediction of drought tolerance of species and biomes: a global meta-analysis: *Ecology Letters*, v. 15, p. 393-405.
- Bartlett, M. K., Y. Zhang, N. Kreidler, S. W. Sun, R. Ardy, K. F. Cao, and L. Sack, 2014, Global analysis of plasticity in turgor loss point, a key drought tolerance trait: *Ecology Letters*, v. 17, p. 1580-1590.
- Bates, D., M. Machler, B. M. Bolker, and S. C. Walker, 2015, Fitting Linear Mixed-Effects Models Using lme4: *Journal of Statistical Software*, v. 67, p. 1-48.
- Beerling, D. J., and W. G. Chaloner, 1993, The impact of atmospheric CO<sub>2</sub> and temperature-change on stomatal density - observations from *Quercus robur* lammas leaves: *Annals of Botany*, v. 71, p. 231-235.
- Benomar, L., M. S. Lamhamedi, A. Rainville, J. Beaulieu, J. Bousquet, and H. A. Margolis, 2016, Genetic Adaptation vs. Ecophysiological Plasticity of Photosynthetic-Related Traits in Young *Picea glauca* Trees along a Regional Climatic Gradient: *Frontiers in Plant Science*, v. 7.
- Bossdorf, O., C. L. Richards, and M. Pigliucci, 2008, Epigenetics for ecologists: *Ecology Letters*, v. 11, p. 106-115.
- Boyko, A., and I. Kovalchuk, 2011, Genome instability and epigenetic modification - heritable responses to environmental stress?: *Current Opinion in Plant Biology*, v. 14, p. 260-266.
- Brothers, A. N., L. A. Weingartner, and L. F. Delph, 2016, Genetically based population divergence of *Silene latifolia* from two climate regions: *Evolutionary Ecology Research*, v. 17, p. 637-650.
- Bussotti, F., M. Pancrazi, G. Matteucci, and G. Gerosa, 2005, Leaf morphology and chemistry in *Fagus sylvatica* (beech) trees as affected by site factors and ozone: results from CONECOFOR permanent monitoring plots in Italy: *Tree Physiology*, v. 25, p. 211-219.
- Butof, A., L. R. von Riedmatten, C. F. Dormann, M. Scherer-Lorenzen, E. Welk, and H. Bruelheide, 2012, The responses of grassland plants to experimentally simulated climate change depend on land use and region: *Global Change Biology*, v. 18, p. 127-137.
- Bzdega, K., A. Janlak, T. Ksiazczyk, A. Lewandowska, M. Gancarek, E. Sliwinska, and B. Tokarska-Guzik, 2016, A Survey of Genetic Variation and Genome Evolution within the Invasive *Fallopia* Complex: *Plos One*, v. 11.
- Cano, L., T. Fuertes-Mendizabal, G. Garcia-Baquero, M. Herrera, and M. B. Gonzalez-Moro, 2016, Plasticity to salinity and transgenerational effects in the nonnative shrub *Baccharis halimifolia*: Insights into an estuarine invasion: *American Journal of Botany*, v. 103, p. 808-820.
- Carlson, J. E., C. A. Adams, and K. E. Holsinger, 2016, Intraspecific variation in stomatal traits, leaf traits and physiology reflects adaptation along aridity gradients in a South African shrub: *Annals of Botany*, v. 117, p. 195-207.
- Castro, S., Z. Munzbergova, J. Raabova, and J. Loureiro, 2011, Breeding barriers at a diploid-hexaploid contact zone in *Aster amellus*: *Evolutionary Ecology*, v. 25, p. 795-814.
- Chaves, M. M., J. S. Pereira, J. Maroco, M. L. Rodrigues, C. P. P. Ricardo, M. L. Osorio, I. Carvalho, T. Faria, and C. Pinheiro, 2002, How plants cope with water stress in the field. Photosynthesis and growth: *Annals of Botany*, v. 89, p. 907-916.

- Cheung, Y. N. S., M. T. Tyree, and J. Dainty, 1975, Water relations parameters on single leaves obtained in a pressure bomb and some ecological interpretations: *Canadian Journal of Botany-Revue Canadienne De Botanique*, v. 53, p. 1342-1346.
- Ciais, P., M. Reichstein, N. Viovy, A. Granier, J. Ogee, V. Allard, M. Aubinet, N. Buchmann, C. Bernhofer, A. Carrara, F. Chevallier, N. De Noblet, A. D. Friend, P. Friedlingstein, T. Grunwald, B. Heinesch, P. Keronen, A. Knohl, G. Krinner, D. Loustau, G. Manca, G. Matteucci, F. Miglietta, J. M. Ourcival, D. Papale, K. Pilegaard, S. Rambal, G. Seufert, J. F. Soussana, M. J. Sanz, E. D. Schulze, T. Vesala, and R. Valentini, 2005, Europe-wide reduction in primary productivity caused by the heat and drought in 2003: *Nature*, v. 437, p. 529-533.
- Correia, M. J., M. M. C. Chaves, and J. S. Pereira, 1990, Afternoon depression in photosynthesis in grapevine leaves - evidence for a high light stress effect: *Journal of Experimental Botany*, v. 41, p. 417-426.
- Cortijo, S., R. Wardenaar, M. Colome-Tatche, A. Gilly, M. Etcheverry, K. Labadie, E. Caillieux, F. Hospital, J.-M. Aury, P. Wincker, F. Roudier, R. C. Jansen, V. Colot, and F. Johannes, 2014, Mapping the Epigenetic Basis of Complex Traits: *Science*, v. 343, p. 1145-1148.
- Cubas, P., C. Vincent, and E. Coen, 1999, An epigenetic mutation responsible for natural variation in floral symmetry: *Nature*, v. 401, p. 157-161.
- Davis, M. B., and R. G. Shaw, 2001, Range shifts and adaptive responses to Quaternary climate change: *Science*, v. 292, p. 673-679.
- De Frenne, P., J. Brunet, A. Shevtsova, A. Kolb, B. J. Graae, O. Chabrierie, S. A. Cousins, G. Decocq, A. De Schrijver, M. Diekmann, R. Gruwez, T. Heinken, M. Hermy, C. Nilsson, S. Stanton, W. Tack, J. Willaert, and K. Verheyen, 2011, Temperature effects on forest herbs assessed by warming and transplant experiments along a latitudinal gradient: *Global Change Biology*, v. 17, p. 3240-3253.
- Douhovnikoff, V., and R. S. Dodd, 2015, Epigenetics: a potential mechanism for clonal plant success: *Plant Ecology*, v. 216, p. 227-233.
- Etterson, J. R., 2004, Evolutionary potential of *Chamaecrista fasciculata* in relation to climate change. 1. Clinal patterns of selection along an environmental gradient in the great plains: *Evolution*, v. 58, p. 1446-1458.
- Fieldes, M. A., and L. M. Amyot, 1999, Evaluating the potential of using 5-azacytidine as an epimutagen: *Canadian Journal of Botany-Revue Canadienne De Botanique*, v. 77, p. 1617-1622.
- Franks, S. J., 2011, Plasticity and evolution in drought avoidance and escape in the annual plant *Brassica rapa*: *New Phytologist*, v. 190, p. 249-257.
- Franks, S. J., J. J. Weber, and S. N. Aitken, 2014, Evolutionary and plastic responses to climate change in terrestrial plant populations: *Evolutionary Applications*, v. 7, p. 123-139.
- Franks, S. J., and A. E. Weis, 2008, A change in climate causes rapid evolution of multiple life-history traits and their interactions in an annual plant: *Journal of Evolutionary Biology*, v. 21, p. 1321-1334.
- Frei, E. R., J. Ghazoul, P. Matter, M. Heggli, and A. R. Pluess, 2014, Plant population differentiation and climate change: responses of grassland species along an elevational gradient: *Global Change Biology*, v. 20, p. 441-455.

- Garnier, E., B. Shipley, C. Roumet, and G. Laurent, 2001, A standardized protocol for the determination of specific leaf area and leaf dry matter content: *Functional Ecology*, v. 15, p. 688-695.
- Ghalambor, C. K., J. K. McKay, S. P. Carroll, and D. N. Reznick, 2007, Adaptive versus non-adaptive phenotypic plasticity and the potential for contemporary adaptation in new environments: *Functional Ecology*, v. 21, p. 394-407.
- Gibson, A. L., E. K. Espeland, V. Wagner, and C. R. Nelson, 2016, Can local adaptation research in plants inform selection of native plant materials? An analysis of experimental methodologies: *Evolutionary Applications*, v. 9, p. 1219-1228.
- Gienapp, P., C. Teplitsky, J. S. Alho, J. A. Mills, and J. Merila, 2008, Climate change and evolution: disentangling environmental and genetic responses: *Molecular Ecology*, v. 17, p. 167-178.
- Gitz, D. C., and J. T. Baker, 2009, Methods for Creating Stomatal Impressions Directly onto Archivable Slides: *Agronomy Journal*, v. 101, p. 232-236.
- Giuliani, A. L., E. F. Kelly, and A. K. Knapp, 2014, Geographic variation in growth and phenology of two dominant central US grasses: consequences for climate change: *Journal of Plant Ecology*, v. 7, p. 211-221.
- Gonzalez, A. P. R., J. Chrtek, P. I. Dobrev, V. Dumalasova, J. Fehrer, P. Mraz, and V. Latzel, 2016, Stress-induced memory alters growth of clonal off spring of white clover (*Trifolium repens*): *American Journal of Botany*, v. 103, p. 1567-1574.
- Gonzalo-Turpin, H., and L. Hazard, 2009, Local adaptation occurs along altitudinal gradient despite the existence of gene flow in the alpine plant species *Festuca eskia*: *Journal of Ecology*, v. 97, p. 742-751.
- Griffin, P. T., C. E. Niederhuth, and R. J. Schmitz, 2016, A Comparative Analysis of 5-Azacytidine- and Zebularine-Induced DNA Demethylation: *G3-Genes Genomes Genetics*, v. 6, p. 2773-2780.
- Haaf, T., 1995, The effect of 5-azacytidine and 5-azadeoxycytidine on chromosome structure and function - implications for methylation-associated cellular processes: *Pharmacology & Therapeutics*, v. 65, p. 19-46.
- Hamann, E., H. Kesselring, G. F. J. Armbruster, J. F. Scheepens, and J. Stocklin, 2016, Evidence of local adaptation to fine- and coarse-grained environmental variability in *Poa alpina* in the Swiss Alps: *Journal of Ecology*, v. 104, p. 1627-1637.
- Hanel, S., and K. Tielborger, 2015, Phenotypic response of plants to simulated climate change in a long-term rain-manipulation experiment: a multi-species study: *Oecologia*, v. 177, p. 1015-1024.
- Hanssen-Bauer, I., C. Achberger, R. E. Benestad, D. Chen, and E. J. Forland, 2005, Statistical downscaling of climate scenarios over Scandinavia: *Climate Research*, v. 29, p. 255-268.
- Harrell, F. E., 2016, Hmisc: Harrell Miscellaneous. R package version 4.0-0, <https://CRAN.R-project.org/package=Hmisc>.
- Hemrova, L., J. Knappova, and Z. Munzbergova, 2016, Assessment of Habitat Suitability Is Affected by Plant-Soil Feedback: Comparison of Field and Garden Experiment: *Plos One*, v. 11.
- Herben, T., F. Krahulec, V. Hadincova, and S. Pechackova, 2001, Clone-specific response of *Festuca rubra* to natural variation in biomass and species composition of neighbours: *Oikos*, v. 95, p. 43-52.

- Herman, J. J., H. G. Spencer, K. Donohue, and S. E. Sultan, 2014, How stable 'should' epigenetic modifications be? Insights from adaptive plasticity and bet hedging: *Evolution*, v. 68, p. 632-643.
- Herrera, C. M., and P. Bazaga, 2010, Epigenetic differentiation and relationship to adaptive genetic divergence in discrete populations of the violet *Viola cazorlensis*: *New Phytologist*, v. 187, p. 867-876.
- Herrera, C. M., and P. Bazaga, 2011, Untangling individual variation in natural populations: ecological, genetic and epigenetic correlates of long-term inequality in herbivory: *Molecular Ecology*, v. 20, p. 1675-1688.
- Hetherington, A. M., and F. I. Woodward, 2003, The role of stomata in sensing and driving environmental change: *Nature*, v. 424, p. 901-908.
- Hoffmann, A. A., and C. M. Sgro, 2011, Climate change and evolutionary adaptation: *Nature*, v. 470, p. 479-485.
- Iwasaki, M., and J. Paszkowski, 2014, Identification of genes preventing transgenerational transmission of stress-induced epigenetic states: *Proceedings of the National Academy of Sciences of the United States of America*, v. 111, p. 8547-8552.
- Johannes, F., E. Porcher, F. K. Teixeira, V. Saliba-Colombani, M. Simon, N. Agier, A. Bulski, J. Albuissou, F. Heredia, P. Audigier, D. Bouchez, C. Dillmann, P. Guerche, F. Hospital, and V. Colot, 2009, Assessing the Impact of Transgenerational Epigenetic Variation on Complex Traits: *Plos Genetics*, v. 5.
- Jones, P. A., S. M. Taylor, and V. L. Wilson, 1983, Inhibition of DNA methylation by 5-azacytidine: *Recent Results in Cancer Research*, v. 84, p. 202-211.
- Jullien, P. E., and F. Berger, 2010, DNA methylation reprogramming during plant sexual reproduction?: *Trends in Genetics*, v. 26, p. 394-399.
- Jump, A. S., and J. Penuelas, 2005, Running to stand still: adaptation and the response of plants to rapid climate change: *Ecology Letters*, v. 8, p. 1010-1020.
- Kalaji, H. M., G. Schansker, R. J. Ladle, V. Goltsev, K. Bosa, S. I. Allakhverdiev, M. Brestic, F. Bussotti, A. Calatayud, P. Dabrowski, N. I. Elsheery, L. Ferroni, L. Guidi, S. W. Hogewoning, A. Jajoo, A. N. Misra, S. G. Nebauer, S. Pancaldi, C. Penella, D. Poli, M. Pollastrini, Z. B. Romanowska-Duda, B. Rutkowska, J. Serodio, K. Suresh, W. Szulc, E. Tambussi, M. Yanniccari, and M. Zivcak, 2014, Frequently asked questions about in vivo chlorophyll fluorescence: practical issues: *Photosynthesis Research*, v. 122, p. 121-158.
- Kawasaki, S. I., J. Tominaga, S. Yabuta, K. Watanabe, T. Jaiphong, M. Ueno, and Y. Kawamitsu, 2015, Responses of growth, photosynthesis, and associated components to hypoxia at different light intensities in red leaf lettuce: *Scientia Horticulturae*, v. 193, p. 330-336.
- Kawecki, T. J., and D. Ebert, 2004, Conceptual issues in local adaptation: *Ecology Letters*, v. 7, p. 1225-1241.
- Kim, E., and K. Donohue, 2013, Local adaptation and plasticity of *Erysimum capitatum* to altitude: its implications for responses to climate change: *Journal of Ecology*, v. 101, p. 796-805.
- Klanderud, K., V. Vandvik, and D. Goldberg, 2015, The Importance of Biotic vs. Abiotic Drivers of Local Plant Community Composition Along Regional Bioclimatic Gradients: *Plos One*, v. 10.

- Knutzen, F., I. C. Meier, and C. Leuschner, 2015, Does reduced precipitation trigger physiological and morphological drought adaptations in European beech (*Fagus sylvatica* L.)? Comparing provenances across a precipitation gradient: *Tree Physiology*, v. 35, p. 949-963.
- Koyama, K., and S. Takemoto, 2014, Morning reduction of photosynthetic capacity before midday depression: *Scientific Reports*, v. 4.
- Lange, O. L., R. Losch, E. D. Schulze, and L. Kappen, 1971, Responses of stomata to changes in humidity: *Planta*, v. 100, p. 76-81.
- Latzel, V., S. Janecek, J. Dolezal, J. Klimesova, and O. Bossdorf, 2014, Adaptive transgenerational plasticity in the perennial *Plantago lanceolata*: *Oikos*, v. 123, p. 41-46.
- Latzel, V., Y. Zhang, K. K. Moritz, M. Fischer, and O. Bossdorf, 2012, Epigenetic variation in plant responses to defence hormones: *Annals of Botany*, v. 110, p. 1423-1428.
- Li-Cor, B., 1998-2012, Using the LI-6400/LI-6400XT, Version 6, <https://www.licor.com/env/support/product?p=6400XT>.
- Lira-Medeiros, C. F., C. Parisod, R. A. Fernandes, C. S. Mata, M. A. Cardoso, and P. C. G. Ferreira, 2010, Epigenetic Variation in Mangrove Plants Occurring in Contrasting Natural Environment: *Plos One*, v. 5.
- Liu, J. Z., L. L. Feng, J. M. Li, and Z. H. He, 2015, Genetic and epigenetic control of plant heat responses: *Frontiers in Plant Science*, v. 6.
- Lu, X. M., G. S. Zhou, Y. H. Wang, and X. L. Song, 2016, Effects of Changing Precipitation and Warming on Functional Traits of Zonal *Stipa* Plants from Inner Mongolian Grassland: *Journal of Meteorological Research*, v. 30, p. 412-425.
- Maricle, B. R., and P. B. Adler, 2011, Effects of precipitation on photosynthesis and water potential in *Andropogon gerardii* and *Schizachyrium scoparium* in a southern mixed grass prairie: *Environmental and Experimental Botany*, v. 72, p. 223-231.
- Maxwell, K., and G. N. Johnson, 2000, Chlorophyll fluorescence - a practical guide: *Journal of Experimental Botany*, v. 51, p. 659-668.
- Meineri, E., O. Skarpaas, J. Spindelbock, T. Bargmann, and V. Vandvik, 2014, Direct and size-dependent effects of climate on flowering performance in alpine and lowland herbaceous species: *Journal of Vegetation Science*, v. 25, p. 275-286.
- Meineri, E., J. Spindelbock, and V. Vandvik, 2013, Seedling emergence responds to both seed source and recruitment site climates: a climate change experiment combining transplant and gradient approaches: *Plant Ecology*, v. 214, p. 607-619.
- Mimura, M., and S. N. Aitken, 2010, Local adaptation at the range peripheries of Sitka spruce: *Journal of Evolutionary Biology*, v. 23, p. 249-258.
- Montoro, A., and V. Sadras, 2014, Elevated Temperature Increased Stomata Size and Leaf Photosynthesis in Shiraz Grapevine: *Vii International Symposium on Irrigation of Horticultural Crops*, v. 1038, p. 443-447.
- Muir, C. D., J. B. Pease, and L. C. Moyle, 2014, Quantitative Genetic Analysis Indicates Natural Selection on Leaf Phenotypes Across Wild Tomato Species (*Solanum* sect. *Lycopersicon*; *Solanaceae*): *Genetics*, v. 198, p. 1629-+.

- Münzbergová, Z., V. Hadincová, H. Skálová, and V. Vandvik, 2017, Genetic differentiation and plasticity interact along temperature and precipitation gradients to determine plant performance under climate change.
- Münzbergová, Z., V. Latzel, and V. Hadincová, in prep., DNA methylation as a possible mechanism affecting ability of natural populations to adapt to changing climate.
- Nicotra, A. B., O. K. Atkin, S. P. Bonser, A. M. Davidson, E. J. Finnegan, U. Mathesius, P. Poot, M. D. Purugganan, C. L. Richards, F. Valladares, and M. van Kleunen, 2010, Plant phenotypic plasticity in a changing climate: Trends in Plant Science, v. 15, p. 684-692.
- Oksanen, J. G. B., F. Friendly, Michael Kindt, Roeland Legendre, Pierre McGlinn, Dan Minchin, Peter R. O'Hara, R. B. Simpson, Gavin L. Solymos, Peter Stevens, M. Henry H. Szoecs, Eduard Wagner, Helene, 2016, Vegan: Community Ecology Package. R package version 2.4-1, <https://CRAN.R-project.org/package=vegan>.
- Ougham, H. J., P. Morris, and H. Thomas, 2005, The colors of autumn leaves as symptoms of cellular recycling and defenses against environmental stresses: Current Topics in Developmental Biology, Vol 66, v. 66, p. 135-160.
- Paun, O., R. M. Bateman, M. F. Fay, M. Hedren, L. Civeyrel, and M. W. Chase, 2010, Stable Epigenetic Effects Impact Adaptation in Allopolyploid Orchids (Dactylorhiza: Orchidaceae): Molecular Biology and Evolution, v. 27, p. 2465-2473.
- Penuelas, J., J. Sardans, M. Estiarte, R. Ogaya, J. Carnicer, M. Coll, A. Barbeta, A. Rivas-Ubach, J. Llusia, M. Garbulsky, I. Filella, and A. S. Jump, 2013, Evidence of current impact of climate change on life: a walk from genes to the biosphere: Global Change Biology, v. 19, p. 2303-2338.
- Pratt, J. D., and K. A. Mooney, 2013, Clinal adaptation and adaptive plasticity in *Artemisia californica*: implications for the response of a foundation species to predicted climate change: Global Change Biology, v. 19, p. 2454-2466.
- Preite, V., J. Stocklin, G. F. J. Armbruster, and J. F. Scheepens, 2015, Adaptation of flowering phenology and fitness-related traits across environmental gradients in the widespread *Campanula rotundifolia*: Evolutionary Ecology, v. 29, p. 249-267.
- Procházka, S., 1998, Fyziologie rostlin: Praha, Academia.
- Psidova, E., L. Ditmarova, G. Jamnicka, D. Kurjak, J. Majerova, T. Czajkowski, and A. Bolte, 2015, Photosynthetic response of beech seedlings of different origin to water deficit: Photosynthetica, v. 53, p. 187-194.
- Ramirez-Valiente, J. A., D. Sanchez-Gomez, I. Aranda, and F. Valladares, 2010, Phenotypic plasticity and local adaptation in leaf ecophysiological traits of 13 contrasting cork oak populations under different water availabilities: Tree Physiology, v. 30, p. 618-627.
- Rappaport, F., D. Beal, A. Joliot, and P. Joliot, 2007, On the advantages of using green light to study fluorescence yield changes in leaves: Biochimica Et Biophysica Acta-Bioenergetics, v. 1767, p. 56-65.
- Reinhardt, K., C. Castanha, M. J. Germino, and L. M. Kueppers, 2011, Ecophysiological variation in two provenances of *Pinus flexilis* seedlings across an elevation gradient from forest to alpine: Tree Physiology, v. 31, p. 615-625.

- ReynaLopez, G. E., J. Simpson, and J. RuizHerrera, 1997, Differences in DNA methylation patterns are detectable during the dimorphic transition of fungi by amplification of restriction polymorphisms: *Molecular & General Genetics*, v. 253, p. 703-710.
- Richards, C. L., A. W. Schrey, and M. Pigliucci, 2012, Invasion of diverse habitats by few Japanese knotweed genotypes is correlated with epigenetic differentiation: *Ecology Letters*, v. 15, p. 1016-1025.
- Robakowski, P., Y. Li, and P. B. Reich, 2012, Local ecotypic and species range-related adaptation influence photosynthetic temperature optima in deciduous broadleaved trees: *Plant Ecology*, v. 213, p. 113-125.
- Sampoux, J. P., and C. Huyghe, 2009, Contribution of ploidy-level variation and adaptive trait diversity to the environmental distribution of taxa in the 'fine-leaved fescue' lineage (genus *Festuca* subg. *Festuca*): *Journal of Biogeography*, v. 36, p. 1978-1993.
- Saze, H., 2008, Epigenetic memory transmission through mitosis and meiosis in plants: *Seminars in Cell & Developmental Biology*, v. 19, p. 527-536.
- Schlichting, C. D., 1986, The evolution of phenotypic plasticity in plants: *Annual Review of Ecology and Systematics*, v. 17, p. 667-693.
- Schrey, A. W., M. Alvarez, C. M. Foust, H. J. Kilvitis, J. D. Lee, A. L. Liebl, L. B. Martin, C. L. Richards, and M. Robertson, 2013, Ecological Epigenetics: Beyond MS-AFLP: Integrative and Comparative Biology, v. 53, p. 340-350.
- Sedlacek, J., J. A. Wheeler, A. J. Cortes, O. Bossdorf, G. Hoch, C. Lexer, S. Wipf, S. Karrenberg, M. van Kleunen, and C. Rixen, 2015, The Response of the Alpine Dwarf Shrub *Salix herbacea* to Altered Snowmelt Timing: Lessons from a Multi-Site Transplant Experiment: *Plos One*, v. 10.
- Shaw, R. G., and J. R. Etterson, 2012, Rapid climate change and the rate of adaptation: insight from experimental quantitative genetics: *New Phytologist*, v. 195, p. 752-765.
- Shi, F. S., Y. Wu, N. Wu, and P. Luo, 2010, Different growth and physiological responses to experimental warming of two dominant plant species *Elymus nutans* and *Potentilla anserina* in an alpine meadow of the eastern Tibetan Plateau: *Photosynthetica*, v. 48, p. 437-445.
- Skalova, H., S. Pechackova, J. Suzuki, T. Herben, T. Hara, V. Hadincova, and F. Krahulec, 1997, Within population genetic differentiation in traits affecting clonal growth: *Festuca rubra* in a mountain grassland: *Journal of Evolutionary Biology*, v. 10, p. 383-406.
- Song, X., Y. Wang, and X. Lv, 2016, Responses of plant biomass, photosynthesis and lipid peroxidation to warming and precipitation change in two dominant species (*Stipa grandis* and *Leymus chinensis*) from North China Grasslands: *Ecology and Evolution*, v. 6, p. 1871-1882.
- Souther, S., M. J. Lechowicz, and J. B. McGraw, 2012, Experimental test for adaptive differentiation of ginseng populations reveals complex response to temperature: *Annals of Botany*, v. 110, p. 829-837.
- Spens, A. E., and V. Douhovnikoff, 2016, Epigenetic variation within *Phragmites australis* among lineages, genotypes, and ramets: *Biological Invasions*, v. 18, p. 2457-2462.
- Stirbet, A., and Govindjee, 2011, On the relation between the Kautsky effect (chlorophyll a fluorescence induction) and Photosystem II: Basics and applications of the OJIP fluorescence transient: *Journal of Photochemistry and Photobiology B-Biology*, v. 104, p. 236-257.

- Sultan, S. E., T. Horgan-Kobelski, L. M. Nichols, C. E. Riggs, and R. K. Waples, 2013, A resurrection study reveals rapid adaptive evolution within populations of an invasive plant: *Evolutionary Applications*, v. 6, p. 266-278.
- Sun, J. D., J. N. Nishio, and T. C. Vogelmann, 1998, Green light drives CO<sub>2</sub> fixation deep within leaves: *Plant and Cell Physiology*, v. 39, p. 1020-1026.
- Taylor, S. H., P. J. Franks, S. P. Hulme, E. Spriggs, P. A. Christin, E. J. Edwards, F. I. Woodward, and C. P. Osborne, 2012, Photosynthetic pathway and ecological adaptation explain stomatal trait diversity amongst grasses: *New Phytologist*, v. 193, p. 387-396.
- Thompson, J. D., 1991, Phenotypic plasticity as a component of evolutionary change: *Trends in Ecology & Evolution*, v. 6, p. 246-249.
- Torang, P., J. Wunder, J. R. Obeso, M. Herzog, G. Coupland, and J. Agren, 2015, Large-scale adaptive differentiation in the alpine perennial herb *Arabis alpina*: *New Phytologist*, v. 206, p. 459-470.
- Tricker, P. J., C. M. R. Lopez, G. Gibbings, P. Hadley, and M. J. Wilkinson, 2013, Transgenerational, Dynamic Methylation of Stomata Genes in Response to Low Relative Humidity: *International Journal of Molecular Sciences*, v. 14, p. 6674-6689.
- Valladares, F., S. Matesanz, F. Guilhaumon, M. B. Araujo, L. Balaguer, M. Benito-Garzon, W. Cornwell, E. Gianoli, M. van Kleunen, D. E. Naya, A. B. Nicotra, H. Poorter, and M. A. Zavala, 2014, The effects of phenotypic plasticity and local adaptation on forecasts of species range shifts under climate change: *Ecology Letters*, v. 17, p. 1351-1364.
- vanTienderen, P. H., 1997, Generalists, specialists, and the evolution of phenotypic plasticity in sympatric populations of distinct species: *Evolution*, v. 51, p. 1372-1380.
- Vaughn, M. W., M. Tanurdzic, Z. Lippman, H. Jiang, R. Carrasquillo, P. D. Rabinowicz, N. Dedhia, W. R. McCombie, N. Agier, A. Bulski, V. Colot, R. W. Doerge, and R. A. Martienssen, 2007, Epigenetic natural variation in *Arabidopsis thaliana*: *Plos Biology*, v. 5, p. 1617-1629.
- Verhoeven, K. J. F., J. J. Jansen, P. J. van Dijk, and A. Biere, 2010, Stress-induced DNA methylation changes and their heritability in asexual dandelions: *New Phytologist*, v. 185, p. 1108-1118.
- Violet-Chabrand, S., J. S. A. Matthews, A. J. Simkin, C. A. Raines, and T. Lawson, 2017, Importance of Fluctuations in Light on Plant Photosynthetic Acclimation: *Plant Physiology*, v. 173, p. 2163-2179.
- Vitasse, Y., A. Lenz, C. Kollas, C. F. Randin, G. Hoch, and C. Korner, 2014, Genetic vs. non-genetic responses of leaf morphology and growth to elevation in temperate tree species: *Functional Ecology*, v. 28, p. 243-252.
- Volis, S., D. Ormanbekova, and K. Yermekbayev, 2015, Role of phenotypic plasticity and population differentiation in adaptation to novel environmental conditions: *Ecology and Evolution*, v. 5, p. 3818-3829.
- Walther, G. R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J. M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein, 2002, Ecological responses to recent climate change: *Nature*, v. 416, p. 389-395.
- Wang, S. P., F. D. Meng, J. C. Duan, Y. F. Wang, X. Y. Cui, S. L. Piao, H. S. Niu, G. P. Xu, C. Y. Luo, Z. H. Zhang, X. X. Zhu, M. G. Shen, Y. N. Li, M. Y. Du, Y. H. Tang, X. Q. Zhao, P. Ciais, B. Kimball, J. Penuelas, I. A. Janssens, S. J. Cui, L. Zhao, and F. W. Zhang, 2014, Asymmetric

- sensitivity of first flowering date to warming and cooling in alpine plants: *Ecology*, v. 95, p. 3387-3398.
- Wilson, P. J., K. Thompson, and J. G. Hodgson, 1999, Specific leaf area and leaf dry matter content as alternative predictors of plant strategies: *New Phytologist*, v. 143, p. 155-162.
- Woodward, F. I., J. A. Lake, and W. P. Quick, 2002, Stomatal development and CO<sub>2</sub>: ecological consequences: *New Phytologist*, v. 153, p. 477-484.
- Wright, I. J., P. B. Reich, M. Westoby, D. D. Ackerly, Z. Baruch, F. Bongers, J. Cavender-Bares, T. Chapin, J. H. C. Cornelissen, M. Diemer, J. Flexas, E. Garnier, P. K. Groom, J. Gulias, K. Hikosaka, B. B. Lamont, T. Lee, W. Lee, C. Lusk, J. J. Midgley, M. L. Navas, U. Niinemets, J. Oleksyn, N. Osada, H. Poorter, P. Poot, L. Prior, V. I. Pyankov, C. Roumet, S. C. Thomas, M. G. Tjoelker, E. J. Veneklaas, and R. Villar, 2004, The worldwide leaf economics spectrum: *Nature*, v. 428, p. 821-827.
- Wu, J. S., S. Wurst, and X. Z. Zhang, 2016, Plant functional trait diversity regulates the nonlinear response of productivity to regional climate change in Tibetan alpine grasslands: *Scientific Reports*, v. 6.
- Xu, P., X. Zhang, C. Zhao, L. Chen, X. Gao, B. Yao, J. Deng, and Y. Deng, 2014, Foliar responses of *Abies fargesii* franch. To altitude in the Taibai mountain, China: *Polish Journal of Ecology*, v. 62, p. 481-492.
- Yamori, W., K. Hikosaka, and D. A. Way, 2014, Temperature response of photosynthesis in C-3, C-4, and CAM plants: temperature acclimation and temperature adaptation: *Photosynthesis Research*, v. 119, p. 101-117.
- Yang, F., X. J. Yang, J. M. Baskin, C. C. Baskin, D. C. Cao, and Z. Y. Huang, 2015, Transgenerational plasticity provides ecological diversity for a seed heteromorphic species in response to environmental heterogeneity: *Perspectives in Plant Ecology Evolution and Systematics*, v. 17, p. 201-208.
- Yeh, C. H., N. J. Kaplinsky, C. Hu, and Y. Y. Charng, 2012, Some like it hot, some like it warm: Phenotyping to explore thermotolerance diversity: *Plant Science*, v. 195, p. 10-23.
- Zhang, L., H. Niu, S. Wang, X. Zhu, C. Luo, Y. Li, and X. Zhao, 2012, Gene or environment? Species-specific control of stomatal density and length: *Ecology and Evolution*, v. 2, p. 1065-1070.
- Zhang, Q., J. L. Peters, E. J. W. Visser, H. de Kroon, and H. Huber, 2016, Hydrologically contrasting environments induce genetic but not phenotypic differentiation in *Solanum dulcamara*: *Journal of Ecology*, v. 104, p. 1649-1661.
- Zhang, Y.-Y., M. Fischer, V. Colot, and O. Bossdorf, 2013, Epigenetic variation creates potential for evolution of plant phenotypic plasticity: *New Phytologist*, v. 197, p. 314-322.
- Zhong, S. H., J. Z. Liu, H. Jin, L. Lin, Q. Li, Y. Chen, Y. X. Yuan, Z. Y. Wang, H. Huang, Y. J. Qi, X. Y. Chen, H. Vaucheret, J. Chory, J. M. Li, and Z. H. He, 2013, Warm temperatures induce transgenerational epigenetic release of RNA silencing by inhibiting siRNA biogenesis in *Arabidopsis*: *Proceedings of the National Academy of Sciences of the United States of America*, v. 110, p. 9171-9176.
- Zhou, W., Z. X. Wang, A. J. Davy, and G. H. Liu, 2013, Geographic variation and local adaptation in *Oryza rufipogon* across its climatic range in China: *Journal of Ecology*, v. 101, p. 1498-1508.



## 7 Appendix

**Appendix 1:** The effect of original (O) and target (T) temperature (temp) and moisture (mois) and their two-way interactions on net photosynthetic rate in the growth chambers. Genotype was used as a random factor and a time of measurement as covariate. Significant values ( $p \leq 0.05$ ) are in bold. Dev. indicates deviance explained by the given variable.

|               | net photosynthetic rate |                  |
|---------------|-------------------------|------------------|
|               | dev.                    | p                |
| Ttemp         | 15.382                  | <b>&lt;0.001</b> |
| Tmois         | 120.9                   | <b>&lt;0.001</b> |
| Otemp         | 0.0001                  | 0.9935           |
| Omois         | 0.0749                  | 0.7844           |
| Otemp x Omois | 0.7848                  | 0.3757           |
| Otemp x Ttemp | 0.0225                  | 0.8807           |
| Otemp x Tmois | 0.2573                  | 0.612            |
| Omois x Ttemp | 0.4142                  | 0.5198           |
| Omois x Tmois | 0.0951                  | 0.7577           |
| Ttemp x Tmois | 36.338                  | <b>&lt;0.001</b> |

**Appendix 2:** The effect of original (O) and target (T) temperature (temp) and moisture (mois) and their two-way interactions on plant performance in the growth chambers using reduced number of samples (160) for all traits. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold. Dev. indicates deviance explained by the given variable. Colored p-values show inconsistency in significant results between full experiment (Table 2) and this analysis. Inconsistency could not occur in  $P_N$  and SLA as original number of samples was 160.

|                | $P_N$  |                  | $\phi P_0$ |                  | SLA    |                  | o. potential |                  | s. density |                  | s. size |                  |
|----------------|--------|------------------|------------|------------------|--------|------------------|--------------|------------------|------------|------------------|---------|------------------|
|                | dev.   | p                | dev.       | p                | dev.   | p                | dev.         | p                | dev.       | p                | dev.    | p                |
| Ttemp          | 13.5   | <b>&lt;0.001</b> | 47.74      | <b>&lt;0.001</b> | 7.8798 | <b>0.005</b>     | 11.259       | <b>&lt;0.001</b> | 0.6462     | 0.4215           | 4.0944  | <b>0.043</b>     |
| Tmois          | 118.56 | <b>&lt;0.001</b> | 190.43     | <b>&lt;0.001</b> | 47.321 | <b>&lt;0.001</b> | 21.532       | <b>&lt;0.001</b> | 2.2245     | 0.1358           | 3.9991  | <b>0.046</b>     |
| Otemp          | 0.2702 | 0.8103           | 0.4259     | 0.514            | 2.9691 | 0.0849           | 0.4416       | 0.5063           | 8.498      | <b>0.004</b>     | 15.642  | <b>&lt;0.001</b> |
| Omois          | 0.0121 | 0.7223           | 0.4525     | 0.5011           | 0.3185 | 0.5725           | 0.074        | 0.7856           | 3.4835     | 0.062            | 0.174   | 0.6766           |
| Otemp x Omois  | 0.7723 | 0.2913           | 7.4692     | <b>0.006</b>     | 1.075  | 0.2998           | 0.8621       | 0.3531           | 20.748     | <b>&lt;0.001</b> | 0.2595  | 0.6105           |
| Otemp x Ttemp  | 0.0078 | 0.8239           | 3.7536     | 0.0527           | 3.2964 | 0.0694           | 0.0025       | 0.9601           | 0.0811     | 0.1599           | 4.7777  | <b>0.0288</b>    |
| Otemp x Tmois  | 0.2947 | 0.8511           | 5.8481     | <b>0.016</b>     | 0.8243 | 0.3639           | 2.553        | 0.1101           | 0.0811     | 0.7758           | 0.0399  | 0.8417           |
| Omois x Ttemp  | 1.1841 | 0.4529           | 8.7802     | <b>0.003</b>     | 0.3617 | 0.5476           | 0.1366       | 0.7117           | 1.1351     | 0.2867           | 1.5999  | 0.2059           |
| Omois x Tmois  | 0.0967 | 0.9953           | 0.194      | 0.0051           | 0.0025 | 0.9605           | 1.227        | 0.268            | 0.2821     | 0.5953           | 0.4693  | 0.4933           |
| Ttemp x Tmois  | 36.213 | <b>&lt;0.001</b> | 7.9671     | <b>0.005</b>     | 18.55  | <b>&lt;0.001</b> | 0.1539       | 0.6948           | 0.7548     | 0.385            | 0.2367  | 0.6266           |
| no. of observ. | 160    |                  | 160        |                  | 160    |                  | 160          |                  | 160        |                  | 160     |                  |

$P_N$  – net photosynthetic rate,  $\phi P_0$  – PSII efficiency, SLA – specific leaf area, o. potential – osmotic potential, s. density – stomatal density, s. size – stomatal size, no. of observ. – number of observations.

**Appendix 3:** Comparison of analysis from the first experiment with different number of genotypes. All samples represent original results from the first experiment. Reduced samples represent another analysis with reduced genotypes as in the main second experiment. The effect of original (O) and target (T) temperature (temp) and moisture (mois) and their two-way interactions on stomatal density in the growth chambers. Genotype was used as a random factor. Significant values ( $p \leq 0.05$ ) are in bold. Dev. indicates deviance explained by the given variable.

|                        | All samples |                | Reduced samples |                |
|------------------------|-------------|----------------|-----------------|----------------|
|                        | dev.        | p              | dev.            | p              |
| Ttemp                  | 0.0643      | 0.7999         | 0.0081          | 0.9283         |
| Tmois                  | 2.1717      | 0.1406         | 1.0957          | 0.2952         |
| Otemp                  | 7.9804      | <b>0.00473</b> | 9.6411          | <b>0.0019</b>  |
| Omois                  | 2.9625      | 0.08522        | 1.3077          | 0.2528         |
| Otemp x Omois          | 10.333      | <b>0.00131</b> | 13.352          | <b>0.00026</b> |
| Otemp x Ttemp          | 4.6597      | <b>0.03088</b> | 0.1936          | 0.6599         |
| Otemp x Tmois          | 0.4054      | 0.5243         | 0.6926          | 0.4053         |
| Omois x Ttemp          | 0.0506      | 0.8221         | 0.4718          | 0.4922         |
| Omois x Tmois          | 0.0355      | 0.8506         | 0.0809          | 0.7761         |
| Ttemp x Tmois          | 6.3424      | <b>0.01179</b> | 3.1234          | 0.07718        |
| number of observations | 440         |                | 96              |                |

## 7.1 Primary data

**Appendix 4:** All primary data used within this diploma thesis are shown below. Data are divided to four parts:

Part 1: First experiment – PSII efficiency and osmotic potential, measured on all (1100) samples.

Part 2: First experiment – PN and SLA, measured on 160 samples.

Part 3: First experiment – stomatal density and stomatal size, measured on 440 samples.

Part 4: Second experiment – PSII efficiency, osmotic potential, stomatal density and stomatal size, measured on all (576) samples.

Used coding system is described in data processing.

Used shortcuts:

Ttemp – target temperature

Tmois – target moisture

Otemp – original temperature

Omois – original moisture

PN – net photosynthetic rate

$\phi P0$  – PSII efficiency

op – osmotic potential

s.size – stomatal size

s. density – stomatal density

treatment A – azacytidine, C – control

g. chamber – growth chamber, WW – warm-wet, CD – cold-dry

Part 1: First experiment –  $\phi P0$  (PSII efficiency) and osmotic potential:

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 51       | 1     | 1     | 2     | 2     | 0.78      | -2.08 | 146      | 1     | 1     | 3     | 2     | 0.77      | -1.67 | 254      | 1     | 1     | 2     | 3     | 0.78      | -1.88 |
| 55       | 1     | 1     | 2     | 2     | 0.75      | -2.20 | 147      | 1     | 1     | 3     | 2     | 0.79      | -1.93 | 255      | 1     | 1     | 2     | 3     | 0.76      | -2.21 |
| 56       | 1     | 1     | 2     | 2     | 0.75      | -1.85 | 148      | 1     | 1     | 3     | 2     | 0.78      | -1.59 | 256      | 1     | 1     | 2     | 3     | 0.78      | -1.66 |
| 57       | 1     | 1     | 2     | 2     | 0.77      | -1.58 | 150      | 1     | 1     | 3     | 2     | 0.76      | -1.66 | 260      | 1     | 1     | 2     | 3     | 0.77      | -1.79 |
| 58       | 1     | 1     | 2     | 2     | 0.76      | -1.49 | 155      | 1     | 1     | 3     | 2     | 0.79      | -1.48 | 261      | 1     | 1     | 2     | 3     | 0.77      | -1.55 |
| 59       | 1     | 1     | 2     | 2     | 0.73      | -1.90 | 156      | 1     | 1     | 3     | 2     | 0.63      | -1.64 | 264      | 1     | 1     | 2     | 3     | 0.77      | -1.46 |
| 61       | 1     | 1     | 2     | 2     | NA        | NA    | 157      | 1     | 1     | 3     | 2     | 0.73      | -1.76 | 265      | 1     | 1     | 2     | 3     | 0.76      | -1.64 |
| 62       | 1     | 1     | 2     | 2     | 0.78      | -1.37 | 181      | 1     | 1     | 1     | 3     | 0.71      | -1.67 | 267      | 1     | 1     | 2     | 3     | 0.75      | -1.71 |
| 64       | 1     | 1     | 2     | 2     | 0.78      | -1.61 | 183      | 1     | 1     | 1     | 3     | 0.74      | -1.91 | 268      | 1     | 1     | 2     | 3     | 0.74      | -1.81 |
| 66       | 1     | 1     | 2     | 2     | 0.78      | -2.23 | 186      | 1     | 1     | 1     | 3     | 0.77      | -1.79 | 271      | 1     | 1     | 2     | 3     | 0.77      | -1.73 |
| 67       | 1     | 1     | 2     | 2     | 0.75      | -1.83 | 188      | 1     | 1     | 1     | 3     | 0.76      | -1.67 | 274      | 1     | 1     | 2     | 3     | 0.76      | -1.73 |
| 68       | 1     | 1     | 2     | 2     | 0.77      | -1.85 | 193      | 1     | 1     | 1     | 3     | 0.75      | -1.73 | 275      | 1     | 1     | 2     | 3     | 0.77      | -1.94 |
| 69       | 1     | 1     | 2     | 2     | 0.78      | -1.85 | 196      | 1     | 1     | 1     | 3     | 0.81      | -1.97 | 278      | 1     | 1     | 2     | 3     | 0.76      | -1.64 |
| 70       | 1     | 1     | 2     | 2     | 0.78      | -1.72 | 197      | 1     | 1     | 1     | 3     | 0.76      | -1.57 | 287      | 1     | 1     | 2     | 3     | 0.78      | -1.67 |
| 71       | 1     | 1     | 2     | 2     | 0.78      | -1.81 | 199      | 1     | 1     | 1     | 3     | 0.71      | -1.50 | 289      | 1     | 1     | 1     | 4     | 0.73      | -1.63 |
| 74       | 1     | 1     | 2     | 2     | 0.77      | -1.81 | 200      | 1     | 1     | 1     | 3     | 0.77      | -1.93 | 291      | 1     | 1     | 1     | 4     | 0.74      | -1.55 |
| 75       | 1     | 1     | 2     | 2     | 0.77      | -2.00 | 201      | 1     | 1     | 1     | 3     | 0.78      | -1.71 | 292      | 1     | 1     | 1     | 4     | 0.76      | -1.50 |
| 76       | 1     | 1     | 2     | 2     | 0.77      | -1.55 | 202      | 1     | 1     | 1     | 3     | 0.76      | -1.78 | 294      | 1     | 1     | 1     | 4     | 0.75      | -1.63 |
| 77       | 1     | 1     | 2     | 2     | 0.77      | -1.69 | 203      | 1     | 1     | 1     | 3     | 0.77      | -1.67 | 296      | 1     | 1     | 1     | 4     | 0.77      | -1.54 |
| 78       | 1     | 1     | 2     | 2     | 0.77      | -1.66 | 204      | 1     | 1     | 1     | 3     | 0.76      | -1.69 | 297      | 1     | 1     | 1     | 4     | 0.74      | -1.68 |
| 83       | 1     | 1     | 2     | 2     | 0.77      | -1.90 | 205      | 1     | 1     | 1     | 3     | 0.77      | -1.69 | 298      | 1     | 1     | 1     | 4     | 0.76      | -1.63 |
| 88       | 1     | 1     | 2     | 2     | 0.78      | -1.84 | 206      | 1     | 1     | 1     | 3     | 0.77      | -1.53 | 299      | 1     | 1     | 1     | 4     | 0.76      | -1.73 |
| 92       | 1     | 1     | 2     | 2     | 0.78      | -1.76 | 208      | 1     | 1     | 1     | 3     | 0.74      | -1.67 | 300      | 1     | 1     | 1     | 4     | 0.74      | -1.62 |
| 99       | 1     | 1     | 2     | 2     | 0.79      | -1.80 | 209      | 1     | 1     | 1     | 3     | 0.76      | -1.96 | 301      | 1     | 1     | 1     | 4     | 0.77      | -1.74 |
| 101      | 1     | 1     | 2     | 2     | 0.78      | -1.97 | 210      | 1     | 1     | 1     | 3     | 0.58      | -1.42 | 306      | 1     | 1     | 1     | 4     | 0.76      | -1.72 |
| 120      | 1     | 1     | 3     | 2     | 0.77      | NA    | 211      | 1     | 1     | 1     | 3     | 0.78      | -2.17 | 307      | 1     | 1     | 1     | 4     | 0.76      | -1.73 |
| 121      | 1     | 1     | 3     | 2     | 0.78      | -1.91 | 212      | 1     | 1     | 1     | 3     | 0.73      | -1.52 | 308      | 1     | 1     | 1     | 4     | 0.76      | -1.59 |
| 122      | 1     | 1     | 3     | 2     | 0.78      | -1.61 | 213      | 1     | 1     | 1     | 3     | 0.74      | -1.81 | 310      | 1     | 1     | 1     | 4     | 0.79      | -1.71 |
| 123      | 1     | 1     | 3     | 2     | 0.74      | -1.79 | 214      | 1     | 1     | 1     | 3     | 0.73      | -1.76 | 312      | 1     | 1     | 1     | 4     | 0.75      | -1.54 |
| 125      | 1     | 1     | 3     | 2     | 0.77      | -1.61 | 216      | 1     | 1     | 1     | 3     | 0.78      | -1.59 | 314      | 1     | 1     | 1     | 4     | 0.77      | -1.74 |
| 127      | 1     | 1     | 3     | 2     | 0.77      | -1.58 | 218      | 1     | 1     | 1     | 3     | 0.78      | -1.73 | 315      | 1     | 1     | 1     | 4     | 0.77      | -1.74 |
| 128      | 1     | 1     | 3     | 2     | 0.76      | -1.79 | 219      | 1     | 1     | 1     | 3     | 0.77      | -2.08 | 316      | 1     | 1     | 1     | 4     | 0.75      | -1.50 |
| 129      | 1     | 1     | 3     | 2     | 0.71      | -1.90 | 242      | 1     | 1     | 2     | 3     | 0.8       | -2.23 | 317      | 1     | 1     | 1     | 4     | 0.78      | -1.53 |
| 130      | 1     | 1     | 3     | 2     | 0.75      | -1.76 | 243      | 1     | 1     | 2     | 3     | 0.76      | -1.84 | 318      | 1     | 1     | 1     | 4     | 0.76      | -1.50 |
| 131      | 1     | 1     | 3     | 2     | 0.77      | -1.67 | 244      | 1     | 1     | 2     | 3     | 0.76      | -1.68 | 319      | 1     | 1     | 1     | 4     | 0.75      | -1.58 |
| 135      | 1     | 1     | 3     | 2     | 0.78      | -1.73 | 246      | 1     | 1     | 2     | 3     | 0.78      | -1.43 | 320      | 1     | 1     | 1     | 4     | 0.79      | -1.90 |
| 137      | 1     | 1     | 3     | 2     | 0.76      | -1.58 | 247      | 1     | 1     | 2     | 3     | 0.73      | -1.61 | 321      | 1     | 1     | 1     | 4     | 0.76      | -1.67 |
| 138      | 1     | 1     | 3     | 2     | 0.76      | -1.67 | 248      | 1     | 1     | 2     | 3     | 0.74      | -1.50 | 322      | 1     | 1     | 1     | 4     | 0.77      | -1.50 |
| 139      | 1     | 1     | 3     | 2     | 0.78      | -1.78 | 249      | 1     | 1     | 2     | 3     | 0.76      | -1.69 | 323      | 1     | 1     | 1     | 4     | 0.63      | -1.84 |
| 140      | 1     | 1     | 3     | 2     | 0.58      | -1.66 | 250      | 1     | 1     | 2     | 3     | 0.77      | -1.73 | 350      | 1     | 1     | 2     | 4     | 0.75      | -1.73 |
| 141      | 1     | 1     | 3     | 2     | 0.78      | -1.59 | 251      | 1     | 1     | 2     | 3     | 0.75      | -1.76 | 351      | 1     | 1     | 2     | 4     | 0.73      | -1.49 |
| 144      | 1     | 1     | 3     | 2     | 0.78      | -1.86 | 252      | 1     | 1     | 2     | 3     | 0.8       | -1.73 | 353      | 1     | 1     | 2     | 4     | 0.79      | -2.08 |
| 145      | 1     | 1     | 3     | 2     | 0.77      | -1.79 | 253      | 1     | 1     | 2     | 3     | 0.79      | -1.71 | 358      | 1     | 1     | 2     | 4     | 0.75      | -1.50 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 359      | 1     | 1     | 2     | 4     | 0.79      | -1.49 | 445      | 1     | 1     | 3     | 4     | 0.76      | -1.69 | 580      | 1     | 1     | 1     | 1     | 0.79      | -1.86 |
| 362      | 1     | 1     | 2     | 4     | 0.76      | -2.10 | 446      | 1     | 1     | 3     | 4     | 0.74      | -2.01 | 581      | 1     | 1     | 1     | 1     | 0.79      | -1.79 |
| 363      | 1     | 1     | 2     | 4     | 0.78      | -1.67 | 447      | 1     | 1     | 3     | 4     | 0.77      | -1.96 | 582      | 1     | 1     | 1     | 1     | 0.74      | -1.51 |
| 365      | 1     | 1     | 2     | 4     | 0.78      | -1.79 | 472      | 1     | 1     | 3     | 3     | 0.75      | -2.06 | 583      | 1     | 1     | 1     | 1     | 0.76      | -1.77 |
| 368      | 1     | 1     | 2     | 4     | 0.79      | -1.61 | 475      | 1     | 1     | 3     | 3     | 0.75      | -1.85 | 584      | 1     | 1     | 1     | 1     | 0.79      | -1.60 |
| 369      | 1     | 1     | 2     | 4     | 0.79      | -1.72 | 478      | 1     | 1     | 3     | 3     | 0.75      | -1.41 | 586      | 1     | 1     | 1     | 1     | 0.76      | -1.55 |
| 370      | 1     | 1     | 2     | 4     | 0.78      | -1.46 | 480      | 1     | 1     | 3     | 3     | 0.76      | -2.14 | 587      | 1     | 1     | 1     | 1     | 0.55      | -1.48 |
| 371      | 1     | 1     | 2     | 4     | 0.7       | -1.76 | 482      | 1     | 1     | 3     | 3     | 0.73      | NA    | 588      | 1     | 1     | 1     | 1     | 0.78      | -1.74 |
| 372      | 1     | 1     | 2     | 4     | 0.8       | -1.67 | 483      | 1     | 1     | 3     | 3     | 0.75      | -2.03 | 589      | 1     | 1     | 1     | 1     | 0.8       | -1.72 |
| 374      | 1     | 1     | 2     | 4     | 0.74      | -1.73 | 486      | 1     | 1     | 3     | 3     | 0.73      | -1.55 | 590      | 1     | 1     | 1     | 1     | 0.74      | -1.76 |
| 375      | 1     | 1     | 2     | 4     | 0.75      | -1.86 | 487      | 1     | 1     | 3     | 3     | 0.73      | -1.59 | 591      | 1     | 1     | 2     | 1     | 0.79      | -1.77 |
| 377      | 1     | 1     | 2     | 4     | 0.79      | -1.46 | 490      | 1     | 1     | 3     | 3     | 0.76      | -1.79 | 592      | 1     | 1     | 2     | 1     | 0.78      | -2.86 |
| 378      | 1     | 1     | 2     | 4     | 0.78      | -1.73 | 494      | 1     | 1     | 3     | 3     | 0.77      | -1.83 | 594      | 1     | 1     | 2     | 1     | 0.8       | -2.08 |
| 379      | 1     | 1     | 2     | 4     | 0.78      | -1.78 | 495      | 1     | 1     | 3     | 3     | 0.78      | -1.73 | 596      | 1     | 1     | 2     | 1     | NA        | NA    |
| 383      | 1     | 1     | 2     | 4     | 0.78      | -1.59 | 501      | 1     | 1     | 3     | 3     | 0.75      | -1.86 | 597      | 1     | 1     | 2     | 1     | 0.79      | -1.67 |
| 386      | 1     | 1     | 2     | 4     | 0.78      | -1.53 | 507      | 1     | 1     | 3     | 3     | 0.78      | -1.83 | 599      | 1     | 1     | 2     | 1     | 0.79      | -1.91 |
| 393      | 1     | 1     | 2     | 4     | 0.75      | -1.64 | 509      | 1     | 1     | 3     | 3     | 0.73      | -1.83 | 601      | 1     | 1     | 2     | 1     | 0.78      | -1.67 |
| 395      | 1     | 1     | 2     | 4     | 0.73      | -1.84 | 511      | 1     | 1     | 3     | 3     | 0.78      | -1.59 | 603      | 1     | 1     | 2     | 1     | 0.77      | -1.79 |
| 396      | 1     | 1     | 2     | 4     | 0.8       | -1.59 | 513      | 1     | 1     | 3     | 3     | 0.78      | -1.40 | 604      | 1     | 1     | 2     | 1     | 0.76      | -1.41 |
| 403      | 1     | 1     | 2     | 4     | 0.77      | -1.80 | 517      | 1     | 1     | 3     | 3     | 0.78      | -1.79 | 605      | 1     | 1     | 2     | 1     | 0.78      | -1.85 |
| 404      | 1     | 1     | 2     | 4     | 0.76      | -1.78 | 519      | 1     | 1     | 3     | 3     | 0.79      | -1.77 | 606      | 1     | 1     | 2     | 1     | 0.76      | -1.49 |
| 409      | 1     | 1     | 3     | 4     | 0.76      | -1.76 | 521      | 1     | 1     | 3     | 3     | 0.78      | -1.59 | 607      | 1     | 1     | 2     | 1     | 0.75      | -1.62 |
| 410      | 1     | 1     | 3     | 4     | 0.78      | -1.67 | 523      | 1     | 1     | 3     | 3     | 0.73      | -1.87 | 611      | 1     | 1     | 2     | 1     | 0.76      | -1.64 |
| 411      | 1     | 1     | 3     | 4     | 0.75      | -1.55 | 524      | 1     | 1     | 3     | 3     | 0.77      | -1.80 | 614      | 1     | 1     | 2     | 1     | 0.77      | -1.98 |
| 413      | 1     | 1     | 3     | 4     | 0.75      | -2.14 | 526      | 1     | 1     | 3     | 3     | 0.78      | -1.88 | 616      | 1     | 1     | 2     | 1     | 0.77      | -1.99 |
| 415      | 1     | 1     | 3     | 4     | 0.75      | -1.77 | 528      | 1     | 1     | 3     | 3     | 0.77      | -1.69 | 622      | 1     | 1     | 2     | 1     | 0.8       | NA    |
| 416      | 1     | 1     | 3     | 4     | 0.73      | -1.55 | 529      | 1     | 1     | 3     | 3     | 0.77      | -1.78 | 625      | 1     | 1     | 2     | 1     | 0.69      | -1.52 |
| 418      | 1     | 1     | 3     | 4     | 0.72      | -1.55 | 530      | 1     | 1     | 3     | 3     | 0.79      | -1.84 | 626      | 1     | 1     | 2     | 1     | 0.79      | -1.88 |
| 422      | 1     | 1     | 3     | 4     | 0.75      | -1.63 | 542      | 1     | 1     | 1     | 1     | 0.78      | -1.77 | 639      | 1     | 1     | 2     | 1     | 0.69      | -1.78 |
| 424      | 1     | 1     | 3     | 4     | 0.79      | -1.67 | 543      | 1     | 1     | 1     | 1     | 0.73      | -1.55 | 640      | 1     | 1     | 2     | 1     | 0.76      | -1.67 |
| 425      | 1     | 1     | 3     | 4     | 0.77      | -1.51 | 549      | 1     | 1     | 1     | 1     | 0.74      | -1.96 | 641      | 1     | 1     | 2     | 1     | 0.76      | -1.74 |
| 426      | 1     | 1     | 3     | 4     | 0.77      | -1.88 | 550      | 1     | 1     | 1     | 1     | 0.76      | -1.54 | 643      | 1     | 1     | 2     | 1     | 0.71      | -1.55 |
| 427      | 1     | 1     | 3     | 4     | 0.55      | -1.67 | 551      | 1     | 1     | 1     | 1     | 0.74      | -1.68 | 645      | 1     | 1     | 2     | 1     | 0.77      | -1.53 |
| 428      | 1     | 1     | 3     | 4     | 0.78      | -2.12 | 552      | 1     | 1     | 1     | 1     | 0.76      | -1.46 | 646      | 1     | 1     | 2     | 1     | 0.75      | -1.63 |
| 430      | 1     | 1     | 3     | 4     | 0.77      | -1.45 | 553      | 1     | 1     | 1     | 1     | 0.75      | -1.68 | 648      | 1     | 1     | 2     | 1     | 0.75      | -1.87 |
| 431      | 1     | 1     | 3     | 4     | 0.76      | -1.73 | 556      | 1     | 1     | 1     | 1     | 0.77      | -1.80 | 653      | 1     | 1     | 3     | 1     | 0.75      | -1.40 |
| 432      | 1     | 1     | 3     | 4     | 0.77      | -1.50 | 557      | 1     | 1     | 1     | 1     | 0.79      | -1.64 | 654      | 1     | 1     | 3     | 1     | 0.75      | -1.10 |
| 433      | 1     | 1     | 3     | 4     | 0.78      | -1.46 | 558      | 1     | 1     | 1     | 1     | 0.78      | -1.69 | 656      | 1     | 1     | 3     | 1     | 0.74      | -1.79 |
| 436      | 1     | 1     | 3     | 4     | 0.82      | -1.84 | 560      | 1     | 1     | 1     | 1     | 0.75      | -1.67 | 657      | 1     | 1     | 3     | 1     | 0.75      | -1.37 |
| 437      | 1     | 1     | 3     | 4     | 0.77      | -1.78 | 573      | 1     | 1     | 1     | 1     | 0.65      | -1.78 | 658      | 1     | 1     | 3     | 1     | 0.76      | -1.46 |
| 438      | 1     | 1     | 3     | 4     | 0.74      | -1.61 | 574      | 1     | 1     | 1     | 1     | 0.79      | -1.74 | 663      | 1     | 1     | 3     | 1     | 0.77      | -1.55 |
| 441      | 1     | 1     | 3     | 4     | 0.65      | -1.74 | 576      | 1     | 1     | 1     | 1     | 0.76      | -1.68 | 672      | 1     | 1     | 3     | 1     | 0.77      | -1.51 |
| 443      | 1     | 1     | 3     | 4     | 0.75      | -1.62 | 579      | 1     | 1     | 1     | 1     | 0.77      | -1.76 | 677      | 1     | 1     | 3     | 1     | 0.76      | -1.64 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 678      | 1     | 1     | 3     | 1     | 0.75      | -1.55 | 121      | 1     | 4     | 3     | 2     | 0.71      | -1.78 | 212      | 1     | 4     | 1     | 3     | 0.72      | -1.68 |
| 680      | 1     | 1     | 3     | 1     | 0.77      | -1.72 | 122      | 1     | 4     | 3     | 2     | 0.7       | -1.92 | 213      | 1     | 4     | 1     | 3     | 0.68      | -1.69 |
| 681      | 1     | 1     | 3     | 1     | 0.76      | -1.33 | 123      | 1     | 4     | 3     | 2     | 0.71      | -1.88 | 214      | 1     | 4     | 1     | 3     | 0.61      | -1.81 |
| 682      | 1     | 1     | 3     | 1     | 0.77      | -1.62 | 125      | 1     | 4     | 3     | 2     | 0.72      | -1.74 | 216      | 1     | 4     | 1     | 3     | 0.7       | -1.55 |
| 683      | 1     | 1     | 3     | 1     | 0.75      | -1.67 | 127      | 1     | 4     | 3     | 2     | 0.69      | -1.77 | 218      | 1     | 4     | 1     | 3     | 0.65      | -1.50 |
| 684      | 1     | 1     | 3     | 1     | 0.79      | -1.77 | 128      | 1     | 4     | 3     | 2     | 0.71      | -1.93 | 219      | 1     | 4     | 1     | 3     | 0.61      | -1.50 |
| 685      | 1     | 1     | 3     | 1     | 0.76      | -1.83 | 129      | 1     | 4     | 3     | 2     | 0.63      | -1.99 | 242      | 1     | 4     | 2     | 3     | 0.72      | -1.78 |
| 686      | 1     | 1     | 3     | 1     | 0.71      | -1.86 | 130      | 1     | 4     | 3     | 2     | 0.72      | -1.55 | 243      | 1     | 4     | 2     | 3     | 0.6       | -2.30 |
| 687      | 1     | 1     | 3     | 1     | 0.75      | -1.67 | 131      | 1     | 4     | 3     | 2     | 0.7       | -1.90 | 244      | 1     | 4     | 2     | 3     | 0.69      | -1.92 |
| 688      | 1     | 1     | 3     | 1     | 0.51      | -1.83 | 135      | 1     | 4     | 3     | 2     | 0.7       | -2.33 | 246      | 1     | 4     | 2     | 3     | 0.54      | -1.90 |
| 691      | 1     | 1     | 3     | 1     | 0.78      | -1.73 | 137      | 1     | 4     | 3     | 2     | 0.66      | -1.70 | 247      | 1     | 4     | 2     | 3     | 0.52      | -1.51 |
| 693      | 1     | 1     | 3     | 1     | 0.8       | -1.81 | 138      | 1     | 4     | 3     | 2     | 0.72      | -1.59 | 248      | 1     | 4     | 2     | 3     | 0.71      | -1.72 |
| 694      | 1     | 1     | 3     | 1     | 0.78      | -1.72 | 139      | 1     | 4     | 3     | 2     | 0.74      | -1.63 | 249      | 1     | 4     | 2     | 3     | 0.68      | -1.60 |
| 704      | 1     | 1     | 3     | 1     | 0.77      | -2.06 | 140      | 1     | 4     | 3     | 2     | 0.72      | -1.55 | 250      | 1     | 4     | 2     | 3     | 0.71      | -1.59 |
| 705      | 1     | 1     | 3     | 1     | 0.76      | -1.74 | 141      | 1     | 4     | 3     | 2     | 0.73      | -1.77 | 251      | 1     | 4     | 2     | 3     | 0.67      | -1.51 |
| 708      | 1     | 1     | 3     | 1     | 0.72      | -1.55 | 144      | 1     | 4     | 3     | 2     | 0.66      | -2.14 | 252      | 1     | 4     | 2     | 3     | 0.78      | -1.46 |
| 710      | 1     | 1     | 3     | 1     | 0.77      | -1.84 | 145      | 1     | 4     | 3     | 2     | 0.64      | -1.96 | 253      | 1     | 4     | 2     | 3     | 0.71      | -1.68 |
| 51       | 1     | 4     | 2     | 2     | 0.7       | -1.93 | 146      | 1     | 4     | 3     | 2     | 0.76      | -1.89 | 254      | 1     | 4     | 2     | 3     | 0.54      | -1.50 |
| 55       | 1     | 4     | 2     | 2     | 0.45      | -1.90 | 147      | 1     | 4     | 3     | 2     | 0.69      | -1.99 | 255      | 1     | 4     | 2     | 3     | 0.72      | -1.89 |
| 56       | 1     | 4     | 2     | 2     | 0.65      | -1.90 | 148      | 1     | 4     | 3     | 2     | 0.75      | -1.59 | 256      | 1     | 4     | 2     | 3     | 0.75      | -1.60 |
| 57       | 1     | 4     | 2     | 2     | 0.64      | -1.37 | 150      | 1     | 4     | 3     | 2     | 0.72      | -1.77 | 260      | 1     | 4     | 2     | 3     | 0.71      | -1.67 |
| 58       | 1     | 4     | 2     | 2     | 0.66      | -1.94 | 155      | 1     | 4     | 3     | 2     | 0.7       | -1.37 | 261      | 1     | 4     | 2     | 3     | 0.68      | -1.96 |
| 59       | 1     | 4     | 2     | 2     | 0.69      | -1.60 | 156      | 1     | 4     | 3     | 2     | 0.66      | -1.80 | 264      | 1     | 4     | 2     | 3     | 0.72      | -1.69 |
| 61       | 1     | 4     | 2     | 2     | 0.54      | -2.01 | 157      | 1     | 4     | 3     | 2     | 0.5       | -1.58 | 265      | 1     | 4     | 2     | 3     | 0.72      | -1.76 |
| 62       | 1     | 4     | 2     | 2     | 0.69      | -1.83 | 181      | 1     | 4     | 1     | 3     | 0.7       | -1.74 | 267      | 1     | 4     | 2     | 3     | 0.72      | -1.94 |
| 64       | 1     | 4     | 2     | 2     | 0.65      | -1.46 | 183      | 1     | 4     | 1     | 3     | 0.68      | -2.18 | 268      | 1     | 4     | 2     | 3     | 0.73      | -1.59 |
| 66       | 1     | 4     | 2     | 2     | 0.7       | -1.78 | 186      | 1     | 4     | 1     | 3     | 0.63      | -1.68 | 271      | 1     | 4     | 2     | 3     | 0.71      | -1.64 |
| 67       | 1     | 4     | 2     | 2     | 0.6       | -1.98 | 188      | 1     | 4     | 1     | 3     | 0.71      | -1.71 | 274      | 1     | 4     | 2     | 3     | 0.67      | -1.72 |
| 68       | 1     | 4     | 2     | 2     | 0.69      | -1.83 | 193      | 1     | 4     | 1     | 3     | NA        | -1.64 | 275      | 1     | 4     | 2     | 3     | 0.63      | -1.93 |
| 69       | 1     | 4     | 2     | 2     | 0.7       | -1.77 | 196      | 1     | 4     | 1     | 3     | 0.74      | -1.60 | 278      | 1     | 4     | 2     | 3     | 0.48      | -2.12 |
| 70       | 1     | 4     | 2     | 2     | 0.68      | -1.90 | 197      | 1     | 4     | 1     | 3     | 0.75      | -1.42 | 287      | 1     | 4     | 2     | 3     | 0.74      | -1.74 |
| 71       | 1     | 4     | 2     | 2     | 0.71      | -1.90 | 199      | 1     | 4     | 1     | 3     | 0.66      | -1.78 | 289      | 1     | 4     | 1     | 4     | 0.71      | -1.80 |
| 74       | 1     | 4     | 2     | 2     | 0.71      | -1.77 | 200      | 1     | 4     | 1     | 3     | 0.66      | -1.46 | 291      | 1     | 4     | 1     | 4     | 0.69      | -1.64 |
| 75       | 1     | 4     | 2     | 2     | 0.74      | -2.01 | 201      | 1     | 4     | 1     | 3     | 0.72      | -1.51 | 292      | 1     | 4     | 1     | 4     | 0.71      | -1.76 |
| 76       | 1     | 4     | 2     | 2     | 0.67      | -1.86 | 202      | 1     | 4     | 1     | 3     | 0.66      | -1.84 | 294      | 1     | 4     | 1     | 4     | 0.72      | -1.87 |
| 77       | 1     | 4     | 2     | 2     | 0.73      | -1.94 | 203      | 1     | 4     | 1     | 3     | 0.71      | -1.58 | 296      | 1     | 4     | 1     | 4     | 0.73      | -1.56 |
| 78       | 1     | 4     | 2     | 2     | 0.7       | -1.76 | 204      | 1     | 4     | 1     | 3     | 0.74      | -1.37 | 297      | 1     | 4     | 1     | 4     | 0.72      | -1.87 |
| 83       | 1     | 4     | 2     | 2     | 0.68      | -2.12 | 205      | 1     | 4     | 1     | 3     | 0.76      | -1.86 | 298      | 1     | 4     | 1     | 4     | 0.72      | -1.55 |
| 88       | 1     | 4     | 2     | 2     | 0.54      | -1.78 | 206      | 1     | 4     | 1     | 3     | 0.71      | -1.55 | 299      | 1     | 4     | 1     | 4     | 0.68      | -1.46 |
| 92       | 1     | 4     | 2     | 2     | 0.64      | -1.92 | 208      | 1     | 4     | 1     | 3     | 0.7       | -1.42 | 300      | 1     | 4     | 1     | 4     | 0.68      | -1.83 |
| 99       | 1     | 4     | 2     | 2     | 0.7       | -2.06 | 209      | 1     | 4     | 1     | 3     | 0.7       | -1.46 | 301      | 1     | 4     | 1     | 4     | 0.65      | -1.76 |
| 101      | 1     | 4     | 2     | 2     | 0.65      | -2.10 | 210      | 1     | 4     | 1     | 3     | 0.72      | -1.50 | 306      | 1     | 4     | 1     | 4     | 0.67      | -1.64 |
| 120      | 1     | 4     | 3     | 2     | 0.55      | -1.77 | 211      | 1     | 4     | 1     | 3     | 0.73      | -1.72 | 307      | 1     | 4     | 1     | 4     | 0.57      | -1.81 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 308      | 1     | 4     | 1     | 4     | 0.68      | -1.69 | 416      | 1     | 4     | 3     | 4     | 0.65      | -2.06 | 529      | 1     | 4     | 3     | 3     | 0.64      | -1.90 |
| 310      | 1     | 4     | 1     | 4     | 0.79      | -1.67 | 418      | 1     | 4     | 3     | 4     | 0.61      | -1.80 | 530      | 1     | 4     | 3     | 3     | 0.69      | -1.64 |
| 312      | 1     | 4     | 1     | 4     | 0.69      | -1.51 | 422      | 1     | 4     | 3     | 4     | 0.58      | -1.83 | 542      | 1     | 4     | 1     | 1     | 0.74      | -1.86 |
| 314      | 1     | 4     | 1     | 4     | 0.7       | -1.80 | 424      | 1     | 4     | 3     | 4     | 0.69      | -1.61 | 543      | 1     | 4     | 1     | 1     | 0.5       | -1.74 |
| 315      | 1     | 4     | 1     | 4     | 0.74      | -1.64 | 425      | 1     | 4     | 3     | 4     | 0.64      | -1.78 | 549      | 1     | 4     | 1     | 1     | 0.66      | -1.86 |
| 316      | 1     | 4     | 1     | 4     | 0.71      | -1.59 | 426      | 1     | 4     | 3     | 4     | 0.67      | -1.72 | 550      | 1     | 4     | 1     | 1     | 0.73      | -1.90 |
| 317      | 1     | 4     | 1     | 4     | 0.75      | -1.81 | 427      | 1     | 4     | 3     | 4     | 0.69      | -1.50 | 551      | 1     | 4     | 1     | 1     | 0.63      | -1.68 |
| 318      | 1     | 4     | 1     | 4     | 0.72      | -1.50 | 428      | 1     | 4     | 3     | 4     | 0.7       | -1.55 | 552      | 1     | 4     | 1     | 1     | 0.63      | -1.75 |
| 319      | 1     | 4     | 1     | 4     | 0.69      | -1.51 | 430      | 1     | 4     | 3     | 4     | 0.71      | -1.37 | 553      | 1     | 4     | 1     | 1     | 0.67      | -1.64 |
| 320      | 1     | 4     | 1     | 4     | 0.71      | -1.68 | 431      | 1     | 4     | 3     | 4     | 0.64      | -1.78 | 556      | 1     | 4     | 1     | 1     | 0.69      | -1.60 |
| 321      | 1     | 4     | 1     | 4     | 0.58      | -1.68 | 432      | 1     | 4     | 3     | 4     | 0.68      | -1.92 | 557      | 1     | 4     | 1     | 1     | 0.75      | -1.60 |
| 322      | 1     | 4     | 1     | 4     | 0.73      | -1.51 | 433      | 1     | 4     | 3     | 4     | 0.64      | -1.59 | 558      | 1     | 4     | 1     | 1     | 0.63      | -1.46 |
| 323      | 1     | 4     | 1     | 4     | 0.65      | -1.90 | 436      | 1     | 4     | 3     | 4     | 0.67      | -1.64 | 560      | 1     | 4     | 1     | 1     | NA        | -1.77 |
| 350      | 1     | 4     | 2     | 4     | 0.68      | -1.63 | 437      | 1     | 4     | 3     | 4     | 0.78      | -1.33 | 573      | 1     | 4     | 1     | 1     | 0.68      | -1.67 |
| 351      | 1     | 4     | 2     | 4     | 0.55      | -2.15 | 438      | 1     | 4     | 3     | 4     | 0.69      | -1.99 | 574      | 1     | 4     | 1     | 1     | 0.76      | -1.81 |
| 353      | 1     | 4     | 2     | 4     | 0.69      | -1.77 | 441      | 1     | 4     | 3     | 4     | 0.67      | -1.74 | 576      | 1     | 4     | 1     | 1     | 0.69      | -1.64 |
| 358      | 1     | 4     | 2     | 4     | 0.75      | -1.81 | 443      | 1     | 4     | 3     | 4     | 0.68      | -1.90 | 579      | 1     | 4     | 1     | 1     | 0.71      | -2.01 |
| 359      | 1     | 4     | 2     | 4     | 0.73      | -1.83 | 445      | 1     | 4     | 3     | 4     | 0.73      | -1.77 | 580      | 1     | 4     | 1     | 1     | 0.74      | -1.60 |
| 362      | 1     | 4     | 2     | 4     | 0.72      | -1.69 | 446      | 1     | 4     | 3     | 4     | 0.62      | -1.84 | 581      | 1     | 4     | 1     | 1     | 0.74      | -1.72 |
| 363      | 1     | 4     | 2     | 4     | 0.7       | -1.86 | 447      | 1     | 4     | 3     | 4     | 0.73      | -1.72 | 582      | 1     | 4     | 1     | 1     | 0.66      | -2.24 |
| 365      | 1     | 4     | 2     | 4     | 0.72      | -1.74 | 472      | 1     | 4     | 3     | 3     | 0.68      | -1.88 | 583      | 1     | 4     | 1     | 1     | 0.72      | -1.51 |
| 368      | 1     | 4     | 2     | 4     | 0.74      | NA    | 475      | 1     | 4     | 3     | 3     | 0.67      | -1.68 | 584      | 1     | 4     | 1     | 1     | 0.75      | -1.69 |
| 369      | 1     | 4     | 2     | 4     | 0.69      | NA    | 478      | 1     | 4     | 3     | 3     | 0.72      | -1.46 | 586      | 1     | 4     | 1     | 1     | 0.72      | -1.50 |
| 370      | 1     | 4     | 2     | 4     | 0.63      | -2.12 | 480      | 1     | 4     | 3     | 3     | 0.75      | -1.81 | 587      | 1     | 4     | 1     | 1     | 0.66      | -1.87 |
| 371      | 1     | 4     | 2     | 4     | 0.68      | -2.35 | 482      | 1     | 4     | 3     | 3     | 0.73      | -2.01 | 588      | 1     | 4     | 1     | 1     | 0.75      | -1.92 |
| 372      | 1     | 4     | 2     | 4     | 0.71      | -1.59 | 483      | 1     | 4     | 3     | 3     | 0.39      | -1.94 | 589      | 1     | 4     | 1     | 1     | 0.69      | -1.99 |
| 374      | 1     | 4     | 2     | 4     | 0.67      | -1.59 | 486      | 1     | 4     | 3     | 3     | 0.73      | -1.55 | 590      | 1     | 4     | 1     | 1     | 0.65      | -1.55 |
| 375      | 1     | 4     | 2     | 4     | 0.69      | -1.84 | 487      | 1     | 4     | 3     | 3     | 0.66      | -1.59 | 591      | 1     | 4     | 2     | 1     | 0.65      | -1.84 |
| 377      | 1     | 4     | 2     | 4     | 0.71      | -1.69 | 490      | 1     | 4     | 3     | 3     | 0.72      | -1.51 | 592      | 1     | 4     | 2     | 1     | 0.75      | -1.97 |
| 378      | 1     | 4     | 2     | 4     | 0.75      | -2.28 | 494      | 1     | 4     | 3     | 3     | 0.59      | -1.69 | 594      | 1     | 4     | 2     | 1     | 0.68      | -1.88 |
| 379      | 1     | 4     | 2     | 4     | 0.69      | -2.03 | 495      | 1     | 4     | 3     | 3     | 0.71      | -1.72 | 596      | 1     | 4     | 2     | 1     | 0.7       | -1.90 |
| 383      | 1     | 4     | 2     | 4     | 0.73      | -1.99 | 501      | 1     | 4     | 3     | 3     | 0.63      | -1.46 | 597      | 1     | 4     | 2     | 1     | 0.76      | -1.83 |
| 386      | 1     | 4     | 2     | 4     | 0.74      | -1.69 | 507      | 1     | 4     | 3     | 3     | 0.74      | -1.67 | 599      | 1     | 4     | 2     | 1     | 0.76      | -1.80 |
| 393      | 1     | 4     | 2     | 4     | 0.76      | -1.59 | 509      | 1     | 4     | 3     | 3     | 0.71      | -1.80 | 601      | 1     | 4     | 2     | 1     | 0.73      | -1.69 |
| 395      | 1     | 4     | 2     | 4     | 0.71      | -2.06 | 511      | 1     | 4     | 3     | 3     | 0.72      | -1.55 | 603      | 1     | 4     | 2     | 1     | 0.68      | -1.72 |
| 396      | 1     | 4     | 2     | 4     | 0.75      | -1.81 | 513      | 1     | 4     | 3     | 3     | 0.68      | -2.08 | 604      | 1     | 4     | 2     | 1     | 0.67      | -1.80 |
| 403      | 1     | 4     | 2     | 4     | 0.61      | -2.30 | 517      | 1     | 4     | 3     | 3     | 0.73      | -1.68 | 605      | 1     | 4     | 2     | 1     | 0.72      | -1.69 |
| 404      | 1     | 4     | 2     | 4     | 0.64      | -1.87 | 519      | 1     | 4     | 3     | 3     | 0.61      | -2.01 | 606      | 1     | 4     | 2     | 1     | 0.74      | NA    |
| 409      | 1     | 4     | 3     | 4     | 0.72      | -1.64 | 521      | 1     | 4     | 3     | 3     | 0.7       | -1.72 | 607      | 1     | 4     | 2     | 1     | 0.72      | NA    |
| 410      | 1     | 4     | 3     | 4     | 0.69      | -1.60 | 523      | 1     | 4     | 3     | 3     | 0.59      | -1.41 | 611      | 1     | 4     | 2     | 1     | 0.69      | -1.69 |
| 411      | 1     | 4     | 3     | 4     | 0.54      | -1.74 | 524      | 1     | 4     | 3     | 3     | 0.72      | -1.55 | 614      | 1     | 4     | 2     | 1     | NA        | NA    |
| 413      | 1     | 4     | 3     | 4     | 0.66      | -2.33 | 526      | 1     | 4     | 3     | 3     | 0.73      | -1.90 | 616      | 1     | 4     | 2     | 1     | 0.67      | -1.64 |
| 415      | 1     | 4     | 3     | 4     | 0.71      | NA    | 528      | 1     | 4     | 3     | 3     | 0.73      | -1.78 | 622      | 1     | 4     | 2     | 1     | 0.64      | -2.06 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 625      | 1     | 4     | 2     | 1     | 0.72      | -1.84 | 66       | 3     | 4     | 2     | 2     | 0.74      | -1.90 | 186      | 3     | 4     | 1     | 3     | 0.7       | -1.64 |
| 626      | 1     | 4     | 2     | 1     | 0.69      | -1.86 | 67       | 3     | 4     | 2     | 2     | 0.77      | -1.50 | 188      | 3     | 4     | 1     | 3     | 0.69      | -1.56 |
| 639      | 1     | 4     | 2     | 1     | 0.78      | -1.77 | 68       | 3     | 4     | 2     | 2     | 0.74      | -2.29 | 193      | 3     | 4     | 1     | 3     | 0.66      | -1.46 |
| 640      | 1     | 4     | 2     | 1     | 0.75      | -1.41 | 69       | 3     | 4     | 2     | 2     | 0.75      | -1.69 | 196      | 3     | 4     | 1     | 3     | 0.78      | -1.64 |
| 641      | 1     | 4     | 2     | 1     | 0.72      | -1.88 | 70       | 3     | 4     | 2     | 2     | 0.76      | -1.69 | 197      | 3     | 4     | 1     | 3     | 0.72      | -1.50 |
| 643      | 1     | 4     | 2     | 1     | 0.72      | -1.64 | 71       | 3     | 4     | 2     | 2     | 0.76      | -2.01 | 199      | 3     | 4     | 1     | 3     | 0.65      | -1.84 |
| 645      | 1     | 4     | 2     | 1     | 0.72      | -1.76 | 74       | 3     | 4     | 2     | 2     | 0.78      | -2.06 | 200      | 3     | 4     | 1     | 3     | 0.74      | -1.59 |
| 646      | 1     | 4     | 2     | 1     | 0.68      | -1.96 | 75       | 3     | 4     | 2     | 2     | 0.78      | -1.63 | 201      | 3     | 4     | 1     | 3     | 0.74      | -1.41 |
| 648      | 1     | 4     | 2     | 1     | 0.72      | -2.01 | 76       | 3     | 4     | 2     | 2     | 0.76      | -1.96 | 202      | 3     | 4     | 1     | 3     | 0.78      | -1.50 |
| 653      | 1     | 4     | 3     | 1     | 0.64      | -1.60 | 77       | 3     | 4     | 2     | 2     | 0.77      | -1.63 | 203      | 3     | 4     | 1     | 3     | 0.77      | -1.37 |
| 654      | 1     | 4     | 3     | 1     | 0.74      | -1.60 | 78       | 3     | 4     | 2     | 2     | NA        | NA    | 204      | 3     | 4     | 1     | 3     | 0.76      | -1.50 |
| 656      | 1     | 4     | 3     | 1     | 0.74      | -1.76 | 83       | 3     | 4     | 2     | 2     | 0.66      | -1.71 | 205      | 3     | 4     | 1     | 3     | 0.76      | -1.87 |
| 657      | 1     | 4     | 3     | 1     | 0.71      | -1.94 | 88       | 3     | 4     | 2     | 2     | 0.73      | -1.68 | 206      | 3     | 4     | 1     | 3     | 0.73      | -1.64 |
| 658      | 1     | 4     | 3     | 1     | 0.69      | -1.46 | 92       | 3     | 4     | 2     | 2     | 0.75      | -1.78 | 208      | 3     | 4     | 1     | 3     | 0.71      | -1.46 |
| 663      | 1     | 4     | 3     | 1     | 0.74      | -2.30 | 99       | 3     | 4     | 2     | 2     | 0.71      | -1.55 | 209      | 3     | 4     | 1     | 3     | 0.71      | -1.64 |
| 672      | 1     | 4     | 3     | 1     | 0.68      | -2.06 | 101      | 3     | 4     | 2     | 2     | 0.74      | -1.78 | 210      | 3     | 4     | 1     | 3     | 0.73      | -1.68 |
| 677      | 1     | 4     | 3     | 1     | 0.67      | -1.87 | 120      | 3     | 4     | 3     | 2     | 0.77      | -1.81 | 211      | 3     | 4     | 1     | 3     | 0.73      | -1.79 |
| 678      | 1     | 4     | 3     | 1     | 0.76      | -1.64 | 121      | 3     | 4     | 3     | 2     | 0.74      | -1.69 | 212      | 3     | 4     | 1     | 3     | 0.77      | -1.72 |
| 680      | 1     | 4     | 3     | 1     | 0.64      | -2.51 | 122      | 3     | 4     | 3     | 2     | 0.69      | -1.83 | 213      | 3     | 4     | 1     | 3     | 0.72      | -1.64 |
| 681      | 1     | 4     | 3     | 1     | 0.66      | -1.42 | 123      | 3     | 4     | 3     | 2     | 0.68      | -1.80 | 214      | 3     | 4     | 1     | 3     | 0.69      | -1.46 |
| 682      | 1     | 4     | 3     | 1     | 0.66      | -1.64 | 125      | 3     | 4     | 3     | 2     | 0.72      | -1.78 | 216      | 3     | 4     | 1     | 3     | 0.72      | -1.54 |
| 683      | 1     | 4     | 3     | 1     | 0.68      | -2.17 | 127      | 3     | 4     | 3     | 2     | 0.7       | -1.76 | 218      | 3     | 4     | 1     | 3     | 0.7       | -1.64 |
| 684      | 1     | 4     | 3     | 1     | 0.69      | -2.17 | 128      | 3     | 4     | 3     | 2     | 0.71      | -1.80 | 219      | 3     | 4     | 1     | 3     | 0.72      | -1.79 |
| 685      | 1     | 4     | 3     | 1     | 0.62      | NA    | 129      | 3     | 4     | 3     | 2     | 0.72      | -2.06 | 242      | 3     | 4     | 2     | 3     | 0.79      | -1.20 |
| 686      | 1     | 4     | 3     | 1     | 0.69      | -1.93 | 130      | 3     | 4     | 3     | 2     | 0.71      | -1.64 | 243      | 3     | 4     | 2     | 3     | 0.73      | -1.71 |
| 687      | 1     | 4     | 3     | 1     | 0.7       | -1.64 | 131      | 3     | 4     | 3     | 2     | 0.74      | -1.81 | 244      | 3     | 4     | 2     | 3     | 0.69      | -1.77 |
| 688      | 1     | 4     | 3     | 1     | 0.75      | -1.41 | 135      | 3     | 4     | 3     | 2     | 0.72      | -1.96 | 246      | 3     | 4     | 2     | 3     | 0.74      | -1.83 |
| 691      | 1     | 4     | 3     | 1     | 0.73      | -1.74 | 137      | 3     | 4     | 3     | 2     | 0.71      | -1.72 | 247      | 3     | 4     | 2     | 3     | 0.7       | -1.80 |
| 693      | 1     | 4     | 3     | 1     | 0.77      | -1.67 | 138      | 3     | 4     | 3     | 2     | 0.74      | -1.64 | 248      | 3     | 4     | 2     | 3     | 0.69      | -1.84 |
| 694      | 1     | 4     | 3     | 1     | 0.72      | -1.55 | 139      | 3     | 4     | 3     | 2     | 0.76      | -1.86 | 249      | 3     | 4     | 2     | 3     | 0.7       | -1.78 |
| 704      | 1     | 4     | 3     | 1     | 0.72      | -1.81 | 140      | 3     | 4     | 3     | 2     | 0.77      | -1.92 | 250      | 3     | 4     | 2     | 3     | 0.75      | -1.74 |
| 705      | 1     | 4     | 3     | 1     | 0.76      | -1.78 | 141      | 3     | 4     | 3     | 2     | 0.77      | -1.46 | 251      | 3     | 4     | 2     | 3     | 0.73      | -1.46 |
| 708      | 1     | 4     | 3     | 1     | 0.68      | -1.72 | 144      | 3     | 4     | 3     | 2     | 0.68      | NA    | 252      | 3     | 4     | 2     | 3     | 0.75      | -1.41 |
| 710      | 1     | 4     | 3     | 1     | 0.67      | -1.68 | 145      | 3     | 4     | 3     | 2     | 0.75      | -1.32 | 253      | 3     | 4     | 2     | 3     | 0.76      | -1.81 |
| 51       | 3     | 4     | 2     | 2     | 0.72      | -1.80 | 146      | 3     | 4     | 3     | 2     | NA        | NA    | 254      | 3     | 4     | 2     | 3     | 0.75      | -1.96 |
| 55       | 3     | 4     | 2     | 2     | 0.58      | -1.78 | 147      | 3     | 4     | 3     | 2     | NA        | -1.69 | 255      | 3     | 4     | 2     | 3     | 0.75      | -1.72 |
| 56       | 3     | 4     | 2     | 2     | 0.72      | -1.74 | 148      | 3     | 4     | 3     | 2     | 0.74      | -1.68 | 256      | 3     | 4     | 2     | 3     | 0.71      | -1.37 |
| 57       | 3     | 4     | 2     | 2     | 0.72      | -1.60 | 150      | 3     | 4     | 3     | 2     | 0.77      | -1.85 | 260      | 3     | 4     | 2     | 3     | 0.75      | -1.64 |
| 58       | 3     | 4     | 2     | 2     | 0.73      | -1.69 | 155      | 3     | 4     | 3     | 2     | 0.75      | -1.46 | 261      | 3     | 4     | 2     | 3     | 0.72      | -2.06 |
| 59       | 3     | 4     | 2     | 2     | 0.67      | -1.88 | 156      | 3     | 4     | 3     | 2     | 0.74      | -1.46 | 264      | 3     | 4     | 2     | 3     | 0.74      | -1.60 |
| 61       | 3     | 4     | 2     | 2     | 0.68      | -1.93 | 157      | 3     | 4     | 3     | 2     | 0.74      | -1.46 | 265      | 3     | 4     | 2     | 3     | 0.7       | -1.28 |
| 62       | 3     | 4     | 2     | 2     | NA        | -1.42 | 181      | 3     | 4     | 1     | 3     | 0.72      | -1.59 | 267      | 3     | 4     | 2     | 3     | 0.73      | -1.78 |
| 64       | 3     | 4     | 2     | 2     | 0.75      | -1.69 | 183      | 3     | 4     | 1     | 3     | 0.69      | -1.88 | 268      | 3     | 4     | 2     | 3     | 0.73      | -1.64 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 271      | 3     | 4     | 2     | 3     | 0.71      | -1.51 | 374      | 3     | 4     | 2     | 4     | 0.75      | -1.69 | 486      | 3     | 4     | 3     | 3     | 0.71      | -1.80 |
| 274      | 3     | 4     | 2     | 3     | 0.71      | -1.60 | 375      | 3     | 4     | 2     | 4     | 0.68      | -1.46 | 487      | 3     | 4     | 3     | 3     | 0.68      | -1.71 |
| 275      | 3     | 4     | 2     | 3     | 0.73      | -1.77 | 377      | 3     | 4     | 2     | 4     | 0.73      | -1.55 | 490      | 3     | 4     | 3     | 3     | 0.75      | -1.32 |
| 278      | 3     | 4     | 2     | 3     | 0.72      | -1.42 | 378      | 3     | 4     | 2     | 4     | 0.76      | -1.64 | 494      | 3     | 4     | 3     | 3     | 0.74      | -1.51 |
| 287      | 3     | 4     | 2     | 3     | 0.72      | -1.42 | 379      | 3     | 4     | 2     | 4     | 0.73      | -1.88 | 495      | 3     | 4     | 3     | 3     | 0.76      | -1.41 |
| 289      | 3     | 4     | 1     | 4     | 0.76      | -1.48 | 383      | 3     | 4     | 2     | 4     | 0.77      | -1.67 | 501      | 3     | 4     | 3     | 3     | 0.75      | -1.68 |
| 291      | 3     | 4     | 1     | 4     | 0.76      | -1.58 | 386      | 3     | 4     | 2     | 4     | 0.74      | -1.74 | 507      | 3     | 4     | 3     | 3     | 0.77      | -1.50 |
| 292      | 3     | 4     | 1     | 4     | 0.74      | -1.67 | 393      | 3     | 4     | 2     | 4     | 0.72      | -1.51 | 509      | 3     | 4     | 3     | 3     | 0.74      | -1.83 |
| 294      | 3     | 4     | 1     | 4     | 0.74      | -1.52 | 395      | 3     | 4     | 2     | 4     | 0.76      | -1.72 | 511      | 3     | 4     | 3     | 3     | 0.75      | -1.19 |
| 296      | 3     | 4     | 1     | 4     | 0.77      | -1.64 | 396      | 3     | 4     | 2     | 4     | 0.77      | -1.55 | 513      | 3     | 4     | 3     | 3     | 0.74      | -1.28 |
| 297      | 3     | 4     | 1     | 4     | 0.76      | -1.68 | 403      | 3     | 4     | 2     | 4     | 0.68      | -1.51 | 517      | 3     | 4     | 3     | 3     | 0.8       | -1.78 |
| 298      | 3     | 4     | 1     | 4     | 0.71      | -1.77 | 404      | 3     | 4     | 2     | 4     | 0.71      | -1.51 | 519      | 3     | 4     | 3     | 3     | 0.74      | -1.64 |
| 299      | 3     | 4     | 1     | 4     | 0.75      | -1.55 | 409      | 3     | 4     | 3     | 4     | 0.72      | -1.56 | 521      | 3     | 4     | 3     | 3     | 0.74      | -1.55 |
| 300      | 3     | 4     | 1     | 4     | 0.76      | -1.51 | 410      | 3     | 4     | 3     | 4     | 0.71      | -1.52 | 523      | 3     | 4     | 3     | 3     | 0.76      | -1.42 |
| 301      | 3     | 4     | 1     | 4     | 0.77      | -1.50 | 411      | 3     | 4     | 3     | 4     | 0.7       | -1.64 | 524      | 3     | 4     | 3     | 3     | 0.7       | -1.51 |
| 306      | 3     | 4     | 1     | 4     | 0.72      | -1.69 | 413      | 3     | 4     | 3     | 4     | 0.72      | -1.90 | 526      | 3     | 4     | 3     | 3     | 0.72      | -1.37 |
| 307      | 3     | 4     | 1     | 4     | 0.72      | -1.64 | 415      | 3     | 4     | 3     | 4     | 0.73      | -1.84 | 528      | 3     | 4     | 3     | 3     | 0.74      | -1.64 |
| 308      | 3     | 4     | 1     | 4     | 0.74      | -1.51 | 416      | 3     | 4     | 3     | 4     | 0.68      | -1.69 | 529      | 3     | 4     | 3     | 3     | 0.75      | -1.72 |
| 310      | 3     | 4     | 1     | 4     | 0.77      | -1.74 | 418      | 3     | 4     | 3     | 4     | 0.7       | -1.50 | 530      | 3     | 4     | 3     | 3     | 0.75      | -1.68 |
| 312      | 3     | 4     | 1     | 4     | 0.75      | -1.64 | 422      | 3     | 4     | 3     | 4     | 0.68      | -1.46 | 542      | 3     | 4     | 1     | 1     | 0.77      | -1.60 |
| 314      | 3     | 4     | 1     | 4     | 0.78      | -1.50 | 424      | 3     | 4     | 3     | 4     | 0.76      | -1.37 | 543      | 3     | 4     | 1     | 1     | 0.71      | -1.74 |
| 315      | 3     | 4     | 1     | 4     | 0.77      | -1.63 | 425      | 3     | 4     | 3     | 4     | 0.69      | -1.55 | 549      | 3     | 4     | 1     | 1     | 0.71      | -1.87 |
| 316      | 3     | 4     | 1     | 4     | 0.74      | -1.69 | 426      | 3     | 4     | 3     | 4     | 0.67      | -1.72 | 550      | 3     | 4     | 1     | 1     | 0.7       | -1.69 |
| 317      | 3     | 4     | 1     | 4     | 0.78      | -1.59 | 427      | 3     | 4     | 3     | 4     | 0.73      | -1.81 | 551      | 3     | 4     | 1     | 1     | 0.65      | -1.74 |
| 318      | 3     | 4     | 1     | 4     | 0.76      | -1.59 | 428      | 3     | 4     | 3     | 4     | 0.76      | -1.83 | 552      | 3     | 4     | 1     | 1     | 0.7       | -1.51 |
| 319      | 3     | 4     | 1     | 4     | 0.75      | -1.55 | 430      | 3     | 4     | 3     | 4     | 0.71      | -1.51 | 553      | 3     | 4     | 1     | 1     | 0.7       | -1.55 |
| 320      | 3     | 4     | 1     | 4     | 0.76      | -1.43 | 431      | 3     | 4     | 3     | 4     | 0.71      | -1.68 | 556      | 3     | 4     | 1     | 1     | 0.68      | -1.63 |
| 321      | 3     | 4     | 1     | 4     | 0.79      | -1.37 | 432      | 3     | 4     | 3     | 4     | 0.69      | -1.86 | 557      | 3     | 4     | 1     | 1     | 0.77      | -1.71 |
| 322      | 3     | 4     | 1     | 4     | 0.76      | -1.64 | 433      | 3     | 4     | 3     | 4     | 0.72      | -1.64 | 558      | 3     | 4     | 1     | 1     | 0.67      | -1.96 |
| 323      | 3     | 4     | 1     | 4     | 0.76      | -1.59 | 436      | 3     | 4     | 3     | 4     | 0.78      | -2.06 | 560      | 3     | 4     | 1     | 1     | 0.7       | -1.72 |
| 350      | 3     | 4     | 2     | 4     | 0.72      | -1.71 | 437      | 3     | 4     | 3     | 4     | 0.69      | -1.71 | 573      | 3     | 4     | 1     | 1     | 0.69      | -1.77 |
| 351      | 3     | 4     | 2     | 4     | 0.7       | -1.33 | 438      | 3     | 4     | 3     | 4     | 0.74      | -1.76 | 574      | 3     | 4     | 1     | 1     | 0.75      | -1.86 |
| 353      | 3     | 4     | 2     | 4     | 0.71      | -1.46 | 441      | 3     | 4     | 3     | 4     | 0.65      | -1.37 | 576      | 3     | 4     | 1     | 1     | 0.74      | -1.64 |
| 358      | 3     | 4     | 2     | 4     | 0.7       | -1.39 | 443      | 3     | 4     | 3     | 4     | 0.69      | -1.37 | 579      | 3     | 4     | 1     | 1     | 0.68      | -1.55 |
| 359      | 3     | 4     | 2     | 4     | 0.68      | -1.89 | 445      | 3     | 4     | 3     | 4     | 0.76      | -1.51 | 580      | 3     | 4     | 1     | 1     | 0.72      | -1.87 |
| 362      | 3     | 4     | 2     | 4     | 0.74      | -2.19 | 446      | 3     | 4     | 3     | 4     | 0.7       | -1.28 | 581      | 3     | 4     | 1     | 1     | 0.72      | -1.54 |
| 363      | 3     | 4     | 2     | 4     | 0.73      | -1.64 | 447      | 3     | 4     | 3     | 4     | 0.7       | -1.60 | 582      | 3     | 4     | 1     | 1     | 0.69      | -1.68 |
| 365      | 3     | 4     | 2     | 4     | 0.71      | -1.71 | 472      | 3     | 4     | 3     | 3     | 0.71      | -1.69 | 583      | 3     | 4     | 1     | 1     | 0.66      | -1.55 |
| 368      | 3     | 4     | 2     | 4     | 0.75      | -1.55 | 475      | 3     | 4     | 3     | 3     | 0.71      | -1.64 | 584      | 3     | 4     | 1     | 1     | 0.77      | -1.55 |
| 369      | 3     | 4     | 2     | 4     | 0.74      | -1.60 | 478      | 3     | 4     | 3     | 3     | 0.73      | -1.67 | 586      | 3     | 4     | 1     | 1     | 0.74      | -1.55 |
| 370      | 3     | 4     | 2     | 4     | 0.71      | -1.59 | 480      | 3     | 4     | 3     | 3     | 0.77      | -1.55 | 587      | 3     | 4     | 1     | 1     | 0.74      | -1.41 |
| 371      | 3     | 4     | 2     | 4     | 0.74      | -1.50 | 482      | 3     | 4     | 3     | 3     | 0.69      | -1.67 | 588      | 3     | 4     | 1     | 1     | 0.76      | -1.50 |
| 372      | 3     | 4     | 2     | 4     | 0.78      | -1.68 | 483      | 3     | 4     | 3     | 3     | 0.71      | -2.04 | 589      | 3     | 4     | 1     | 1     | 0.78      | -1.96 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 590      | 3     | 4     | 1     | 1     | 0.67      | -1.51 | 688      | 3     | 4     | 3     | 1     | 0.73      | -1.72 | 135      | 3     | 1     | 3     | 2     | 0.78      | -1.92 |
| 591      | 3     | 4     | 2     | 1     | 0.72      | -1.83 | 691      | 3     | 4     | 3     | 1     | 0.71      | -1.68 | 137      | 3     | 1     | 3     | 2     | 0.79      | -1.96 |
| 592      | 3     | 4     | 2     | 1     | 0.73      | -1.73 | 693      | 3     | 4     | 3     | 1     | 0.75      | -1.64 | 138      | 3     | 1     | 3     | 2     | 0.8       | -1.60 |
| 594      | 3     | 4     | 2     | 1     | 0.73      | -1.74 | 694      | 3     | 4     | 3     | 1     | 0.74      | -1.94 | 139      | 3     | 1     | 3     | 2     | 0.79      | -1.67 |
| 596      | 3     | 4     | 2     | 1     | 0.72      | -1.67 | 704      | 3     | 4     | 3     | 1     | 0.74      | -1.88 | 140      | 3     | 1     | 3     | 2     | 0.8       | -1.50 |
| 597      | 3     | 4     | 2     | 1     | 0.74      | -2.19 | 705      | 3     | 4     | 3     | 1     | 0.78      | -1.52 | 141      | 3     | 1     | 3     | 2     | 0.8       | -1.63 |
| 599      | 3     | 4     | 2     | 1     | 0.75      | -1.46 | 708      | 3     | 4     | 3     | 1     | 0.75      | -1.59 | 144      | 3     | 1     | 3     | 2     | 0.75      | -1.40 |
| 601      | 3     | 4     | 2     | 1     | 0.71      | -1.55 | 710      | 3     | 4     | 3     | 1     | 0.76      | -1.50 | 145      | 3     | 1     | 3     | 2     | 0.77      | -1.71 |
| 603      | 3     | 4     | 2     | 1     | 0.72      | -1.23 | 51       | 3     | 1     | 2     | 2     | 0.78      | -1.73 | 146      | 3     | 1     | 3     | 2     | 0.79      | -1.65 |
| 604      | 3     | 4     | 2     | 1     | 0.71      | -1.63 | 55       | 3     | 1     | 2     | 2     | 0.74      | -1.90 | 147      | 3     | 1     | 3     | 2     | 0.8       | -2.12 |
| 605      | 3     | 4     | 2     | 1     | 0.73      | -1.69 | 56       | 3     | 1     | 2     | 2     | 0.77      | -2.02 | 148      | 3     | 1     | 3     | 2     | 0.78      | -1.76 |
| 606      | 3     | 4     | 2     | 1     | 0.72      | -1.76 | 57       | 3     | 1     | 2     | 2     | 0.77      | -1.56 | 150      | 3     | 1     | 3     | 2     | 0.79      | -1.89 |
| 607      | 3     | 4     | 2     | 1     | 0.62      | -1.67 | 58       | 3     | 1     | 2     | 2     | 0.77      | -1.35 | 155      | 3     | 1     | 3     | 2     | 0.79      | -1.79 |
| 611      | 3     | 4     | 2     | 1     | 0.68      | -1.69 | 59       | 3     | 1     | 2     | 2     | 0.77      | -1.93 | 156      | 3     | 1     | 3     | 2     | 0.78      | -1.55 |
| 614      | 3     | 4     | 2     | 1     | 0.72      | -1.55 | 61       | 3     | 1     | 2     | 2     | 0.77      | -1.72 | 157      | 3     | 1     | 3     | 2     | 0.78      | -1.71 |
| 616      | 3     | 4     | 2     | 1     | 0.76      | -1.46 | 62       | 3     | 1     | 2     | 2     | 0.8       | -2.07 | 181      | 3     | 1     | 1     | 3     | 0.76      | -1.98 |
| 622      | 3     | 4     | 2     | 1     | 0.71      | -1.84 | 64       | 3     | 1     | 2     | 2     | 0.77      | -1.58 | 183      | 3     | 1     | 1     | 3     | 0.78      | -1.79 |
| 625      | 3     | 4     | 2     | 1     | 0.72      | -1.72 | 66       | 3     | 1     | 2     | 2     | 0.77      | -2.14 | 186      | 3     | 1     | 1     | 3     | 0.77      | -1.98 |
| 626      | 3     | 4     | 2     | 1     | 0.76      | -1.81 | 67       | 3     | 1     | 2     | 2     | 0.79      | -1.50 | 188      | 3     | 1     | 1     | 3     | 0.78      | -1.59 |
| 639      | 3     | 4     | 2     | 1     | 0.76      | -2.01 | 68       | 3     | 1     | 2     | 2     | 0.78      | -2.02 | 193      | 3     | 1     | 1     | 3     | 0.77      | -1.57 |
| 640      | 3     | 4     | 2     | 1     | 0.73      | -1.51 | 69       | 3     | 1     | 2     | 2     | 0.77      | -1.75 | 196      | 3     | 1     | 1     | 3     | 0.79      | -1.88 |
| 641      | 3     | 4     | 2     | 1     | 0.73      | -1.68 | 70       | 3     | 1     | 2     | 2     | 0.76      | -1.60 | 197      | 3     | 1     | 1     | 3     | 0.78      | -1.68 |
| 643      | 3     | 4     | 2     | 1     | 0.77      | -1.37 | 71       | 3     | 1     | 2     | 2     | 0.77      | -1.40 | 199      | 3     | 1     | 1     | 3     | 0.76      | -1.72 |
| 645      | 3     | 4     | 2     | 1     | 0.74      | -1.37 | 74       | 3     | 1     | 2     | 2     | 0.78      | -2.00 | 200      | 3     | 1     | 1     | 3     | 0.77      | -1.52 |
| 646      | 3     | 4     | 2     | 1     | 0.71      | -1.63 | 75       | 3     | 1     | 2     | 2     | 0.79      | -1.85 | 201      | 3     | 1     | 1     | 3     | 0.77      | -1.86 |
| 648      | 3     | 4     | 2     | 1     | 0.75      | -1.69 | 76       | 3     | 1     | 2     | 2     | 0.8       | -1.45 | 202      | 3     | 1     | 1     | 3     | 0.78      | -2.14 |
| 653      | 3     | 4     | 3     | 1     | 0.71      | -1.51 | 77       | 3     | 1     | 2     | 2     | 0.81      | -1.69 | 203      | 3     | 1     | 1     | 3     | 0.78      | -1.50 |
| 654      | 3     | 4     | 3     | 1     | 0.65      | -1.55 | 78       | 3     | 1     | 2     | 2     | 0.8       | -1.71 | 204      | 3     | 1     | 1     | 3     | 0.78      | -1.60 |
| 656      | 3     | 4     | 3     | 1     | 0.73      | -1.64 | 83       | 3     | 1     | 2     | 2     | 0.79      | -1.73 | 205      | 3     | 1     | 1     | 3     | 0.78      | -1.77 |
| 657      | 3     | 4     | 3     | 1     | 0.75      | -1.84 | 88       | 3     | 1     | 2     | 2     | 0.78      | -1.67 | 206      | 3     | 1     | 1     | 3     | 0.78      | -1.74 |
| 658      | 3     | 4     | 3     | 1     | 0.73      | -1.37 | 92       | 3     | 1     | 2     | 2     | 0.81      | -1.94 | 208      | 3     | 1     | 1     | 3     | 0.77      | -2.00 |
| 663      | 3     | 4     | 3     | 1     | 0.7       | -2.14 | 99       | 3     | 1     | 2     | 2     | 0.8       | -1.81 | 209      | 3     | 1     | 1     | 3     | 0.76      | -1.47 |
| 672      | 3     | 4     | 3     | 1     | 0.71      | -1.76 | 101      | 3     | 1     | 2     | 2     | 0.8       | -1.86 | 210      | 3     | 1     | 1     | 3     | 0.76      | -1.70 |
| 677      | 3     | 4     | 3     | 1     | 0.7       | -1.87 | 120      | 3     | 1     | 3     | 2     | 0.78      | -2.06 | 211      | 3     | 1     | 1     | 3     | 0.78      | -1.79 |
| 678      | 3     | 4     | 3     | 1     | 0.67      | -1.72 | 121      | 3     | 1     | 3     | 2     | 0.79      | -1.67 | 212      | 3     | 1     | 1     | 3     | 0.77      | -1.71 |
| 680      | 3     | 4     | 3     | 1     | 0.71      | -1.87 | 122      | 3     | 1     | 3     | 2     | 0.78      | -1.88 | 213      | 3     | 1     | 1     | 3     | 0.77      | -1.73 |
| 681      | 3     | 4     | 3     | 1     | 0.74      | -1.68 | 123      | 3     | 1     | 3     | 2     | 0.76      | -1.64 | 214      | 3     | 1     | 1     | 3     | 0.75      | -1.92 |
| 682      | 3     | 4     | 3     | 1     | 0.75      | -1.69 | 125      | 3     | 1     | 3     | 2     | 0.78      | -1.37 | 216      | 3     | 1     | 1     | 3     | 0.79      | -1.58 |
| 683      | 3     | 4     | 3     | 1     | 0.71      | -1.69 | 127      | 3     | 1     | 3     | 2     | 0.77      | -1.49 | 218      | 3     | 1     | 1     | 3     | 0.78      | -1.64 |
| 684      | 3     | 4     | 3     | 1     | 0.73      | -1.99 | 128      | 3     | 1     | 3     | 2     | 0.77      | -1.54 | 219      | 3     | 1     | 1     | 3     | 0.77      | -1.50 |
| 685      | 3     | 4     | 3     | 1     | 0.76      | -1.81 | 129      | 3     | 1     | 3     | 2     | 0.79      | -1.73 | 242      | 3     | 1     | 2     | 3     | 0.79      | -1.42 |
| 686      | 3     | 4     | 3     | 1     | 0.74      | -1.81 | 130      | 3     | 1     | 3     | 2     | 0.8       | -1.91 | 243      | 3     | 1     | 2     | 3     | 0.77      | -1.59 |
| 687      | 3     | 4     | 3     | 1     | 0.71      | -1.50 | 131      | 3     | 1     | 3     | 2     | 0.78      | -1.58 | 244      | 3     | 1     | 2     | 3     | 0.77      | -1.64 |

| genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    | genotype | Ttemp | Tmois | Otemp | Omois | $\phi P0$ | op    |
|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|----------|-------|-------|-------|-------|-----------|-------|
| 246      | 3     | 1     | 2     | 3     | 0.77      | -1.63 | 320      | 3     | 1     | 1     | 4     | 0.8       | -2.27 | 431      | 3     | 1     | 3     | 4     | 0.75      | -1.62 |
| 247      | 3     | 1     | 2     | 3     | 0.77      | -1.44 | 321      | 3     | 1     | 1     | 4     | 0.79      | -1.97 | 432      | 3     | 1     | 3     | 4     | 0.77      | -1.62 |
| 248      | 3     | 1     | 2     | 3     | 0.76      | -1.72 | 322      | 3     | 1     | 1     | 4     | 0.77      | -1.67 | 433      | 3     | 1     | 3     | 4     | 0.79      | -1.47 |
| 249      | 3     | 1     | 2     | 3     | 0.77      | -1.44 | 323      | 3     | 1     | 1     | 4     | 0.79      | -2.07 | 436      | 3     | 1     | 3     | 4     | 0.8       | -1.86 |
| 250      | 3     | 1     | 2     | 3     | 0.77      | -1.57 | 350      | 3     | 1     | 2     | 4     | 0.76      | -1.56 | 437      | 3     | 1     | 3     | 4     | 0.76      | -1.55 |
| 251      | 3     | 1     | 2     | 3     | 0.78      | -1.96 | 351      | 3     | 1     | 2     | 4     | 0.77      | -1.59 | 438      | 3     | 1     | 3     | 4     | 0.77      | -1.71 |
| 252      | 3     | 1     | 2     | 3     | 0.8       | -1.50 | 353      | 3     | 1     | 2     | 4     | 0.79      | -1.62 | 441      | 3     | 1     | 3     | 4     | 0.76      | -1.58 |
| 253      | 3     | 1     | 2     | 3     | 0.8       | -1.65 | 358      | 3     | 1     | 2     | 4     | 0.78      | -1.59 | 443      | 3     | 1     | 3     | 4     | 0.73      | -1.51 |
| 254      | 3     | 1     | 2     | 3     | 0.78      | -1.97 | 359      | 3     | 1     | 2     | 4     | 0.79      | -1.47 | 445      | 3     | 1     | 3     | 4     | 0.77      | -1.85 |
| 255      | 3     | 1     | 2     | 3     | 0.78      | -2.12 | 362      | 3     | 1     | 2     | 4     | 0.77      | -1.17 | 446      | 3     | 1     | 3     | 4     | 0.78      | -2.57 |
| 256      | 3     | 1     | 2     | 3     | 0.78      | -1.37 | 363      | 3     | 1     | 2     | 4     | 0.78      | -1.42 | 447      | 3     | 1     | 3     | 4     | 0.76      | -1.72 |
| 260      | 3     | 1     | 2     | 3     | 0.78      | -1.60 | 365      | 3     | 1     | 2     | 4     | 0.78      | -1.44 | 472      | 3     | 1     | 3     | 3     | 0.76      | -2.02 |
| 261      | 3     | 1     | 2     | 3     | 0.79      | -1.69 | 368      | 3     | 1     | 2     | 4     | 0.76      | -1.26 | 475      | 3     | 1     | 3     | 3     | 0.76      | -1.45 |
| 264      | 3     | 1     | 2     | 3     | 0.77      | -1.60 | 369      | 3     | 1     | 2     | 4     | 0.79      | -1.76 | 478      | 3     | 1     | 3     | 3     | 0.78      | -1.47 |
| 265      | 3     | 1     | 2     | 3     | 0.78      | -1.59 | 370      | 3     | 1     | 2     | 4     | 0.79      | -1.91 | 480      | 3     | 1     | 3     | 3     | 0.79      | -1.98 |
| 267      | 3     | 1     | 2     | 3     | 0.79      | -1.97 | 371      | 3     | 1     | 2     | 4     | 0.77      | -1.73 | 482      | 3     | 1     | 3     | 3     | 0.78      | -1.72 |
| 268      | 3     | 1     | 2     | 3     | 0.78      | -2.00 | 372      | 3     | 1     | 2     | 4     | 0.79      | -1.60 | 483      | 3     | 1     | 3     | 3     | 0.78      | -2.04 |
| 271      | 3     | 1     | 2     | 3     | 0.78      | -1.64 | 374      | 3     | 1     | 2     | 4     | 0.78      | -1.91 | 486      | 3     | 1     | 3     | 3     | 0.79      | -1.67 |
| 274      | 3     | 1     | 2     | 3     | 0.77      | -1.50 | 375      | 3     | 1     | 2     | 4     | 0.78      | -1.89 | 487      | 3     | 1     | 3     | 3     | 0.77      | -1.93 |
| 275      | 3     | 1     | 2     | 3     | 0.79      | -2.14 | 377      | 3     | 1     | 2     | 4     | 0.78      | -1.97 | 490      | 3     | 1     | 3     | 3     | 0.78      | -1.73 |
| 278      | 3     | 1     | 2     | 3     | 0.77      | -2.06 | 378      | 3     | 1     | 2     | 4     | 0.79      | -1.64 | 494      | 3     | 1     | 3     | 3     | 0.79      | -1.83 |
| 287      | 3     | 1     | 2     | 3     | 0.78      | -1.71 | 379      | 3     | 1     | 2     | 4     | 0.77      | -2.31 | 495      | 3     | 1     | 3     | 3     | 0.78      | -1.81 |
| 289      | 3     | 1     | 1     | 4     | 0.79      | -1.39 | 383      | 3     | 1     | 2     | 4     | 0.79      | -1.98 | 501      | 3     | 1     | 3     | 3     | 0.78      | -1.60 |
| 291      | 3     | 1     | 1     | 4     | 0.78      | -1.57 | 386      | 3     | 1     | 2     | 4     | 0.78      | -1.63 | 507      | 3     | 1     | 3     | 3     | 0.79      | -1.91 |
| 292      | 3     | 1     | 1     | 4     | 0.8       | -1.72 | 393      | 3     | 1     | 2     | 4     | 0.78      | -2.01 | 509      | 3     | 1     | 3     | 3     | 0.78      | -1.34 |
| 294      | 3     | 1     | 1     | 4     | 0.79      | -1.64 | 395      | 3     | 1     | 2     | 4     | 0.77      | -2.22 | 511      | 3     | 1     | 3     | 3     | 0.78      | -1.62 |
| 296      | 3     | 1     | 1     | 4     | 0.79      | -1.65 | 396      | 3     | 1     | 2     | 4     | 0.78      | -1.75 | 513      | 3     | 1     | 3     | 3     | 0.79      | -1.37 |
| 297      | 3     | 1     | 1     | 4     | 0.8       | -1.29 | 403      | 3     | 1     | 2     | 4     | 0.77      | -1.55 | 517      | 3     | 1     | 3     | 3     | 0.79      | -1.53 |
| 298      | 3     | 1     | 1     | 4     | 0.79      | -2.19 | 404      | 3     | 1     | 2     | 4     | 0.77      | -1.91 | 519      | 3     | 1     | 3     | 3     | 0.79      | -1.76 |
| 299      | 3     | 1     | 1     | 4     | 0.79      | -1.65 | 409      | 3     | 1     | 3     | 4     | 0.76      | -1.62 | 521      | 3     | 1     | 3     | 3     | 0.77      | -2.01 |
| 300      | 3     | 1     | 1     | 4     | 0.79      | -1.68 | 410      | 3     | 1     | 3     | 4     | 0.77      | -1.48 | 523      | 3     | 1     | 3     | 3     | 0.77      | -1.95 |
| 301      | 3     | 1     | 1     | 4     | 0.79      | -1.55 | 411      | 3     | 1     | 3     | 4     | 0.77      | -1.05 | 524      | 3     | 1     | 3     | 3     | 0.77      | -1.86 |
| 306      | 3     | 1     | 1     | 4     | 0.77      | -1.68 | 413      | 3     | 1     | 3     | 4     | 0.75      | -1.78 | 526      | 3     | 1     | 3     | 3     | 0.78      | -1.81 |
| 307      | 3     | 1     | 1     | 4     | 0.78      | -1.50 | 415      | 3     | 1     | 3     | 4     | 0.79      | -1.64 | 528      | 3     | 1     | 3     | 3     | 0.79      | -2.32 |
| 308      | 3     | 1     | 1     | 4     | 0.78      | -1.52 | 416      | 3     | 1     | 3     | 4     | 0.75      | -1.75 | 529      | 3     | 1     | 3     | 3     | 0.77      | -2.17 |
| 310      | 3     | 1     | 1     | 4     | 0.79      | -2.14 | 418      | 3     | 1     | 3     | 4     | 0.76      | -1.62 | 530      | 3     | 1     | 3     | 3     | 0.78      | -2.39 |
| 312      | 3     | 1     | 1     | 4     | 0.78      | -1.62 | 422      | 3     | 1     | 3     | 4     | 0.76      | -1.73 | 542      | 3     | 1     | 1     | 1     | 0.78      | -1.35 |
| 314      | 3     | 1     | 1     | 4     | 0.79      | -1.77 | 424      | 3     | 1     | 3     | 4     | 0.79      | -1.71 | 543      | 3     | 1     | 1     | 1     | 0.72      | -1.79 |
| 315      | 3     | 1     | 1     | 4     | 0.8       | -1.98 | 425      | 3     | 1     | 3     | 4     | 0.77      | -1.23 | 549      | 3     | 1     | 1     | 1     | 0.76      | -1.64 |
| 316      | 3     | 1     | 1     | 4     | 0.78      | -1.59 | 426      | 3     | 1     | 3     | 4     | 0.76      | -2.06 | 550      | 3     | 1     | 1     | 1     | 0.75      | -1.49 |
| 317      | 3     | 1     | 1     | 4     | 0.8       | -2.03 | 427      | 3     | 1     | 3     | 4     | 0.76      | -1.96 | 551      | 3     | 1     | 1     | 1     | 0.75      | -1.68 |
| 318      | 3     | 1     | 1     | 4     | 0.77      | -1.59 | 428      | 3     | 1     | 3     | 4     | 0.78      | -2.14 | 552      | 3     | 1     | 1     | 1     | 0.75      | -1.45 |
| 319      | 3     | 1     | 1     | 4     | 0.78      | -1.52 | 430      | 3     | 1     | 3     | 4     | 0.77      | -1.51 | 553      | 3     | 1     | 1     | 1     | 0.75      | -1.13 |

| genotype | Ttemp | Tmois | Otemp | Omois | qP0  | op    | genotype | Ttemp | Tmois | Otemp | Omois | qP0  | op    |
|----------|-------|-------|-------|-------|------|-------|----------|-------|-------|-------|-------|------|-------|
| 556      | 3     | 1     | 1     | 1     | 0.77 | -1.64 | 653      | 3     | 1     | 3     | 1     | 0.77 | -1.28 |
| 557      | 3     | 1     | 1     | 1     | 0.79 | -1.42 | 654      | 3     | 1     | 3     | 1     | 0.78 | -1.68 |
| 558      | 3     | 1     | 1     | 1     | 0.77 | -1.76 | 656      | 3     | 1     | 3     | 1     | 0.79 | -1.53 |
| 560      | 3     | 1     | 1     | 1     | 0.77 | -2.06 | 657      | 3     | 1     | 3     | 1     | 0.79 | -1.39 |
| 573      | 3     | 1     | 1     | 1     | 0.78 | -1.48 | 658      | 3     | 1     | 3     | 1     | 0.77 | -1.50 |
| 574      | 3     | 1     | 1     | 1     | 0.77 | -1.50 | 663      | 3     | 1     | 3     | 1     | 0.78 | -1.83 |
| 576      | 3     | 1     | 1     | 1     | 0.75 | -1.51 | 672      | 3     | 1     | 3     | 1     | 0.78 | -1.98 |
| 579      | 3     | 1     | 1     | 1     | 0.77 | -1.73 | 677      | 3     | 1     | 3     | 1     | 0.77 | -1.46 |
| 580      | 3     | 1     | 1     | 1     | 0.78 | -2.20 | 678      | 3     | 1     | 3     | 1     | 0.76 | -1.42 |
| 581      | 3     | 1     | 1     | 1     | 0.8  | -1.67 | 680      | 3     | 1     | 3     | 1     | 0.77 | -1.62 |
| 582      | 3     | 1     | 1     | 1     | 0.75 | -1.59 | 681      | 3     | 1     | 3     | 1     | 0.77 | -1.51 |
| 583      | 3     | 1     | 1     | 1     | 0.77 | -1.52 | 682      | 3     | 1     | 3     | 1     | 0.78 | -1.34 |
| 584      | 3     | 1     | 1     | 1     | 0.77 | -2.20 | 683      | 3     | 1     | 3     | 1     | 0.79 | -1.70 |
| 586      | 3     | 1     | 1     | 1     | 0.77 | -1.26 | 684      | 3     | 1     | 3     | 1     | 0.8  | -2.12 |
| 587      | 3     | 1     | 1     | 1     | 0.78 | -1.70 | 685      | 3     | 1     | 3     | 1     | 0.78 | -1.71 |
| 588      | 3     | 1     | 1     | 1     | 0.81 | -1.87 | 686      | 3     | 1     | 3     | 1     | 0.8  | -2.38 |
| 589      | 3     | 1     | 1     | 1     | 0.79 | -1.85 | 687      | 3     | 1     | 3     | 1     | 0.78 | -1.57 |
| 590      | 3     | 1     | 1     | 1     | 0.78 | -2.20 | 688      | 3     | 1     | 3     | 1     | 0.78 | -1.55 |
| 591      | 3     | 1     | 2     | 1     | 0.75 | -1.91 | 691      | 3     | 1     | 3     | 1     | 0.79 | -1.52 |
| 592      | 3     | 1     | 2     | 1     | 0.78 | -1.35 | 693      | 3     | 1     | 3     | 1     | 0.8  | -1.71 |
| 594      | 3     | 1     | 2     | 1     | 0.78 | -1.73 | 694      | 3     | 1     | 3     | 1     | 0.79 | -1.76 |
| 596      | 3     | 1     | 2     | 1     | 0.79 | -1.83 | 704      | 3     | 1     | 3     | 1     | 0.79 | -1.87 |
| 597      | 3     | 1     | 2     | 1     | 0.79 | -1.84 | 705      | 3     | 1     | 3     | 1     | 0.81 | -2.27 |
| 599      | 3     | 1     | 2     | 1     | 0.79 | -1.42 | 708      | 3     | 1     | 3     | 1     | 0.77 | -2.25 |
| 601      | 3     | 1     | 2     | 1     | 0.75 | -1.67 | 710      | 3     | 1     | 3     | 1     | 0.77 | -1.81 |
| 603      | 3     | 1     | 2     | 1     | 0.76 | -1.32 |          |       |       |       |       |      |       |
| 604      | 3     | 1     | 2     | 1     | 0.79 | -1.25 |          |       |       |       |       |      |       |
| 605      | 3     | 1     | 2     | 1     | 0.78 | -1.73 |          |       |       |       |       |      |       |
| 606      | 3     | 1     | 2     | 1     | 0.78 | -1.67 |          |       |       |       |       |      |       |
| 607      | 3     | 1     | 2     | 1     | 0.76 | -1.45 |          |       |       |       |       |      |       |
| 611      | 3     | 1     | 2     | 1     | 0.79 | -1.70 |          |       |       |       |       |      |       |
| 614      | 3     | 1     | 2     | 1     | 0.78 | -1.50 |          |       |       |       |       |      |       |
| 616      | 3     | 1     | 2     | 1     | 0.76 | -1.71 |          |       |       |       |       |      |       |
| 622      | 3     | 1     | 2     | 1     | 0.78 | -1.60 |          |       |       |       |       |      |       |
| 625      | 3     | 1     | 2     | 1     | 0.77 | -1.49 |          |       |       |       |       |      |       |
| 626      | 3     | 1     | 2     | 1     | 0.79 | -1.91 |          |       |       |       |       |      |       |
| 639      | 3     | 1     | 2     | 1     | 0.78 | -1.65 |          |       |       |       |       |      |       |
| 640      | 3     | 1     | 2     | 1     | 0.8  | -1.70 |          |       |       |       |       |      |       |
| 641      | 3     | 1     | 2     | 1     | 0.78 | -1.94 |          |       |       |       |       |      |       |
| 643      | 3     | 1     | 2     | 1     | 0.79 | -1.58 |          |       |       |       |       |      |       |
| 645      | 3     | 1     | 2     | 1     | 0.78 | -1.63 |          |       |       |       |       |      |       |
| 646      | 3     | 1     | 2     | 1     | 0.77 | -1.77 |          |       |       |       |       |      |       |
| 648      | 3     | 1     | 2     | 1     | 0.75 | -1.92 |          |       |       |       |       |      |       |

Part 2: First experiment: SLA (specific leaf area) and PN (net photosynthetic rate)

| genotype | Ttemp | Tmois | Otemp | Omois | SLA  | PN   | genotype | Ttemp | Tmois | Otemp | Omois | SLA  | PN   | genotype | Ttemp | Tmois | Otemp | Omois | SLA  | PN   |
|----------|-------|-------|-------|-------|------|------|----------|-------|-------|-------|-------|------|------|----------|-------|-------|-------|-------|------|------|
| 297      | 1     | 4     | 1     | 4     | 16.9 | 4.7  | 307      | 3     | 4     | 1     | 4     | 24.3 | 4.35 | 316      | 1     | 1     | 1     | 4     | 27.8 | 11.2 |
| 300      | 1     | 4     | 1     | 4     | 12.3 | 2.36 | 308      | 3     | 4     | 1     | 4     | 18.1 | 5.8  | 318      | 1     | 1     | 1     | 4     | 25.7 | 10.4 |
| 306      | 1     | 4     | 1     | 4     | 12.4 | 1.72 | 312      | 3     | 4     | 1     | 4     | 15.8 | 3.25 | 319      | 1     | 1     | 1     | 4     | 31.7 | 11.1 |
| 307      | 1     | 4     | 1     | 4     | 13.3 | 1.96 | 316      | 3     | 4     | 1     | 4     | 14.5 | 1.33 | 322      | 1     | 1     | 1     | 4     | 26.1 | 9.35 |
| 308      | 1     | 4     | 1     | 4     | 12.3 | 1.44 | 318      | 3     | 4     | 1     | 4     | 17.3 | 4.35 | 411      | 1     | 1     | 3     | 4     | 23.3 | 13   |
| 312      | 1     | 4     | 1     | 4     | 15   | 2.98 | 319      | 3     | 4     | 1     | 4     | 17.8 | 2.02 | 418      | 1     | 1     | 3     | 4     | 20.5 | 11.1 |
| 316      | 1     | 4     | 1     | 4     | 12.6 | 5.2  | 322      | 3     | 4     | 1     | 4     | 20.8 | 3.99 | 422      | 1     | 1     | 3     | 4     | 25.6 | 11.5 |
| 318      | 1     | 4     | 1     | 4     | 11.9 | 2.24 | 411      | 3     | 4     | 3     | 4     | 23.8 | 6.74 | 425      | 1     | 1     | 3     | 4     | 24.9 | 9.2  |
| 319      | 1     | 4     | 1     | 4     | 12.8 | 2.81 | 418      | 3     | 4     | 3     | 4     | 24   | 3.88 | 430      | 1     | 1     | 3     | 4     | 19.6 | 13.3 |
| 322      | 1     | 4     | 1     | 4     | 14.8 | 4.89 | 422      | 3     | 4     | 3     | 4     | 21.7 | 4.3  | 431      | 1     | 1     | 3     | 4     | 26.7 | 8.54 |
| 411      | 1     | 4     | 3     | 4     | 14.5 | 1.44 | 425      | 3     | 4     | 3     | 4     | 21.4 | 5.98 | 432      | 1     | 1     | 3     | 4     | 21.8 | 4.74 |
| 418      | 1     | 4     | 3     | 4     | 15.4 | 1.52 | 430      | 3     | 4     | 3     | 4     | 22.3 | 5.9  | 433      | 1     | 1     | 3     | 4     | 22.7 | 15.3 |
| 422      | 1     | 4     | 3     | 4     | 14.5 | 1.89 | 431      | 3     | 4     | 3     | 4     | 20.7 | 2.31 | 443      | 1     | 1     | 3     | 4     | 27.2 | 6.25 |
| 425      | 1     | 4     | 3     | 4     | 15.7 | 1.18 | 432      | 3     | 4     | 3     | 4     | 19.4 | 1.99 | 447      | 1     | 1     | 3     | 4     | 25.1 | 6.6  |
| 430      | 1     | 4     | 3     | 4     | 12.8 | 4.77 | 433      | 3     | 4     | 3     | 4     | 17.8 | 1.3  | 543      | 1     | 1     | 1     | 1     | 20.8 | 9.71 |
| 431      | 1     | 4     | 3     | 4     | 15   | 7.09 | 443      | 3     | 4     | 3     | 4     | 18.6 | 3.66 | 549      | 1     | 1     | 1     | 1     | 24.1 | 7.39 |
| 432      | 1     | 4     | 3     | 4     | 13.8 | 1.48 | 447      | 3     | 4     | 3     | 4     | 19.7 | 3.25 | 551      | 1     | 1     | 1     | 1     | 23.8 | 6.2  |
| 433      | 1     | 4     | 3     | 4     | 15   | 2.56 | 543      | 3     | 4     | 1     | 1     | 21.2 | 5.72 | 552      | 1     | 1     | 1     | 1     | 27.5 | 14.5 |
| 443      | 1     | 4     | 3     | 4     | 13.3 | 1.51 | 549      | 3     | 4     | 1     | 1     | 21.7 | 2.31 | 553      | 1     | 1     | 1     | 1     | 23.8 | 8.92 |
| 447      | 1     | 4     | 3     | 4     | 15.2 | 4.06 | 551      | 3     | 4     | 1     | 1     | 15.6 | 2.65 | 576      | 1     | 1     | 1     | 1     | 28.3 | 10.9 |
| 543      | 1     | 4     | 1     | 1     | 15.1 | 2.29 | 552      | 3     | 4     | 1     | 1     | 19.2 | 3.51 | 579      | 1     | 1     | 1     | 1     | 26.4 | 10.2 |
| 549      | 1     | 4     | 1     | 1     | 13.5 | 5.8  | 553      | 3     | 4     | 1     | 1     | 16.6 | 2.57 | 582      | 1     | 1     | 1     | 1     | 23   | 9.49 |
| 551      | 1     | 4     | 1     | 1     | 12.4 | 3.05 | 576      | 3     | 4     | 1     | 1     | 20.1 | 2.34 | 583      | 1     | 1     | 1     | 1     | 25.2 | 10.5 |
| 552      | 1     | 4     | 1     | 1     | 13   | 2.14 | 579      | 3     | 4     | 1     | 1     | 20.8 | 5.04 | 586      | 1     | 1     | 1     | 1     | 28.3 | 7.11 |
| 553      | 1     | 4     | 1     | 1     | 13.1 | 0.43 | 582      | 3     | 4     | 1     | 1     | 17.4 | 3.35 | 653      | 1     | 1     | 3     | 1     | 30.2 | 12.3 |
| 576      | 1     | 4     | 1     | 1     | 12.5 | 3.39 | 583      | 3     | 4     | 1     | 1     | 14.7 | 4.98 | 654      | 1     | 1     | 3     | 1     | 25.3 | 15.2 |
| 579      | 1     | 4     | 1     | 1     | 12.5 | 6.17 | 586      | 3     | 4     | 1     | 1     | 16.2 | 2.39 | 658      | 1     | 1     | 3     | 1     | 24.8 | 16.4 |
| 582      | 1     | 4     | 1     | 1     | 0    | NA   | 653      | 3     | 4     | 3     | 1     | 0    | 1.66 | 677      | 1     | 1     | 3     | 1     | 17.3 | 13.1 |
| 583      | 1     | 4     | 1     | 1     | 12.3 | 5.57 | 654      | 3     | 4     | 3     | 1     | 20.2 | 5.63 | 678      | 1     | 1     | 3     | 1     | 23.6 | 11.7 |
| 586      | 1     | 4     | 1     | 1     | 11.7 | 5.31 | 658      | 3     | 4     | 3     | 1     | 17.5 | 1.68 | 680      | 1     | 1     | 3     | 1     | 24.3 | 12.4 |
| 653      | 1     | 4     | 3     | 1     | 15.5 | 0.95 | 677      | 3     | 4     | 3     | 1     | 16   | 7.43 | 681      | 1     | 1     | 3     | 1     | 31.6 | 5.79 |
| 654      | 1     | 4     | 3     | 1     | 14.3 | 8.76 | 678      | 3     | 4     | 3     | 1     | 17.3 | 6.62 | 682      | 1     | 1     | 3     | 1     | 23.4 | 11   |
| 658      | 1     | 4     | 3     | 1     | 13.1 | 3.49 | 680      | 3     | 4     | 3     | 1     | 17.9 | 0.31 | 687      | 1     | 1     | 3     | 1     | 32.2 | 5.45 |
| 677      | 1     | 4     | 3     | 1     | 11.9 | 3.69 | 681      | 3     | 4     | 3     | 1     | 16.3 | 1.37 | 691      | 1     | 1     | 3     | 1     | 25.5 | 8.43 |
| 678      | 1     | 4     | 3     | 1     | 15.5 | 5.46 | 682      | 3     | 4     | 3     | 1     | 18.7 | 2.8  | 297      | 3     | 1     | 1     | 4     | 19.9 | 10.5 |
| 680      | 1     | 4     | 3     | 1     | 14.6 | 2.47 | 687      | 3     | 4     | 3     | 1     | 19   | 5.04 | 300      | 3     | 1     | 1     | 4     | 26.3 | 7.42 |
| 681      | 1     | 4     | 3     | 1     | 14.2 | 3.25 | 691      | 3     | 4     | 3     | 1     | 16.4 | 2.08 | 306      | 3     | 1     | 1     | 4     | 23.3 | 6.49 |
| 682      | 1     | 4     | 3     | 1     | 16.8 | 1.66 | 297      | 1     | 1     | 1     | 4     | 22.6 | 10.5 | 307      | 3     | 1     | 1     | 4     | 20.3 | 7.74 |
| 687      | 1     | 4     | 3     | 1     | 13.5 | 2.17 | 300      | 1     | 1     | 1     | 4     | 26.6 | 15.5 | 308      | 3     | 1     | 1     | 4     | 19.8 | 6.29 |
| 691      | 1     | 4     | 3     | 1     | 13   | 2.3  | 306      | 1     | 1     | 1     | 4     | 25.2 | 11.7 | 312      | 3     | 1     | 1     | 4     | 22.2 | 7.03 |
| 297      | 3     | 4     | 1     | 4     | 25.3 | 5    | 307      | 1     | 1     | 1     | 4     | 30.6 | 14.2 | 316      | 3     | 1     | 1     | 4     | 26.7 | 3.72 |
| 300      | 3     | 4     | 1     | 4     | 21.8 | 5.01 | 308      | 1     | 1     | 1     | 4     | 23.1 | 9.23 | 318      | 3     | 1     | 1     | 4     | 19.8 | 5.57 |
| 306      | 3     | 4     | 1     | 4     | 15.7 | 4.24 | 312      | 1     | 1     | 1     | 4     | 26   | 9.9  | 319      | 3     | 1     | 1     | 4     | 22.7 | 5.28 |

| genotype | Ttemp | Tmois | Otemp | Omois | SLA  | PN   |
|----------|-------|-------|-------|-------|------|------|
| 322      | 3     | 1     | 1     | 4     | 20.5 | 6.24 |
| 411      | 3     | 1     | 3     | 4     | 23.2 | 10   |
| 418      | 3     | 1     | 3     | 4     | 20.6 | 6.02 |
| 422      | 3     | 1     | 3     | 4     | 35.6 | 6.86 |
| 425      | 3     | 1     | 3     | 4     | 23.4 | 5.59 |
| 430      | 3     | 1     | 3     | 4     | 26.5 | 5.67 |
| 431      | 3     | 1     | 3     | 4     | 26   | 4.81 |
| 432      | 3     | 1     | 3     | 4     | 28.1 | 7.25 |
| 433      | 3     | 1     | 3     | 4     | 23.1 | 7.99 |
| 443      | 3     | 1     | 3     | 4     | 25.8 | 3.14 |
| 447      | 3     | 1     | 3     | 4     | 19.5 | 4.04 |
| 543      | 3     | 1     | 1     | 1     | 19.4 | 5.86 |
| 549      | 3     | 1     | 1     | 1     | 24.4 | 4.75 |
| 551      | 3     | 1     | 1     | 1     | 21.3 | 5.46 |
| 552      | 3     | 1     | 1     | 1     | 18.2 | 8.22 |
| 553      | 3     | 1     | 1     | 1     | 25.9 | 5.15 |
| 576      | 3     | 1     | 1     | 1     | 24.4 | 4.63 |
| 579      | 3     | 1     | 1     | 1     | 24.1 | 8.09 |
| 582      | 3     | 1     | 1     | 1     | 20.8 | 4.85 |
| 583      | 3     | 1     | 1     | 1     | 21.5 | 7.91 |
| 586      | 3     | 1     | 1     | 1     | 30.7 | 5.62 |
| 653      | 3     | 1     | 3     | 1     | 21.4 | 8.38 |
| 654      | 3     | 1     | 3     | 1     | 22.7 | 8.53 |
| 658      | 3     | 1     | 3     | 1     | 26.1 | 10.9 |
| 677      | 3     | 1     | 3     | 1     | 19.8 | 6.43 |
| 678      | 3     | 1     | 3     | 1     | 34.7 | 6.1  |
| 680      | 3     | 1     | 3     | 1     | 31.2 | 3.72 |
| 681      | 3     | 1     | 3     | 1     | 26.5 | 2.91 |
| 682      | 3     | 1     | 3     | 1     | 25.6 | 6.82 |
| 687      | 3     | 1     | 3     | 1     | 27.8 | 4.71 |
| 691      | 3     | 1     | 3     | 1     | 22.5 | 7.28 |

### Part 3: First experiment: stomatal size and stomatal density

| genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density |
|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|
| 55       | 1     | 4     | 2     | 2     | 27.4   | 59.3      | 307      | 1     | 4     | 1     | 4     | 26.5   | 85.3      | 579      | 1     | 4     | 1     | 1     | 26.2   | 73.7      |
| 56       | 1     | 4     | 2     | 2     | 24.2   | 88.8      | 308      | 1     | 4     | 1     | 4     | 24.4   | 74.1      | 582      | 1     | 4     | 1     | 1     | 19.1   | 70.6      |
| 64       | 1     | 4     | 2     | 2     | 27.8   | 61.8      | 312      | 1     | 4     | 1     | 4     | 30.7   | 65.4      | 583      | 1     | 4     | 1     | 1     | 26.3   | 57.2      |
| 68       | 1     | 4     | 2     | 2     | 29.9   | 69.8      | 316      | 1     | 4     | 1     | 4     | 25.8   | 85.7      | 586      | 1     | 4     | 1     | 1     | 25.2   | 14.2      |
| 69       | 1     | 4     | 2     | 2     | 29     | 44.4      | 318      | 1     | 4     | 1     | 4     | 25.1   | 62        | 591      | 1     | 4     | 2     | 1     | 31.1   | 54.5      |
| 70       | 1     | 4     | 2     | 2     | 35.8   | 41.9      | 319      | 1     | 4     | 1     | 4     | 26.2   | 62.7      | 594      | 1     | 4     | 2     | 1     | 28.1   | 34.6      |
| 76       | 1     | 4     | 2     | 2     | 29.9   | 42.7      | 322      | 1     | 4     | 1     | 4     | 25.3   | 71        | 597      | 1     | 4     | 2     | 1     | 27.8   | 45.7      |
| 78       | 1     | 4     | 2     | 2     | 24.4   | 44.5      | 353      | 1     | 4     | 2     | 4     | NA     | NA        | 599      | 1     | 4     | 2     | 1     | 30     | 49.8      |
| 99       | 1     | 4     | 2     | 2     | 30.1   | 91.5      | 359      | 1     | 4     | 2     | 4     | 30.1   | 40.5      | 601      | 1     | 4     | 2     | 1     | 33.5   | 36.1      |
| 101      | 1     | 4     | 2     | 2     | 35.7   | 39.4      | 362      | 1     | 4     | 2     | 4     | 29.7   | 76.5      | 603      | 1     | 4     | 2     | 1     | 31.4   | 63.3      |
| 120      | 1     | 4     | 3     | 2     | 25.7   | 55.7      | 363      | 1     | 4     | 2     | 4     | 30.7   | 65.1      | 605      | 1     | 4     | 2     | 1     | 29.2   | 68.5      |
| 121      | 1     | 4     | 3     | 2     | 29     | 43.8      | 368      | 1     | 4     | 2     | 4     | 32.4   | 28.2      | 614      | 1     | 4     | 2     | 1     | 28     | 34.9      |
| 122      | 1     | 4     | 3     | 2     | 25.9   | 93.2      | 378      | 1     | 4     | 2     | 4     | 30.2   | 38.9      | 622      | 1     | 4     | 2     | 1     | 34.6   | 46.5      |
| 125      | 1     | 4     | 3     | 2     | 25.7   | 60.7      | 386      | 1     | 4     | 2     | 4     | 23.8   | 62.1      | 640      | 1     | 4     | 2     | 1     | 29     | 36.1      |
| 131      | 1     | 4     | 3     | 2     | 21.6   | 69.2      | 396      | 1     | 4     | 2     | 4     | 27.6   | 42.8      | 653      | 1     | 4     | 3     | 1     | 24.4   | 53.2      |
| 135      | 1     | 4     | 3     | 2     | NA     | NA        | 403      | 1     | 4     | 2     | 4     | 33.9   | 47.6      | 654      | 1     | 4     | 3     | 1     | 32.7   | 39        |
| 141      | 1     | 4     | 3     | 2     | 29.8   | 47.4      | 404      | 1     | 4     | 2     | 4     | 27.8   | 57.8      | 658      | 1     | 4     | 3     | 1     | 26.3   | 68.5      |
| 145      | 1     | 4     | 3     | 2     | 30.4   | 47.2      | 411      | 1     | 4     | 3     | 4     | 30.3   | 71.3      | 677      | 1     | 4     | 3     | 1     | 26.3   | 75.1      |
| 146      | 1     | 4     | 3     | 2     | 32.9   | 37.2      | 418      | 1     | 4     | 3     | 4     | 25.5   | 79        | 678      | 1     | 4     | 3     | 1     | 30.7   | 45.1      |
| 147      | 1     | 4     | 3     | 2     | 27.6   | 102       | 422      | 1     | 4     | 3     | 4     | 28.3   | 72.9      | 680      | 1     | 4     | 3     | 1     | NA     | NA        |
| 181      | 1     | 4     | 1     | 3     | 25.2   | 55.9      | 425      | 1     | 4     | 3     | 4     | 28.6   | 65.1      | 681      | 1     | 4     | 3     | 1     | 26.3   | 71.5      |
| 186      | 1     | 4     | 1     | 3     | 32.7   | 53.4      | 430      | 1     | 4     | 3     | 4     | 29.9   | 30.7      | 682      | 1     | 4     | 3     | 1     | 26.5   | 57.3      |
| 196      | 1     | 4     | 1     | 3     | 29     | 55.6      | 431      | 1     | 4     | 3     | 4     | 27.5   | 83        | 687      | 1     | 4     | 3     | 1     | 30.6   | 43.5      |
| 200      | 1     | 4     | 1     | 3     | 29.5   | 33.2      | 432      | 1     | 4     | 3     | 4     | NA     | NA        | 691      | 1     | 4     | 3     | 1     | 28     | 67.4      |
| 206      | 1     | 4     | 1     | 3     | 27.7   | 45.2      | 433      | 1     | 4     | 3     | 4     | 33.8   | 67.5      | 55       | 3     | 4     | 2     | 2     | 28.9   | 66.3      |
| 208      | 1     | 4     | 1     | 3     | 28.4   | 60.6      | 443      | 1     | 4     | 3     | 4     | 32.8   | 59.9      | 56       | 3     | 4     | 2     | 2     | 24     | 49.2      |
| 209      | 1     | 4     | 1     | 3     | 34.6   | 53.7      | 447      | 1     | 4     | 3     | 4     | 30.9   | 43.1      | 64       | 3     | 4     | 2     | 2     | 24.2   | 49.7      |
| 216      | 1     | 4     | 1     | 3     | 27.1   | 40.6      | 472      | 1     | 4     | 3     | 3     | 29.1   | 58.8      | 68       | 3     | 4     | 2     | 2     | 23     | 79.9      |
| 218      | 1     | 4     | 1     | 3     | 27.6   | 66.2      | 480      | 1     | 4     | 3     | 3     | 25.4   | 42.5      | 69       | 3     | 4     | 2     | 2     | 19.4   | 73.3      |
| 219      | 1     | 4     | 1     | 3     | 27.1   | 84.2      | 483      | 1     | 4     | 3     | 3     | 25.5   | 68.2      | 70       | 3     | 4     | 2     | 2     | 36     | 40        |
| 242      | 1     | 4     | 2     | 3     | 27.3   | 84.8      | 490      | 1     | 4     | 3     | 3     | 30.4   | 42.1      | 76       | 3     | 4     | 2     | 2     | 29.2   | 54.8      |
| 246      | 1     | 4     | 2     | 3     | 24.5   | 61.9      | 511      | 1     | 4     | 3     | 3     | 29.4   | 66.5      | 78       | 3     | 4     | 2     | 2     | NA     | NA        |
| 250      | 1     | 4     | 2     | 3     | 30.4   | 79.8      | 513      | 1     | 4     | 3     | 3     | 23     | 63.7      | 99       | 3     | 4     | 2     | 2     | 27.2   | 87.8      |
| 256      | 1     | 4     | 2     | 3     | 34     | 41.6      | 517      | 1     | 4     | 3     | 3     | 26.9   | 75.4      | 101      | 3     | 4     | 2     | 2     | 35.7   | 54.8      |
| 261      | 1     | 4     | 2     | 3     | 24.6   | 55.8      | 519      | 1     | 4     | 3     | 3     | 25.4   | 64.2      | 120      | 3     | 4     | 3     | 2     | 26.6   | 35.1      |
| 264      | 1     | 4     | 2     | 3     | 35.7   | 24.2      | 524      | 1     | 4     | 3     | 3     | 24.9   | 51.5      | 121      | 3     | 4     | 3     | 2     | 29.4   | 48.4      |
| 265      | 1     | 4     | 2     | 3     | 26.9   | 47.7      | 526      | 1     | 4     | 3     | 3     | 27.8   | 39        | 122      | 3     | 4     | 3     | 2     | 25.2   | 48.2      |
| 271      | 1     | 4     | 2     | 3     | 30.9   | 32.1      | 543      | 1     | 4     | 1     | 1     | 30.6   | 57.3      | 125      | 3     | 4     | 3     | 2     | 26.5   | 37.5      |
| 274      | 1     | 4     | 2     | 3     | 32.2   | 52.1      | 549      | 1     | 4     | 1     | 1     | 27     | 64.9      | 131      | 3     | 4     | 3     | 2     | 28.5   | 37.1      |
| 287      | 1     | 4     | 2     | 3     | 34.6   | 71.5      | 551      | 1     | 4     | 1     | 1     | 30.1   | 54.7      | 135      | 3     | 4     | 3     | 2     | 26.7   | 58.6      |
| 297      | 1     | 4     | 1     | 4     | 17.9   | 67        | 552      | 1     | 4     | 1     | 1     | 26.5   | 56.6      | 141      | 3     | 4     | 3     | 2     | 34     | 40.8      |
| 300      | 1     | 4     | 1     | 4     | 30.7   | 59.7      | 553      | 1     | 4     | 1     | 1     | 23.3   | 67.3      | 145      | 3     | 4     | 3     | 2     | 33.7   | 55.6      |
| 306      | 1     | 4     | 1     | 4     | 25.1   | 78.1      | 576      | 1     | 4     | 1     | 1     | 26.4   | 52.1      | 146      | 3     | 4     | 3     | 2     | 29.4   | 27.1      |

| genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density |
|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|
| 147      | 3     | 4     | 3     | 2     | 27.2   | 72.2      | 422      | 3     | 4     | 3     | 4     | 28.4   | 51.6      | 680      | 3     | 4     | 3     | 1     | 29.4   | 66.9      |
| 181      | 3     | 4     | 1     | 3     | 25.2   | 69.1      | 425      | 3     | 4     | 3     | 4     | 31.3   | 57.4      | 681      | 3     | 4     | 3     | 1     | 29.8   | 58.3      |
| 186      | 3     | 4     | 1     | 3     | 36.6   | 34.2      | 430      | 3     | 4     | 3     | 4     | 26.3   | 31.7      | 682      | 3     | 4     | 3     | 1     | 27.5   | 37.8      |
| 196      | 3     | 4     | 1     | 3     | 22.2   | 45.4      | 431      | 3     | 4     | 3     | 4     | 27.5   | 44.5      | 687      | 3     | 4     | 3     | 1     | 28.7   | 67.3      |
| 200      | 3     | 4     | 1     | 3     | 30.9   | 75.7      | 432      | 3     | 4     | 3     | 4     | 29.7   | 57.5      | 691      | 3     | 4     | 3     | 1     | 28     | 67.1      |
| 206      | 3     | 4     | 1     | 3     | 32.5   | 39        | 433      | 3     | 4     | 3     | 4     | 29.6   | 39.4      | 55       | 1     | 1     | 2     | 2     | 28.9   | 64        |
| 208      | 3     | 4     | 1     | 3     | NA     | NA        | 443      | 3     | 4     | 3     | 4     | 26.8   | 63.4      | 56       | 1     | 1     | 2     | 2     | 27.7   | 82.7      |
| 209      | 3     | 4     | 1     | 3     | 27.6   | 70.3      | 447      | 3     | 4     | 3     | 4     | 33.9   | 42        | 64       | 1     | 1     | 2     | 2     | NA     | NA        |
| 216      | 3     | 4     | 1     | 3     | 29.4   | 60.9      | 472      | 3     | 4     | 3     | 3     | 34.4   | 36.1      | 68       | 1     | 1     | 2     | 2     | 27.3   | 67.3      |
| 218      | 3     | 4     | 1     | 3     | 26.5   | 88.8      | 480      | 3     | 4     | 3     | 3     | 29.2   | 62.9      | 69       | 1     | 1     | 2     | 2     | 27.5   | 67.7      |
| 219      | 3     | 4     | 1     | 3     | 25.3   | 99.4      | 483      | 3     | 4     | 3     | 3     | 24.5   | 84.4      | 70       | 1     | 1     | 2     | 2     | 31     | 55.4      |
| 242      | 3     | 4     | 2     | 3     | 27     | 81.3      | 490      | 3     | 4     | 3     | 3     | 32.5   | 60.2      | 76       | 1     | 1     | 2     | 2     | 27.2   | 37.1      |
| 246      | 3     | 4     | 2     | 3     | 23.7   | 67.8      | 511      | 3     | 4     | 3     | 3     | 31.1   | 47.9      | 78       | 1     | 1     | 2     | 2     | 26.9   | 64.8      |
| 250      | 3     | 4     | 2     | 3     | 29.3   | 52.8      | 513      | 3     | 4     | 3     | 3     | 27.5   | 78.4      | 99       | 1     | 1     | 2     | 2     | 31.8   | 76.5      |
| 256      | 3     | 4     | 2     | 3     | 30.9   | 40.4      | 517      | 3     | 4     | 3     | 3     | 29     | 68.9      | 101      | 1     | 1     | 2     | 2     | 32.8   | 50.5      |
| 261      | 3     | 4     | 2     | 3     | 25.3   | 56.7      | 519      | 3     | 4     | 3     | 3     | 29.6   | 33.5      | 120      | 1     | 1     | 3     | 2     | 25.9   | 33.2      |
| 264      | 3     | 4     | 2     | 3     | 31.2   | 33        | 524      | 3     | 4     | 3     | 3     | 26.3   | 61.8      | 121      | 1     | 1     | 3     | 2     | 29     | 58        |
| 265      | 3     | 4     | 2     | 3     | 30.9   | 37.7      | 526      | 3     | 4     | 3     | 3     | 28.7   | 43.4      | 122      | 1     | 1     | 3     | 2     | 27.9   | 82.7      |
| 271      | 3     | 4     | 2     | 3     | 31.4   | 66.6      | 543      | 3     | 4     | 1     | 1     | 25.3   | 86.8      | 125      | 1     | 1     | 3     | 2     | 25.6   | 45.8      |
| 274      | 3     | 4     | 2     | 3     | 30.9   | 41.7      | 549      | 3     | 4     | 1     | 1     | 32.2   | 57.7      | 131      | 1     | 1     | 3     | 2     | 28.1   | 42.9      |
| 287      | 3     | 4     | 2     | 3     | 31.9   | 46.9      | 551      | 3     | 4     | 1     | 1     | 32.1   | 46.8      | 135      | 1     | 1     | 3     | 2     | 25     | 85.3      |
| 297      | 3     | 4     | 1     | 4     | 24.2   | 77.3      | 552      | 3     | 4     | 1     | 1     | 24.6   | 73.1      | 141      | 1     | 1     | 3     | 2     | NA     | NA        |
| 300      | 3     | 4     | 1     | 4     | 28.5   | 105       | 553      | 3     | 4     | 1     | 1     | 22.4   | 50.9      | 145      | 1     | 1     | 3     | 2     | 31.6   | 54.9      |
| 306      | 3     | 4     | 1     | 4     | 29.8   | 94.1      | 576      | 3     | 4     | 1     | 1     | 26.1   | 78.4      | 146      | 1     | 1     | 3     | 2     | 31.4   | 46.6      |
| 307      | 3     | 4     | 1     | 4     | 27.8   | 78.6      | 579      | 3     | 4     | 1     | 1     | 32.1   | 50.8      | 147      | 1     | 1     | 3     | 2     | 30.7   | 50.3      |
| 308      | 3     | 4     | 1     | 4     | 25.8   | 94.7      | 582      | 3     | 4     | 1     | 1     | 25.6   | 74        | 181      | 1     | 1     | 1     | 3     | 27.2   | 68.5      |
| 312      | 3     | 4     | 1     | 4     | 25.9   | 109       | 583      | 3     | 4     | 1     | 1     | 29     | 56.1      | 186      | 1     | 1     | 1     | 3     | 28     | 60.2      |
| 316      | 3     | 4     | 1     | 4     | 28.1   | 79.2      | 586      | 3     | 4     | 1     | 1     | 30.2   | 32.5      | 196      | 1     | 1     | 1     | 3     | NA     | NA        |
| 318      | 3     | 4     | 1     | 4     | 27.1   | 93        | 591      | 3     | 4     | 2     | 1     | 31.5   | 44.6      | 200      | 1     | 1     | 1     | 3     | 30.5   | 70.9      |
| 319      | 3     | 4     | 1     | 4     | 27.3   | 82.4      | 594      | 3     | 4     | 2     | 1     | 30.2   | 56.6      | 206      | 1     | 1     | 1     | 3     | 30.3   | 50.2      |
| 322      | 3     | 4     | 1     | 4     | 26.5   | 114       | 597      | 3     | 4     | 2     | 1     | 22     | 110       | 208      | 1     | 1     | 1     | 3     | 29.6   | 62        |
| 353      | 3     | 4     | 2     | 4     | 28.6   | 47.1      | 599      | 3     | 4     | 2     | 1     | 31     | 55.5      | 209      | 1     | 1     | 1     | 3     | 27.2   | 68.6      |
| 359      | 3     | 4     | 2     | 4     | 29.6   | 62.3      | 601      | 3     | 4     | 2     | 1     | 29.4   | 53.6      | 216      | 1     | 1     | 1     | 3     | 28.4   | 65.4      |
| 362      | 3     | 4     | 2     | 4     | 32.7   | 55.5      | 603      | 3     | 4     | 2     | 1     | 30.5   | 68.5      | 218      | 1     | 1     | 1     | 3     | 28.3   | 77.7      |
| 363      | 3     | 4     | 2     | 4     | 30.3   | 44.2      | 605      | 3     | 4     | 2     | 1     | 30.3   | 60.5      | 219      | 1     | 1     | 1     | 3     | 29.2   | 127       |
| 368      | 3     | 4     | 2     | 4     | 32.3   | 37.6      | 614      | 3     | 4     | 2     | 1     | 24.5   | 47.8      | 242      | 1     | 1     | 2     | 3     | 28.8   | 80.7      |
| 378      | 3     | 4     | 2     | 4     | 30.9   | 58.1      | 622      | 3     | 4     | 2     | 1     | 31.2   | 33.3      | 246      | 1     | 1     | 2     | 3     | 29.6   | 63.5      |
| 386      | 3     | 4     | 2     | 4     | 24.9   | 62.7      | 640      | 3     | 4     | 2     | 1     | 22.1   | 49.9      | 250      | 1     | 1     | 2     | 3     | 28.4   | 65        |
| 396      | 3     | 4     | 2     | 4     | 20.6   | 112       | 653      | 3     | 4     | 3     | 1     | 32.8   | 57.5      | 256      | 1     | 1     | 2     | 3     | 33.9   | 67.6      |
| 403      | 3     | 4     | 2     | 4     | 24.5   | 113       | 654      | 3     | 4     | 3     | 1     | 31     | 88.2      | 261      | 1     | 1     | 2     | 3     | 23.2   | 64.6      |
| 404      | 3     | 4     | 2     | 4     | 28.2   | 51        | 658      | 3     | 4     | 3     | 1     | 29.9   | 83.8      | 264      | 1     | 1     | 2     | 3     | 28.3   | 30.1      |
| 411      | 3     | 4     | 3     | 4     | NA     | NA        | 677      | 3     | 4     | 3     | 1     | 27.2   | 76.2      | 265      | 1     | 1     | 2     | 3     | 28.1   | 43.2      |
| 418      | 3     | 4     | 3     | 4     | 25.6   | 42.3      | 678      | 3     | 4     | 3     | 1     | 33.3   | 49.2      | 271      | 1     | 1     | 2     | 3     | 31.4   | 39.4      |

| genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density | genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density |
|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|----------|-------|-------|-------|-------|--------|-----------|
| 274      | 1     | 1     | 2     | 3     | 27.6   | 42.2      | 549      | 1     | 1     | 1     | 1     | 29.5   | 49.1      | 131      | 3     | 1     | 3     | 2     | 29.9   | 70.8      |
| 287      | 1     | 1     | 2     | 3     | 31.7   | 61.2      | 551      | 1     | 1     | 1     | 1     | 27     | 57.3      | 135      | 3     | 1     | 3     | 2     | 29     | 56.5      |
| 297      | 1     | 1     | 1     | 4     | 29.1   | 61.9      | 552      | 1     | 1     | 1     | 1     | 24.7   | 79.3      | 141      | 3     | 1     | 3     | 2     | 32.1   | 39.7      |
| 300      | 1     | 1     | 1     | 4     | 25.9   | 106       | 553      | 1     | 1     | 1     | 1     | 23.1   | 107       | 145      | 3     | 1     | 3     | 2     | 32     | 52        |
| 306      | 1     | 1     | 1     | 4     | 26.3   | 77.5      | 576      | 1     | 1     | 1     | 1     | 30.3   | 46.8      | 146      | 3     | 1     | 3     | 2     | 33.6   | 41.6      |
| 307      | 1     | 1     | 1     | 4     | 26     | 107       | 579      | 1     | 1     | 1     | 1     | 26.2   | 76.8      | 147      | 3     | 1     | 3     | 2     | 28.9   | 53.7      |
| 308      | 1     | 1     | 1     | 4     | 29     | 88.4      | 582      | 1     | 1     | 1     | 1     | 28.3   | 51        | 181      | 3     | 1     | 1     | 3     | 35.9   | 62.3      |
| 312      | 1     | 1     | 1     | 4     | 26.1   | 81.2      | 583      | 1     | 1     | 1     | 1     | 21     | 109       | 186      | 3     | 1     | 1     | 3     | 34.5   | 61.9      |
| 316      | 1     | 1     | 1     | 4     | 26     | 41.5      | 586      | 1     | 1     | 1     | 1     | 31.4   | 42.7      | 196      | 3     | 1     | 1     | 3     | 34.5   | 42.8      |
| 318      | 1     | 1     | 1     | 4     | 26.3   | 77.1      | 591      | 1     | 1     | 2     | 1     | 28.3   | 61.6      | 200      | 3     | 1     | 1     | 3     | 32.5   | 33.6      |
| 319      | 1     | 1     | 1     | 4     | 28.8   | 70.9      | 594      | 1     | 1     | 2     | 1     | 29.3   | 69.5      | 206      | 3     | 1     | 1     | 3     | 36.2   | 27.7      |
| 322      | 1     | 1     | 1     | 4     | 21.5   | 109       | 597      | 1     | 1     | 2     | 1     | 24.6   | 52.9      | 208      | 3     | 1     | 1     | 3     | 26.3   | 78        |
| 353      | 1     | 1     | 2     | 4     | 27.4   | 78        | 599      | 1     | 1     | 2     | 1     | 29.4   | 39.3      | 209      | 3     | 1     | 1     | 3     | 28.4   | 51.5      |
| 359      | 1     | 1     | 2     | 4     | 24.4   | 54.6      | 601      | 1     | 1     | 2     | 1     | 31.4   | 45.5      | 216      | 3     | 1     | 1     | 3     | 33.9   | 44.7      |
| 362      | 1     | 1     | 2     | 4     | 29.5   | 86        | 603      | 1     | 1     | 2     | 1     | 28     | 51.7      | 218      | 3     | 1     | 1     | 3     | 29.1   | 83.8      |
| 363      | 1     | 1     | 2     | 4     | 30     | 63.1      | 605      | 1     | 1     | 2     | 1     | 31.2   | 35.6      | 219      | 3     | 1     | 1     | 3     | 27.2   | 122       |
| 368      | 1     | 1     | 2     | 4     | 25.9   | 26.8      | 614      | 1     | 1     | 2     | 1     | NA     | NA        | 242      | 3     | 1     | 2     | 3     | 35.6   | 76.3      |
| 378      | 1     | 1     | 2     | 4     | 27.1   | 92.3      | 622      | 1     | 1     | 2     | 1     | NA     | NA        | 246      | 3     | 1     | 2     | 3     | 28.1   | 62.1      |
| 386      | 1     | 1     | 2     | 4     | 18.2   | 37.6      | 640      | 1     | 1     | 2     | 1     | 27.2   | 53.1      | 250      | 3     | 1     | 2     | 3     | 27.3   | 71.9      |
| 396      | 1     | 1     | 2     | 4     | 22.1   | 72.9      | 653      | 1     | 1     | 3     | 1     | 35.3   | 73.5      | 256      | 3     | 1     | 2     | 3     | 28.9   | 64.7      |
| 403      | 1     | 1     | 2     | 4     | 27.5   | 62        | 654      | 1     | 1     | 3     | 1     | 30.2   | 52.1      | 261      | 3     | 1     | 2     | 3     | 21.8   | 51.9      |
| 404      | 1     | 1     | 2     | 4     | 24     | 79.1      | 658      | 1     | 1     | 3     | 1     | 33.5   | 55        | 264      | 3     | 1     | 2     | 3     | 32     | 29        |
| 411      | 1     | 1     | 3     | 4     | 24.9   | 62.8      | 677      | 1     | 1     | 3     | 1     | 33     | 57.1      | 265      | 3     | 1     | 2     | 3     | 29.8   | 31.4      |
| 418      | 1     | 1     | 3     | 4     | 31.3   | 56.7      | 678      | 1     | 1     | 3     | 1     | 30.8   | 50.4      | 271      | 3     | 1     | 2     | 3     | 34.6   | 57.3      |
| 422      | 1     | 1     | 3     | 4     | 28.9   | 67.9      | 680      | 1     | 1     | 3     | 1     | 24.5   | 64.3      | 274      | 3     | 1     | 2     | 3     | 32     | 45.6      |
| 425      | 1     | 1     | 3     | 4     | 32.2   | 44.7      | 681      | 1     | 1     | 3     | 1     | 30.1   | 91.5      | 287      | 3     | 1     | 2     | 3     | 33.3   | 38.2      |
| 430      | 1     | 1     | 3     | 4     | 30.9   | 34.4      | 682      | 1     | 1     | 3     | 1     | 27.6   | 56.5      | 297      | 3     | 1     | 1     | 4     | 26.6   | 84.3      |
| 431      | 1     | 1     | 3     | 4     | 28.1   | 50.6      | 687      | 1     | 1     | 3     | 1     | 28.1   | 105       | 300      | 3     | 1     | 1     | 4     | 26.5   | 97.3      |
| 432      | 1     | 1     | 3     | 4     | 29     | 71.5      | 691      | 1     | 1     | 3     | 1     | 33.4   | 77.8      | 306      | 3     | 1     | 1     | 4     | 29.4   | 113       |
| 433      | 1     | 1     | 3     | 4     | 32.9   | 50.4      | 55       | 3     | 1     | 2     | 2     | 23.4   | 74        | 307      | 3     | 1     | 1     | 4     | 27.6   | 73.3      |
| 443      | 1     | 1     | 3     | 4     | 28.6   | 49        | 56       | 3     | 1     | 2     | 2     | 30.3   | 82.4      | 308      | 3     | 1     | 1     | 4     | NA     | 84.8      |
| 447      | 1     | 1     | 3     | 4     | 31.3   | 53        | 64       | 3     | 1     | 2     | 2     | 25.3   | 69.8      | 312      | 3     | 1     | 1     | 4     | 31.4   | 85        |
| 472      | 1     | 1     | 3     | 3     | 29     | 50.7      | 68       | 3     | 1     | 2     | 2     | 27.3   | 66.8      | 316      | 3     | 1     | 1     | 4     | 21.2   | 114       |
| 480      | 1     | 1     | 3     | 3     | 27.6   | 77.6      | 69       | 3     | 1     | 2     | 2     | 26.1   | 49.7      | 318      | 3     | 1     | 1     | 4     | 27.5   | 87.2      |
| 483      | 1     | 1     | 3     | 3     | 27     | 60.1      | 70       | 3     | 1     | 2     | 2     | 28.9   | 62.6      | 319      | 3     | 1     | 1     | 4     | 29.9   | 88.8      |
| 490      | 1     | 1     | 3     | 3     | NA     | NA        | 76       | 3     | 1     | 2     | 2     | 28.4   | 46.2      | 322      | 3     | 1     | 1     | 4     | 29.6   | 73.6      |
| 511      | 1     | 1     | 3     | 3     | 27.1   | 69.8      | 78       | 3     | 1     | 2     | 2     | 26.1   | 64.4      | 353      | 3     | 1     | 2     | 4     | 30.3   | 45.3      |
| 513      | 1     | 1     | 3     | 3     | 30.6   | 72.4      | 99       | 3     | 1     | 2     | 2     | 28.8   | 71.8      | 359      | 3     | 1     | 2     | 4     | 24.2   | 70.7      |
| 517      | 1     | 1     | 3     | 3     | 28.7   | 58.3      | 101      | 3     | 1     | 2     | 2     | 31.3   | 45.8      | 362      | 3     | 1     | 2     | 4     | 30.2   | 34.2      |
| 519      | 1     | 1     | 3     | 3     | 32.3   | 41.3      | 120      | 3     | 1     | 3     | 2     | 25.7   | 51.3      | 363      | 3     | 1     | 2     | 4     | 31.8   | 38.1      |
| 524      | 1     | 1     | 3     | 3     | 29.8   | 75.2      | 121      | 3     | 1     | 3     | 2     | 25.3   | 72.3      | 368      | 3     | 1     | 2     | 4     | 32.9   | 35.9      |
| 526      | 1     | 1     | 3     | 3     | 29.8   | 70.3      | 122      | 3     | 1     | 3     | 2     | 28.4   | 68        | 378      | 3     | 1     | 2     | 4     | 32.2   | 79.9      |
| 543      | 1     | 1     | 1     | 1     | 24.7   | 77.2      | 125      | 3     | 1     | 3     | 2     | 32.5   | 32.4      | 386      | 3     | 1     | 2     | 4     | 24.3   | 51.1      |

| genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density |
|----------|-------|-------|-------|-------|--------|-----------|
| 396      | 3     | 1     | 2     | 4     | 27.8   | 53.4      |
| 403      | 3     | 1     | 2     | 4     | 29.5   | 53.5      |
| 404      | 3     | 1     | 2     | 4     | 27.3   | 44.8      |
| 411      | 3     | 1     | 3     | 4     | 28     | 53.9      |
| 418      | 3     | 1     | 3     | 4     | 31.7   | 57.1      |
| 422      | 3     | 1     | 3     | 4     | 29.9   | 78.3      |
| 425      | 3     | 1     | 3     | 4     | 28.4   | 56.1      |
| 430      | 3     | 1     | 3     | 4     | 30.2   | 55.8      |
| 431      | 3     | 1     | 3     | 4     | 25.1   | 61.2      |
| 432      | 3     | 1     | 3     | 4     | 29     | 76.9      |
| 433      | 3     | 1     | 3     | 4     | 32.4   | 44        |
| 443      | 3     | 1     | 3     | 4     | 31.2   | 61.9      |
| 447      | 3     | 1     | 3     | 4     | 29     | 46.8      |
| 472      | 3     | 1     | 3     | 3     | 32.1   | 43.5      |
| 480      | 3     | 1     | 3     | 3     | 28.1   | 48.8      |
| 483      | 3     | 1     | 3     | 3     | 32.8   | 60        |
| 490      | 3     | 1     | 3     | 3     | 33.4   | 48.3      |
| 511      | 3     | 1     | 3     | 3     | 33.3   | 45        |
| 513      | 3     | 1     | 3     | 3     | 28.8   | 60.5      |
| 517      | 3     | 1     | 3     | 3     | 27.1   | 60        |
| 519      | 3     | 1     | 3     | 3     | 29.2   | 60.1      |
| 524      | 3     | 1     | 3     | 3     | 30.1   | 52.2      |
| 526      | 3     | 1     | 3     | 3     | 29.5   | 56        |
| 543      | 3     | 1     | 1     | 1     | 31.4   | 49.2      |
| 549      | 3     | 1     | 1     | 1     | 31.7   | 69.6      |
| 551      | 3     | 1     | 1     | 1     | 28.2   | 77.9      |
| 552      | 3     | 1     | 1     | 1     | 27.2   | 64.2      |
| 553      | 3     | 1     | 1     | 1     | 25.4   | 69.6      |
| 576      | 3     | 1     | 1     | 1     | 34.5   | 28.4      |
| 579      | 3     | 1     | 1     | 1     | 24.6   | 54.9      |
| 582      | 3     | 1     | 1     | 1     | 27.7   | 64.6      |
| 583      | 3     | 1     | 1     | 1     | 30.6   | 57.7      |
| 586      | 3     | 1     | 1     | 1     | 29.4   | 46.4      |
| 591      | 3     | 1     | 2     | 1     | 31     | 41.2      |
| 594      | 3     | 1     | 2     | 1     | 23.7   | 50.8      |
| 597      | 3     | 1     | 2     | 1     | 29.2   | 81.2      |
| 599      | 3     | 1     | 2     | 1     | 32.3   | 38.3      |
| 601      | 3     | 1     | 2     | 1     | 30.7   | 52.7      |
| 603      | 3     | 1     | 2     | 1     | 31     | 66.5      |
| 605      | 3     | 1     | 2     | 1     | 30.2   | 49.4      |
| 614      | 3     | 1     | 2     | 1     | 28     | 22.2      |
| 622      | 3     | 1     | 2     | 1     | 32.8   | 34.7      |
| 640      | 3     | 1     | 2     | 1     | 23.2   | 49.4      |

| genotype | Ttemp | Tmois | Otemp | Omois | s.size | s.density |
|----------|-------|-------|-------|-------|--------|-----------|
| 653      | 3     | 1     | 3     | 1     | 33.5   | 66        |
| 654      | 3     | 1     | 3     | 1     | 35     | 85.6      |
| 658      | 3     | 1     | 3     | 1     | 33.4   | 65.4      |
| 677      | 3     | 1     | 3     | 1     | 32     | 53.7      |
| 678      | 3     | 1     | 3     | 1     | 30.5   | 50.9      |
| 680      | 3     | 1     | 3     | 1     | 24.7   | 79.4      |
| 681      | 3     | 1     | 3     | 1     | 27.8   | 55.6      |
| 682      | 3     | 1     | 3     | 1     | 25.5   | 65.4      |
| 687      | 3     | 1     | 3     | 1     | 25.8   | 74.6      |
| 691      | 3     | 1     | 3     | 1     | 29.9   | 48.8      |

## Part 4: Second experiment: All data

| genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|
| 307      | A         | WW        | 1     | 4     | 0.78      | -1.2 | 64.8      | 24     | 318      | C         | WW        | 1     | 4     | 0.77      | -1.3 | 73.3      | 23.9   |
| 307      | A         | WW        | 1     | 4     | 0.76      | -1.3 | 42.9      | 22.4   | 318      | C         | WW        | 1     | 4     | 0.76      | -1.4 | 110       | 23.1   |
| 307      | A         | WW        | 1     | 4     | 0.78      | -1.3 | 85.7      | 27.3   | 318      | C         | WW        | 1     | 4     | 0.74      | -1.4 | 96.2      | 25.3   |
| 307      | A         | WW        | 1     | 4     | 0.76      | -1.4 | 59        | 25.9   | 318      | C         | WW        | 1     | 4     | 0.74      | -1.2 | 54.3      | 25.3   |
| 307      | A         | WW        | 1     | 4     | 0.77      | -1.3 | 62.9      | 23.4   | 318      | C         | WW        | 1     | 4     | 0.77      | -1.3 | 53.3      | 21.6   |
| 307      | A         | WW        | 1     | 4     | 0.77      | -1.5 | 74.3      | 23.7   | 319      | A         | WW        | 1     | 4     | 0.76      | -1.3 | 37.1      | 25.6   |
| 307      | C         | WW        | 1     | 4     | 0.78      | -1.3 | 59        | 27.4   | 319      | A         | WW        | 1     | 4     | 0.77      | -1.2 | 77.1      | 30.7   |
| 307      | C         | WW        | 1     | 4     | 0.75      | -1.3 | 79        | 26     | 319      | A         | WW        | 1     | 4     | 0.75      | -1.5 | 56.2      | 23.1   |
| 307      | C         | WW        | 1     | 4     | 0.78      | -1.4 | 64.8      | 26.7   | 319      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 89.5      | 26.8   |
| 307      | C         | WW        | 1     | 4     | 0.79      | -1.4 | 62.9      | 28.1   | 319      | A         | WW        | 1     | 4     | 0.77      | -1.7 | 69.5      | 23.3   |
| 307      | C         | WW        | 1     | 4     | 0.79      | -1.3 | 64.8      | 26.4   | 319      | A         | WW        | 1     | 4     | 0.77      | -1.2 | 82.9      | 24     |
| 307      | C         | WW        | 1     | 4     | 0.74      | -1.5 | 0         | 0      | 319      | C         | WW        | 1     | 4     | 0.75      | -1.4 | 26.7      | 25.1   |
| 308      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 84.8      | 24.3   | 319      | C         | WW        | 1     | 4     | 0.77      | -1.2 | 78.1      | 29.9   |
| 308      | A         | WW        | 1     | 4     | 0.76      | -1.3 | 65.7      | 21.7   | 319      | C         | WW        | 1     | 4     | 0.77      | -1.5 | 78.1      | 24.9   |
| 308      | A         | WW        | 1     | 4     | 0.79      | -1.3 | 68.6      | 22.6   | 319      | C         | WW        | 1     | 4     | 0.8       | -1.5 | 107       | 22.4   |
| 308      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 77.1      | 24.6   | 319      | C         | WW        | 1     | 4     | 0.76      | -1.2 | 85.7      | 24.8   |
| 308      | A         | WW        | 1     | 4     | 0.78      | -1.4 | 60        | 24.9   | 319      | C         | WW        | 1     | 4     | 0.79      | -1.7 | 67.6      | 26.4   |
| 308      | A         | WW        | 1     | 4     | 0.77      | -1.2 | 75.2      | 24.2   | 322      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 105       | 23.2   |
| 308      | C         | WW        | 1     | 4     | 0.76      | -1.2 | 60        | 24.6   | 322      | A         | WW        | 1     | 4     | 0.78      | -1.4 | 43.8      | 29.6   |
| 308      | C         | WW        | 1     | 4     | 0.75      | -1.1 | 44.8      | 21.2   | 322      | A         | WW        | 1     | 4     | 0.79      | -1.4 | 66.7      | 19.8   |
| 308      | C         | WW        | 1     | 4     | 0.77      | -1.5 | 66.7      | 22.6   | 322      | A         | WW        | 1     | 4     | 0.79      | -1.4 | 82.9      | 22.2   |
| 308      | C         | WW        | 1     | 4     | 0.76      | -1.3 | 81.9      | 23.6   | 322      | A         | WW        | 1     | 4     | 0.76      | -1.5 | 86.7      | 29.3   |
| 308      | C         | WW        | 1     | 4     | 0.77      | -1.2 | 61        | 24     | 322      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 67.6      | 24.3   |
| 308      | C         | WW        | 1     | 4     | NA        | -1.3 | 47.1      | 28.8   | 322      | C         | WW        | 1     | 4     | 0.78      | -1.3 | 63.8      | 23.1   |
| 312      | A         | WW        | 1     | 4     | 0.76      | -1.5 | 81.9      | 20.9   | 322      | C         | WW        | 1     | 4     | 0.78      | -1.5 | 71.4      | 24.4   |
| 312      | A         | WW        | 1     | 4     | 0.78      | -1.2 | 76.2      | 20.2   | 322      | C         | WW        | 1     | 4     | 0.78      | -1.7 | 64.3      | 29.8   |
| 312      | A         | WW        | 1     | 4     | 0.78      | -1.4 | 61        | 26.1   | 322      | C         | WW        | 1     | 4     | 0.78      | -1.3 | 81        | 24.8   |
| 312      | A         | WW        | 1     | 4     | 0.79      | -1.6 | 85.7      | 24.9   | 322      | C         | WW        | 1     | 4     | 0.77      | -1.3 | 101       | 20.2   |
| 312      | A         | WW        | 1     | 4     | 0.77      | -1.3 | 48.6      | 26.3   | 322      | C         | WW        | 1     | 4     | 0.76      | -1.2 | 56.2      | 23.4   |
| 312      | A         | WW        | 1     | 4     | 0.75      | -1.3 | 45.7      | 25     | 411      | A         | WW        | 3     | 4     | 0.74      | -1.4 | 52.4      | 31.8   |
| 312      | C         | WW        | 1     | 4     | 0.77      | -1.2 | 64.8      | 23.9   | 411      | A         | WW        | 3     | 4     | 0.73      | -1.2 | 89.5      | 21.9   |
| 312      | C         | WW        | 1     | 4     | 0.76      | -1.1 | 58.1      | 25.3   | 411      | A         | WW        | 3     | 4     | 0.77      | -1.4 | 52.4      | 26.7   |
| 312      | C         | WW        | 1     | 4     | 0.75      | -1.5 | 51.4      | 27     | 411      | A         | WW        | 3     | 4     | 0.75      | -1.7 | 25.7      | 29.4   |
| 312      | C         | WW        | 1     | 4     | 0.75      | -1.2 | 73.3      | 26.2   | 411      | A         | WW        | 3     | 4     | 0.74      | -1.2 | 71.4      | 22.6   |
| 312      | C         | WW        | 1     | 4     | 0.79      | -1.4 | 53.3      | 27.6   | 411      | A         | WW        | 3     | 4     | 0.74      | -1.3 | 30.5      | 26.2   |
| 312      | C         | WW        | 1     | 4     | 0.79      | -1.2 | 60        | 25.7   | 411      | C         | WW        | 3     | 4     | 0.73      | -1.4 | 52.4      | 29     |
| 318      | A         | WW        | 1     | 4     | 0.77      | -1.4 | 82.9      | 24     | 411      | C         | WW        | 3     | 4     | NA        | -1.4 | 54.3      | 22.8   |
| 318      | A         | WW        | 1     | 4     | 0.77      | -1.3 | 61.9      | 23.8   | 411      | C         | WW        | 3     | 4     | 0.75      | -1.4 | 44.8      | 29.8   |
| 318      | A         | WW        | 1     | 4     | 0.78      | -1.4 | 100       | 23.8   | 411      | C         | WW        | 3     | 4     | 0.76      | -1.6 | 35.2      | 25.1   |
| 318      | A         | WW        | 1     | 4     | 0.79      | -1.4 | 81.9      | 27.1   | 411      | C         | WW        | 3     | 4     | 0.74      | -1.4 | 30        | 24.3   |
| 318      | A         | WW        | 1     | 4     | 0.76      | -1.2 | 76.2      | 22     | 411      | C         | WW        | 3     | 4     | 0.74      | -1.7 | 58.1      | 22.7   |
| 318      | A         | WW        | 1     | 4     | 0.76      | -1.3 | 35.2      | 26     | 422      | A         | WW        | 3     | 4     | 0.75      | -1.2 | 48.6      | 29.4   |
| 318      | C         | WW        | 1     | 4     | NA        | -1.4 | 75.2      | 24.3   | 422      | A         | WW        | 3     | 4     | 0.77      | -1.6 | 45.7      | 28.2   |

| genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|------|------|-----------|--------|----------|-----------|-----------|-------|-------|------|------|-----------|--------|
| 422 A    | WW        | 3         | 4     | 0.76  | -1.3 | 37.1 | 33.2      |        | 433 C    | WW        | 3         | 4     | 0.78  | -1.6 | 70.5 | 32.1      |        |
| 422 A    | WW        | 3         | 4     | 0.73  | -1.6 | 45.7 | 32.6      |        | 433 C    | WW        | 3         | 4     | 0.79  | -1.3 | 73.3 | 28.3      |        |
| 422 A    | WW        | 3         | 4     | 0.74  | -1.4 | 52.4 | 30.3      |        | 433 C    | WW        | 3         | 4     | 0.78  | -1.6 | 50   | 27.2      |        |
| 422 A    | WW        | 3         | 4     | 0.73  | -1.5 | 58.6 | 30.8      |        | 447 A    | WW        | 3         | 4     | 0.77  | -1.2 | 82.9 | 27.1      |        |
| 422 C    | WW        | 3         | 4     | 0.72  | -1.2 | 41   | 26.8      |        | 447 A    | WW        | 3         | 4     | 0.73  | NA   | 102  | 30.6      |        |
| 422 C    | WW        | 3         | 4     | 0.72  | -1.2 | 33.3 | 33.9      |        | 447 A    | WW        | 3         | 4     | 0.73  | -1.4 | 50.5 | 26.7      |        |
| 422 C    | WW        | 3         | 4     | 0.71  | -1.3 | 41.9 | 31        |        | 447 A    | WW        | 3         | 4     | 0.76  | -1.5 | 67.6 | 38.6      |        |
| 422 C    | WW        | 3         | 4     | 0.72  | -1.3 | 55.2 | 30.8      |        | 447 A    | WW        | 3         | 4     | 0.73  | -1.1 | 52.4 | 29.9      |        |
| 422 C    | WW        | 3         | 4     | 0.73  | -1.3 | 41   | 27        |        | 447 A    | WW        | 3         | 4     | 0.75  | -1.2 | 81.9 | 30.2      |        |
| 422 C    | WW        | 3         | 4     | 0.72  | -1.3 | 33.3 | 31.3      |        | 447 C    | WW        | 3         | 4     | 0.73  | -1.7 | 64.8 | 30.7      |        |
| 430 A    | WW        | 3         | 4     | 0.75  | -1.5 | 23.8 | 20.1      |        | 447 C    | WW        | 3         | 4     | 0.75  | -1.3 | 50.5 | 33.2      |        |
| 430 A    | WW        | 3         | 4     | 0.77  | -1.4 | 32.4 | 27.9      |        | 447 C    | WW        | 3         | 4     | 0.74  | -1.7 | 61.9 | 30.3      |        |
| 430 A    | WW        | 3         | 4     | 0.75  | -1.3 | 29.5 | 37.3      |        | 447 C    | WW        | 3         | 4     | 0.73  | -1.5 | 103  | 19.7      |        |
| 430 A    | WW        | 3         | 4     | 0.77  | -1.3 | 27.6 | 29.9      |        | 447 C    | WW        | 3         | 4     | 0.74  | -1.3 | 64.8 | 29.6      |        |
| 430 A    | WW        | 3         | 4     | 0.74  | -1.5 | 39   | 30.1      |        | 447 C    | WW        | 3         | 4     | 0.75  | -1.5 | 73.3 | 32.1      |        |
| 430 A    | WW        | 3         | 4     | 0.76  | -1.2 | 29.5 | 30.4      |        | 543 A    | WW        | 1         | 1     | 0.71  | -1.4 | 42.9 | 33.1      |        |
| 430 C    | WW        | 3         | 4     | 0.74  | -1.4 | 30.5 | 29.8      |        | 543 A    | WW        | 1         | 1     | 0.68  | -1.4 | 69.5 | 30        |        |
| 430 C    | WW        | 3         | 4     | 0.76  | -1.2 | 28.6 | 25.9      |        | 543 A    | WW        | 1         | 1     | 0.69  | -1.6 | 20   | 32        |        |
| 430 C    | WW        | 3         | 4     | 0.74  | -1.1 | NA   | 29.3      |        | 543 A    | WW        | 1         | 1     | 0.71  | -1.2 | 33.3 | 30        |        |
| 430 C    | WW        | 3         | 4     | 0.75  | -1.7 | 24.3 | 32.2      |        | 543 A    | WW        | 1         | 1     | 0.68  | -1.3 | 57.1 | 32        |        |
| 430 C    | WW        | 3         | 4     | 0.76  | -1.4 | 32.4 | 26.9      |        | 543 A    | WW        | 1         | 1     | 0.71  | NA   | 61   | 36        |        |
| 430 C    | WW        | 3         | 4     | 0.77  | -1.5 | 36.2 | 22.1      |        | 543 C    | WW        | 1         | 1     | 0.69  | -1.3 | 58.1 | 37        |        |
| 431 A    | WW        | 3         | 4     | 0.75  | -1.4 | 61   | 29.9      |        | 543 C    | WW        | 1         | 1     | 0.72  | -1.5 | 54.3 | 32        |        |
| 431 A    | WW        | 3         | 4     | 0.73  | -1.4 | 60   | 31.3      |        | 543 C    | WW        | 1         | 1     | NA    | -1.3 | 34.3 | 35        |        |
| 431 A    | WW        | 3         | 4     | 0.74  | -1.5 | 68.6 | 26.8      |        | 543 C    | WW        | 1         | 1     | 0.69  | -1.3 | 51.4 | 31        |        |
| 431 A    | WW        | 3         | 4     | 0.75  | -1.5 | 44.8 | 29.6      |        | 543 C    | WW        | 1         | 1     | 0.73  | -1.2 | 31.4 | 30        |        |
| 431 A    | WW        | 3         | 4     | 0.76  | -1.5 | 70.5 | 29.4      |        | 543 C    | WW        | 1         | 1     | 0.73  | -1.6 | 43.8 | 36        |        |
| 431 A    | WW        | 3         | 4     | 0.78  | -1.2 | 66.7 | 24        |        | 549 A    | WW        | 1         | 1     | 0.75  | NA   | 23.8 | 26.9      |        |
| 431 C    | WW        | 3         | 4     | 0.76  | -1.3 | 66.7 | 26        |        | 549 A    | WW        | 1         | 1     | 0.74  | -1.7 | 33.3 | 28.6      |        |
| 431 C    | WW        | 3         | 4     | 0.74  | -1.6 | 85.7 | 26.6      |        | 549 A    | WW        | 1         | 1     | 0.74  | -1.3 | 59   | 30.9      |        |
| 431 C    | WW        | 3         | 4     | 0.73  | -1.3 | 44.8 | 26.8      |        | 549 A    | WW        | 1         | 1     | 0.73  | -1.4 | 45.7 | 27        |        |
| 431 C    | WW        | 3         | 4     | 0.76  | -1.6 | 65.7 | 25.8      |        | 549 A    | WW        | 1         | 1     | 0.75  | -1.6 | 41   | 25        |        |
| 431 C    | WW        | 3         | 4     | 0.77  | -1.4 | 33.3 | 29.1      |        | 549 A    | WW        | 1         | 1     | 0.74  | -1.7 | 0    | 0         |        |
| 431 C    | WW        | 3         | 4     | 0.75  | NA   | 19   | 26.8      |        | 549 C    | WW        | 1         | 1     | 0.77  | -1.3 | 41   | 35.1      |        |
| 433 A    | WW        | 3         | 4     | 0.78  | -1.7 | 59   | 33        |        | 549 C    | WW        | 1         | 1     | 0.74  | -1.5 | 37.1 | 23        |        |
| 433 A    | WW        | 3         | 4     | 0.78  | -1.3 | 48.6 | 31.7      |        | 549 C    | WW        | 1         | 1     | 0.77  | -1.4 | 67.6 | 27        |        |
| 433 A    | WW        | 3         | 4     | 0.75  | -1.6 | 86.7 | 25.8      |        | 549 C    | WW        | 1         | 1     | 0.75  | -1.4 | 54.3 | 29        |        |
| 433 A    | WW        | 3         | 4     | 0.78  | -1.5 | 77.1 | 37        |        | 549 C    | WW        | 1         | 1     | 0.78  | -1.4 | 67.6 | 25        |        |
| 433 A    | WW        | 3         | 4     | 0.8   | -1.2 | 75.2 | 31.7      |        | 549 C    | WW        | 1         | 1     | 0.75  | -1.4 | 33.3 | 35        |        |
| 433 A    | WW        | 3         | 4     | 0.78  | -1.5 | 24.8 | 31.4      |        | 522 A    | WW        | 1         | 1     | 0.76  | -1.3 | 38.1 | 25.7      |        |
| 433 C    | WW        | 3         | 4     | 0.78  | -1.3 | 122  | 29.9      |        | 522 A    | WW        | 1         | 1     | 0.75  | -1.3 | 62.9 | 24        |        |
| 433 C    | WW        | 3         | 4     | 0.77  | -1.5 | 83.8 | 24.4      |        | 522 A    | WW        | 1         | 1     | 0.76  | -1.6 | 55.2 | 23        |        |
| 433 C    | WW        | 3         | 4     | 0.77  | -1.5 | NA   | 25.6      |        | 522 A    | WW        | 1         | 1     | 0.77  | -1.4 | 70.5 | 26        |        |

| genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|
| 552 A    | WW        | 1         | 1     | 0.73  | -1.6      | 59   | 25        |        | 579 C    | WW        | 1         | 1     | 0.73  | -1.5      | 67.6 | 24        |        |
| 552 A    | WW        | 1         | 1     | 0.74  | -1.7      | 47.6 | 22        |        | 654 A    | WW        | 3         | 1     | 0.74  | -1.2      | 49.5 | 32        |        |
| 552 C    | WW        | 1         | 1     | 0.77  | -1.4      | 53.3 | 26.4      |        | 654 A    | WW        | 3         | 1     | 0.75  | -1.4      | 39   | 33        |        |
| 552 C    | WW        | 1         | 1     | 0.75  | -1.4      | 55.2 | 24        |        | 654 A    | WW        | 3         | 1     | 0.75  | -1.3      | 38.1 | 27        |        |
| 552 C    | WW        | 1         | 1     | 0.76  | -1.6      | 50.5 | 23        |        | 654 A    | WW        | 3         | 1     | 0.77  | -1.2      | 48.6 | 35        |        |
| 552 C    | WW        | 1         | 1     | 0.74  | -1.5      | 56.2 | 28        |        | 654 A    | WW        | 3         | 1     | 0.77  | -1.2      | 61   | 41        |        |
| 552 C    | WW        | 1         | 1     | 0.74  | NA        | 76.2 | 26        |        | 654 A    | WW        | 3         | 1     | 0.76  | -1.6      | 62.9 | 36        |        |
| 552 C    | WW        | 1         | 1     | 0.74  | -1.6      | 44.8 | 24        |        | 654 C    | WW        | 3         | 1     | 0.75  | -1.4      | 42.9 | 36        |        |
| 553 A    | WW        | 1         | 1     | 0.78  | -1.4      | 29.5 | 30.7      |        | 654 C    | WW        | 3         | 1     | 0.75  | -1.2      | 58.1 | 37        |        |
| 553 A    | WW        | 1         | 1     | 0.69  | -1.4      | 61   | 27        |        | 654 C    | WW        | 3         | 1     | 0.75  | -1.3      | 41.9 | 32        |        |
| 553 A    | WW        | 1         | 1     | 0.75  | -1.5      | 55.2 | 26        |        | 654 C    | WW        | 3         | 1     | 0.73  | -1.3      | 31.4 | 32        |        |
| 553 A    | WW        | 1         | 1     | 0.63  | -1.3      | 65.7 | 23        |        | 654 C    | WW        | 3         | 1     | 0.74  | -1.3      | 53.3 | 37        |        |
| 553 A    | WW        | 1         | 1     | 0.76  | -1.6      | 48.6 | 28        |        | 654 C    | WW        | 3         | 1     | 0.76  | -1.4      | 55.2 | 31        |        |
| 553 A    | WW        | 1         | 1     | 0.75  | -1.3      | 61   | 26        |        | 654 A    | WW        | 3         | 1     | NA    | -1.4      | 50.5 | 33        |        |
| 553 C    | WW        | 1         | 1     | 0.74  | -1.5      | 69.5 | 23        |        | 678 A    | WW        | 3         | 1     | 0.77  | -1.5      | 42.9 | 36        |        |
| 553 C    | WW        | 1         | 1     | 0.77  | -1.4      | 74.3 | 21        |        | 678 A    | WW        | 3         | 1     | 0.76  | -1.7      | 56.2 | 30        |        |
| 553 C    | WW        | 1         | 1     | 0.73  | -1.4      | 44.8 | 25        |        | 678 A    | WW        | 3         | 1     | 0.76  | -1.3      | 54.3 | 30        |        |
| 553 C    | WW        | 1         | 1     | 0.74  | -1.4      | 61   | 24        |        | 678 A    | WW        | 3         | 1     | 0.79  | -1.5      | 59   | 32        |        |
| 553 C    | WW        | 1         | 1     | 0.74  | -1.4      | 72.4 | 25        |        | 678 A    | WW        | 3         | 1     | 0.76  | -1.3      | NA   | 35        |        |
| 553 C    | WW        | 1         | 1     | 0.71  | -1.4      | 64.8 | 28        |        | 678 C    | WW        | 3         | 1     | 0.76  | -1.4      | 43.8 | 27.4      |        |
| 576 A    | WW        | 1         | 1     | 0.74  | -1.4      | 45.7 | 37.6      |        | 678 C    | WW        | 3         | 1     | 0.78  | -1.2      | 63.8 | 33.6      |        |
| 576 A    | WW        | 1         | 1     | 0.73  | -1.5      | 53.3 | 33.7      |        | 678 C    | WW        | 3         | 1     | 0.78  | -1.3      | 42.9 | 35        |        |
| 576 A    | WW        | 1         | 1     | 0.77  | -1.6      | 24.8 | 30        |        | 678 C    | WW        | 3         | 1     | 0.77  | -1.4      | 40   | 30        |        |
| 576 A    | WW        | 1         | 1     | 0.73  | -1.5      | 56.2 | 33        |        | 678 C    | WW        | 3         | 1     | 0.78  | -1.2      | 57.1 | 32        |        |
| 576 A    | WW        | 1         | 1     | 0.77  | -1.5      | 60   | 30        |        | 678 C    | WW        | 3         | 1     | 0.78  | -1.3      | 54.3 | 33        |        |
| 576 A    | WW        | 1         | 1     | 0.75  | -1.6      | 50.5 | 28        |        | 680 A    | WW        | 3         | 1     | 0.78  | -1.3      | 58.1 | 25        |        |
| 576 C    | WW        | 1         | 1     | 0.77  | -1.6      | 60   | 30.6      |        | 680 A    | WW        | 3         | 1     | 0.75  | -1.5      | 48.6 | 30        |        |
| 576 C    | WW        | 1         | 1     | 0.75  | -1.3      | 40   | 32.9      |        | 680 A    | WW        | 3         | 1     | 0.77  | -1.4      | 32.4 | 27        |        |
| 576 C    | WW        | 1         | 1     | 0.75  | -1.3      | 50.5 | 28        |        | 680 A    | WW        | 3         | 1     | 0.79  | -1.2      | 61.9 | 26        |        |
| 576 C    | WW        | 1         | 1     | 0.78  | -1.4      | 56.2 | 32        |        | 680 A    | WW        | 3         | 1     | 0.79  | -1.4      | 26.7 | 33        |        |
| 576 C    | WW        | 1         | 1     | 0.77  | -1.6      | 43.8 | 31        |        | 680 A    | WW        | 3         | 1     | 0.78  | -1.3      | 48.6 | 30        |        |
| 576 C    | WW        | 1         | 1     | 0.75  | -1.6      | 49.5 | 28        |        | 680 C    | WW        | 3         | 1     | 0.76  | -1.2      | 72.4 | 32        |        |
| 579 A    | WW        | 1         | 1     | 0.75  | -1.6      | 54.3 | 26        |        | 680 C    | WW        | 3         | 1     | 0.74  | -1.3      | 61   | 34        |        |
| 579 A    | WW        | 1         | 1     | 0.74  | -1.3      | 41.9 | 30        |        | 680 C    | WW        | 3         | 1     | NA    | -1.4      | 56.2 | 30        |        |
| 579 A    | WW        | 1         | 1     | 0.69  | -1.4      | 59   | 27        |        | 680 C    | WW        | 3         | 1     | 0.78  | -1.3      | 58.1 | 30        |        |
| 579 A    | WW        | 1         | 1     | 0.76  | -1.4      | 50.5 | 26        |        | 680 C    | WW        | 3         | 1     | 0.75  | -1.2      | 41   | 35        |        |
| 579 A    | WW        | 1         | 1     | 0.74  | -1.2      | 47.6 | 25        |        | 680 C    | WW        | 3         | 1     | 0.78  | -1.3      | NA   | 33        |        |
| 579 A    | WW        | 1         | 1     | 0.77  | -1.4      | 32.4 | 30        |        | 681 A    | WW        | 3         | 1     | 0.77  | -1.3      | 46.7 | 31        |        |
| 579 C    | WW        | 1         | 1     | 0.72  | -1.3      | 45.7 | 32        |        | 681 A    | WW        | 3         | 1     | 0.78  | -1.6      | 37.1 | 37        |        |
| 579 C    | WW        | 1         | 1     | 0.75  | -1.2      | 45.7 | 29        |        | 681 A    | WW        | 3         | 1     | 0.78  | -1.5      | 45.7 | 27        |        |
| 579 C    | WW        | 1         | 1     | 0.73  | -1.4      | 46.7 | 29        |        | 681 A    | WW        | 3         | 1     | 0.72  | -1.4      | 43.8 | 28        |        |
| 579 C    | WW        | 1         | 1     | 0.73  | -1.6      | 21.9 | 34        |        | 681 A    | WW        | 3         | 1     | 0.78  | -1.4      | 50.5 | 27        |        |
| 579 C    | WW        | 1         | 1     | 0.74  | -1.2      | 56.2 | 31        |        | 681 A    | WW        | 3         | 1     | 0.76  | -1.2      | 37.1 | 34        |        |

| genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|
| 681 C    | WW        | 3         | 1     | 0.77  | -1.4      | 55.2 | 30        |        | 308 A    | CD        | 1         | 4     | 0.75  | -1.6      | 72.4 | 29.4      |        |
| 681 C    | WW        | 3         | 1     | 0.77  | -1.2      | 48.6 | 30        |        | 308 A    | CD        | 1         | 4     | 0.74  | -1.9      | 70.5 | 26.7      |        |
| 681 C    | WW        | 3         | 1     | 0.76  | -1.4      | 63.8 | 31        |        | 308 A    | CD        | 1         | 4     | 0.75  | -1.9      | 86.7 | 25.1      |        |
| 681 C    | WW        | 3         | 1     | 0.76  | NA        | NA   | 32        |        | 308 A    | CD        | 1         | 4     | 0.73  | -2.1      | 60   | 27.8      |        |
| 681 C    | WW        | 3         | 1     | 0.78  | -1.1      | 31.4 | 30        |        | 308 A    | CD        | 1         | 4     | 0.73  | -1.7      | 54.3 | 27.9      |        |
| 681 C    | WW        | 3         | 1     | 0.78  | -1.2      | 55.2 | 30        |        | 308 C    | CD        | 1         | 4     | 0.74  | -1.9      | 79   | 28.7      |        |
| 682 A    | WW        | 3         | 1     | 0.79  | -1.4      | 74.3 | 29.2      |        | 308 C    | CD        | 1         | 4     | 0.75  | -1.6      | 58.1 | 21.4      |        |
| 682 A    | WW        | 3         | 1     | 0.77  | -1.2      | 62.9 | 30        |        | 308 C    | CD        | 1         | 4     | 0.72  | -2.1      | 61   | 19.3      |        |
| 682 A    | WW        | 3         | 1     | 0.79  | -1.4      | 60   | 38        |        | 308 C    | CD        | 1         | 4     | 0.78  | NA        | 47.6 | 25.6      |        |
| 682 A    | WW        | 3         | 1     | 0.77  | -1.3      | 60   | 28        |        | 308 C    | CD        | 1         | 4     | 0.73  | -2.1      | 66.7 | 22.1      |        |
| 682 A    | WW        | 3         | 1     | 0.76  | -1.3      | 66.7 | 33        |        | 308 C    | CD        | 1         | 4     | 0.74  | NA        | 51.4 | 23.1      |        |
| 682 A    | WW        | 3         | 1     | 0.77  | -1.3      | 71.4 | 36        |        | 312 A    | CD        | 1         | 4     | 0.76  | -1.5      | 65.7 | 28.9      |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.2      | 55.2 | 32.8      |        | 312 A    | CD        | 1         | 4     | 0.74  | -1.7      | 63.8 | 30        |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.3      | 64.8 | 29        |        | 312 A    | CD        | 1         | 4     | 0.77  | -1.9      | 84.8 | 23.2      |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.5      | 59   | 33        |        | 312 A    | CD        | 1         | 4     | 0.73  | -1.6      | 62.9 | 29.8      |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.3      | 52.4 | 33        |        | 312 A    | CD        | 1         | 4     | 0.77  | -1.7      | 77.1 | 29.6      |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.3      | 26.7 | 33        |        | 312 A    | CD        | 1         | 4     | 0.73  | -1.9      | 44.8 | 21.2      |        |
| 682 C    | WW        | 3         | 1     | 0.77  | -1.4      | 57.1 | 33        |        | 312 C    | CD        | 1         | 4     | 0.74  | -2        | 80   | 28.4      |        |
| 691 A    | WW        | 3         | 1     | 0.75  | -1.3      | 49.5 | 34        |        | 312 C    | CD        | 1         | 4     | 0.76  | -2.1      | 54.3 | 27.1      |        |
| 691 A    | WW        | 3         | 1     | 0.78  | -1.3      | 38.1 | 31        |        | 312 C    | CD        | 1         | 4     | 0.78  | -1.8      | 78.1 | 26.6      |        |
| 691 A    | WW        | 3         | 1     | 0.78  | -1.7      | 47.6 | 34        |        | 312 C    | CD        | 1         | 4     | 0.77  | -1.6      | 49.5 | 20.6      |        |
| 691 A    | WW        | 3         | 1     | 0.78  | -1.3      | 47.6 | 30        |        | 312 C    | CD        | 1         | 4     | 0.77  | -2        | 57.1 | 25.4      |        |
| 691 A    | WW        | 3         | 1     | 0.77  | -1.4      | 41   | 26        |        | 312 C    | CD        | 1         | 4     | 0.74  | -2        | 41   | 25.2      |        |
| 691 A    | WW        | 3         | 1     | 0.77  | -1.4      | 35.2 | 31        |        | 318 A    | CD        | 1         | 4     | 0.75  | -1.9      | 43.8 | 25.9      |        |
| 691 C    | WW        | 3         | 1     | 0.79  | -1.5      | 79   | 28.8      |        | 318 A    | CD        | 1         | 4     | 0.76  | -1.8      | 83.8 | 22.9      |        |
| 691 C    | WW        | 3         | 1     | 0.77  | -1.7      | 45.7 | 38        |        | 318 A    | CD        | 1         | 4     | 0.77  | -1.8      | 61   | 29.6      |        |
| 691 C    | WW        | 3         | 1     | 0.81  | -1.5      | 75.2 | 33        |        | 318 A    | CD        | 1         | 4     | 0.74  | -1.8      | 89.5 | 26.6      |        |
| 691 C    | WW        | 3         | 1     | 0.78  | -1.3      | 57.1 | 34        |        | 318 A    | CD        | 1         | 4     | 0.75  | -1.8      | 51.4 | 30.4      |        |
| 691 C    | WW        | 3         | 1     | 0.79  | -1.2      | 34.3 | 28        |        | 318 A    | CD        | 1         | 4     | 0.73  | NA        | 36.2 | 24        |        |
| 691 C    | WW        | 3         | 1     | 0.77  | -1.5      | 66.7 | 35        |        | 318 C    | CD        | 1         | 4     | 0.75  | -1.5      | 45.7 | 26        |        |
| 307 A    | CD        | 1         | 4     | 0.75  | -1.8      | 51.4 | 28.8      |        | 318 C    | CD        | 1         | 4     | 0.77  | -2        | 55.2 | 28        |        |
| 307 A    | CD        | 1         | 4     | 0.69  | -1.6      | 47.6 | 24.1      |        | 318 C    | CD        | 1         | 4     | 0.74  | -1.8      | 68.6 | 25.2      |        |
| 307 A    | CD        | 1         | 4     | 0.74  | -2        | 82.9 | 23.1      |        | 318 C    | CD        | 1         | 4     | 0.75  | -2        | 80   | 26.9      |        |
| 307 A    | CD        | 1         | 4     | 0.73  | -2        | 54.3 | 27        |        | 318 C    | CD        | 1         | 4     | 0.77  | -2.4      | 36.2 | 26.8      |        |
| 307 A    | CD        | 1         | 4     | 0.76  | -2        | 76.2 | 25        |        | 318 C    | CD        | 1         | 4     | 0.74  | -1.8      | 43.8 | 24.6      |        |
| 307 A    | CD        | 1         | 4     | 0.78  | -1.7      | 29.5 | 23        |        | 319 A    | CD        | 1         | 4     | 0.74  | -2.2      | 100  | 22.6      |        |
| 307 C    | CD        | 1         | 4     | 0.79  | -1.4      | 39   | 22.6      |        | 319 A    | CD        | 1         | 4     | 0.74  | -2.1      | 46.7 | 19.4      |        |
| 307 C    | CD        | 1         | 4     | 0.75  | -1.8      | 48.6 | 26.2      |        | 319 A    | CD        | 1         | 4     | 0.77  | -1.9      | 62.9 | 24.4      |        |
| 307 C    | CD        | 1         | 4     | 0.76  | -1.8      | 65.7 | 28.2      |        | 319 A    | CD        | 1         | 4     | 0.74  | -2        | 35.2 | 21.8      |        |
| 307 C    | CD        | 1         | 4     | 0.78  | -1.8      | 62.9 | 22.8      |        | 319 A    | CD        | 1         | 4     | 0.76  | -1.8      | 102  | 27.2      |        |
| 307 C    | CD        | 1         | 4     | 0.74  | -1.7      | 64.8 | 30.2      |        | 319 A    | CD        | 1         | 4     | 0.78  | NA        | 52.4 | 27.8      |        |
| 307 C    | CD        | 1         | 4     | 0.76  | NA        | 80   | 26.4      |        | 319 C    | CD        | 1         | 4     | 0.73  | -2        | 81.9 | 26.8      |        |
| 308 A    | CD        | 1         | 4     | 0.76  | -2.1      | 36.2 | 22.9      |        | 319 C    | CD        | 1         | 4     | 0.75  | -1.8      | 76.2 | 29.3      |        |

| genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|------|------|-----------|--------|----------|-----------|-----------|-------|-------|------|------|-----------|--------|
| 319 C    | CD        |           | 1     | 4     | 0.76 | -2   | 68.6      | 28.6   | 430 A    | CD        |           | 3     | 4     | 0.76 | -2   | 45.7      | 25.7   |
| 319 C    | CD        |           | 1     | 4     | 0.74 | -1.8 | 38.1      | 29.7   | 430 A    | CD        |           | 3     | 4     | 0.76 | -1.9 | 65.7      | 30.3   |
| 319 C    | CD        |           | 1     | 4     | 0.74 | -2   | 41.9      | 28.9   | 430 A    | CD        |           | 3     | 4     | 0.75 | -2.2 | 30.5      | 30.7   |
| 319 C    | CD        |           | 1     | 4     | 0.77 | -1.8 | 46.7      | 23.2   | 430 C    | CD        |           | 3     | 4     | 0.75 | -2.1 | 33.3      | 31.1   |
| 322 A    | CD        |           | 1     | 4     | 0.75 | -1.8 | 35.2      | 25.2   | 430 C    | CD        |           | 3     | 4     | 0.76 | -1.8 | 29.5      | 31.3   |
| 322 A    | CD        |           | 1     | 4     | 0.75 | -1.8 | 61        | 29     | 430 C    | CD        |           | 3     | 4     | 0.74 | -2.1 | 41.9      | 34     |
| 322 A    | CD        |           | 1     | 4     | 0.76 | -2   | 66.7      | 28.6   | 430 C    | CD        |           | 3     | 4     | 0.73 | -2   | 57.1      | 27.9   |
| 322 A    | CD        |           | 1     | 4     | 0.76 | -2.3 | 52.4      | 30.1   | 430 C    | CD        |           | 3     | 4     | 0.74 | -2.1 | 38.1      | 29.1   |
| 322 A    | CD        |           | 1     | 4     | 0.75 | NA   | 82.9      | 25     | 430 C    | CD        |           | 3     | 4     | 0.77 | NA   | 54.3      | 32     |
| 322 A    | CD        |           | 1     | 4     | 0.76 | -2.5 | 52.4      | 15.8   | 431 A    | CD        |           | 3     | 4     | 0.73 | -2   | 45.7      | 35.3   |
| 322 C    | CD        |           | 1     | 4     | 0.76 | -1.7 | 62.9      | 28.6   | 431 A    | CD        |           | 3     | 4     | 0.74 | -1.5 | 75.2      | 30.4   |
| 322 C    | CD        |           | 1     | 4     | 0.75 | -2   | 53.3      | 27.4   | 431 A    | CD        |           | 3     | 4     | 0.71 | -2.4 | 54.3      | 30     |
| 322 C    | CD        |           | 1     | 4     | 0.74 | -1.4 | 78.1      | 26.6   | 431 A    | CD        |           | 3     | 4     | 0.74 | -2.4 | 41.9      | 39.9   |
| 322 C    | CD        |           | 1     | 4     | 0.76 | -1.7 | 43.8      | 29.8   | 431 A    | CD        |           | 3     | 4     | 0.71 | -1.9 | 66.7      | 32.8   |
| 322 C    | CD        |           | 1     | 4     | 0.75 | -1.6 | 44.8      | 32.4   | 431 A    | CD        |           | 3     | 4     | 0.76 | -2.2 | 51.4      | 34.4   |
| 322 C    | CD        |           | 1     | 4     | 0.76 | NA   | 90.5      | 28.1   | 431 C    | CD        |           | 3     | 4     | 0.72 | -2.2 | 61        | 34.2   |
| 411 A    | CD        |           | 3     | 4     | 0.71 | -2.6 | 34.3      | 25.1   | 431 C    | CD        |           | 3     | 4     | 0.66 | -2   | 64.8      | 32.9   |
| 411 A    | CD        |           | 3     | 4     | 0.75 | -2.1 | 42.9      | 29.2   | 431 C    | CD        |           | 3     | 4     | 0.75 | -2.3 | 34.3      | 30.1   |
| 411 A    | CD        |           | 3     | 4     | 0.74 | -2.4 | 47.6      | 33.6   | 431 C    | CD        |           | 3     | 4     | 0.68 | -2.7 | 61        | 27     |
| 411 A    | CD        |           | 3     | 4     | 0.74 | -2.1 | 67.6      | 33.4   | 431 C    | CD        |           | 3     | 4     | 0.74 | -2.3 | 84.8      | 30.4   |
| 411 A    | CD        |           | 3     | 4     | 0.74 | -2.5 | 56.2      | 34.3   | 431 C    | CD        |           | 3     | 4     | 0.74 | -2.5 | 62.9      | 31.8   |
| 411 A    | CD        |           | 3     | 4     | 0.74 | -2.5 | 38.1      | 33.1   | 433 A    | CD        |           | 3     | 4     | 0.78 | NA   | 53.3      | 32.8   |
| 411 C    | CD        |           | 3     | 4     | 0.74 | NA   | 67.6      | 33.2   | 433 A    | CD        |           | 3     | 4     | 0.74 | -2.5 | 40        | 35.2   |
| 411 C    | CD        |           | 3     | 4     | 0.72 | -2.1 | 47.6      | 33.9   | 433 A    | CD        |           | 3     | 4     | 0.78 | -1.7 | 63.8      | 32.2   |
| 411 C    | CD        |           | 3     | 4     | 0.74 | -2.5 | 57.1      | 31.7   | 433 A    | CD        |           | 3     | 4     | 0.75 | -2.1 | 61.9      | 35     |
| 411 C    | CD        |           | 3     | 4     | 0.67 | -2.4 | 68.6      | 37.7   | 433 A    | CD        |           | 3     | 4     | 0.76 | -2.4 | 48.6      | 38.3   |
| 411 C    | CD        |           | 3     | 4     | 0.71 | -2.6 | 62.9      | 36.4   | 433 A    | CD        |           | 3     | 4     | 0.77 | -2.5 | 43.8      | 30.6   |
| 411 C    | CD        |           | 3     | 4     | 0.75 | -2.4 | 61.9      | 35.8   | 433 C    | CD        |           | 3     | 4     | 0.77 | -2   | 107       | 27.7   |
| 422 A    | CD        |           | 3     | 4     | 0.75 | -2.2 | 44.8      | 35     | 433 C    | CD        |           | 3     | 4     | 0.76 | -2.3 | 61        | 27     |
| 422 A    | CD        |           | 3     | 4     | 0.74 | -1.6 | 48.6      | 34     | 433 C    | CD        |           | 3     | 4     | 0.75 | -2.6 | 68.6      | 30.2   |
| 422 A    | CD        |           | 3     | 4     | 0.73 | -2   | 32.4      | 33.9   | 433 C    | CD        |           | 3     | 4     | 0.78 | -2.2 | 63.8      | 35     |
| 422 A    | CD        |           | 3     | 4     | 0.75 | -2   | 44.8      | 31.4   | 433 C    | CD        |           | 3     | 4     | 0.77 | -1.9 | 77.1      | 28.8   |
| 422 A    | CD        |           | 3     | 4     | 0.69 | -2.4 | 40        | 40.3   | 433 C    | CD        |           | 3     | 4     | 0.77 | -2.5 | 79        | 28.3   |
| 422 A    | CD        |           | 3     | 4     | 0.73 | -2.2 | 44.8      | 38.1   | 447 A    | CD        |           | 3     | 4     | 0.71 | -2.3 | 35.2      | 34.7   |
| 422 C    | CD        |           | 3     | 4     | 0.75 | -2.1 | 37.1      | 38.3   | 447 A    | CD        |           | 3     | 4     | 0.74 | -2.4 | 52.4      | 37.4   |
| 422 C    | CD        |           | 3     | 4     | 0.74 | -2   | 42.9      | 33.1   | 447 A    | CD        |           | 3     | 4     | 0.76 | -2.6 | 71.4      | 34.9   |
| 422 C    | CD        |           | 3     | 4     | 0.71 | -2   | 46.7      | 33     | 447 A    | CD        |           | 3     | 4     | 0.73 | -2   | 57.1      | 32.7   |
| 422 C    | CD        |           | 3     | 4     | 0.73 | -2.2 | 42.9      | 34.9   | 447 A    | CD        |           | 3     | 4     | 0.74 | -2.3 | 47.6      | 31.8   |
| 422 C    | CD        |           | 3     | 4     | 0.75 | -2.1 | 46.7      | 31     | 447 A    | CD        |           | 3     | 4     | 0.73 | -2.4 | 69.5      | 32.4   |
| 422 C    | CD        |           | 3     | 4     | 0.75 | -1.9 | 50.5      | 28.9   | 447 C    | CD        |           | 3     | 4     | 0.76 | -2.6 | 46.7      | 31.8   |
| 430 A    | CD        |           | 3     | 4     | 0.79 | -1.8 | 51.4      | 27.1   | 447 C    | CD        |           | 3     | 4     | 0.77 | -2.4 | 61        | 35.2   |
| 430 A    | CD        |           | 3     | 4     | 0.74 | -1.9 | 36.2      | 26.7   | 447 C    | CD        |           | 3     | 4     | 0.74 | -2.1 | 58.1      | 35.9   |
| 430 A    | CD        |           | 3     | 4     | 0.77 | -2.3 | 28.6      | 30.2   | 447 C    | CD        |           | 3     | 4     | 0.77 | -2   | 41        | 33.8   |

| genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | φP0  | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|------|------|-----------|--------|----------|-----------|-----------|-------|-------|------|------|-----------|--------|
| 447      | C         | CD        | 3     | 4     | 0.77 | -2.1 | 91.4      | 32     | 553      | A         | CD        | 1     | 1     | 0.72 | NA   | 66.7      | 29.3   |
| 447      | C         | CD        | 3     | 4     | 0.75 | -2.1 | 37.1      | 26.2   | 553      | C         | CD        | 1     | 1     | 0.76 | -2.1 | 72.4      | 25.7   |
| 543      | A         | CD        | 1     | 1     | 0.74 | -2.4 | 41.9      | 34.9   | 553      | C         | CD        | 1     | 1     | 0.72 | -1.6 | 64.8      | 25.2   |
| 543      | A         | CD        | 1     | 1     | 0.73 | -2.2 | 45.7      | 34.2   | 553      | C         | CD        | 1     | 1     | 0.74 | -1.9 | 65.7      | 33     |
| 543      | A         | CD        | 1     | 1     | 0.75 | -1.9 | 40        | 35.6   | 553      | C         | CD        | 1     | 1     | 0.73 | -2.1 | 73.3      | 36.3   |
| 543      | A         | CD        | 1     | 1     | 0.77 | -2.5 | 45.7      | 34.1   | 553      | C         | CD        | 1     | 1     | 0.74 | -1.8 | 61        | 25.4   |
| 543      | A         | CD        | 1     | 1     | 0.76 | -1.6 | 29.5      | 29.2   | 553      | C         | CD        | 1     | 1     | 0.74 | -1.6 | 39        | 31.1   |
| 543      | A         | CD        | 1     | 1     | 0.72 | -2.3 | 30.5      | 34.4   | 576      | A         | CD        | 1     | 1     | 0.76 | -2.5 | 37.1      | 32.2   |
| 543      | C         | CD        | 1     | 1     | 0.71 | -1.8 | 49.5      | 35.7   | 576      | A         | CD        | 1     | 1     | 0.75 | -2.5 | 50.5      | 34.4   |
| 543      | C         | CD        | 1     | 1     | 0.72 | -2.5 | 41.9      | 34.9   | 576      | A         | CD        | 1     | 1     | 0.77 | -2.3 | 28.6      | 37.2   |
| 543      | C         | CD        | 1     | 1     | 0.74 | -2.5 | NA        | NA     | 576      | A         | CD        | 1     | 1     | 0.72 | -2.1 | 50.5      | 36.9   |
| 543      | C         | CD        | 1     | 1     | 0.74 | -2.1 | 41        | 31.3   | 576      | A         | CD        | 1     | 1     | 0.74 | -2.2 | 34.3      | 34.4   |
| 543      | C         | CD        | 1     | 1     | 0.71 | -2.1 | 41.9      | 34.7   | 576      | A         | CD        | 1     | 1     | 0.75 | -2.8 | 33.3      | 31.2   |
| 543      | C         | CD        | 1     | 1     | 0.74 | -2.4 | 59        | 35.2   | 576      | C         | CD        | 1     | 1     | 0.78 | -2.4 | 44.8      | 34.4   |
| 549      | A         | CD        | 1     | 1     | 0.74 | -2   | 46.7      | 30.1   | 576      | C         | CD        | 1     | 1     | 0.76 | -1.9 | 60        | 32.7   |
| 549      | A         | CD        | 1     | 1     | 0.74 | -2.1 | 41        | 44.2   | 576      | C         | CD        | 1     | 1     | 0.74 | -2.4 | 26.7      | 32     |
| 549      | A         | CD        | 1     | 1     | 0.71 | -2.5 | 38.1      | 29.3   | 576      | C         | CD        | 1     | 1     | 0.73 | -2.5 | 34.3      | 32.7   |
| 549      | A         | CD        | 1     | 1     | 0.77 | NA   | 73.3      | 31.4   | 576      | C         | CD        | 1     | 1     | 0.76 | -2.4 | 49.5      | 33.2   |
| 549      | A         | CD        | 1     | 1     | 0.77 | NA   | 45.7      | 25.1   | 576      | C         | CD        | 1     | 1     | 0.77 | -2.2 | 30.5      | 29.9   |
| 549      | A         | CD        | 1     | 1     | 0.78 | -2.5 | 56.2      | 28.6   | 579      | A         | CD        | 1     | 1     | 0.79 | -1.7 | 72.4      | 29.3   |
| 549      | C         | CD        | 1     | 1     | 0.74 | -2.1 | 45.7      | 26.8   | 579      | A         | CD        | 1     | 1     | 0.73 | -1.8 | 66.7      | 31.7   |
| 549      | C         | CD        | 1     | 1     | 0.75 | -2.2 | 69.5      | 28.6   | 579      | A         | CD        | 1     | 1     | 0.74 | -2.7 | 52.4      | 31     |
| 549      | C         | CD        | 1     | 1     | 0.74 | -2.3 | 61        | 30.9   | 579      | A         | CD        | 1     | 1     | 0.78 | -2   | 47.6      | 26.3   |
| 549      | C         | CD        | 1     | 1     | 0.76 | -2.4 | 57.1      | 22.4   | 579      | A         | CD        | 1     | 1     | 0.78 | -2.6 | 61.9      | 23.4   |
| 549      | C         | CD        | 1     | 1     | 0.75 | -2.1 | 35.2      | 32.6   | 579      | A         | CD        | 1     | 1     | 0.76 | -2.9 | 45.7      | 32     |
| 549      | C         | CD        | 1     | 1     | 0.62 | -2.5 | 41        | 24.8   | 579      | C         | CD        | 1     | 1     | 0.76 | -2   | 57.1      | 34.3   |
| 552      | A         | CD        | 1     | 1     | 0.74 | -1.8 | 45.7      | 31.2   | 579      | C         | CD        | 1     | 1     | 0.75 | -2.3 | 61.9      | 27.4   |
| 552      | A         | CD        | 1     | 1     | 0.75 | -2.1 | 93.3      | 26     | 579      | C         | CD        | 1     | 1     | 0.72 | -2.4 | 37.1      | 33.8   |
| 552      | A         | CD        | 1     | 1     | 0.74 | -2   | 53.3      | 29.2   | 579      | C         | CD        | 1     | 1     | 0.75 | -2.7 | 47.6      | 29.6   |
| 552      | A         | CD        | 1     | 1     | 0.74 | -2.2 | 53.3      | 27.1   | 579      | C         | CD        | 1     | 1     | 0.75 | -1.9 | 79        | 24.9   |
| 552      | A         | CD        | 1     | 1     | 0.73 | -2.1 | 82.9      | 28.7   | 579      | C         | CD        | 1     | 1     | 0.78 | -2.7 | 32.4      | 31.9   |
| 552      | A         | CD        | 1     | 1     | 0.75 | -2   | 82.9      | 26.1   | 654      | A         | CD        | 3     | 1     | 0.81 | -1.7 | 32.4      | 40.8   |
| 552      | C         | CD        | 1     | 1     | 0.74 | -2   | 70.5      | 23.2   | 654      | A         | CD        | 3     | 1     | 0.78 | -2.5 | 42.9      | 37.6   |
| 552      | C         | CD        | 1     | 1     | 0.75 | -2.4 | 76.2      | 33.7   | 654      | A         | CD        | 3     | 1     | 0.78 | -2.1 | 55.2      | 36.1   |
| 552      | C         | CD        | 1     | 1     | 0.75 | -1.9 | 33.3      | 24.3   | 654      | A         | CD        | 3     | 1     | 0.75 | -1.9 | 41.9      | 38.9   |
| 552      | C         | CD        | 1     | 1     | 0.75 | -2.5 | 49.5      | 28     | 654      | A         | CD        | 3     | 1     | 0.76 | -2   | 25.7      | 38.4   |
| 552      | C         | CD        | 1     | 1     | 0.68 | -1.9 | 41        | 35.9   | 654      | A         | CD        | 3     | 1     | 0.77 | -1.7 | 58.1      | 36.3   |
| 552      | C         | CD        | 1     | 1     | 0.75 | NA   | 26.7      | 25.3   | 654      | C         | CD        | 3     | 1     | 0.78 | -1.8 | 54.3      | 37.7   |
| 553      | A         | CD        | 1     | 1     | 0.75 | -2.4 | 72.4      | 27.1   | 654      | C         | CD        | 3     | 1     | 0.75 | -2.1 | 53.3      | 41.4   |
| 553      | A         | CD        | 1     | 1     | 0.74 | -2.3 | 55.2      | 32     | 654      | C         | CD        | 3     | 1     | 0.75 | -1.8 | 45.7      | 37.2   |
| 553      | A         | CD        | 1     | 1     | 0.76 | -2.2 | 71.4      | 27.4   | 654      | C         | CD        | 3     | 1     | 0.78 | -2   | 43.8      | 35.4   |
| 553      | A         | CD        | 1     | 1     | 0.78 | -2.4 | 49.5      | 30.6   | 654      | C         | CD        | 3     | 1     | 0.76 | -1.8 | 58.1      | 38.9   |
| 553      | A         | CD        | 1     | 1     | 0.72 | -2   | 55.2      | 27.4   | 654      | C         | CD        | 3     | 1     | 0.75 | -1.9 | 40        | 44.8   |

| genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size | genotype | treatment | g.chamber | Otemp | Omois | $\phi P0$ | op   | s.density | s.size |
|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|----------|-----------|-----------|-------|-------|-----------|------|-----------|--------|
| 678 A    | CD        |           | 3     | 1     | 0.77      | -2.3 | 33.3      | 39.1   | 682 C    | CD        |           | 3     | 1     | 0.75      | -2   | 42.9      | 28.7   |
| 678 A    | CD        |           | 3     | 1     | 0.74      | -2   | 46.7      | 38.2   | 682 C    | CD        |           | 3     | 1     | 0.76      | -2.5 | 41.9      | 41.3   |
| 678 A    | CD        |           | 3     | 1     | 0.75      | -1.8 | 34.3      | 35.3   | 682 C    | CD        |           | 3     | 1     | 0.77      | -2.1 | 55.2      | 39.4   |
| 678 A    | CD        |           | 3     | 1     | 0.78      | -1.8 | 46.7      | 41.9   | 682 C    | CD        |           | 3     | 1     | 0.79      | -2.2 | 32.4      | 36.4   |
| 678 A    | CD        |           | 3     | 1     | 0.77      | NA   | 46.7      | 35.3   | 682 C    | CD        |           | 3     | 1     | 0.75      | -2   | 68.6      | 29.9   |
| 678 A    | CD        |           | 3     | 1     | 0.74      | -2.2 | 30.5      | 40.1   | 691 A    | CD        |           | 3     | 1     | 0.8       | -1.8 | 59        | 38.9   |
| 678 C    | CD        |           | 3     | 1     | 0.74      | -1.8 | 61        | 33     | 691 A    | CD        |           | 3     | 1     | 0.8       | -2.6 | 37.1      | 34.9   |
| 678 C    | CD        |           | 3     | 1     | 0.78      | -2.4 | 62.9      | 44.2   | 691 A    | CD        |           | 3     | 1     | 0.8       | -2.2 | 61.9      | 36.9   |
| 678 C    | CD        |           | 3     | 1     | 0.75      | -2.3 | 62.9      | 34.8   | 691 A    | CD        |           | 3     | 1     | 0.78      | -2.4 | 51.4      | 34     |
| 678 C    | CD        |           | 3     | 1     | 0.73      | -1.7 | 51.4      | 32.8   | 691 A    | CD        |           | 3     | 1     | 0.77      | NA   | 74.3      | 25.8   |
| 678 C    | CD        |           | 3     | 1     | 0.75      | -1.6 | 54.3      | 38.7   | 691 A    | CD        |           | 3     | 1     | 0.77      | -2.6 | 31.4      | 28.8   |
| 678 C    | CD        |           | 3     | 1     | 0.78      | -2.3 | 42.9      | 34.6   | 691 C    | CD        |           | 3     | 1     | 0.78      | -1.8 | 50.5      | 37.3   |
| 680 A    | CD        |           | 3     | 1     | 0.77      | -2.1 | 50.5      | 28.9   | 691 C    | CD        |           | 3     | 1     | 0.77      | -2.3 | 30.5      | 28.8   |
| 680 A    | CD        |           | 3     | 1     | 0.76      | -2   | 68.6      | 26.9   | 691 C    | CD        |           | 3     | 1     | 0.78      | -2.3 | 69.5      | 34.6   |
| 680 A    | CD        |           | 3     | 1     | 0.78      | -2.2 | 59        | 31.8   | 691 C    | CD        |           | 3     | 1     | 0.8       | -2.4 | 63.8      | 36.1   |
| 680 A    | CD        |           | 3     | 1     | 0.77      | -1.7 | 56.2      | 33.4   | 691 C    | CD        |           | 3     | 1     | 0.68      | -2.1 | 37.1      | 35.2   |
| 680 A    | CD        |           | 3     | 1     | 0.77      | -1.9 | 65.7      | 30.2   | 691 C    | CD        |           | 3     | 1     | 0.78      | -1.9 | 68.6      | 37     |
| 680 A    | CD        |           | 3     | 1     | 0.78      | -2.4 | 69.5      | 36.2   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.8       | -2.1 | 61.9      | 35.8   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.77      | -2.4 | 55.2      | 34.2   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.79      | -2.2 | 61        | 32.7   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.75      | -2   | 49.5      | 31.8   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.74      | -2   | 50.5      | 34.3   |          |           |           |       |       |           |      |           |        |
| 680 C    | CD        |           | 3     | 1     | 0.79      | -2.9 | 58.1      | 33.3   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.75      | -1.9 | 53.3      | 31.2   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.75      | -1.5 | 64.8      | 30.1   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.77      | -2.4 | 38.1      | 30.8   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.74      | -2.3 | 77.1      | 28.9   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.77      | -1.8 | 60        | 29.2   |          |           |           |       |       |           |      |           |        |
| 681 A    | CD        |           | 3     | 1     | 0.76      | -2.4 | 41        | 34     |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.74      | -1.6 | 68.6      | 34.6   |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.73      | -1.9 | 65.7      | 35.4   |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.78      | -2.2 | 32.4      | 34.9   |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.76      | -2.1 | 60        | 37.1   |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.77      | -2   | 30.5      | 30.4   |          |           |           |       |       |           |      |           |        |
| 681 C    | CD        |           | 3     | 1     | 0.76      | -2.1 | 73.3      | 27     |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.74      | -1.5 | 58.1      | 37.3   |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.75      | -2   | 48.6      | 34.2   |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.76      | -2.5 | 64.8      | 39.8   |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.77      | -2   | 61.9      | 35.7   |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.74      | -2   | 54.3      | 40.7   |          |           |           |       |       |           |      |           |        |
| 682 A    | CD        |           | 3     | 1     | 0.78      | -2.4 | 54.3      | 34     |          |           |           |       |       |           |      |           |        |
| 682 C    | CD        |           | 3     | 1     | 0.75      | -2.2 | 57.1      | 32.6   |          |           |           |       |       |           |      |           |        |