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Designed foraging behavior of *Lasioderma sericone* and future dividend for procreation

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Abstract
The present research work explains experimentally about how the foraging behaviour of cigarette beetle larvae can make an excellent opportunity for its reproductive success in future when same larvae become adult. The larvae was found to make burrows and tunnels in grains as a part of its normal feeding activity and incidentally the adult insects emerged from the same larvae selectively uses the burrows and tunnels in the grain to lay eggs. Besides the burrows and tunnels offering protection to eggs, the eggs laid inside the above sites showed significantly short egg to pupa conversion time and short pupal phase when compared to the eggs laid in the open field. Our findings indicate the larval foraging behavior is not just part of its physical survival but has got great evolutionary significance for higher reproductive success. We have studied the above by harvesting age and sex matched cigarette beetle in grains as well as the flour made of above grains. Also we studied the insects reared from the larvae that were grown in grains found to make burrows and tunnels as well as the larvae grown in flour.

Keywords: *Lasioderma serricone*, future dividend, cigarette beetle

Introduction
Lasioderma serricone is otherwise called as cigarette beetle; has earned the title of notoriety all over the world for damaging various food items, agricultural produce, grains, tobacco and museum artifacts etc. Although several measures are employed for controlling insect infestation still an effective method is far from near [1].

Eusocial and defined division of labor hierarchy is well established in several insects like an ant, termite, honey bee etc., but cigarette beetle still shows primitive level of evolution when compared to several eusocial insects but with a high success rate [2]. In our recent experimental observation we have established that the future vision and dividends for procreation are well implanted in the foraging behavior of the larvae of the cigarette beetle. The larvae of most insects are known to be voracious feeders and gluttons causing great damage to agriculture, stored food and tobacco [3]. But even in such foraging design of the larvae, a future dividend for its successful procreation is implanted in the case of cigarette beetle which is unknown.

We believe that the foraging behavior linked future dividend assurance pattern seen among the larvae of cigarette beetle may be one of the reasons for its remarkable success in the biome besides several measures taken by man to contain them. The above behavior seen among the larvae whether is a conscious gift of evolution or an accidental discovery perfected over time is difficult to establish.

We in the present paper have made attempt to explain through an experiment that the larval foraging behavior of making tunnels and burrows in the grains although may be a natural foraging pattern but the burrows and tunnels in the grains offer a definite future dividend to the same larvae to safely lay its eggs and complete the life cycle quickly. Details are presented in the paper.

Materials and Methods
Collection and culture of larvae
All the experiments were planned as per the method of Kohno, 1982 with small modifications wherever required [4].

The larvae hatched out (of the same age) from the eggs in our previous batch that was grown in wheat and corn flour mixture were collected and were divided into two groups of 12 larvae each.

One set of the 12 larvae were grown in pre-sterilized (alcohol whiped) chana dal and urdu dal grains in equal proportion in a beaker and incubated at ambient temperature for 45 days with regular observation at every 5 day interval and the other set of larvae where grown in equal proportion of channa dal and urdu dal flour and kept for 45 days with regular observation at every 5th day.

Collection of grains with burrows and tunnels and inoculation of adult insects

The grains from the above setup with burrows and tunnels were collected and were used for growing the adult insects. The above grains were separated into two parts and to one part, 6 pairs of adult insects (of the same age) were infested and the other part was mixed with the flour combination of urdu dal and chana and then infected the same with insects. Similarly, the third set of experiments was also run parallel to the above by infesting 6 pairs of adult insects in only flour mix of urdu dal and chana dal.

After 6-13 days, the grains were observed for eggs and the proportion of eggs inside the burrows and tunnels in each grain and as well as outside the grain were estimated with the help of a magnifying lens. Similarly the number of eggs inside the grain versus flour mix was also counted.

The fourth set of control experiments was conducted by infecting grains of chana dal and urdu dal (without burrows and tunnels) mixture with adult insects and then counted the proportion of burrows and tunnels made by the adult cigarette beetles vis-à-vis oviposition.

Larvae to pupa conversion time in grains with and without burrows and tunnels

Twelve pairs of larvae of the same age were infected in grains with burrows and tunnels as soon as the larvae got emerged from the eggs. Similarly another 12 pairs of larvae of same age were infected in grains without any burrows and tunnels as well as in a flour mix of urdu dal and channa dal. From the day of inoculation, pupa conversion time was recorded in all three conditions. Similarly, a battery of grains such as corn, rice, wheat, toor dal and coriander seeds with and without grains and burrows were also used to check the larva to pupa conversion time.

Results

Preferential oviposition tendency was observed in adult cigarette beetles in laying eggs inside the burrows and tunnels of grains than outside of it. This was observed strongly when combination of grains with burrows and tunnels along with flour mix was used. Whereas, in grains without tunnels and burrows the adults although laid eggs but the number of eggs was far too low in numbers in comparison to the grains with burrows and tunnels. (Table-1)

Table 1: Details of oviposition

Sample Details	Total number of eggs	Proportion of oviposition (%)	
		Inside burrows/tunnels	Outside burrows/tunnels
Control–urdu dal + chana dal (grains without burrows and tunnels)	±66	-	100
Urdu dal + chana dal (grains with burrows and tunnels)	± 130	80	20
Urdu dal + chana dal (grains with burrows and tunnels) along with flour mix	± 126	60	40
Flour combination of urdu dal and chana dal	± 120	-	100

Egg laying time also differed significantly in grains with burrows and tunnels where the adult insects were grown. In 2-4 days, the egg laying process has started in the above setup, whereas, in grains without burrows and tunnels it took 12-15 days for the insects to lay eggs. Similarly, in the combination of grains with burrows and flour mix were when used, the egg laying time remains short whereas only flour combination was used, the egg laying time got delayed by 5-7 days from 2-4 days (table-2).

Table 2: Egg laying time Vis-à-vis Egg hatching time

Sample Details	Time in days	
	Egg laying	Egg hatching
Control–urdu dal + chana dal (grains without burrows and tunnels)	12-15	6-8
Urdu dal + chana dal (grains with burrows and tunnels)	2-4	6-8
Urdu dal + chana dal (grains with burrows and tunnels) along with flour	2-4	6-8
Flour combination of urdu dal and chana dal	5-7	6-8

Larvae to pupa conversion time

Different types of grains such as urdu dal, channa dal, corn, rice and toor dal with burrows and tunnels have significantly reduced the larva to pupa conversion time from a minimum of two days to a maximum of six days. Whereas, the above grains without burrows and tunnels when used, we observed an increased larva to pupa conversion time with a minimum of 5 to a maximum of 13 days. Table- 3

Table 3: Larva to Pupa conversion time

Sample details	Days taken for larva to pupa conversion	
	Minimum	Maximum
Urdu dal (grains with burrows and tunnels)	2	4
Urdu dal (grains without burrows and tunnels)	7	10
Channa dal (grains with burrows and tunnels)	2	3
Channa dal (grains without burrows and tunnels)	5	8
Corn (Corn with burrows and tunnels)	2	3
Corn (Corn without burrows and tunnels)	7	8

Rice (grains with burrows and tunnels)	4	6
Rice (grains without burrows and tunnels)	10	13
Toor dal (grains with burrows and tunnels)	2	3
Toor dal (grains without burrows and tunnels)	10	12

Discussion

Implantation of the extravagant intelligence in the larval foraging behavior of cigarette beetles leading to certain oviposition linked economic dividend by the evolution, we have established through an experiment. When grains with burrows and tunnels were available for the adult insects to lay eggs, the insect preferentially chooses the hidden sites to lay its eggs than the open field in the given material (flour or grain). Further when the grains with burrows and tunnels were available, the laying time of the egg also got shortened significantly whereas when the grains devoid of burrows and tunnels delayed the laying time of the egg.

The above facet we have confirmed through creating an ecosystem where we have provided both grains with burrows and or just flour mix alone. When only flour mix was used, the egg laying time got delayed. We presume that when the adult insects were when released in the above ecosystem, probably the insect may be searching for a safer place to lay its eggs.

When the grains with plenty of burrows and tunnels are available, the probability of the searching time of the insects for a safer place to lay their eggs may naturally reduce and hence they may start laying eggs immediately. The above hypothesis gains its support from the experiment where the insects were when grown in flour mix which did not allow early oviposition. In the flour mix, the hiding place for the eggs is not available however the insect may need to explore until it exhaust its hope and therefore the egg laying time might have got delayed.

The larvae of cigarette beetle are although credited with the title of notoriety, described as voracious eater, glutton etc [2, 3] such foraging behavior of the larvae has a definite dividend possibly to itself when it becomes adult after pupa metamorphosis.

During the larval stage when the larvae could make sufficient burrows and tunnels in grains as a part of its foraging requirement, the same burrows and tunnels also provides a safe haven for the adults to lay eggs safely inside the burrows and tunnels in the grains. Further when grains with burrows and tunnels are available in plenty the egg laying time also gets shortened and which in turn favors reducing the lifecycle of the insect greatly and the biological necessity of the procreation faster.

Different food items like tobacco, cereals, millets, wheat, coriander seeds, zinger etc., are reported to either alter the duration of the life cycle of the insect or reproductive fecundity or the number of eggs per session or the pupal stage time positively or negatively. Similarly the incubation temperature is also reported to play a significant role in the life cycle of the cigarette beetle [5, 6].

We have also observed significantly low larva to pupa conversion time in the case of grains with lots of burrows and tunnels. When grains with lots of burrows and tunnels are available it may push larva to quickly convert to pupa stage so that the next adult stage can soon exploit the burrows and tunnels for laying eggs. In essence grains with burrows and tunnels reduce the duration of life cycle of insect and increasing its success and rate of procreation.

The above possibility once again reiterates the fact that the foraging behavior of larvae and making tunnels and burrows in grains is not just a consequence of its feeding behavior but a well-intended intelligent act where the adult insects can use the burrows and tunnels in the grains to lay its eggs. The immediate shifting of larvae in two days to pupil stage validates its above possibility.

We do not believe the quality or nutritive value of the inner portion of the grains in the rapid shift of larvae to pupa seen among the larvae grown in grains with lots of burrow and tunnels because such feature was not observed in the experimental set up where we have used only flour of the same grains where the labor to the larvae was damn too low. It suggests that the larvae may be sensing the availability of the burrows and tunnels in the grains to increase its egg hatching success and then to become adult and therefore it may be shifting spontaneously to pupa stage.

Although some more intense research may be required to establish our observation undoubtedly, but our findings nevertheless points towards an important dimension in the process of evolution that had implanted an intelligent dividend mechanism in the foraging behaviour of the larvae.

By corroborating all our observations, we can confidently conclude that there is intelligence in the foraging behaviour of the larvae with definite future vision and profit, which, from the evolutionary parlance assumes high significance. Uncommon intelligence in the evolutionary events of several species of flora and fauna is well known [7].

We are the first to report the possibility of how the evolution of foraging behavior of cigarette beetle larvae ensures future dividend for the same insect to reap when it becomes an adult and thereby the saga of its lifecycle flows smoothly. The tunnel making behavior of cigarette beetle larvae may not be a mere foraging consequence but can be a purposeful act for maximizing egg safety, shortened egg laying time and increased insect emergence from any given egg cluster. Perhaps the successful existence of cigarette beetle despite all preventive measures of man may be linked and programmed in the behavior of larvae to pupa to adult which is consciously gifted by the evolution.

Conclusion

The foraging behavior of the larvae of cigarette beetle in making tunnels and burrows in grains has a great significance in their reproductive success. The eggs laid inside the burrows and tunnels in the grains showed very short larval phase and pupal phase may be due to maximize the reproductive success. Whereas, the eggs laid in open field (flour) showed long larval phase and pupa phase. The findings suggest that the foraging behavior of larvae has a significant objective in fulfilling the reproductive success.

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