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Limb regeneration in coccinellids

Ruta C. Barot[1] and Shailesh D. Patel[2]

[1] Department of Entomology, B. A. College of Agriculture, AAU, Anand- 388110, India

[2] Directorate of Extention Education, AAU, Anand-388110, India

Corresponding author: barotruta97@gmail.com

Ladybirds (Coleoptera: Coccinellidae), also called ladybugs and ladybird beetles, are considered as beneficial because they are predators of aphids, mites, whiteflies, scale insects *etc*. Worldwide, nearly 6,000 species of ladybirds are known. Eggs of ladybird beetles are elongate-ovoidal in shape. Larvae are mobile and in some species are protected by waxy secretions. Cannibalism of eggs, larvae and pupae is common, especially when prey is scarce. Pupae are adecticous obtect type. Adults are oval shaped that can be yellow, pink, orange, red, or black in colour. They are usually marked with distinct spots. Their length ranges from about 0.8 mm to over 18 mm depending upon species. Females are generally larger than males (Anon., 2014).

Limb regeneration

Limb regeneration is the process of re-growth of lost body parts in an organism (Saxena *et al.*, 2016). It is reported in 36 genera of 11 orders of insects, including Blattodea, Phasmatodea, Ephemeroptera, Odonata, Orthoptera, Hemiptera, Diptera, Lepidoptera, Coleoptera *etc*. Regeneration in arthropods can occur only during the process of moulting when the epidermis separates from the cuticle. Wound healing takes place just immediately after amputation, while full regeneration will take place during the moult.

Types of regeneration

(1) Physiological regeneration: In which replacement of constant loss of many kinds of cells due to wear and tear caused by day-to-day activities**.** (2) Reparative regeneration: During reparative regeneration lost parts are repaired or replaced. (3) Autotomy: Self multiplication of body part which is broken off on being threatened by a predator. Wu *et al*. (2015) reported three phenotypes in leg regeneration *viz*. (1) no regeneration (2) partial regeneration and (3) complete regeneration. Maruzzo and Bortolin (2013) reported four levels of regeneration potential *viz*., (1) lack of regenerative potential (mite) (2) poor regenerative potential (scorpion) (3) good regenerative potential (black widow spider) and (4) very good limb regenerative potential (cockroaches).

Modes of regeneration

Das (2015) described two modes of regeneration: epimorphosis and morphollaxis. Epimorphic regeneration involves the

formation of a specialized and transient structure called a blastema. The regenerating blastema is a mass of dedifferentiated cells, obtained through the loss of cellular specialization, with the ability to proliferate and re-differentiate into all cellular components of the lost structure. During morphallaxis, insect regenerates by reorganizing the remaining tissues following an injury or loss of body parts, requiring little or no cell division.

Mechanism of limb regeneration

Epimorphosis mode of limb regeneration has been divided into 4 general stages, which involved (1) wound healing (2) blastema formation, (3) blastema proliferation and (4) subsequent re-patterning of the de-differentiated tissue (Wu *et al*. 2015).

Effect of limb regeneration on coccinellids

Growth parameters

Wu *et al.* (2015) observed that the regeneration frequency in *Coccinella septempunctata* (seven spotted ladybeetle) was greater in half ablation as compared to complete ablation and it decreased with increasing instar, but it was unaffected by the thoracic location of the ablated leg and the side of the body to which the leg was attached. Wang *et al*. (2015) reported that regenerated *Harmonia axyridis* (Asian ladybeetle) adults spent more time during pupation and male as well as female were heavier than unregenerate and control adults. Saxena et al. (2016) revealed that the site of amputation influenced the degree of regeneration in *Menochilus sexmaculatus* (Zig-zag ladybird) adults. Distal amputation of forelimb led to more regeneration than proximal ones, and amputation in the fourth instar led to more regeneration than the third instar. Abdelwahab *et al*. (2017) revealed that regenerated beetles (*H. axyridis*) spent longer time in pupation, and fresh body weight of emerging females was lower than that of controls.

Reproductive parameters

Wang *et al.* (2015) found that *H. axyridis* females preferred to mate with regenerated males as compared to unregenerated and control males in choice tests. They further found that females mating with regenerated males produced more fertile eggs than unregenerate and control males. Abdelwahab *et al*. (2017) reported that reproductive parameters of *H. axyridis* were unaffected by different pair wise crosses of control and regenerated adults. However, Wu *et al*, (2018) reported that the *C. septempunctata* females paired with leg-regenerated males laid a significantly high number of eggs as compared to that paired with normal male.

Effect on progeny

Wang *et al*. (2015) observed that progeny of female mated with leg regenerated male had higher immature survival rate as compared to unregenerated male in *H.*

axyridis. Abdelwahab*et al*. (2017) did not find a significant difference for the incubation period, pupal period and male fresh weight in the progeny of *H. axyridis* produced by different pair-wise crosses of control and regenerated adult beetles. Whereas, female fresh weight of progeny was significantly higher, if any one or both of the parents had regenerated as compared to that of control parents.

Cost of limb regeneration

According to Wu *et al*. (2018) costs of limb regeneration are: (1) high pupation period (2) decrease foraging ability (3) decrease grasping ability (4) decrease sensory capability (5) decrease consumption rate (6) decrease competitive ability.

Conclusion

Regeneration is a developmental process of re-growth of lost body part. Reparative type of regeneration takes place in coccinellids through epimophosis mode. Regeneration increases pupation time, pupal weight, fecundity and egg viability (in some cases). Females prefer to mate with limb regenerated males over un-regenerated and control males. Female fresh weight of progeny of limb regenerated coccinellid was higher as compared to that of control parents.

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