A clue for maintenance of aggregation in millipede, *Streptogonopus phipsoni* , (Diplopoda: Polydesmida)

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ABSTRACT *Immature stadia of Streptogonopus phipsoni (Pocock) form aggregates on the soil surface. Size of aggregates and number of individuals per aggregate varies greatly in different stadia (stadia II to V). An instrument was devised to detect the locomotory behavior of different stadia within the aggregate. Experimental results suggest that loop formation during locomotion is the only reason for maintenance of aggregation in different stadia of millipede.*

Keywords: *Millipede, stadia, aggregation, loop formation*

Introduction

Most adult millipedes are solitary in habit, but immature stadia of some of the polydesmoid millipedes form aggregate (Hingston, 1931; Fryer, 1957; Toye, 1967; Lewis, 1971,1974; Bellairs *et al*., 1983; Bhakat *et al.*, 1989).

Among polydesmid, *Streptogonopus phipsoni* (Pocock) is a very common millipede in West Bengal (India) (Mukherjee, 1962; Bhakat, 1987, 1989). In the monsoon, its immature stadia form compact aggregate of red to reddish brown in colour in the soil surface rich in organic matter or on the rotting leaves of different plants (Bellairs *et al.*, 1983; Bhakat *et al.*, 1989).

It is not rare to see that the total aggregate moved away if disturbed and sometimes to avoid scorching heat of the sun during late morning.

Why they aggregate? To answer the question different authors (Fryer, 1957; Toye, 1967; Lewis, 1971; Wilson, 2006; Wesner & Schiitte 2010) proposed different hypotheses. But according to our opinion, it shows a warning colouration to avoid predation and total exploitation of good resources, i. e. palatable food. But the answer of how they maintain their aggregate is not satisfactory till today.

In this paper, we have tried to prove experimentally that the locomotory behavior of millipede is responsible to maintain the aggregate.

Materials and methods

In order to study the pattern of movement of the immature stadia, the following instrument was devised. It consists of a horizontal wooden piece (21cm ×36cm) in the middle of which a groove was cut so that the area left on the sides of the groove was 21cm×18cm and 21cm×17.5cm (Fig.1).

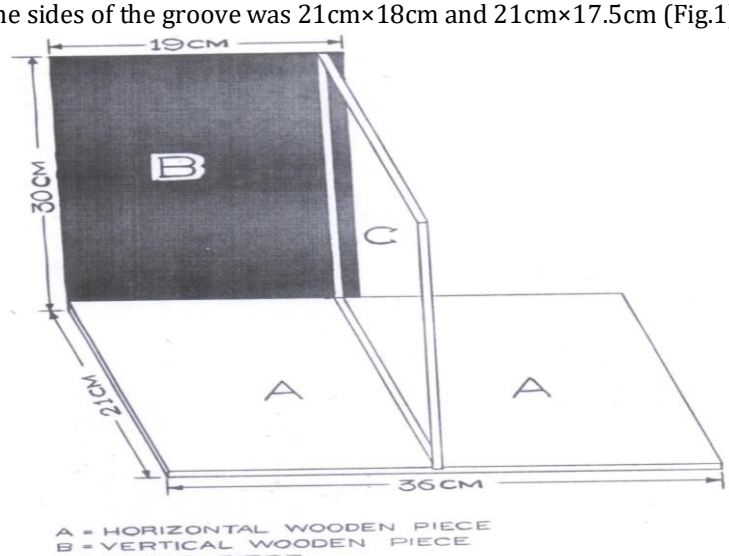

Figure 1. Instrument to detect locomotory pathway of different stadia of *S. phipsoni*

A vertical wooden piece (30cm×19cm) painted black inside was fitted with the horizontal one that its groove and that of the horizontal piece formed a 90^0 angle. Now a glass piece (30cm×21cm) was fitted in between the grooves of the two wooden pieces. On the left half of the horizontal piece, a thin layer (5mm thick) of field soil was uniformly spread while on the right a white paper was put. When an immature stadium was taken from its aggregate and put on the thin layer of soil, the path traversed by the individual could be traced from the shadow falling on the paper kept on the right side for the purpose. When viewed through the glass of the left hand side the shadow of the millipede movement on the paper on the right hand side could be clearly seen and the pathway traversed by the immature millipede could be traced by a pen or pencil. With the help of this instrument, locomotory pattern of the immature was studied.

From the culture media (as described by Bhakat, 1986) the soil surface (1.5cm deep) including II or III or IV stadia was carefully transferred to a circular plastic trough (440sq.cm) by breaking the earthen pot. The plastic trough is full of organic matter rich in soil (4cm deep) collected from the natural habitat of the millipede. In case of V stadium, aggregates were recovered from field. For this aggregates were lured by introducing a few mass of soft rotting leaves (recovered from natural habitat of millipede) in a plain surface of the soil in the evening near the moving aggregates. Within a few minutes, the aggregate clumped in a particular bait of their preference and form a heap over the bait. In this condition each aggregate was carefully transferred by spading the soil (1.5cm deep) including bait in the plastic trough. Later the bait is withdrawn and millipedes form aggregate in the flat surface of the soil.

To observe the movement pattern, one individual from a particular aggregate (present in the trough) was quickly (<3sec) transferred to the soil surface of the instrument and its movement was traced by a pen.

In another experiment, one individual of a particular stadium was transferred into a similar trough (soil filled but without millipede) and retained there for definite period of time (5min, 10min, and 15min) before transferring it into the instrument.

Result

When the stadium was released on the soil surface uniformly spread over the horizontal wooden piece, at first it walked on a straight line for some distance and then began to change its direction frequently and formed a loop which was sometimes circular or irregular in shape. It again walked for some distance along a particular direction and formed another loop. In this way the individual traced several irregular or circular pathways before it go straight or come to the edge of the wooden plate (Fig.2). These observations were repeated with 40 individuals taken from stadium II to V 10 from each stadium.

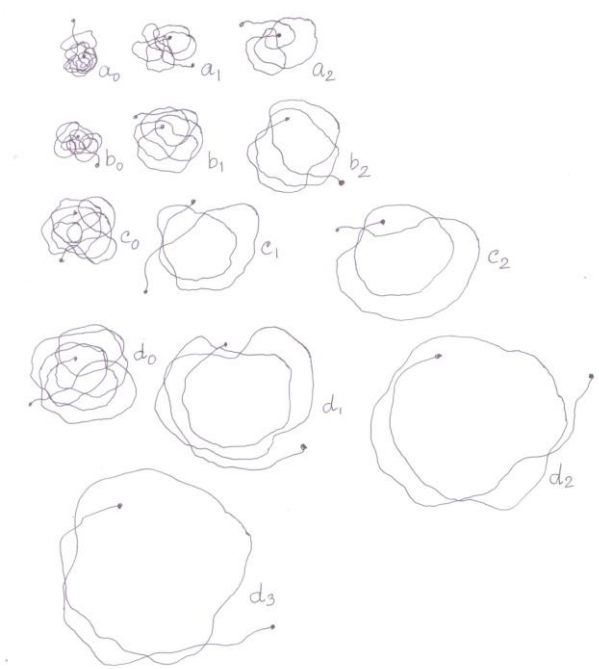

Figure 2. Path traversed by different stadia of *S. phipsoni* (a_0-a_2=II,b_0-b_2=III,c_0-c_2=IV,d_0-d_3=V) [Letters with subscript 0,1,2,&3 indicate separation time>30 sec.,5 min.,10 min.,&15 min. respectively]

Table-I Characteristics of aggregate and duration of loop formation by different stadia of *S. phipsoni* of variable separation time (n=10) (±SD)

Stadia	Size of the aggregate(sq. cm)	Individual per sq.cm	Duration of loop formation (sec)			
			<3 sec.	5 min.	10 min	15 min
II	5.45 (1.10)	68.69 (20.52)	365 (21.50)	85 (12.38)	20 (5.24)	
III	11.83 (3.25)	40.92 (18.39)	423 (18.57)	160 (10.29)	80 (6.35)	
IV	15.69 (7.29)	28.95 (9.25)	470 (15.55)	180 (10.79)	50 (4.67)	
V	19.45 (8.35)	20.75 (10.45)	520 (12.34)	215 (12.11)	105 (5.78)	45 (2.45)

Table I showed that the size of aggregate increases as the stadia progresses and number of individuals per sq. cm are in decreasing order. There are two reasons behind it, some of the individuals died due to different reasons and a few were unable to return to the aggregate while the aggregate was moving. Increment of body size and the area covered by the individual increases the size of the aggregate. Duration of loop formation is maximum in all the stadia when they were immediately (<3sec) transferred to the instrument. But when the separation time increases, duration of loop formation are in decreasing order (Table I). Separation time from aggregate affect the duration of loop formation significantly ($F_{(df3,3)}$=36.98; P<0.01). Moreover, mature stadium(stadium V) spent more time for loop formation than the early stadium(stadium II) though stadium V can form one or two loops after separation of aggregates for 15 min while stadium II is unable to form loops after 5 min.(Table II).

Table –II Number and size of loops formed by different stadia of *S. phipsoni* of variable separation time (n=10)

Stadia	Mean no. of loops formed (ranges)				Size of loops (mean approximate diameter in mm)							
	<3 sec	5 min	10 min	15 min	<3 sec		5 min		10 min		15 min	
					I	F	I	F	I	F	I	F
II	10(5-14)	4(2-6)	1(0-2)		4.1	10	5.2	11	5.8	12.5		
III	8.9(5-12)	4.2(3-6)	1.2(0-2)		8.5	18	9	20	10.5	22		
IV	7.2(4-10)	3(2-5)	1.8(0-3)		12	20	13	28	15	35		
V	6.5(4-9)	4(3-5)	2(1-3)	1(0-2)	16	24	21	32	28	40	48	52

I=Initial diameter, F=Final diameter

Number and size of loops always varies in different stadium (Table II). Early stadia form more loops to maintain the aggregate while late stadium (stadium V) forms less number of loops. Moreover, number of loops decreases as the separation time increases ($F_{3,9}$=35.04,P<0.01, Table II).In all the cases initial size of loops were small but as the time progresses it increases significantly(for stadium II t=4.604, P<0.01;stadium III t=8.1969, P<0.01; stadium IV t=3.1744, P<0.05; stadium V t=19.8389, P<0.01). Actually they always tried to find out its mate by increasing the area of movement.

Discussion

Validity of Bellairs *et al*. (1983) experiment by using different concentration of benzaldehyde is not beyond doubt. They proposed that larvae aggregate at low concentration and dispersed at high concentration. But the question is how they regulate their concentration? Moreover, the number of individuals in an aggregate varied widely. So when the number becomes more the total concentration of benzaldehyde in the area of aggregate will be high and the reverse is true. So how in both cases (aggregate containing more and less number of individuals) aggregates are maintained in those two extreme concentrations?

Bellairs *et al*. (1983), like Haacker (1974) supported that tactile sensation may have some role in the maintenance of aggregation in *S. phipson*i. But as they are very tiny animals, vibration created by constant tapping with the antennae on the soil surface is not enough to communicate with other individuals at a distance of one cm or more.

Bellairs *et al*. (1983) while describing the movement of a marked individual never trace the pattern of movement. They only mentioned that the individual took 13 sec to move from rear end to the front of an aggregate.

In an aggregate of a particular stadium, each individual always move vigorously in the patches of food and if they move a few cm distant from the centre of their circle of movement, the aggregate lose its compactness but if they move towards the centre the aggregate become compact. Any type of palatable food attract more individuals, hence the aggregate become a heap of numerous individuals. The stadia always tried to maintain the aggregate by forming several loops for certain period of time that varies widely in

different stadia. If they are unable to find their mate within a stipulated period of time they become vagrant and separated from the aggregate.

So it can be concluded that typical movement pattern (loop formation) along with mate sensing by antenna and palatability of resources (food) are responsible for maintenance of aggregate in immature stadia of *S. phipsoni*.

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