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Pupal summer diapause in Chilean *Pieris brassicae* (Linnaeus, 1758) (Lepidoptera, Pieridae)

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Summary

The European butterfly pest *Pieris brassicae* (L.) has been known from Chile since the early 1970's, when it was probably introduced from Europe. Evidence is presented to suggest that it has developed a pupal summer diapause, previously not known in this species, to survive the dry mediterranean summer of central Chile.

Résumé

L'espèces européenne *Pieris brassicae* (L.), dont la chenille ravage parfois les plantations de choux, est connue depuis le début des années 1970 au Chili, où elle a probablement été introduite d'Europe. Les constatations faites suggèrent qu'il s'est établi une diapause estivale au stade chrysalide — inconnue jusqu'à présent chez cette espèce — pour lui permettre de survivre à l'été de type méditerranéen qui règne dans la région centrale du Chili.

Introduction

The biology of the Palaearctic *Pieris brassicae* (Linnaeus, 1758) is well known and documented in hundreds of books and publications. This pest and migratory species is widespread in the whole of Europe, the western part of North Africa, and Asia north to about 62° of latitude.

In Central Europe and Asia, the adults are on the wing during the summer from April to October in successive broods. During the winter it hibernates in the pupal stage (Chinery, 1989 ; Pullin & Bale, 1989 ; Pullin *et al.*, 1991). In southern, warmer climates the winter pupal diapause is short or non-existant and during the summer the lack of wild crucifers forces it to switch to cultivated areas, or to other plants, e.g. *Capparis spinosa* L. (Capparaceae) in Israel (Benyamini, 1990).

In the early 1970's this butterfly suddenly appeared in Chile (Gardiner, 1974). At that time, it is known that the Allende regime imported potatoes by boat from Poland to feed the starving population. Specimens of *P. brassicae*, probably as pupae, were possibly accidentally imported with these ships from Poland, although other sources cannot be excluded.

If the species was introduced to Chile in the pupal stage it would have had a relatively good chance to survive, especially during the months Sept.-Dec. and April-May :

a. If European winter diapausing pupae arrived in the Chilean summer the switching would be natural except during the months of Feb.-March when the central valley of Chile is dry, not offering any green wild foodplant to the larvae. The only available food source would be cultivated crucifers.

b. European spring pupae/adults arriving to the Chilean autumn can find fresh newly grown crucifers, larvae can feed up quickly and pupae may go immediately into winter diapause as they do in central and northern Europe.

c. European summer pupae/adults arriving to the Chilean winter will either remain in diapause or die of cold temperatures.

d. European autumn pupae/adults arriving to the Chilean spring will have the best season for acclimatisation.

Unfortunately, no work was done to follow year by year this fascinating "field-experiment" of an introduced insect whose annual seasonality was switched suddenly by 180°, from summer to winter, from spring to autumn or vice-versa. Angulo & Weigert (1982) stated that "a set of 30 pupae hatched after 90 days, probably after staying in diapause or anabiotic stage". No dates or season were given. Angulo however remembers that the rearing was done during the Chilean autumn and that the said diapause was actually a normal "European" winter diapause (pers. comm.).

From late 1992 to mid 1995 the author had the opportunity to check the present-day situation and found that the species had fully adapted to the Chilean climate.

Observations

On 12th Dec. 1992, a female was observed flying around a yellow crucifer at Rio Mapocho (1100m) on the eastern outskirts of Santiago de Chile. The 95cm tall *Brassica campestris* L. that was located half in the shade was a perfect choice for the female to settle on and lay its eggs. Three batches of 14, 40 and 59 eggs were layed on the underside of the leaves, 35 to 40 cm above the ground. The eggs were brought to Santiago and under a 26/17°C 14L/10D regime started to hatch on 15th Dec. 1992. The newly hatched larvae were partly transparent green turning within a few hours to light-green, similar to the colour of the leaves ; the head was black.

The larvae were fed on fresh wild crucifer leaves and grew up quickly. Pupation started on 30th Dec. and ended on 6th Jan. 1993. A total of 52 pupae were obtained. The pupae were kept outside, but protected from rain, in Santiago. The first adult, a male, emerged on 9th Jan., the second, a female, on 11th Jan. Up to the 18th Jan., 36 butterflies had emerged. No more specimens emerged until one on 2nd Feb. The emergences proceeded with 2, 3 and 6 adults for March, April and May respectively, although 2 of the May specimens died during emergence. The last adult emerged on 8th May, four full months after pupation. Four pupae turned dark-brown and died.

The monthly and cumulative emergences are illustrated in Fig. 1. Within 10 days of pupation, 68.6% of the butterflies had emerged. A further 23.4% emerged gradually during the summer. From the end of March when the temperatures started to drop, heralding the first autumn rains, the emergences intensified, reaching a peak in the first week of May when 5 of the 6 remaining live pupae produced adults simultaneously on the 2nd and the 3rd. Eight percent of the pupae died.

In the Chilean summer of 1994-95 field observations yielded the same results as those of 1992-93 from the laboratory ; from mid-January to mid-February 1995 no adults were observed. On February 17th the first adult was recorded from Coronel, a coastal locality near Concepcion which is about 500 km south of Santiago. In Santiago the first appearance was about two weeks later, starting March 6th and then 8th & 10th in El Bosque (southern Santiago, one specimen each time) and on the 11th in Providencia Gardens in the centre of the city (three specimens). The adults were active until April 17th (El Bosque), when a two week period of cold and rainy weather set in. May 1st was sunny and warm (26° at midday) and three specimens were observed (Collina, Santiago region). At El Bosque the following day, 11 specimens were observed between 11 :30 a.m. and 2 :00 p.m., and on May 3rd, 13 specimens were observed in ten minutes at 1 :30 p.m. May 4th was partially cloudy and only three specimens were observed between 1 :00-2 :00 p.m., May 5th was rainy and no butterflies were seen. The emergences of the wild summer pupae as observed during

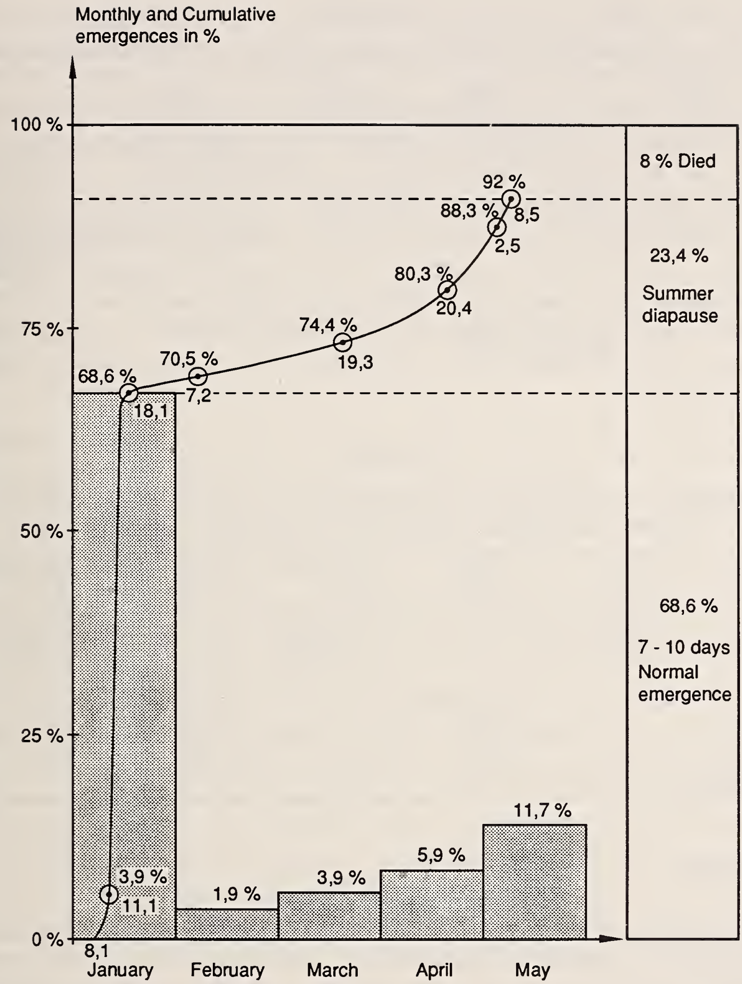

Fig. 1. Monthly and cumulative pupal emergences in one brood of Chilean *P. brassicae*.

the autumn of 1994-95 season perfectly match the laboratory results as shown in Fig. 1 : No observations during mid-summer and a slow build up of emergences during February, March until the peak in early May.

In order to have a comparison with a native Pierid, rearing material of the legume feeder *Tatochila theodice* Boisduval were obtained. On the 15th and 19th Nov. 1994 in Villa Paulina (Valle de la Yerba Loca) about 20 km east of Santiago 2000 m.a.s.l. eggs, 1st and 3rd instar larvae were found on *Vicia* sp. (Fabiaceae). Of the 15 eggs and larvae that were collected and bred in Santiago 9 pupae were obtained between 27.11 and 8.12.1994 (3 eggs were parasitised and 3 larvae died of starvation). Three pupae turned dark brown or black and died during Jan. 1995, probably because the larvae were tested unsuccessfully for feeding on *Trifolium repens* L. Of the 6 remaining pupae 1 ♂ emerged on 17.12.1994. No more emergences took place during the next two and a half months, but during the first fortnight of March 3 pupae hatched. The last two pupae went into winter diapause. Table 2 summarizes this observation which, although based on very little material, suggests the same phenomenon of two seasonal pupal diapauses. Over summer for two and a half months and in winter for eight months.

Table 1

Emergences of Tatochila theodice Boisduval from the western Andes Precordillera slopes of the Santiago Metropolitan Region, Chile 1994-1995.

Month	Nov. 1994	Dec. 1994	Jan, Feb. 1995	Mar. 1995	Apr.-Oct. 1995
Behaviour	1st brood (wild)	1 ♂ 17.12 2nd brood (lab.)	Summer diapause	1 ♂ 1.3 1 ♀ 7.3 1 ♂ 15.3 3rd brood (lab.)	Winter diapause
Pupal emergences		17%		50%	33%

Discussion

The European annual life-cycle of *P. brassicae* is composed of spring and summer continuous generations and winter diapausing pupae (Table 2). In southern Europe, North Africa and the Middle East the behaviour is slightly different (Benyamini, 1990) ; the local temperatures are not low enough to initiate diapause. Instead, metamorphosis is simply slowed down, larvae taking longer to feed up and pupae taking longer to hatch. In the dry summer of Israel, when no fresh wild crucifers exist, the adults switch to laying eggs on *C. spinosa* and on cultivated crucifers, and pupae have no summer diapause.

In Chile we see a modified survival technique. With the lack of potential alternative wild summer foodplants, the pupae go into a second annual diapause. It has previously been shown that a short day-length, vitamin A and cryoprotectant accumulation are the essential factors for winter

Table 2

Seasonal metamorphosis of *P. brassicae* in three different regions of the world.

	Winter	Spring	Summer	Autumn
	Nov. - April	*April - July*	*July - Sept.*	*Sept. - Nov.*
C. & N. Europe	Diapausing pupae	Continuous breeding		Pupae
	Nov. - Feb.	*Feb. - May*	*May - Nov.*	
Middle East (Israel), southern Europe & North Africa	Slower metamorphosis	Breeding	Breeding, switching to other foodplants	
	June - Sept.	*Sept. - Jan.*	*Jan. - April*	*April - June*
Chile	Diapausing pupae	Breeding	Diapausing pupae & gradual emergences	Breeding

diapause (Claret *et al.*, 1981 ; Claret, 1985 ; 1989 ; Claret & Volkoff, 1992 ; Lavialle & Dumortier, 1990 ; Spieth & Sauer 1991 ; Veerman *et al.* 1985 ; 1988). Of these, only vitamin A could possibly be playing a role in the summer diapause. It would also suggest that while a short day-length induces diapause, a long day-length does not prevent it.

During March 1995 a similar emergence pattern was seen in other butterfly species in the wild. On 18.3.95 at Baño Morales, 2200m, Santiago Metropolitan region 6 adults of *T. theodice* were observed. In El Bosque daily more species and individuals of *Colias vauthieri* Guerin, *P. brassicae* L., *Tatochila autodice blanchardi* Butler, (Pieridae), *Vanessa carye* Hübner (Nymphalidae), *Erynnis funeralis* Scudder & Burgess and *Hylephila faciolata* Blanchard (Hesperiidae) were observed. This phenomenon of a second peak of butterfly activity (shown schematically in Fig. 2) is typical of Mediterranean zones where early autumn rains produce a second spring-like period with many plants having a second flowering period, side by side with the young growth of annuals. The emergence of *P. brassicae* adults after the summer diapause perfectly coincides with this second peak of seasonal butterfly activity.

Dr. Torben Larsen, who studied the butterflies of the Lebanon for 4 years (Larsen, 1974) also found larvae switching to *Capparis*, but believed that the few adults observed by him during the summer months in the mountains "**may be** migrating specimens.. but most of the summer brood **probably** aestivates in pupal stage". This "aestivation" was not proven by Larsen. If he had bred the *Capparis* larvae, he would have found that not a single pupa diapauses, as in neighbouring Israel (pers. obs.). Larsen & Nakamura (1983 : 159) considered the same theory in their work on the butterflies of East Jordan : "There

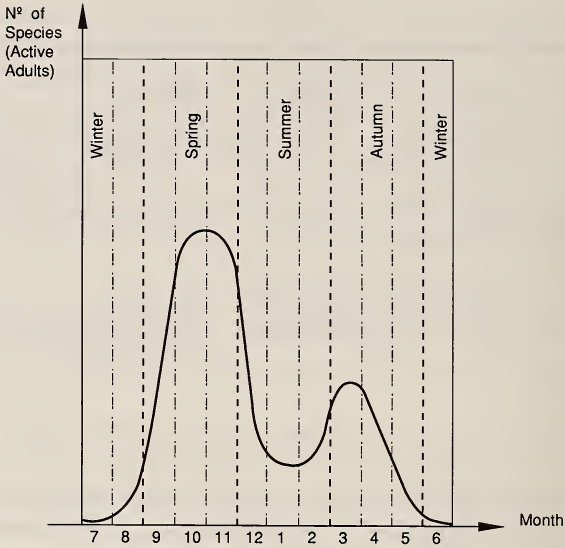

Fig. 2. Schematic diagram of the flight activity of butterflies in the Chilean (Mediterranean) central valley.

is a **tendency** towards both hibernation and aestivation in the pupal stage". In his excellent review on *P. brassicae*, Feltwell (1981 : 222-225) did not find any definite evidence of a summer pupal diapause, but quoted Larsen (1974). The closest observation to my own is that of Bowden (1966) who noted that Corsican larvae that were brought back to England and pupated there "hatched out much later than their own kin, but in a shorter time than those which diapause". Seventeen males and females hatched normally, but four pupae hatched three weeks to three months later, being 19% of the total emergences. He termed this "irregular diapause". The fact that emergences took place in a different country under different conditions could however have influenced the results. Danilevskii (1965) who bred *P. brassicae* from Sukhumi (Georgia) found that when he kept the pupae at a constant temperature of 23°C the emergences took place within two and a half to three months. Bowden (1966 : 68) wrote : "Thus the more southern the Russian *P. brassicae* seems to enter a **shallow diapause** which does not require cold to terminate it".

It is important to note that in other genera of the Pieridae inhabiting Mediterranean climates i.e. *Euchloe*, a summer pupal diapause is very common.

Dr. Angulo states that *P. brassicae* has become less common since its sudden appearance in Chile (pers. comm.). It seems that a new ecological balance has been achieved. Its well-known Palaearctic parasite *Apanteles glomeratus* (Hymenoptera, Braconidae) also appeared in Chile and I found it in a few of the 1994-95 wild collected larvae (e.g. 28.11.94 Rio Clario 800m, Santiago Metropolitan Region).
Feltwell (1981 : 223) suggested "to investigate the seasonality of *P. brassicae* in Chile, as it has a similar climate to that of the Lebanon". I suggest checking the biology of *P. brassicae* in Corsica and in southern central Asia, as both these regions have a similar climate to the Chilean central valley.

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