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Migration of cabbage butterfly (*Pieris brassicae*): Influence of environmental factors on dispersal

Dispersal and migration play a crucial role as evolutionary adaptations, allowing organisms to escape adverse conditions, exploit other habitats and maintain gene flow between populations. Nevertheless, migratory behaviour is often difficult or impossible for organisms that have already locally adapted to a certain environment. One model of this balance between migration and local adaptation is the large white butterfly, *Pieris brassicae* (Lepidoptera: Pieridae). Indigenous to regions as varied and often improbable as Europe and Asia, this pretty little butterfly can also travel up to hundreds of kilometres in a single year. Conversely, populations of *P. brassicae* possess local adaptations in response to downstream selection revealed by the regulation of overwintering life stages based upon geographic variation in day length despite high vagility. During short autumn days, northern populations go into diapause but southern north remain active for the year. These local adaptations imply historical stability within regional populations, but these results may only counteract a single broad range event.

THE ability of organisms to spread and relocate to new areas through dispersal and migration represents a crucial evolutionary strategy. This adaptation enables them to avoid unfavourable circumstances in their current habitat, thereby increasing their chances of survival and reproductive success. Migratory behaviour can, however, be maladaptive for species that are locally adapted to specific environmental conditions. The large white butterfly, *Pieris brassicae* (Lepidoptera: Pieridae) is an example of such species. It is a widely distributed and multivoltine species, inhabiting various climatic zones from Europe to Asia. Its broad distribution is supported by annual migrations spanning hundreds of kilometers. Despite their high mobility, *P. brassicae* populations exhibit local adaptations, synchronizing their life cycles with regional environments. A significant adaptation is the regulation of overwintering in response to geographic variation in day length and seasonal changes. In areas with long winters, such as northern Germany, *P. brassicae* enters diapause during the pupal stage due to shortening autumn day lengths. Conversely, populations in the south remain active throughout winter, undergoing direct development without entering diapause. This variation in diapause strategies is governed by genetic differences in the critical photoperiod required to trigger diapause. The photoperiodic response threshold varies, with southern French populations requiring about 12 hours of daylight per day, while high-latitude Danish populations need over 16 hours. When relocated, *P. brassicae* populations maintain their local diapause responses, highlighting the strong genetic control over this adaptation. Emerging technologies such as radar, radio transmitter tracking, molecular ecology, and stable isotope analysis are starting to elucidate insect migration patterns. However, comprehensive details on behavioural patterns and demographic processes are still lacking. To overcome these challenges, Spieth and colleagues employed a semi-natural experimental approach to investigate the migratory flight behaviour of *P. brassicae* from various geographic origins and seasonal conditions.

Biology and distribution

Morphology: *Pieris brassicae* is characterized by its large white wings with black tips and spots. The wingspan ranges from 50 to 65 mm, with females generally larger than males. The caterpillars are green with yellow stripes and black spots, making them easily distinguishable.

Life cycle and reproduction: The life cycle of *Pieris brassicae* includes four stages viz. egg, larva (caterpillar), pupa (chrysalis), and adult butterfly.

Eggs: Clusters of eggs are deposited by the female butterfly. The eggs are yellowish at first, but as time goes on, they progressively became darker yellow and, finally grey at the time of hatching. The eggs are unlike any other because of the elaborate designs on their shells, which resemble the roughness of a corn cob. The female butterfly release a brownish material that acted as a natural adhesive to keep the eggs firmly connected to the leaf. Before the baby butterflies emerg, the eggs undergoes a four-to five-day incubation period

Larvae: There are five different instars and four moults during the larval stage of the butterfly. The larvae

in the first instar have bright yellow bodies with glossy black heads when they initially emerge. The larvae retain their black heads and become greenish-yellow in their second instar, at which time their bodies begin to sprout small hairs. By their third instar, the larvae develops raised bumps on their bodies and are green with black heads. Five yellowish longitudinal lines are also visible, two on each side and one going along the back. The larvae in their fourth instar bear a striking resemblance to those in their third. The larval stage is responsible for the greatest extent of plant damage, as the larvae consume the leaves, leaving behind only the skeletal framework of the leaf structure.

Pupae: Larvae pupate on or near the host plant, forming a chrysalis that lasts 10-20 days, depending on temperature and environmental conditions.

Adults: The adult stage of the butterfly lifecycle, characterized by the emergence of fully developed butterflies from their chrysalides, marks the initiation of the reproductive phase. The mature butterflies exhibit pale white colouration with a smoky shade on the dorsal side of their bodies. A distinct sexual dimorphism is observed in the female adults, featuring two prominent dark black spots located on the distal end of the forewings, enabling easy differentiation from their male counterparts. Upon emergence, the primary objective of the adult butterflies is to engage in mating and subsequently lay eggs to ensure the continuation of the species. The lifespan of adult butterflies typically ranges from one to three weeks, with variations influenced by prevailing environmental conditions.

Migration patterns of *Pieris brassicae*

The large white butterfly, *Pieris brassicae*, is a widespread and familiar species across much of the Palearctic region, including India. While it is resident across northern and central India, this butterfly exhibits seasonal migration patterns in certain parts of the subcontinent. Understanding *Pieris brassicae*'s migratory behaviour is important for its population management and control as a significant agricultural pest.

***Pieris brassicae* in India**

The large white butterfly is widely distributed in India, found in the northwestern, northern, northeastern and eastern states, as well as parts of central and western India. It thrives particularly well in the low elevations up to around 2000 m. In the western Himalayas, *Pieris brassicae* is common. It is an altitudinal migratory that migrates back in the summer after declining to plains and lower slopes in the winter. As a multivoltine species, *Pieris brassicae* can have multiple overlapping broods in a year in the milder parts of its Indian range. In the northern plains region, it generally has 3-4 generations annually, with the first brood emerging in early spring from overwintered pupae. Subsequent generations continue developing throughout the warm months. However, the number of annual life cycles declines at higher latitudes and elevations where summers are shorter. In the Himalayan foothills and mountains, *Pieris brassicae* may only have 1-2 generations before the onset of winter when dormancy is induced. This plasticity in number of annual generations is regulated by photoperiodic responses that trigger diapause (dormancy) in the pupal stage when day lengths decrease below a population-specific critical point in autumn. Populations from milder areas enter diapause at shorter day lengths compared to those adapted to harsher winter conditions.

Life cycle of cabbage butterfly

Host plants and pest status

Pieris brassicae is primarily a pest of cruciferous crops like cabbage, cauliflower mustard, and related vegetables in the family Brassicaceae. The larvae can cause complete defoliation of the host plants if left unchecked. In India, it is considered as a major pest on cultivated crucifers across the northern plains, particularly in Uttar Pradesh, Punjab, Haryana and western Himachal Pradesh. Infestations can significantly impact production of important vegetable and oilseed mustard crops in this region.

Migration patterns

While *Pieris brassicae* is generally resident across northern India, some populations do undertake seasonal migrations. These are most notable in the mountainous regions of the Himalayan ranges and northeastern India.

Himachal Pradesh: In Himachal Pradesh, mass migrations of *Pieris brassicae* occur from the mid elevations between 1000-2000 m into the higher mountain valleys above 2500 m in early summer. The butterflies disperse in mass from their overwintering sites in search of young cruciferous plants to deposit eggs. This migration coincides with the start of the growing season in the high altitude regions after winter snow melt. Crops like cauliflower cultivated in these elevated locales are vulnerable to heavy infestations during this influx. A reversal of this migratory movement back to the mid elevations occurs in late summer/early fall as conditions deteriorate at the highest elevations. The butterflies then return to more favourable overwintering grounds.

Sikkim and Arunachal Pradesh: In Sikkim and Arunachal Pradesh in India's northeastern mountains, *Pieris brassicae* engages in altitudinal migration similar to Himachal Pradesh. However, there is also evidence of more long-range latitudinal and longitudinal migrations into these

states from outside bordering regions. Monitoring with radar has detected mass influxes of *Pieris brassicae* arriving in spring in Sikkim from overwintering grounds in Nepal, Bhutan and Bangladesh to the south and southeast. These migrations originate at lower elevations and latitudes.

Future prospects

Pieris brassicae is a significant pest of key cruciferous crops such as cabbage and cauliflower. In order to reduce the damage caused by this insect, it is very crucial to be able to predict migration and monitor adult mass movements. Ultimately damage of the migration biology of this insect can advise. Future research on the migration patterns of *Pieris brassicae* should definitely focus on understanding the potential impacts of climate change. Climatic changes affecting temperature, moisture, and seasonality will inevitably impact the availability and quality of *Pieris brassicae*'s habitats, both along migration routes and in breeding/overwintering areas. Monitoring things like host plant distributions, nectar sources, overwintering sites, and refugia from extreme conditions will be crucial for conservation management. As the climate envelopes favourable to *Pieris brassicae* shift geographically, there is a range contractions in some areas and expansions into newly suitable regions. This could facilitate colonization of new habitats, or exacerbate pest impacts if ranges expand into crucial agricultural areas. Models projecting potential range shifts will aid preparedness. To persist, *Pieris brassicae* populations may need to adapt higher thermal tolerances and altered seasonal phenological triggers like critical photoperiods. Research tracking micro evolutionary changes in traits like diapause initiation, heat tolerance, host preferences, and other adaptations will indicate if and how this insect is evolving resilience.

Pieris brassicae larval infestation: Skeletonizing leaves

Larvae feeding on leaves

SUMMARY

Pieris brassicae migration is a complicated phenomenon that is influenced by a variety of environmental, genetic, and ecological factors. The migratory behaviour of this species is greatly influenced by seasonal movements, intergenerational migrations, climatic conditions, habitat availability, and predation pressure. Despite the challenges posed by long-distance travel and potential gene flow, *Pieris brassicae* populations maintain local adaptations, such as photoperiodic regulation of diapause, which are crucial for synchronizing their life cycles with regional environments. Understanding the intricate interplay between these factors is essential for comprehending the evolutionary advantages of migration and the mechanisms that enable *Pieris brassicae* to navigate and survive across diverse climatic zones. As climate change and habitat loss continue to impact their migratory routes and destinations, ongoing research and conservation efforts will be vital to ensure the persistence and ecological success of this widely distributed butterfly. Future research should focus on the genetic basis of migration, the effects of climate change on migratory patterns, and the development of innovative tracking technologies to gain deeper insights into the behaviour and adaptations of *Pieris brassicae*. By advancing our understanding of these dynamics, we can better predict and mitigate the impacts of environmental changes on this species, contributing to the broader knowledge of insect migration and conservation biology.

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Infestation of lesser grain borer on roasted makhana seeds under storage

The internal stored grain insect (lesser grain borer), *Rhizopertha dominica* (Coleoptera: Bostrichidae) was found infesting on the roasted makhana seeds of 3 standard size grades, i.e. 7 mm, 9 mm and 11 mm. It was recorded that insects preferred to feed on 11 mm size seeds, followed by 9 mm and 7 mm, respectively. Both grub and adult stages were able to cause substantial damage. The adult laid the eggs on the seeds by entering inside the kernels through the apical natural opening. The average temperature and relative humidity for *R. dominica* development was maintained as 32.5 ± 1°C and 70 ± 5°C, respectively. It took 35–50 days for completing its life cycle, which included four stages: egg, larva, pupa and adult. Females laid about 200–500 eggs in their lifetime, singly. Incubation period lasted for 5±0.3–9±0.4 days, while larval and pupal period took 30±5 and 8±2 days, respectively. Mean longevity of adult male and female was 26 and 17 weeks, respectively. The damage potential was assessed using the artificial infestation (purposive samples) with different numbers of tested insect. The study indicated that significant loss of roasted makhana seeds during 15 days of storage with 40±1.24% losses, caused by 10 adults per 100g seeds. The total quantitative losses observed for 6 months storage period was 64±1.16% in the samples with 10 adults per 100g of roasted makhana seeds. The initial losses were very high and became slow after 20 days. Presently available method of fumigation by aluminium phosphide was practised and found feasible for the insect control.

Internal makhana feeding

Lesser grain borer (adult and grub)