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Insect Diapause: A review

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Introduction

To adapt to the alternating periods of favourable and unfavourable environmental circumstances over a range of time scales, all creatures on Earth have evolved biological rhythms. Diapause is a seasonal state of dormancy that has evolved to withstand repeated bouts of unfavourable environmental circumstances. It is brought on by biotic and abiotic processes that occur before the onset of these conditions. In many insect species, diapause is a crucial adaptation that allows them to live in areas that would otherwise be unsuitable for permanent occupancy and to maintain high populations in environments that may otherwise only be able to support a small population. (Wheeler, W. M. 1893) used the word "diapause" to describe the period of the grasshopper Conocephalusensiferum's development when it was still in the egg. The definition of diapause was further expanded by (Henneguy, L. F. 1903) to include several insect life phases as "periods of arrest in ontogenetic (origin and development of organisms) development." Insects have a high chance of surviving a lot of seasonal changes in the environment thanks to the diapause process. According to (Beck, S. D. 1962), "state of arrested development in which the arrest is enforced by a physiological mechanism rather than by concurrently unfavourable environmental conditions".

Incidence of Diapause:-

Diapause may occur in any stage of the life cycle of insects, such as eggs, larvae, pupae or adults. The stage at which diapause occurs is highly characteristic for each species. Moreover, there is no case known in which diapause occurs in more than one stage in the same life cycle. At the egg stage, it may begin when the embryo is still very young (e.g., *Gryllulus, Austroicetes*); when embryo is half-grown (e.g., differential grasshopper, *Melanoplusdiflerentialis*); or when embryo is fully grown and apparently almost ready to hatch (e.g., red-legged grasshopper, forest tent caterpillar). In nymphs and larvae, diapause may occur more often in the last instar than other instars. The incidence of diapause may be

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quite variable, not only from species to species, but also between different populations of the same species.

Types of Diapause:-

Diapause can be either obligatory or facultative:

Insects with obligatory diapause will undergo this period of arrested development at the predetermined point in their life cycle, regardless of the environmental conditions. Diapause occurs in every generation. Obligatory diapause is most often associated with univoltine insects, meaning insects that have one generation per year.

Insects with facultative diapause undergo a period of suspended development only when conditions require it for survival. Facultative diapause is found in most insects and is associated with bivoltine (two generations per year) or multivoltine insects (more than two generations per year).

Phases/Stages of Diapause:-

Insect diapause is a dynamic process consisting of several successive phases. In the literature, the conception and naming of diapause phases are ambiguous and unsettled. The phases of diapause were distinguished by (Koštál, V. 2006). The definitions of different phases are given below as suggested by (Koštál, V. 2006).

Pre-diapause Phase:-

Induction Phase:

It occur at a genetically predetermined stage of life and occur well in advance of the environmental stress. This sensitive stage may occur within the lifetime of the diapause individual, or in preceding generations i.e., resulting in egg diapause. During this phase, insects are responsive to external cues called token stimuli. Token stimuli can may be any change in photoperiod, thermoperoiod orallelochemical from food source.This triggers the switch from direct development pathways to diapause pathways

Preparation Phase:

"Preparation phase occurs where the phases of diapause induction and initiation are separated by a period of direct development, during which the individual is covertly programmed for later expression of diapause. Behavioral and physiological preparations for diapause may take place." Changes taking place during this phase are food storage, behavioral changes and some changes in rate of development.

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Diapause Phase:-

Initiation Phase:

"Direct development (morphogenesis) ceases, which is usually followed by regulated metabolic suppression. Mobile diapause stages may continue accepting food, building of energy reserves and seeking suitable microhabitat. Physiological preparations for the period of adversity may take place and intensity of diapause may increase."

Maintenance Phase

The preparation phase usually follows the induction phase. Though insects may go directly from induction to initiation without a preparation phase. During this phase, insects accumulate and store molecules such as lipids, proteins and carbohydrates. These molecules are used to maintain the insect throughout diapause and to provide supplement for development following diapause termination. Diapause puparia of the flesh fly, *Sarcophagacrassipalpis* increase the amount of cuticular hydrocarbons lining the puparium, effectively reducing the ability of water to cross the cuticle.

Termination Phase

In insects that undergo obligate diapause, termination may occur spontaneously, without any external stimuli.In facultative diapauses, token stimuli must occur to termination diapause.These stimuli may include chilling, freezing or contact with water, depending on the environment conditions being avoided.These stimuli are important in preventing the insect from termination diapause too soon.The effect of diapause until the insect can resume its developmental process under favorable condition.

Post-diapause Phase

Diapause frequently ends prior to the end of unfavourable conditions and is followed by a state of quiescence from which the insect can arouse and begin direct development, should conditions change to become more favourable. This allows the insect to continue to withstand harsh conditions while being ready to take advantage of good conditions as soon as possible.

Evolutionary Aspects of Diapause:-

Species separated by geographic areas encounter a great variation in climate changes and thus leading to variation in their life cycles, like variable number of generations per year (univoltine, bivoltine, multivoltine and non diapausing strains). This phenomenon was first

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reported in [Union of Soviet Socialist Republics (USSR)]. For example, in the Northern Great Plains of North America, populations of red-legged grasshopper (*Melanoplussanguinipes*) are univoltine. (Fisher, J. R. 1993) reported that eggs laid in the late summer and fall continues their embryonic development until diapause or cold temperatures terminate development. In alpine and high latitude environments, the growing season is short, which delays insect egg hatching sometimes up to two seasons, while areas with longer growing seasons support bivoltine insect populations(Kreasky, J. B. 1960). (Dean, J. M. 1982) showed that *M. sanguinipes* from Kansas produced a high proportion of non-diapausing eggs when parents were exposed to increasing photoperiods. Similarly, corn borer (*Pyraustanubilalis*) is univoltine in northern states in U.S., while it is bivoltine or multivoltine in warmer states of Missouri and Kansas.

Environmental Factors Affecting:-

Diapause in insects is induced or terminated in response to environmental cues. These cues may include changes in the length of daylight, temperature, food quality and availability, moisture, pH, and other factors. No single cue solely determines the start or end of diapause. Their combined influence, along with programmed genetic factors, controls diapause.

- **Photoperiod:** A photoperiod is the alternating phases of light and dark in the day. Seasonal changes to the photoperiod (such as shorter days as winter approaches) cue the start or end of diapause for many insects. Photoperiod is the most important. During diapause, insects rely on photoperiod for a period of time, but varying temperature and other environmental factors modify photoperiodic effects on diapause. For example, European corn borer (*Ostrinianubilalis*) is a long day insect and larval diapause is induced by naturally occurring photoperiods with scotophases of 10-14 hr.
- **Temperature:** Along with photoperiod, changes in temperature (such as an extreme cold spell) can influence the start or end of diapause. The thermoperiod, alternating phases of cooler and warmer temperatures, also influences diapause. Some insects require specific thermal cues to end the diapause phase. For example, the woolly bear caterpillar must endure a period of chilling to trigger the end of diapause and continuation of the life cycle.

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- **Food:** As the growing season ends, the diminishing quality of their food sources may help trigger a diapause phase in an insect species. As potato plants and other hosts turn brown and dry, for example, Colorado potato beetle adults enter a state of diapause.

Conclusion:-

Diapause is a developmental stage that occurs in some animals during which morphological growth and development are stopped or significantly slowed.

Numerous scientists have given their own unique definitions of this phenomena, yet the fundamental concept is the same in all of them. Insects go through diapause at several phases of their lives, including embryo, egg, larvae, pupae, and adults. Even though it is considerably different from "quiescence," it can occasionally be challenging to tell the two occurrences apart.

Diapause is influenced by a number of variables, including temperature, photoperiod, moisture, diet, and location. Diapause can alter a variety of processes, including migration, polyphenism, and dormancy. Chemicals, hormones, oxygen levels, chromosome numbers, injury, and genetics can all be used to end diapause.

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