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ROLE OF EGG SURFACE ALKALOIDS IN CANNIBALISM AND INTRAGUILD PREDATION IN TWO SPECIES OF APHIDOPHAGOUS LADYBIRD BEETLES (COLEOPTERA: COCCINELLIDAE)

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ABSTRACT

Cannibalism and intraguild predation (IGP) are two very imperative constituents determining the structure of biological communities. Ladybird beetles, frequently known as the farmer's friends, easily partake in cannibalism and IGP when their usual prey i.e., aphid population declines. Eggs although defenseless, fall easy victim both for the adults as well as the larvae of the ladybirds and are demolished thus, providing a chance to endure life. The eggs are encrusted with alkaloids helping in easy recognition of conspecific as well as heterospecific eggs. A study was conducted to identify the role of these alkaloids in cannibalism and intraguild predation among two aphidophagous ladybird species namely, *Cheilomenes sexmaculata* and *Coccinella transversalis*. Results specify that the fourth instar and adult female of *C. sexmaculata* have a strapping propensity to chip in intraguild predation while *C. transversalis* favours cannibalism.

KEY WORDS: Cannibalism, *Cheilomenes sexmaculata*, *Coccinella transversalis* , intraguild predation (IGP).

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INTRODUCTION

The interfaces among natural-enemy species can be multifaceted and in the biological communities cannibalism and intraguild predation (IGP) are among the most imperative determinants of the population dynamics and community structure [1]. Cannibalism is pervasive among generalist predators like ladybird beetles [2]. Cannibalistic feeding carries numerous impending costs counting thrash of comprehensive fitness if relatives are consumed [3] and the jeopardy of injury and disease transmission during attack. This facilitates the fittest survivors to prosper on conspecifics and complete their development so that on becoming adults they can fly to other prey sites for reproduction and subsistence. Cannibalism incidence is known to augment when food accessibility beg s off and the eggs, lower and same stage larvae, pre-pupae and pupae of ladybirds are recurrently cannibalized both in the fields as well as under laboratory conditions [4].

Intraguild predation (IGP) is familiar in ecological systems [5]. IGP occurs when one species in a predatory guild feeds on another predatory species within the guild. The assailant is the intraguild predator (IG predator), the victim is the intraguild prey (IG prey) and the regular resource is the extraguild prey. It not only provides a supplementary food resource to IG predators but also lessens inter or intraspecific competition and predation risk in cases of mutual IGP. At the community level, IGP can cause spatial and temporal segregation of intraguild predators and prey with the IG prey confined to less apposite habitats or periods [6]. Unhatched eggs in the inconsistent habitat are the easy targets. Thus, conditions favouring aphid paucity encourage cannibalism and IGP in ladybirds.

Ladybird beetles (Coleoptera: Coccinellidae) frequently branded as Farmers Friends are known to predate on aphids, mealy bugs, scale-insects, whiteflies, thrips, leafhoppers, mites and other small soft bodied insect pests[7]. They are known to prey on about 39 arthropod species [8]. The predatory coccinellids dwell in all the habitats and niches of their preys and are allocated worldwide. Slight is known about the vital elements unswervingly correlated with cannibalism and intraguild predation (IGP) in the ladybirds [9]. It is well ascertained that ladybirds lay eggs in the environs of high concentration of aphids [10] that permits new born larvae to eat young aphids. Any hindrance in the form of inters or intraspecific competition or population crumple of aphids may result in cannibalism and intraguild predation in the larvae which are under tremendous pressure to complete their development.

Ladybirds are shielded by autogenously produced alkaloids, which are interspecifically variable and generally persist through all stages of the life cycle [11]. When a ladybird eats another ladybird species, with different alkaloid defences, it frequently suffers noxious effects [12][13], and many species employ egg-surface hydrocarbons to avoid interspecific prey, unless starving [14][15]. Nonetheless, IGP does occur between ladybird species and a few species appear to be adapted to assail and eat other species of ladybird [16][17]. *Cheilomenes sexmaculata Fabricius* and *Coccinella transversalis* Fabricius are two heterospecific species of ladybird beetles recurrently encountered in the gardens as well as agricultural fields. Both have a colossal prey range like other members and aggressively partake in the episodes of cannibalism as well as intraguild predation both in laboratory as well as field conditions [18].

Our study deals with the episodes of cannibalism and intraguild predation among these species when both conspecific and heterospecific eggs were taken into consideration and the results point out that the frequency of cannibalism was superior in *C. transversalis* while the episodes of intraguild predation were elevated in *C. sexmaculata*.

MATERIALS AND METHODS

Stock Culture

For the maintenance of the stock culture, adults of *C. sexmaculata* and *C. transversalis* were unruffled from the agricultural fields neighboring Allahabad region and brought to the laboratory. Mating pairs were parted and kept in plastic Petri dishes (9.0x 2.0 cm) in the environmental test chamber (27±1°C; 65±5% RH; 14:10 LD) and allowed to feed on different species of aphids viz., *Aphis craccivora* (Koch), *Aphis gossypii* (Glover), *Lipaphis erysimi* (Kaltenbach) and *Hysteroneura setariae* (Thomas) infested on *Dolichos lablab*, *Lagenaria vulgaris*, *Raphanus sativus* and *Cynodon dactylon*. The mated females laid eggs daily which were separated and observed for hatching. Hatched larvae were used for the commencement of the experiment. The dried twigs and leftover aphids were replenished after every 24 hour in order to avoid the microbial onslaught. All the experimental trials were performed in the plastic Petri dishes of the same size and replicated 20 times.

Experimental Protocol

For the execution of the experiment different set ups were designed. Eggs of related mothers were chosen. In all the experimental set ups two parallel lines were drawn in the centre of the Petri dish and eggs of both the species were placed on them at equal distances separately and following combinations were made:

(i) Normal conspecific eggs (N=10), washed conspecific eggs (N=10).
(ii) Normal conspecific eggs (N=10), heterospecific eggs (N=10)

The eggs were washed with n-hexane for 10 minutes in order to remove the egg surface chemicals. 24-hour starved fourth instar larvae as well as adult females of both the species were released in the centre of the Petri dish. Observations were taken for the first contact, total number of eggs cannibalized as well as for the intraguild predation for 30 minutes, 1, 2 and 3 hours. The data obtained was analyzed by Kruskal-Wallis Test. The data on consumption of conspecific and heterospecific eggs was analyzed by Chi square test. All the analyses were performed by the statistical software Minitab 13.2 [19].

RESULTS

Kruskal-Wallis test gave a significant effect on the first contact and total egg consumption of the normal and washed eggs by the fourth instar of both the species. (H=4.89; P<0.001; df=5) (**Fig.1**). Significant effect was also noticed in case of the adult female of both the species by the same test (H=14.29; P<0.001; df=5) (**Fig.2**). Chi square shows a significant effect on the consumption of conspecific and heterospecific eggs by the fourth instar of both the species (χ^2=; P) (**Fig.3**). Significant was also obtained on the consumption of conspecific and heterospecific consumption of eggs by the adult females of both the species (χ^2=; P) (**Fig.4**).

DISCUSSION

Our study specifies that both the fourth instar as well as the adult females of *C. transversalis* and *C. sexmaculata* prefer to contact as well as cannibalize the normal conspecific eggs in comparison to the washed conspecific eggs. This can be recommended by the fact that the eggs are coated with species specific alkaloids that are identified by the adult females a well as the instars. Chemical protection of eggs has been well documented in an assorted array of insect species [20]. These chemicals are also known as semiochemicals in more refined terms and are accountable for determining insect life situations such as feeding, mating, and egg-laying (ovipositing). Semiochemicals are diminutive organic compounds that convey chemical messages. They are used by insects for intra- and interspecies communication. Insects sense semiochemicals directly from the air with olfactory receptors. In most insects, the receptors are positioned in sensilla hairs on the antennae. Both the adult females as well as the larvae are able to be acquainted with conspecific eggs as these species-specific alkaloids are relocated from the mother to the offspring through genes and also environmental cues energetically contribute in this process. Analogous verdicts have been obtained in *C. septempunctata* [21] and *Apis mellifera* [22].

Cannibalism is indispensable for survival when aphids become sparse and former studies have supported the advantages of egg cannibalism because of its nutritional benefits [23] and squat perils from ingesting detrimental species-specific surface alkanes [24]. These chemicals covering the egg surface negotiate ladybird survival [25] and play a major role in kin recognition [26] as insects hardly differentiate con-and heterospecific eggs once these surfaces are washed off. The nutritional benefits of cannibalism are of two kinds. First, it means admittance to an energy source that is not accessible for cannibals and thus, boosts the food availability for the cannibals [27]. Second, conspecifics may have a dissimilar composition of nutrients than alternative prey types and cannibalism may provide nutrients in proportions that are more optimal heterospecific diets [28]. Conspecific egg cannibalism provides enhanced nutritional prerequisites as they are affluent in cholesterol [29]. It materializes that egg cholesterols are also species specific and more appetizing to conspecifics than heterospecific insects and alike findings are also acquired in our study.

The consumption of heterospecific eggs was also less in the adult females of both species and this can be proposed by the fact that chemical cues have a substantial role in insect ecology. The conspecific egg surface alkanes attract cannibals [30] while heterospecific ones shield eggs from IGP [21]. Both females preferred to devour the conspecific eggs and this can be linked with the verity that adult females are better in sensing species-specific alkaloids and evade consuming too many toxic alkaloids from heterospecific eggs. Being extremely reactive to semiochemicals females acclimatize themselves to optimal foraging [31] and avoid ovipositing on prey patches freshly visited by heterospefic predators. Fourth instars of *C. transversalis* also preferred to consume conspecific eggs in contrast to the heterospecific eggs and this can be coupled with the fact that larvae are also able to recognize the ‘self’ eggs from the ‘non’self’ eggs as they are able to sense the chemicals present on the surface of eggs and consumption of heterospecific may result in mortality and the population of ladybirds may crumple. These species specific chemicals have also been segregated from the larval trails. Our studies are in swift agreement with studies on *C. transversalis* [18].

However, the fourth instars of *C. sexmaculata* preferred consume the heterospecific eggs. This can be envisaged by the fact preying on the heterospecific eggs may be advantageous as it acts as a food source and also the threat of potential predators is curtailed. Unhatched eggs in the patchy habitat of ladybirds are easy targets and thus, the conditions favouring aphid scarcity also promote cannibalism in ladybirds. Fresh eggs are more nutritive than the older eggs and it costs less to eat eggs and helps in survival of larvae as the fourth instars are under peer pressure of undergoing pupation. Here in our study also the fourth instars emerged as strong intraguild predators. IGP mainly occurs with generalist predators that attack prey of smaller size [5]. In most taxa, the frequency of mortality is inversely correlated with size, with smaller individuals being more vulnerable and threatened by more predators. So, eggs being smaller in size and defenceless are frequently attacked by the larvae no matter whether they are self or ‘non-self’. Our findings are in connection with those carried out on the larvae of *C. septempunctata, Chrysoperla carnea* and *C. sexmaculata* where the larger individual preyed on the smaller individual supporting intraguild predation [32][33][18].

CONCLUSION

It can be concluded from our studies that:
1. Fourth instar and adult female of *C. sexmaculata* participate frequently in intraguild predation
2. While *C. transversalis* favours cannibalism.

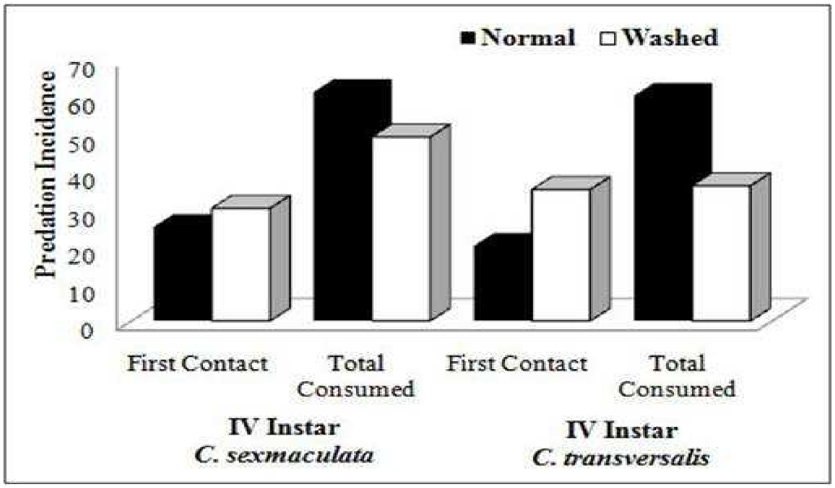

Figure 1
Graph showing predation incidence of fourth instars of Cheilomenes sexmaculata and Coccinella transversalis when fed on normal and washed conspecific eggs.

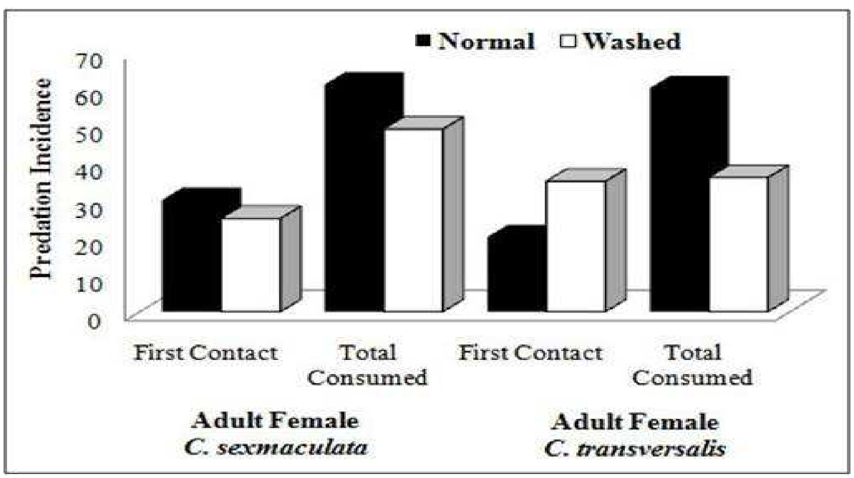

Figure 2
Graph showing predation incidence of adult females of Cheilomenes sexmaculata and Coccinella transversalis when fed on normal and washed conspecific eggs

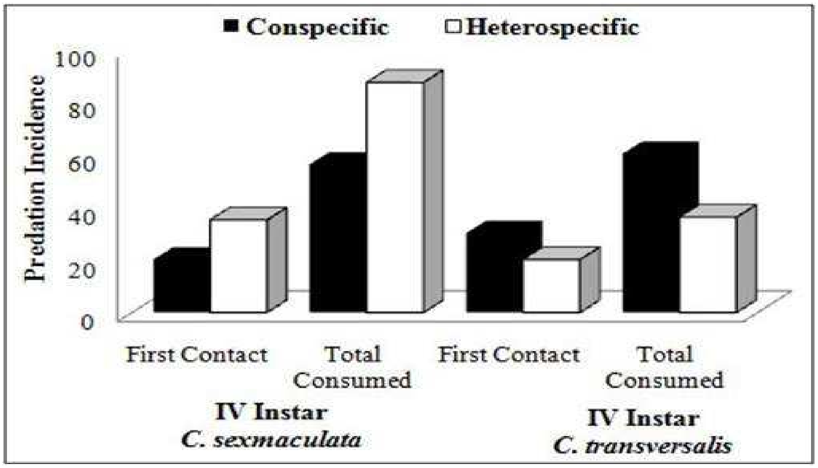

Figure 3
Graph showing predation incidence of fourth instars of Cheilomenes sexmaculata and Coccinella transversalis when fed on conspecific and heterospecific eggs.

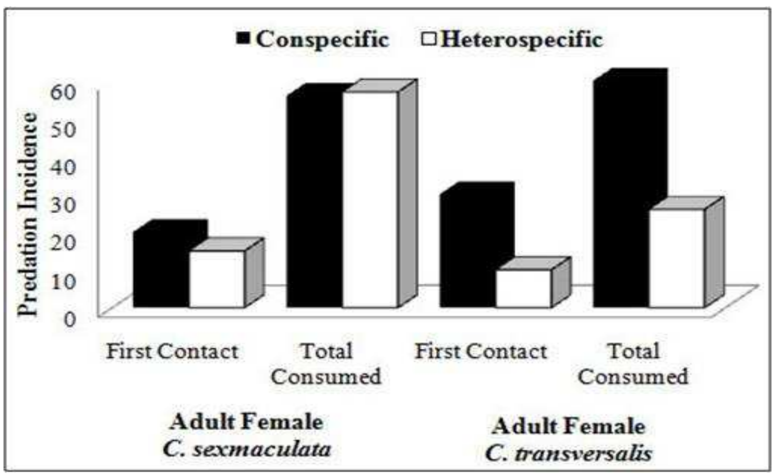

Figure 4
Graph showing predation incidence of adult females of Cheilomenes sexmaculata and Coccinella transversalis when fed on conspecific and heterospecific eggs.

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REFERENCES

1. Omkar, Mishra, G. and A. Pervez, Intraguild predation by ladybeetles: An ultimate survival strategy or an aid to advanced aphid biocontrol?. Professor S.B. Singh Commemorative Volume, Zoological Society, India, 77-90, (2002)

2. Rosenheim, J. A., Higher-order predators and the regulation of insect herbivore populations. Annu Rev Entomol, 43: 421–447, (1998)
3. Joseph, S. B., Snyder, W.E. and A.J. Moore, Cannibalizing *Harmonia axyridis* (Coleoptera: Coccinellidae) larvae used endogenous cues to avoid eating relatives. J Evol Biol, 12: 792-797, (1999)
4. Dixon, A.F.G., Patch quality and fitness in predatory ladybirds. Ecological studies analysis and synthesis. 130: 205-233, (1997)
5. Polis, G.A., Mysers, C.A. and R. Holt, The ecology and evolution of intraguild predation: potential competitors that eat each other. Annu Rev Ecol Syst, 20: 297-330, (1989)
6. Moran, M.D., Rooney, T.P. and L. E. Hurd, Top-down cascade from a bitrophic predator in an old-field community. Ecol, 77: 2219-2227, (1996)
7. Omkar and Pervez, A., Biodiversity in predaceous coccinellids (Coleoptera: Coccinellidae) in India- A review. J Aphidol, 14: 41-66, (2000)
8. Gautam, R.D., Influence of different hosts on the adults of *Menochilus sexmaculatus* (Fab). J Biol Cont, 3**:** 90–92, (1989)
9. Yasuda, H., Kikuchi, T. and P. Kindlmann, Relationships between attack and escape rates, cannibalism and intraguild predation in larvae of two predatory ladybirds. J Ins Behav, 14: 373-383, (2001)
10. Dixon, A.F.G., An experimental study in the searching behavior of the predatory coccinellid beetle *Adalia decempunctata* (L.). J Anim Ecol, 28: 259-281, (1959)
11. King, A.G. and J. Meinwald, Review of the defensive chemistry of coccinellids. Chem Rev, 96: 1105–1122, (1996)
12. Hemptinne, J.-L., Lognay, G., Gauthier, C. and A.F.G. Dixon, Role of surface chemical signals in egg cannibalism and intraguild predation in ladybirds (Coleoptera: Coccinellidae). Chemoecol, 10: 123–128, (2000a)
13. Cottrell, T.E., Predation and cannibalism of ladybeetle eggs by adult ladybeetles. Biol Cont, 34: 159-164, (2005)
14. Hemptinne, J.-L., Dixon, A.F.G. and C. Gauthier, Nutritive cost of intraguild predation on eggs of *Coccinella septempunctata* and *Adalia bipunctata* (Coleoptera: Coccinellidae). Eur J Entomol, 97: 559– 562, (2000b)
15. Omkar, Pervez, A. and A.K. Gupta, Role of surface chemicals in egg cannibalism and intraguild predation by neonates of two aphidophagous ladybirds, *Propylea dissecta* and *Coccinella transversalis.* J Appl Entomol, 128: 691-695, (2004)
16. Lucas, É., Intraguild predation among aphidophagous predators. Eur J Entomol, 102: 351-364, (2005)
17. Sloggett, J.J., Haynes, K.F. and J.J. Obrycki, Hidden costs to an invasive intraguild predator from chemically defended native prey Oikos, 118: 1396–1404, (2009a)
18. Maurice, N. and A. Kumar, Effect of food quantity and food consumed on the body weight and the developmental duration of two species of ladybirds (Coleoptera: Coccinellidae). Ann Plt Protect Sci, 19 (1): 59-62**, (**2011)
19. Minitab 13.2., MINITAB Statistical Software, Minitab Release 13.2. Minitab, Inc., Pennsylvania, USA, (2003).
20. Ware, R.L., Majerus, M.E.N., Ramon, F., Ducamp, C., Hemptinne, J.L. and A. Margo, Chemical protection of *Calvia quaturodecimguttata* eggs against intraguild predation by the invasive ladybird *Harmonia axyridis*. Biological Control to Invasion: Ladybird *Harmonia axyridis.* BioCont (this issue), doi:10.1007/s10526-007-9129-6, (2007)
21. Khan, R.M., Khan, R.M. and M.Y. Hussein, Cannibalism and interspecific predation in ladybird beetle *Coccinella septempunctata* (L.) (Coleoptera: Coccinellidae) in laboratory. Pak J Biol Sci, 6(24): 2013-2016, (2003)

22. Martin, S.J., Chậline, N., Oldroyd, B.P., Jones, G.R. and F.L.W. Ratnieks, Egg marking pheromones of anarchistic worker honey bees (*Apis mellifera*). Behav Ecol, 15(5): 839-844, (2004)
23. Snyder, W.E., Joseph, J.B., Preziosi, R.F. and A.J. Moore, Nutritional benefits of cannibalism for the lady beetle *Harmonia axyridis* (Coleoptera: Coccinellidae) when prey quality is poor, Env Entomol, 29: 1173-1179, (2000)
24. Hemptinne, J.-L., Doumbia, M., Dixon, A.F.G., Assessment of patch quality by ladybirds: role of aphid and plant phenology J Insect Behav 2000, 13, 353-359.
25. Hemptinne, J.-L., Doumbia, M. and A.F.G. Dixon, Chemical nature and persistence of the oviposition deterring pheromone in the tracks of the larvae of the two spot ladybird, *Adalia bipunctata* (Coleoptera: Coccinellidae). Chemoecol, 11: 43-47, (2001)
26. Agarwala, B.K. and A.F.G. Dixon, Kin recognition: egg and larval cannibalism in *Adalia bipunctata* (Coleoptera: Coccinellidae). Eur J Entomol, 90: 45-50, (1993)
27. Rohwer, S., Parent cannibalism of offspring and egg raiding as a courtship strategy. Am Nat, 112: 429-440, (1978)
28. Fagan, W.F., Siemann, E., Mitter, C., Denno, R.F., Huberty, A.F., Woods, H.A. and J.J. Elser, Nitrogen in insects: implications for trophic complexity and species diversification. Am Nat, 160: 784-802, (2002)
29. MacDonald, D.L., Nham, D. N., Cochran, W.K., and K.S. Ritter, Differences in the sterol composition of *Heliothis zea* fed *Zea mays* versus *Medicago sativa.* Insect Biochem, 20: 437-442, (1990)
30. Gagne I., Coderre D. and Y. Mauffette, Egg cannibalism by Coleomegilla maculata lengi neonates: Preference even in the presence of essential prey. Ecol Entomol, 27: 285–291, (2002)
31. Kindlmann, P. and A.F.G. Dixon, Optimal foraging in ladybird beetles (Coleoptera: Coccinellidae) and its consequences for their use in biological control. Eur J Entomol, 90: 443-450, (1993)
32. Blackman, R.L. and V.F. Eastop, Aphids on the World's Crops: An Identification and Information Guide. John Wiley& Sons, Chichester, (1984), pp 414,
33. Agarwala, K. and J.L. Saha, Larval voracity, development and relative abundance predators of *Aphis gossypii* on cotton in India. In: I. Hodek ed., Ecol Aphid Academia, Prague, 339–344, (1986)