ADHESIVE STRENGTHS OF SOME BIOFOULING ORGANISMS

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THE adhesive and compressive strengths of a variety of shell dwelling, marine sedentary organisms have been determined by several workers in the past in the context of their shell architecture, shell strength, environment, wave action and predation[1]. Young and Crisp[2], who examined in greater detail the adhesion of ship-fouling mussel *Mytilus edulis*, brought out the importance of this study in the context of the development of low energy antifouling coatings. Low energy coatings, particularly on offshore structures, according to them, should render the initial layer of mussels vulnerable to detachment by heavy wave action and facilitate cleaning prior to mandatory inspection.

Mytilopsis sallei, a dreissenid mollusc, attaches to the underwater substratum with the help of the byssus apparatus comprised of 100 to 300 slender threads, each ending in an adhesive disc of about 200 μm^2 surface area[3-4]. The present note incorporates observations made on the adhesive strengths of some of the major fouling species. The observations on the adhesive ability of *M. sallei* on materials like slate, glass perspex and teflon (P. T. F. E) are recorded in greater detail in this note.

In order to measure the adhesive bond strength, freshly collected organisms were allowed to resettle on the desired surfaces under laboratory conditions. Organisms attached to these surfaces for 10 days were loaded statically in an Instron tensile testing machine. The load was applied at 20 mm/min and the maximum load borne prior to catastrophic failure resulting in the complete detachment of the organism from the substrate was recorded[1].

Table 1 gives the relationship between the size of *M. sallei* shell and the number of byssus threads of the organisms both under natural and laboratory conditions. It is noted that with the increasing shell size, there is an increased number of threads and therefore increased adhesive surface for the attachment. The number of threads in the organisms resettled in the laboratory, however, is very small as compared to that collected from the field.

The areas of 212 discs of 20 individuals settled on glass surface were measured. Figure 1 shows the relationship between the mean disc area for each individual and its shell length. The area of the individual disc was found to rise linearly with increasing length.

Table 2 gives the mean disc area in mm²(averaged over 8 to 10 individuals in each of the three independent experiments) for all the four surfaces. There is no correlation between the areas and the polarities of the surfaces offered for the settlement. Both polar and non polar surfaces like slate and teflon respectively show smaller adhesive areas as compared to glass and perspex.

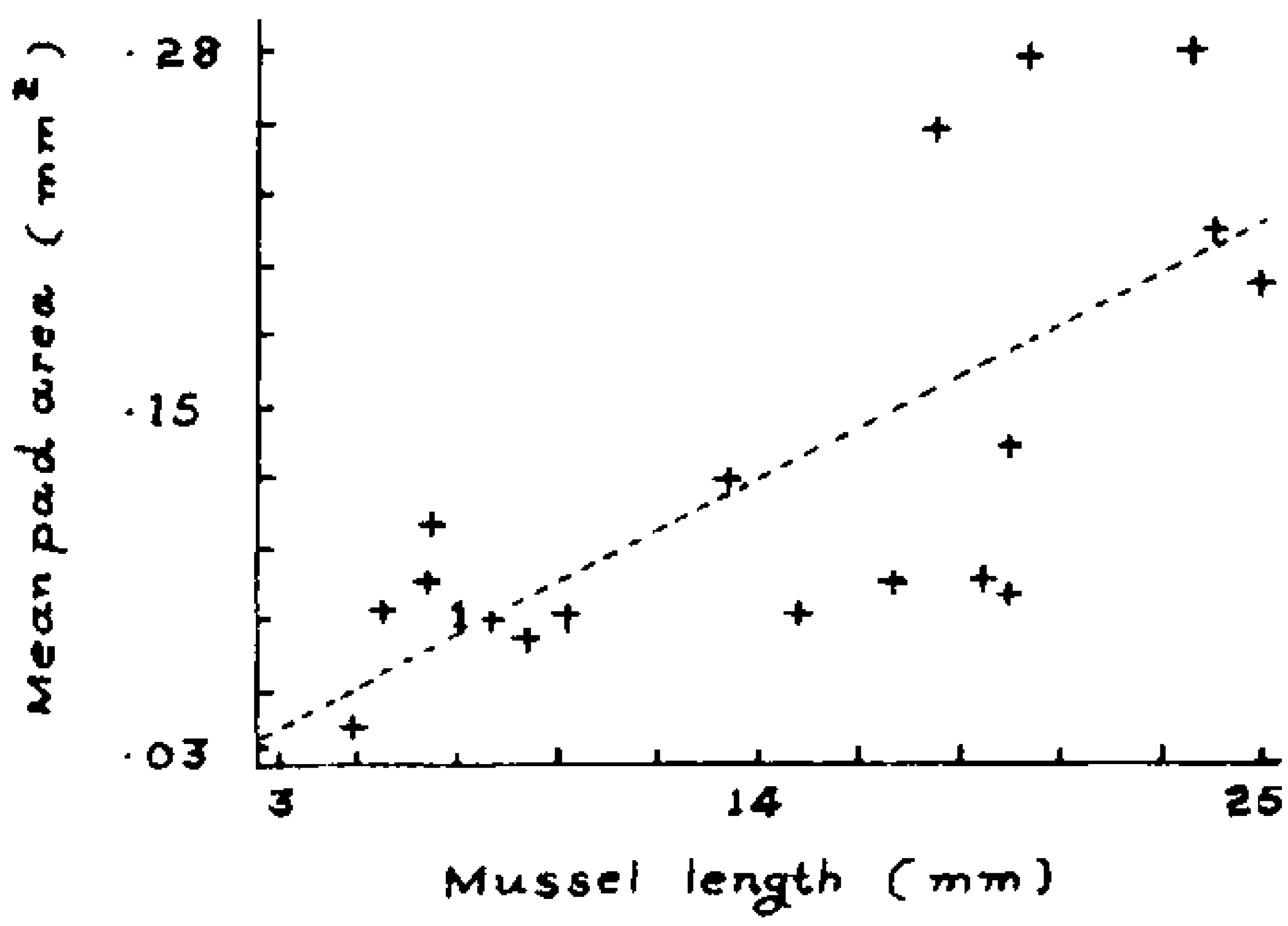

Figure 1. The relationship between *M. sallei* length and mean pad area.

Table 1 *Number of byssus threads and the shell sizes of M. sallei on glass substrate*

Size group	10 mm	15 mm	20 mm	25 mm
Number of threads, natural habitat	119 ± 24	159 ± 10	255 ± 21	304 ± 44
24 hours after settlement in laboratory	48 ± 6	49 ± 9	26 ± 4	31 ± 9
10 days after settlement in laboratory	–	95	67	–

Table 2 *Adhesive disc areas of M. sallei on various surfaces*

Surface	Average mean disc area (mm²) (3 experiments, 8–10 animals each)
Slate	0.13
Glass	0.21
Perspex	0.26
Teflon	0.16

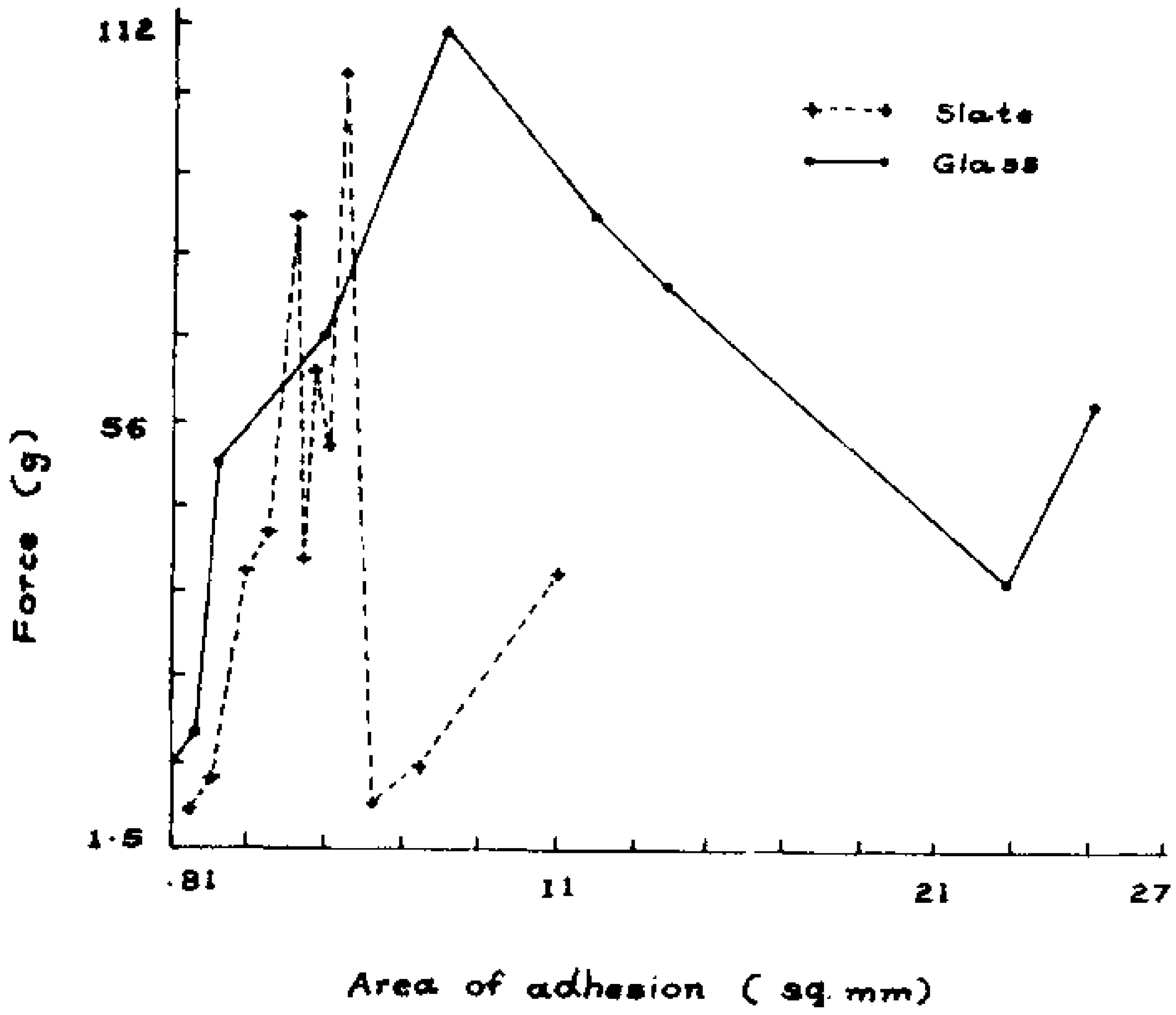

Figure 2. Forces required to remove byssus pads from slate and glass surfaces.

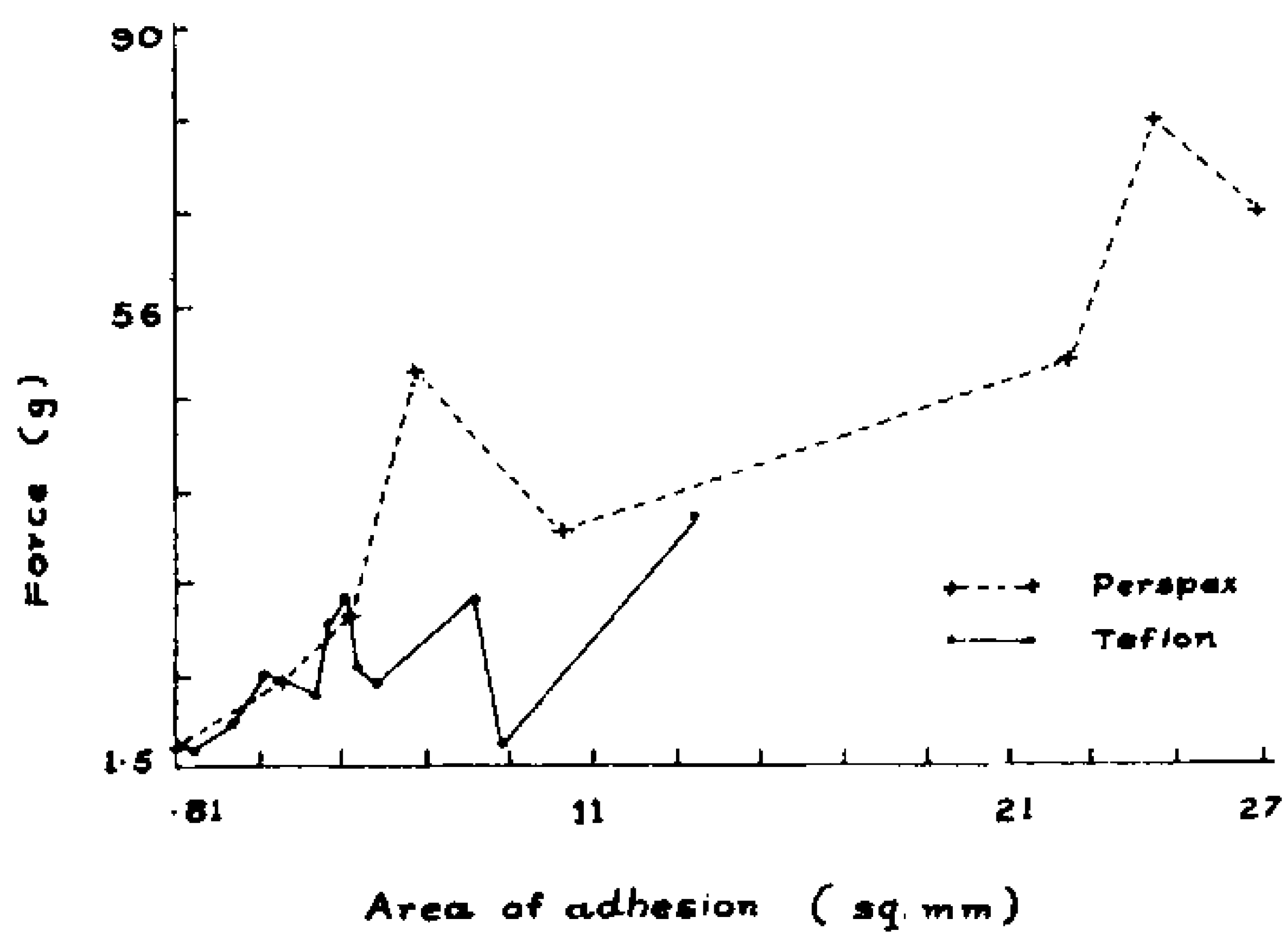

Figure 3. Forces required to remove byssus pads from perspex and teflon (P. T. F. E) surfaces.

Table 3 *Force (Nm^{-2}) required for dislodging M. sallei from various surfaces*

Experiment	Force required (Nm^{-2}) ($\times 10^8$)			
	Slate	Glass	Perspex	Teflon
1	0.09	0.08	0.03	0.02
2	0.09	0.06	0.02	0.03
$\bar{X}$	0.09	0.07	0.03	0.02

Figures 2 and 3 show the relationships between the adhered areas of discs on various surfaces and the forces required for the dislodgement of the individual organism. There appears to be no relation between these two. From this figure, however, it is observed that the forces required for the two polar surfaces, namely, slate and glass, and to a lesser degree for perspex, are greater (up to 112 g) than that needed for teflon (32 g). This is also reflected in the data tabulated in table 3. In figures 2 and 3, values are given in gram force for individual organism whereas in table 3, the values are averages of several individuals. The trend, however, is similar.

The results tabulated in table 4 show that the force required for the removal of a small sized *M. sallei* is far less than that required for bigger green mussels, *M. edulis*. It is also less than that required for dislodging oyster and for both balanid and chthamalid barnacles. The former has calcareous base while the latter has membraneous base.

In *M. sallei*, it is observed that the size of adhesive disc increased with the growth of the shell. However, adhesive bond secured by the organism is not proportional to the area of adhesion achieved. This implies that the discs lose the adhesive strength as the animal grows older. The development of fresh adhesive threads is, therefore, a continuous process in this

Table 4 *Break load per unit area (Nm^{-2}) for some mussels, barnacles and oyster species*

Animal species	Experimental preparation	Break load/ unit (Nm^{-2})	References
Mytilus edulis	Whole thread	3.6×10^8	Young and Crisp[2]
-do-	Distal thread	1.27×10^8	-do-
-do-	Adhesive disc	8.3×10^5	Allen *et al*[5]
Mytilopsis sallei	Whole mussel	0.09×10^8	Present work
Balanus amphitrite	Whole barnacle	1.14×10^8	-do-
Chthamalus malayensis	Whole barnacle	0.13×10^8	-do-
Crassostrea cuculata	Whole oyster	0.35×10^8	-do-

species. The species is known to discard its whole byssus apparatus and form a new one on arriving at the next point of attachment. In the laboratory for instance, one individual had been observed to discard byssus apparatus as often as six times in the course of 24 hours, each time forming 7, 11, 13, 20, 18 and 7 threads.

Young and Crisp[2] showed that the size of the disc in *M. edulis* is influenced by the surface, the polar surfaces showing lesser sizes than the non-polar. They have also observed a variation in adhesive force of the order of 2 decades between high and low energy surfaces. In the present study on *M. sallei*, no such correlation between the area of adhesion and the polarity was observed. However, the adhesive strength on polar surfaces like slate and glass was four times greater than that on the non-polar surface of teflon.

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1. Gubbay, S., *J. Mar. Biol. Assn.* UK., 1983, **63**, 541.
2. Young, G. A. and Crisp, D. J., *Adhesion*, (ed.) K. W., Allen, Applied Science Publishers, UK., 1982, Vol. 6, p. 19.
3. Ganapati, P. N., Lakshmana Rao, M. V. and Varghese, A. G., *Curr. Sci.*, 1971, **40**, 409.
4. Karande, A. A. and Menon, K. B., *Bull. Dept. Mar.* Univ.,Cochin, 1975, **7**, 455.
5. Allen, J. A., Cook, M., Jackson, D. J., Preston, S. and Worth, E. M., *J. Moll. Stud.*, 1976, **42**, 279.

CYTOMIXIS IN PLANTAGO OVATA

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THE phenomenon of cytomixis which is characterized by transmigration of nuclear substances between adjacent cells through chromatin and cytoplasmic strands has been reported in many plant species[1], since it was first reported in *Oenothera gigas* and *O. biennis*[2]. In addition to meiotic cells, it has been reported to occur in meristematic tissues[3] and in the interference between somatic and meiotic cells[4]. Cytomixis has also been induced in meristematic cells of root-tips, vegetative-tips and tapetal cells by herbicide, trifluraline treatment in *Vicia faba*[5]. In the present study, cytomixis and other minor meiotic abnormalities were detected in the pollen mother cells of *Plantago ovata* Forsk, an annual herb belonging to the family *Plantagenaceae*. The *ovata* species is the only cultivated medicinally important among the ten *Plantago* species found in wild state in various parts of India.

Young spikes were fixed in Carnoy's solution. Meiosis and pollen stainability were studied following 2% iron-aceto-cormine staining. *P. ovata* is a diploid ($2n = 8$) with normal meiotic behaviour. However, due to unknown factors chromatin migration through prominant intercommunicating cytoplasmic strands and connections was noted in less than 3% PMCs of an anther, while the remaining ones displayed a normal behaviour. Cytomictic anomalies were not only confined to the first meiotic division but also noticed in second nuclear division. Cells at early prophase I, showed a greater frequency of cytomixis as compared with the later stages. In certain PMCs nuclear material appeared to be clumpy and sticky. Rarely PMCs were connected in a series of 3–5 or even 7 cells (figure 3) and a single cell was found to be connected to 3 or more cells. The amount of migrating chromatin varied greatly in different meiocytes, ranging from a portion of chromatin material to the entire genome complement of a nucleus. Empty pollen mother cells and those with double the normal amount of chromatin were observed indicating that the entire chromatin mass had moved to the recipient cell leaving only a small portion of it in the donor cell, that too inclined towards the cytoplasmic channel. However, the probability of inclusion of migrated chromosome into the nucleus of recipient cells and the degree of viability of donor cell are still unknown.

High pollen sterility (54.5%) and normal ovule fertility were recorded. Whether the increased pollen sterility was due to cytomictic phenomenon or due to other environmental factor is not clear.

The cytomixis resulted in cells having chromosome number deviating from the diploid number. PMCs with 3 (figure 1) and 5 (figure 2) bivalents were observed in different frequencies. Thus it appears that cytomixis is an important factor for causing variations in chromosome numbers in the meiocytes producing aneuploid gametes; which in turn may give rise to aneuploid and polyploid lines in subsequent generations.

The factors responsible for cytomixis are not yet clearly understood. Many non-genetic factors, including mechanical pressure applied during squashing[3] and even genetic manifestation[6] are suggested for