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Research Article

PHENOLOGICAL BEHAVIOURS OF THE LOCAL ENDEMIC *Paeonia mascula* (L.) Mill. subsp. *bodurii* Özhatay IN ÇANAKKALE, TURKEY

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Abstract: This study covers the observation, recording and interpretation of the phenological behaviour of the local endemic *Paeonia mascula* (L.) Mill. subsp. *bodurii* Özhatay in its life cycle. Although phenological observations are mostly applied on cultivated plants, the data obtained from this study on an endemic taxon constitute an important resource for the preparation of a conservation action plan. While the phenological cycle time of the geophyte plant on the ground is determined as 206 days on average, it spends the winter months in dormancy with an average of 159 days underground. It was determined that the populations at lower altitudes in their natural habitats entered the flowering, fruit formation and seed maturation stages relatively earlier than those grown at higher altitudes and remained in these phenophases for longer periods. The total life cycle was more or less the same, although there were differences in phenophases durations and beginnings-ends.

Özet: Bu araştırma, lokal endemik *Paeonia mascula* (L.) Mill. subsp. *bodurii* Özhatay'ın yaşam döngüsü içerisindeki fenolojik davranışlarının gözlemlenmesini, kaydedilmesini ve yorumlanmasını kapsamaktadır. Fenolojik gözlemler çoğunlukla kültür bitkileri üzerinde uygulanmakla birlikte, endemik bir taksonunun üzerinde yapılan bu çalışmadan elde edilen veriler, koruma eylem planı hazırlanmasında önemli bir kaynak oluşturmaktadır. Geofit olan bitkinin toprak üstünde geçirdiği fenolojik döngü süresi ortalama 206 gün olarak tespit edilirken, kış aylarını toprak altında ortalama 159 gün olarak dormanside geçirmektedir. Doğal habitatlarında daha düşük rakımlarda bulunan populasyonların yüksek rakımlarda yetişenlere göre çiçeklenme, meyve oluşturma ve tohum olgunlaşması gibi evrelere nispeten daha erken bir dönemde girdiği ve bu fenofazlarda daha uzun süreli kaldığı belirlenmiştir. Fenofaz sürelerinin, başlangıç-bitişlerinde fark olmasına rağmen toplam yaşam döngüsünün aşağı yukarı aynı olduğu görülmüştür.

Introduction

Climate is the most important complex of ecological factors affecting the main character and distribution areas of plants and plant communities in the world (Daysal 2013). The collective effects of climatic elements such as temperature, humidity, precipitation, wind and light play an important role in both the distributions and life cycles of organisms. Phenology (derived from the Greek word "phainein or Phainestai" meaning 'to show' or 'appear') is a science that studies the repetition times of natural events (Fenner 1998). The duration and time of these natural events vary according to changes in climatic conditions particularly depending on temperature, humidity, precipitation amount and insolation times of plants (Topal 2020).

The results obtained from phenological observations and their long-term averages are very important for a country's agriculture and economy. The averages of phenological observations are the values that should be taken into account in the selection or breeding of crop plants that can best adapt to the climatic conditions of any region (Şimşek *et al.* 2014). Therefore, most of the scientific studies have focused on the phenological observations of agricultural plants. On the other hand, the number of studies revealing the relationship between phenology and the conservation of endemic and rare plants is not too much in number. Endemic and rare plants are species that can be more sensitive and vulnerable to changes in environmental conditions compared to other species. Therefore, the priority of the studies to be carried out should be to determine the phenological characteristics of these sensitive species and to evaluate their results in the preparation of species protection action plans. However, the effects of

phenology on conservation biology and nature management have not yet been adequately studied on a global scale (Morellato *et al.* 2016).

The genus *Paeonia* L. belongs to the *Paeoniaceae* family, and it has 52 taxa under 36 species in the world (The Plant List 2021). *Paeonia* is divided into three sections: sect. *Moutan* DC. (woody or tree peonies, all in China), sect. *Onaepia* Lindl. (the two species restricted to North America) and sect. *Paeonia* (herbaceous peonies, 22 species distributed in Europe, North Africa and Asia) (Hong 2010). All Turkish species belong to the sect. *Paeonia*. In the first volume of "Flora of Turkey and the East Aegean Islands", 6 species were listed from the genus *Paeonia* (Davis & Cullen 1965). In volume 10 published in 1988, *P. wittmanniana* Hartwiss. ex Lindl., and in volume 11 published in 2000 *Paeonia mascula* (L.) Mill. subsp. *bodurii* Özhatay and *P. tenuifolia* L. were published (Davis 1988, Özhatay 2000). There are 6 species and 8 under species taxa reported in the latest available checklist, in Turkey (Körüklü 2012). Among these taxa, only *Paeonia mascula* subsp. *bodurii*, are indicated as endemic (Körüklü 2012).

Paeonia mascula subsp. *bodurii* was described by Özhatay in 1995 as a new subspecies from NW Turkey (Çanakkale province). *Paeonia mascula* is a highly variable species, the leaves are ternately or pinnately compound. This subspecies is very closely related to subsp. *hellenica* Tzanoud., which is distributed in Greece, but it differs from it by its mostly ternate upper cauline leaves, the central and lateral primary segments of the leaves having only 3 (undivided) leaflets, whereas subsp. *hellenica* usually has 9 uppermost leaflets (Özhatay & Özhatay 1995).

When the taxon was first published, it was known from only one locality. The IUCN threatening category of the taxon is given as EN (Ekim *et al.* 2000). However, in later field studies performed by us, it was determined that the taxon was also naturally distributed in different localities within the Çanakkale province (Kökçü & Karabacak 2020). Although the area of the extend of occurrence of the subspecies has expanded with these new localities, the area of occupancy is still rather low. This endemic peony is under high pressure from deforestation, road constructions, wind power plants, mining operations and illegal plant gatherings, and their populations are increasingly negatively affected. Due to lack of information about the phenological behaviour of this highly threatened taxon needed for developing a conservation strategy, the present study was performed with conservation prospective. Phenological observations, together with what can be done on this taxon and other taxa in the future, will both contribute to the conservation of the species and will be an important data source in the monitoring of possible effects of climate changes.

Materials and Methods

The study area

The study was carried out during the vegetation seasons between 2018-2021. During field studies, four localities in Çanakkale province, which is the only natural distribution of *Paeonia mascula* subsp. *bodurii*, were surveyed for assessing the distribution and growth of the taxon (Fig. 1). These are Ağı Mountain (921 m), Kiraztaşı (Üçpınar) (720 m), Beşiktepe (Karamusalar) (454 m) and Aşağıçavuş (440 m).

The climate is warm and of temperate Mediterranean type in Çanakkale. Rainfall in the province is mostly in winter months, while it is relatively less rainy in summer. The annual average temperature is 15.1°C and the amount of precipitation per year is 624 mm (Table 1).

The driest month is August, with 9.4 mm of rainfall. In December, the precipitation reaches its peak, with an average of 105.4 mm. The warmest month of the year is July, with an average temperature of 25.1°C, and January is the coldest month with 6.2°C on average (Table 1).

Phenological Observations

No tools or devices are used during phenology observations (Şimşek *et al.* 2014). Instead, the intensities of phenological events are semi-quantitatively determined and recorded in the field for each phenological stage. Weekly visits were made to the four study areas, and phenological observations on selected plants were recorded in terms of sprouting, bud formation, anthesis, fruiting, seed maturation and senescence.

The phenophase calendars of the taxon at four different altitudes in Çanakkale were determined, and the beginning and ending dates of the phenological periods were recorded. In addition, the phenophase times of the individuals in each population were recorded, so the total phenological cycle times that could occur with altitude and latitude variation were calculated. Fertile plant samples randomly selected for each locality (10-30 individuals selected depending on the population density at the locality) were tagged and monitored throughout the growing season. For the Ağı Mount, where optimum conditions are best, the number of individuals in the population is very high, but the Aşağıçavuş site is the southernmost place where the plant can live, and the number of individuals here is relatively low. For this reason, differences in the number of individuals between locations were used in the selection of the studied sample.

The time between the first date of aerial shoot emergence and the last date of senescence were considered for calculation of the active periods of the taxon.

Coordinates were taken from the Global Positioning System (GPS) device for each locality and the distribution map of the taxon was prepared in ArcView 10.5 software. Photos were taken with Canon 750 D model.

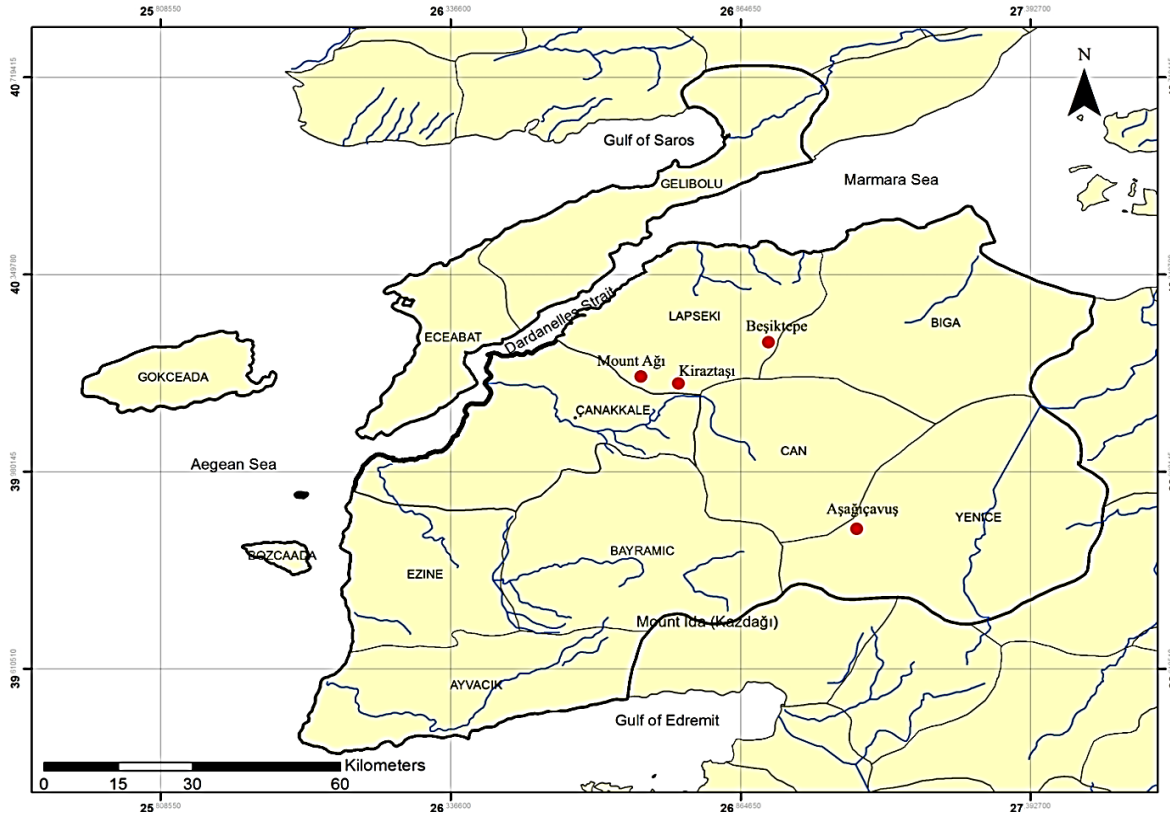

Fig. 1. Distribution map of *Paeonia mascula* subsp. *bodurii* in Çanakkale. Solid red circles denote the localities where the taxon was recorded so far.

Table 1. Long-term climate data table for Çanakkale province between 1929-2020 (Meteorological Service 2021).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temp. (°C)	6.2	6.7	8.4	12.6	17.5	22.2	25.1	25.0	21.1	16.3	12.0	8.4	15.1
Average Max. Temp. (°C)	9.6	10.2	12.5	17.2	22.6	27.7	30.7	30.6	26.4	20.8	15.9	11.7	19.7
Average Min. Temp. (°C)	3.1	3.4	4.7	8.3	12.7	16.6	19.3	19.6	16.0	12.1	8.5	5.3	10.8
Average Precipitation (mm)	91.6	71.7	65.9	45.0	29.8	25.3	14.5	9.4	25.2	55.3	84.9	105.4	624.0

Results

Seven phenological stages including sprouting phase, vegetative phase, bud formation, flowering phase, fruiting phase, seed maturation phase and senescence were observed (Fig. 2). These phenological stages were monitored in all four selected natural populations. This investigation revealed that the plant species entered the vegetative and reproductive stages relatively earlier with the decrease in altitude and the life cycles were longer (Fig. 3).

During the field studies, *Paeonia mascula* subsp. *bodurii* was determined to lived naturally in Ağı Mountain (921 m), Kiraztaşı (Üçpınar) (720 m), Beşiktepe (Karamusalar) (454 m) and Aşağıçavuş (440 m). The plant retreats underground during the fall (by 9 October at the latest) and goes dormant during the winter months (Table 2).

The first plant sprouts in the studied populations started in the 2nd week of March and continued until the end of the 1st week of April. In the mature plants, after the completion of the sprouting stage, the plant started the vegetative phase where flower buds formed. Bud formation began in the last days of March and continued until the last week of April. The anthesis began in the 2nd week of April and continued until the 3rd week of May. The flowers remained active for approximately 6-10 days, depending on the air temperature and precipitation. In the middle of the flowering period, the plant began to bear fruit, and towards the end of the fruiting period, and immature seeds began to appear. Fertile seeds began to mature in the 1st week of June and maturation continued until the 2nd week of August. Senescence and withdrawal of air shoots began in the 3rd week of August and lasted until the 2nd week of October. Thus, the phenological cycle period of the taxon was calculated as 206 days on average. Although the phenophase durations are somewhat prolonged with the lowering of the altitude, the total life cycle is more or less the same in the general perspective (Fig. 4). The geophyte endemic plant spends its winter months underground in dormancy in an average of 159 days.

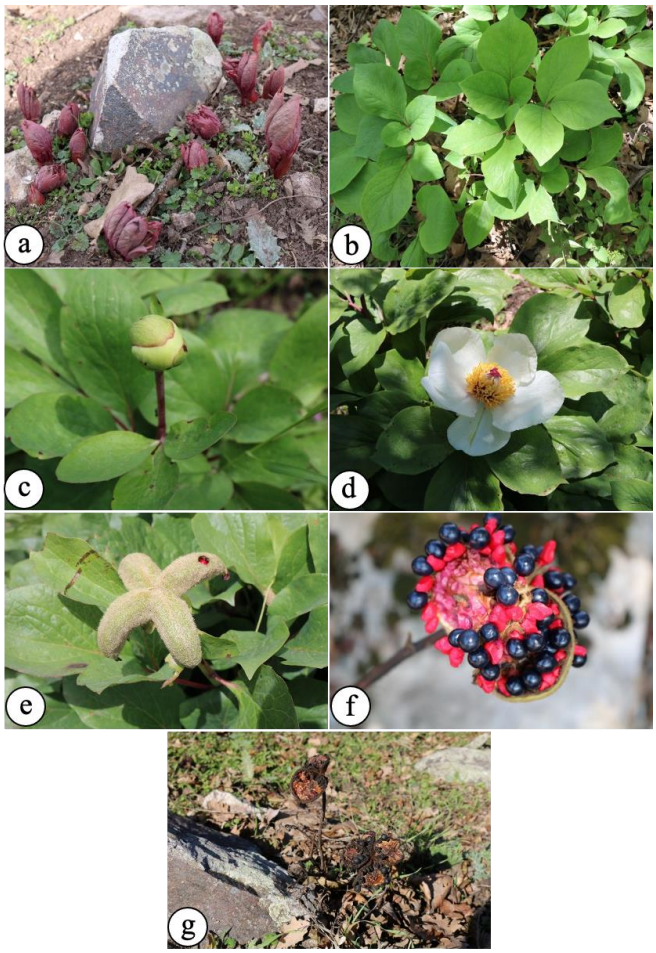

Fig. 2. Phennological stages of *Paeonia mascula* subsp. *bodurii*.a. Sprouting phase, b. vegetative phase, c. bud formation, d. flowering phase, e. fruiting phase, f. seed maturation phase, g. senescence.

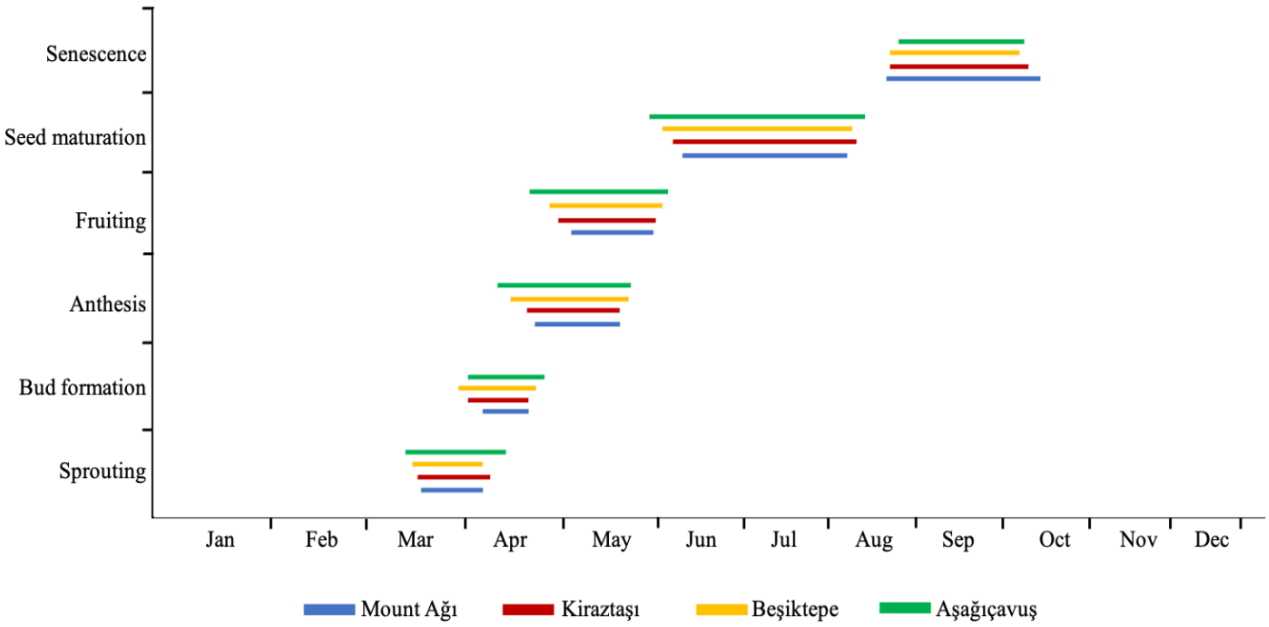

Fig. 3. Phenogram of *Paeonia mascula* subsp. *bodurii* in studied localities.

Table 2. Phenophase dates and durations in four natural populations of the taxon.

Phenophases		Ağı Mountain (921 m)	Kiraztaşı (Üçpınar) (720 m)	Beşiktepe (Karamusalar) (454 m)	Aşağıçavuş (440 m)
Sprouting	Initial	15 Mar	14 Mar	12 Mar	10 Mar
	Completion	5 Apr	6 Apr	5 Apr	11 Apr
	Duration	**22 days**	**24 days**	**25 days**	**33 days**
Bud formation	Initial	4 Apr	1 Apr	30 Mar	1 Apr
	Completion	19 Apr	19 Apr	21 Apr	25 Apr
	Duration	**15 days**	**18 days**	**21 days**	**24 days**
Anthesis	Initial	20 Apr	18 Apr	15 Apr	13 Apr
	Completion	20 May	20 May	22 May	23 May
	Duration	**30 days**	**32 days**	**37 days**	**40 days**
Fruiting	Initial	2 May	29 Apr	27 Apr	22 Apr
	Completion	29 May	30 May	1 Jun	2 Jun
	Duration	**27 days**	**32 days**	**35 days**	**41 days**
Seed maturation	Initial	7 Jun	4 Jun	1 Jun	28 May
	Completion	5 Aug	7 Aug	6 Aug	13 Aug
	Duration	**59 days**	**64 days**	**66 days**	**78 days**
Senescence	Initial	20 Aug	21 Aug	21 Aug	24 Aug
	Completion	9 Oct	5 Oct	2 Oct	4 Oct
	Duration	**50 days**	**46 days**	**43 days**	**42 days**
Duration of phenological cycle		**208 days**	**205 days**	**205 days**	**205 days**

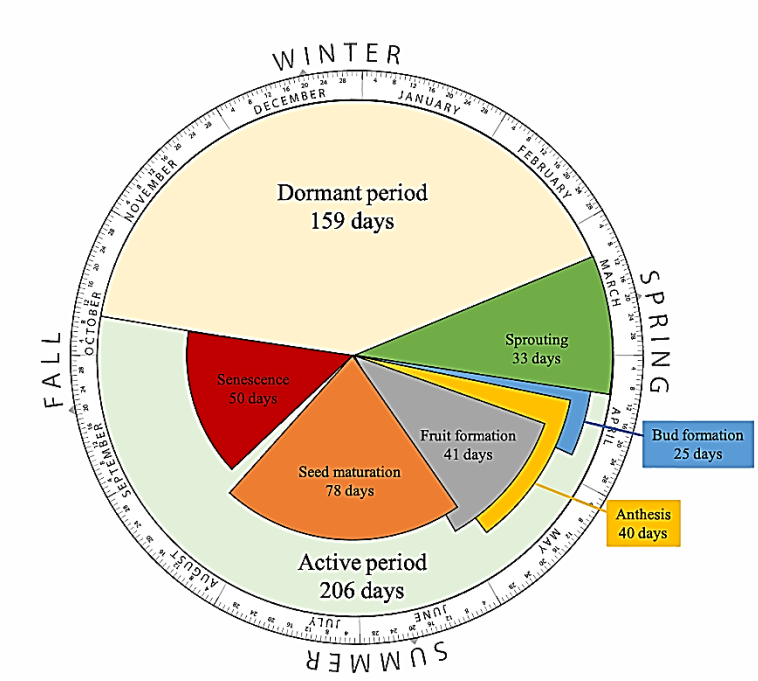

Fig. 4. Phenographic life cycle of *Paeonia mascula* subsp. *bodurii*.

Discussion

Plant phenology includes the timing and duration of repetitive biological events, including reproductive events such as sprouting, flowering, fruiting, and seed dispersal. Therefore, flowering phenology is a very important developmental process to determine the reproductive success of plants. Differences in reproductive cycle times between species and their populations can have important evolutionary consequences (Waser 1978). The information obtained from phenological studies is very important for the planning of successful conservation strategies of endangered plant species and their future ex-situ conservation studies (Gopalakrishnan & Thomas 2014).

The results of this study revealed that there was partial asynchrony in all phenophases of the samples distributed in the studied populations as a result of altitude

differences between the populations and the location differences in the north-south direction. Because the temperature decreases gradually as the altitude increases, the same phenomenon is seen from south to north. Consistent with the present results and that of previous studies (Ziello *et al.* 2009, Nazir *et al.* 2017), as the altitude increases, the plants bloom relatively later than those at lower altitudes. The blooming asynchronization between populations is very useful for increasing the efficiency of pollinators, reducing intraspecific competition and promoting out crossing. In order for a threatened species to be successful in its struggle for survival, it is extremely important that the flowering period is healthy and long, and especially that the pollinators work effectively during that period.

All populations of *Paeonia mascula* subsp. *bodurii* have a life period of 205-208 days from their sprouting to the senescence of the aerial shoots. This knowledge is invaluable in understanding phenological behaviour and developing strategies to effectively conserve wild populations *in-situ* or *ex-situ* in botanical gardens. Although reproductive biology is widely researched in plant conservation biology in Turkey, our present results, which reveal the full life cycle of the local endemic *P. mascula* subsp. *bodurii*, will serve as an exemplary model for further similar studies, since there exists no detailed phenological atlas study as reported here.

Since *Paeonia* species are potentially ornamental plants worldwide, the results of this study will shed light on the evaluation of *P. mascula* subsp. *bodurii* as an ornamental plant natural gene source in terms of agronomical studies in the future.

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