CHAPTER 3

RESULTS

1. Short-term laboratory experiments

In the set I of the experiments (Fig. 2), when the colonies of two different species were brought into contact, extrusion of mesenterial filaments were observed in some pairs. After retraction of mesenterial filaments of the stronger corals, tissues at the contact area of the less aggressive neighbors were dissolved. In other cases no mesenterial filament extrusion was detected, only tissue injury appeared later on. Many xenogeneic pairs showed neither extrustion of mesenterial filaments nor tissue damage. Any aggressive means such as extruded polyps, sweeper tentacles, etc. were unnoticeable. The ranking of aggression as presented in Fig. 2 was linear dominance hierarchy. In 60 allogeneic pairs including allogeneic pairs between the different morphs of M. foliosa and 50 isogeneic pairs did not show any signs of reactions during one week after setting the experiment.

For short-term laboratory experiments, xenogeneic pairs which were conducted under four different combinations of Light and temperature conditions and observed every 15 - minute intervals showed irregular patterns of mesenterial filament extrusion (Table 1). In this experiment, the low rate of extrustion of mesenterial filament was notable. In the combinations of M. foliosa - M. ehrenbergii and

M. foliosa - M. digitata, extrusion of mesenterial filaments occurred frequently (> 50% of 20 pairs) whereas the others exhibited only occasionally. Among the four combinations of the experimental conditions, no notable differences were observable between dark and light conditions at both higher and lower temperature in all the species combinations, whereas in cases of M. foliosa - M. ehrenbergii and M. foliosa - M. digitata combinations, more mesenterial filament extrusions were observed at lower temperature than at higher temperature. Numbers of no reaction pairs of M. foliosa (purple) seemed to be higher than that of the normal type but this might be due to the effects of setting procedure and experimental conditions. Interestingly, bilateral mesenterial filament extrusions were observed in the pairs of M. foliosa - M. foveolata under two experimental conditions but only M. foliosa was later damaged.

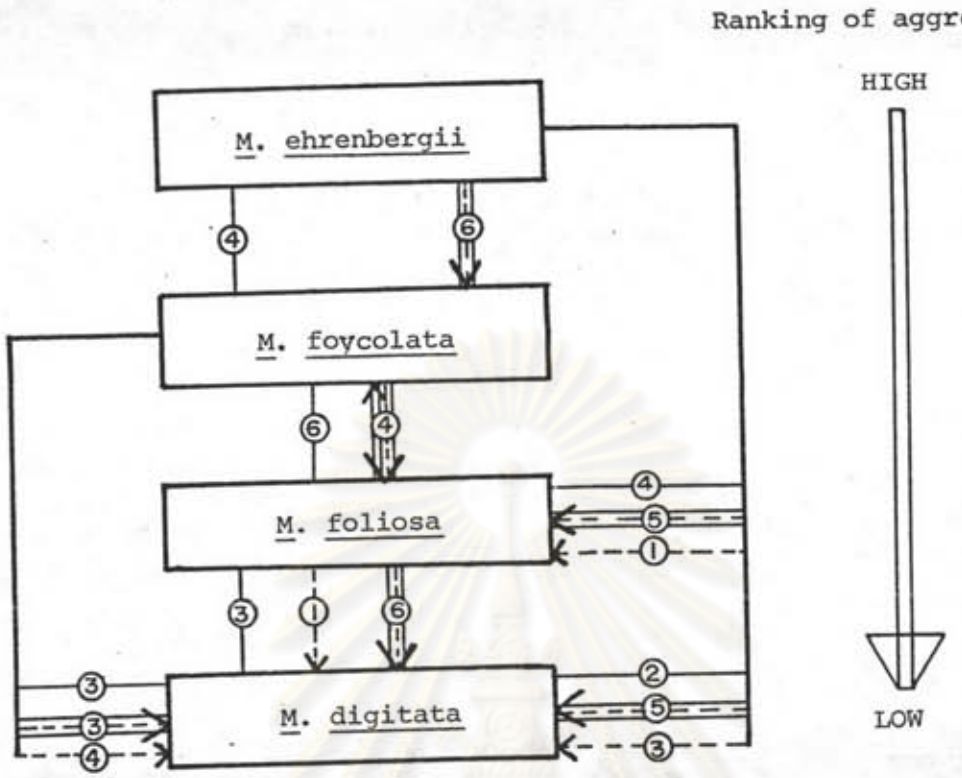
The begining period and extrusion period seemed to be irregular both in the same experimental condition and the different one. It was 20 - 210 minutes for the beginning of extrusion and the filamental extrusion lasted for 1 - 17 hours.

Table 1 Interactions of different species in four experimental conditions '→' : colonies of left side species in the column of 'combinations' extruded mesenterial filaments and '←' indicate the opposite. ⇄ : bilateral mesenterial filament extrusion. N : no. notable mesenterial filament observed.

Combinations	High temp - Dark 30 °C 0 lux					High temp - Light 30 °C 5500 lux					Low temp - Dark 20 °C 0 lux					Low temp - Light 20 °C 5500 lux					Total*
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
M. foliosa - M. ehrenbergii	←	←	N	N	N	N	N	←	N	N	←	←	←	←	←	←	←	←	←	←	13
M. foliosa (purple) - M. ehrenbergii	N	N	←	N	N	N	←	N	N	N	←	N	←	N	N	N	N	N	←	N	5
M. foliosa - M. digitata	N	N	→	→	N	→	→	N	N	N	→	→	→	→	→	→	N	→	N	→	12
M. foliosa (purple) - M. digitata	N	N	→	N	N	→	N	N	N	N	N	N	→	N	N	N	N	→	N	N	4
M. foliosa - M. foveolata	N	←	N	N	N	N	⇄	N	N	N	N	N	N	⇄	N	←	←	←	N	N	6
M. foliosa (purple)** - M. foveolata	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	0
M. ehrenbergii - M. digitata	→	N	N	→	N	N	→	N	N	N	→	→	N	N	→	→	N	N	→	→	9
M. ehrenbergii - M. foveolata	N	→	N	N	N	N	→	N	N	N	→	N	N	N	N	→	N	N	N	→	5
M. digitata - M. foveolata	N	N	←	N	N	N	←	N	N	N	N	←	N	N	N	N	N	N	←	N	4

* total numbers of mesenterial filament extrusion pairs

** The corals showed sign of stress by mucus released



: no reaction

x : x-colony damages y-colony y

x : x-colony extrudes mesenterial filaments and damages y-colony y

x : bidirectional extrusion of mesenterial filaments and y-colony is damaged y

Fig. 2 Interactions of xenogeneic pairs at the initial stage of grafting in short-term laboratory experiments. Figures in the circles indicate number of pairs.

2. Long-term experiments

2.1 Interactions in xenografts

Summary of data on interspecific interactions from field experiments at the last observations and schematic diagram of ranking of competitive ability are presented in Table 2 and Fig. 3 respectively. Moreover, the processes of interactions through time for each combinations are given in Figs 4 to 12. In this study, even though various types of interactions were observed, they were categorized into five types, i.e., tissues of one colony damaged, tissues of both colonies damaged, overgrowth with damage, overgrowth without damage, and indifference. The term damage was defined as the tissue was harmed at the contact area of one or both colony, overgrowth was used in case of one colony produces growing edge advanced over the surface of the second colony. The term indifference is the state in which no appearent interactions were observed between the coral pairs. This term included 'gap' and 'retreat growth' as reported by the other authors. In the pairs of M. ehrenbergii - M. digitata, the former damaged the latter in all cases. High rate of indifference exhibited in the pairs of M. digitata - M. foveolata (36%), M. foliosa - M. foveolata (34%) and M. foliosa (purple) - M. foveolata (32%). In the pairs of M. foliosa- M. foveolata, M. ehrenbergii - M. foveolata and M. foliosa (purple)- M. foveolata, tissue damaged of both colonies occurred at the rate of 29%, 20% and 12% respectively. In general, xenogeneic pairs of two morphs of M. foliosa showed the similar interactions. Surprisingly, the interactions in the pairs of M. foliosa - M. foveolata and

M. foliosa (purple) - M. foveolata changed with time. At the initial stage of interactions (4 weeks after setting), both morphs of M. foliosa were remarkably damaged and the results corresponded with the aggression by extrusion of mesenterial filaments in short-term laboratory experiments. However, M. foliosa could overgrow M. foveolata later on. Ranking of competitive ability was constructed based on the results of the last observations in regard to both overgrowth and damage (Fig. 3). The linear hierarchy of competitive ability can be recognized as : M. ehrenbergii > M. foliosa > M. foveolata > M. digitata.

2.2 Interactions in allografts

2.2.1 Intra-reef allografts

Various types of interactions were observed and categorized into four types, i.e., overgrowth, filling, fusion and indifference. The term filling is defined as both colonies developing growing edge in which the tissue is neither damaged nor fused at the contact area. The interactions of intra-reef allografts for the three species, M. foliosa, M. ehrenbergii and M. digitata at the last observations (14 or 16 week after setting) are given in Figs. 13 to 22. The processes of interactions through time are also presented in Figs. 23 to 32. The results indicated that types of interactions changed during the experiment. In case of M. foliosa, filling and overgrowth were the major types of interactions (48% and 35%, respectively). However, intra-reef allografts of M. ehrenbergii exhibited high rate of indifference and filling (the same rate of 40.3%). For M. digitata, filling was the remarkable types of

interaction (62.4%). The dominance hierarchical relations resulted from overgrowth and damage among allografts were complicated and not simple linear one. Between the same colony pairs, types of interactions were also different. So it is not safe to conclude whether the relationships among colonies are transitive. Interestingly, the 'fusion' type seemed to be consistent. Table 3 shows the number of fusion and non-fusion colony pairs at various distances. In this study, no fusions were observed among the colony pair combinations taken from the same coral aggregate area in which the distances between colonies were more than 8 m. Generally, types of interactions of allografts in the field experiments were similar to that in the laboratory experiments. However, it is noted that allografts of M. foliosa and M. digitata in the laboratory experiments exhibited 'indifference' which did not appear in the field experiments (Table 4).

2.2.2 Inter-reef allografts

Table 4 and Figs. 33 to 39 show the interactions in inter-reef allografts at the end of 14 - and 16 - week period in the field and laboratory. The processes of interactions through time are also given in Figs. 40 to 46. The interactions were irregular even though in the same colony pairs. The data clearly show that no fusion pairs were observed at all. In M. digitata, damage in one and both colonies were also inspected but these inte interactions did not show in intra-reef allografts. In general, the processes and types of interactions in the field and laboratory experiments seemed to be similar.

2.2.3 Across-island allografts

Types of interactions at the end of a 16 week period of across-island allografts are given in Table 4 and Figs. 47 to 49. The processes of interactions through time are also presented in Figs. 50 to 52. No fusion pairs were observed. The difference in the aggressive ability among colonies was not clearly demonstrated because most pairs resulted in filling and indifference. In general, the interactions of inter-reef allografts and across-island allografts were similar.

2.2.4 Inter-morphs allografts

In M. foliosa, two different morphs are clearly recognized, i.e., normal type or brown colony and purple edged colony. Interactions between the two morphs at the last observation (14 and 18 weeks after setting) are given in Table 4 and Figs. 53 - 54. The interactions through time are also presented in Figs. 55 - 56. Filling are the major types of interactions. The aggressive ability of the two morphs was not clearly shown. M. foliosa (purple) was overgrown by M. foliosa (nomal type) and the opposition was also observed in this experiment. Fusions were not seen in all inter-morph grafting pairs.

2.2.5 The effects of fragment size and region of colony in contact on allograft interactions.

In order to explain the variation of interactions in the same colony pairs by some factors such as the region of colony from which the fragments were taken and the size of colony fragments used for grafting, many allografts were performed.

Table 5 shows the interactions among different regions of colonies in allografts of M. foliosa, M. ehrenbergii and M. digitata. The results seem to indicate that the region of colonies from which the fragments were taken did not play any role in interactions of allografts. The results of the experiment dealing with the effect of the size on the allogeneic interactions are presented in Table 6. These results did not indicate the tendency that a large fragment overgrown a small one.

2.3 Interactions in isografts

All isografts resulted in complete tissue fusion within one month after setting. Interactions in isografts concerning the region of colony and fragment size in contacts are given in Table 7. All isografts resulted in tissue and skeleton of the two fragments were completely fused with each other and no sign of boundary was inspected.

Table 2 Summary of data on interspecific interaction in the four Montipora species from field experiments at the last observations. Damaged (one): Upper figures : number of colonies of the right species in the column of 'combinations' damaged, lower figures : number of colonies of the left species in the column of 'combinations' damaged; Damaged (Both) : Both colonies are damaged at the contact area; OG + Damaged : Overgrowth with damage the opponent; OG - Damage : Overgrowth without damage; Ind : indifference

Combinations	No. of pairs	Type of interaction				Ind.	Time after setting (weeks)
		Damaged		OG			
		One	Both	+ Damaged	- Damaged		
M. foliosa -	50	0	0	0	0	4	16
M. ehrenbergii		32		14	0		
M. foliosa (purple)	25	0	0	0	0	3	18
M. ehrenbergii		14		n	0		
M. foliosa -	50	10	0	28	2	10	16
M. digitata		0		0	0		
M. foliosa (purple)	25	4	0	13	4	4	18
M. digitata		0		0	0		
M. foliosa -	35	0	10	0	13	12	16
M. faveolata		0		0	0		
M. foliosa (purple)	25	0	3	14	0	8	18
M. foveolata				0	0		
M. ehrenbergii -	50	23	0	27	0	0	16
M. digitata		0		0	0		
M. ehrenbergii -	50	20	10	6	0	14	16
M. foveolata		0		0	0		
M. digitata -	50	0	0	0	0	18	16
M. foveolata		17		14	1		

Table 3 Numbers of fusion and non-fusion colony pairs for the three Montipora species at various distances. Data compiled from intra-reef allografts of the field and laboratory experiments

Distance between colonies (m)	M. foliosa		M. ehrenbergii		M. digitata	
	fusion	non-fusion	fusion	non-fusion	fusion	non-fusion
0 - 1.9	0	5	1	4	0	0
2.0 - 3.9	4	6	2	3	1	2
4.0 - 5.9	2	9	1	8	2	8
6.0 - 7.9	0	5	0	7	1	8
8.0 - 9.9	0	3	0	3	0	5
10.0 - 11.9	0	4	0	1	0	2
12.0 - 13.9	0	1	0	0	0	1
Total	6	33	4	26	4	26
Pecent of total	15.4	84.6	13.3	86.7	13.3	86.7

Table 4 Summary of data on intraspecific interaction in the three Montipora species from field and laboratory experiments. Figures in parentheses indicate percentage. ind:indifference, Fill-filling; Ovg: overgrowth; Fus: fusion; D : one damaged; DD : both damaged; F : field experiment; L : Laboratory experiment.

Grafting	No. of pairs	Type of interaction						Type of experiment
		ind	Fill	Ovg	D	DD	Fus	
Intra-reef allografts								
M. foliosa (A)	44	0	21	20	0	0	3	F
	(100)		(47.7)	(45.5)			(6.8)	
(G)	46	0	24	18	0	0	4	F
	(100)		(52.1)	(39.1)			(8.7)	
(L)	43	4	24	11	0	0	4	L
	(100)	(9.3)	(55.8)	(25.6)			(9.3)	
(M)	44	3	16	13	0	0	12	L
	(100)	(6.8)	(36.4)	(29.5)			(27.3)	
(A + G + L + M)	177	7	85	62	0	0	23	F + L
	(100)	(4.0)	(48.0)	(35.0)			(13.0)	
M. ehrenbergi (B)	50	19	29	2	0	0	0	F
	(100)	(38.0)	(58.0)	(4.0)				
(H)	50	24	17	4	0	0	5	L
	(100)	(48.0)	(34.0)	(8.0)			(10.0)	
(I)	44	15	12	7	0	0	10	L
	(100)	(34.0)	(27.3)	(15.9)			(22.7)	L
(B + H + I)	144	58	58	13	0	0	15	F + L
	(100)	(40.3)	(40.3)	(9.0)			(10.4)	
M. digitata (C)	39	0	34	0	0	0	5	F
	(100)		(87.2)				(12.8)	
(J)	37	7	20	6	0	0	4	L
	(100)	(18.5)	(54.0)	(16.2)			(10.8)	
(K)	41	4	19	11	0	0	7	L
	(100)	(9.8)	(46.3)	(26.8)			(17.0)	
(C + J + K)	117	11	73	17	0	0	16	F + L
	(100)	(9.4)	(62.4)	(14.5)			(13.7)	
Inter-reef allografts								
M. foliosa (A - D)	17	0	9	8	0	0	0	F
	(100)		(52.9)	(47.1)				
(A - E)	24	0	14	10	0	0	0	F
	(100)		(58.3)	(41.6)				
(M - D)	22	1	13	8	0	0	0	L
	(100)	(4.5)	(59.1)	(36.4)				
(A - D)+(A - E)+(M - D)	63	1	36	26	0	0	0	F + L
	(100)	(1.6)	(57.1)	(41.3)				

Table 4 (cont.)

Grafting	No. of pairs	Type of interaction						Type of experiment
		ind	Fill	ovg	D	DD	Fus	
Inter-reef allografts								
M. ehrenbergii (B - F)	23	14	7	2	0	0	0	F
	(100)	(60.9)	(30.4)	(8.7)				
(I - F)	22	9	7	6	0	0	0	F
	(100)	(40.9)	(31.8)	(29.3)				
(B - F)+(I - F)	45	23	14	8	0	0	0	F + L
	(100)	(51.1)	(31.1)	(17.8)				
M. digitata (C - N)	24	0	23	1	0	0	0	F
	(100)		(95.8)	(4.2)				
(J - O)	20	1	11	5	1	2	0	L
	(100)	(5.0)	(55.0)	(25.0)	(5.0)	(20.0)		
(C - N)+(J - O)	44	1	34	6	1	2	0	F + L
	(100)	(2.3)	(77.3)	(13.6)	(2.3)	(4.6)		
Across-Island allografts								
M. foliosa	23	0	11	12	0	0	0	F
	(100)		(47.8)	(52.2)				
M. ehrenbergii	25	11	11	3	0	0	0	F
	(100)	(44.0)	(44.0)	(12.0)				
M. digitata	22	0	20	2	0	0	0	F
	(100)		(90.9)	(9.1)				
Inter-morph allografts								
M. foliosa								
M. foliosa (purple) (I)	25	0	14	← 7 → 4	0	0	0	F
	(100)		(56.0)	(28.0) (16.0)				
(II)	20	0	13	← 4 → 3	0	0	0	L
	(100)		(65.0)	(20.0) (15.0)				
(I)+(III)	45	0	27	← 11 → 7	0	0	0	F + L
	(100)		(60.0)	(24.4) (15.6)				

* the arrows indicate direction of overgrowth, "← ": M. foliosa (purple) overgrows M. foliosa; "→" : M. foliosa overgrows M. foliosa (purple)

Table 5 Interactions among different regions of colonies in allografts were observed at the end of a 14-week period. Each set consists of different colonies. L : left colony; R : right colony; Top, Side, Upper, Lower : region of colony used in grafting pairs.

Species	Set	Combination L - R	No. of coral pairs observed	Type of interaction: Overgrowth L → R	Overgrowth R → L	Indifference	Filling
M. foliosa	I	Upper - Upper	5	1		1	3
		Lower - Lower	5	1			4
		Upper - Lower	3			1	2
		Lower - Upper	4	2			2
	II	Upper - Upper	5	1		2	2
		Lower - Lower	4	1	1		2
		Upper - Lower	4				4
		Lower - Upper	4	1		1	2
	III	Upper - Upper	5				5
		Lower - Lower	5		1		4
		Upper - Lower	3		1		2
		Lower - Upper	4		2		2
M. ehrenbergii	I	Top - Top	5			4	1
		Side - Side	5	1		3	1
		Top - Side	5			3	2
		Side - Top	4			1	3
M. digitata	I	Top - Top	4				4
		Side - Side	4	1			3
		Top - Side	4				4
		Side - Top	4			1	3
	II	Top - Top	5				5
		Side - Side	5				5
		Top - Side	4		1		3
		Side - Top	3				3

Table 6 Allograft interactions concerning the effect of fragment size were observed at the end of a 14-week period in laboratory experiments. Each set consists of different colonies. Differences in size between large and small fragments are approximately 5-fold.

Species	Set	Combinations L —— R	No. of coral pairs observed	Type of interaction: Overgrowth L → R	Overgrowth R → L	Indifference	Filling
M. foliosa	I	Large - Small	5	2			3
		Medium - Medium	5	1			4
		Small - Large	5	2			3
	II	Large - Small	3		2		1
		Medium - Medium	4		2		2
		Small - Large	4	1			3
	III	Large - Small	4				4
		Medium - Medium	4		2		2
		Small - Large	5	3			2
	Total	Large - Small	12	2	2		8
		Medium- Medium	13	1	4		8
		Small - Large	14	6			8
M. ehrenbergii	I	Large - Small	4			3	1
		Medium- Medium	5			1	4
		Small - Large	5		1	2	2
	II	Large - Small	5				5
		Medium- Medium	5			4	1
		Small - Large	3			2	1
	III	Large - Small	5			2	3
		Medium- Medium	4	1		3	
		Small - Large	5			2	3
	Total	Large - Small	14			5	9
		Medium- Medium	14	1		8	5
		Small - Large	13		1	6	6

Table 7 Isograft interactions concerning the region of colony and fragment size in contacts. Upper, Lower, top and side indicate regions of colony.

Species	Combination	Interactions	No. of pairs	No. of colonies used
M. foliosa	Upper - Upper	fusion	15	5
	Upper - Lower	fusion	14	5
	Lower - Lower	fusion	12	5
M. ehrenbergii	Top - Top	fusion	7	3
	Top - Side	fusion	9	3
	Side - Side	fusion	9	3
M. digitata	Top - Top	fusion	10	5
	Top - Side	fusion	9	5
	Side - Side	fusion	8	5
M. foveolata	Top - Top	fusion	6	3
	Top - Side	fusion	5	3
	Side - Side	fusion	3	3
M. foliosa	Small - Large	fusion	10	5
M. ehrenbergii	Small - Large	fusion	6	3
M. digilata	Small - Large	fusion	10	5
M. foveolata	Small - Large	fusion	6	3

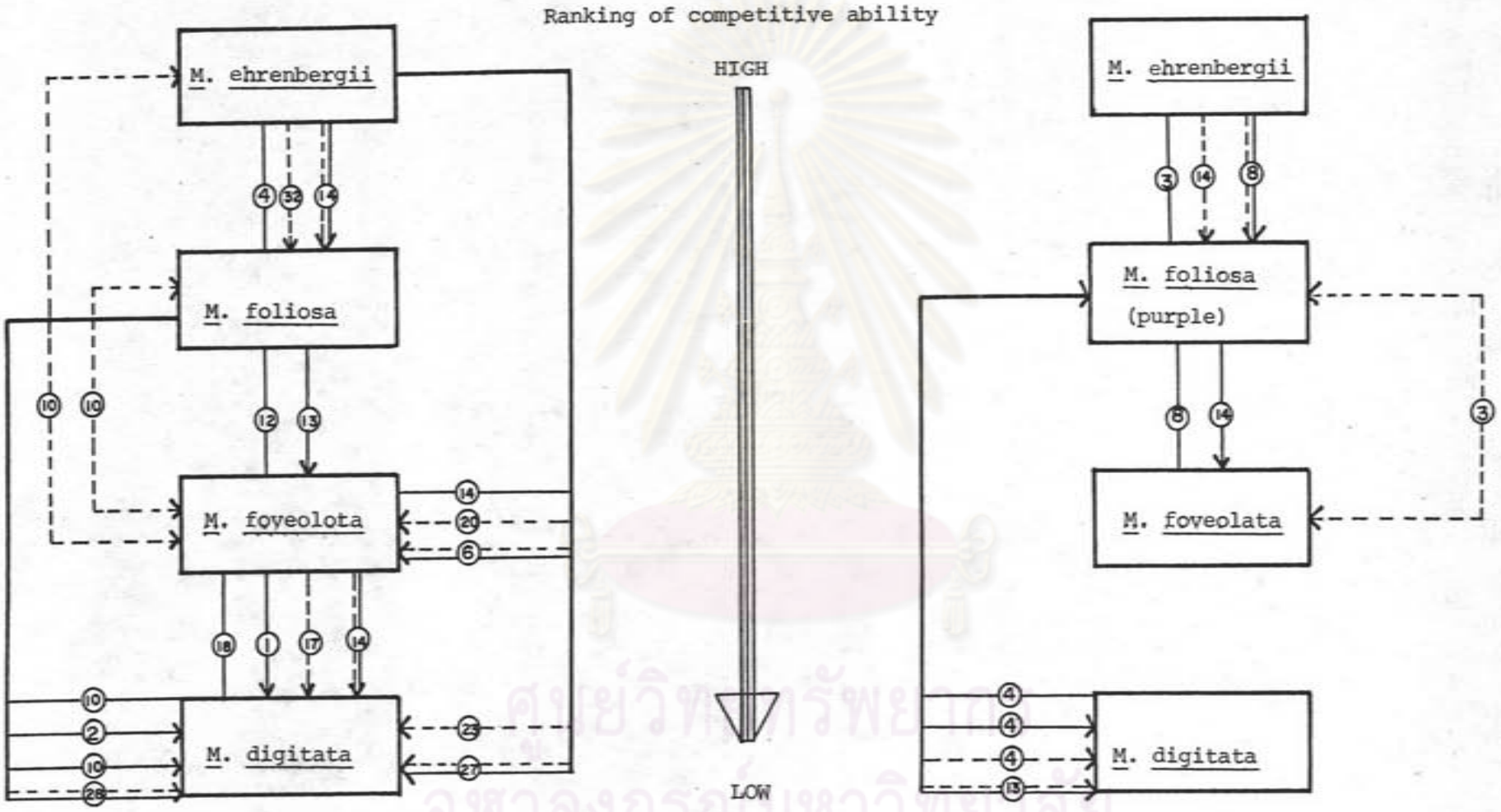


Fig 3 Xenograft interactions among four species of Montipora were observed at the end of 16- and 18- week. period for left- and right-hand schematic diagram respectively. Symbols show type of interactions as in Fig. 13

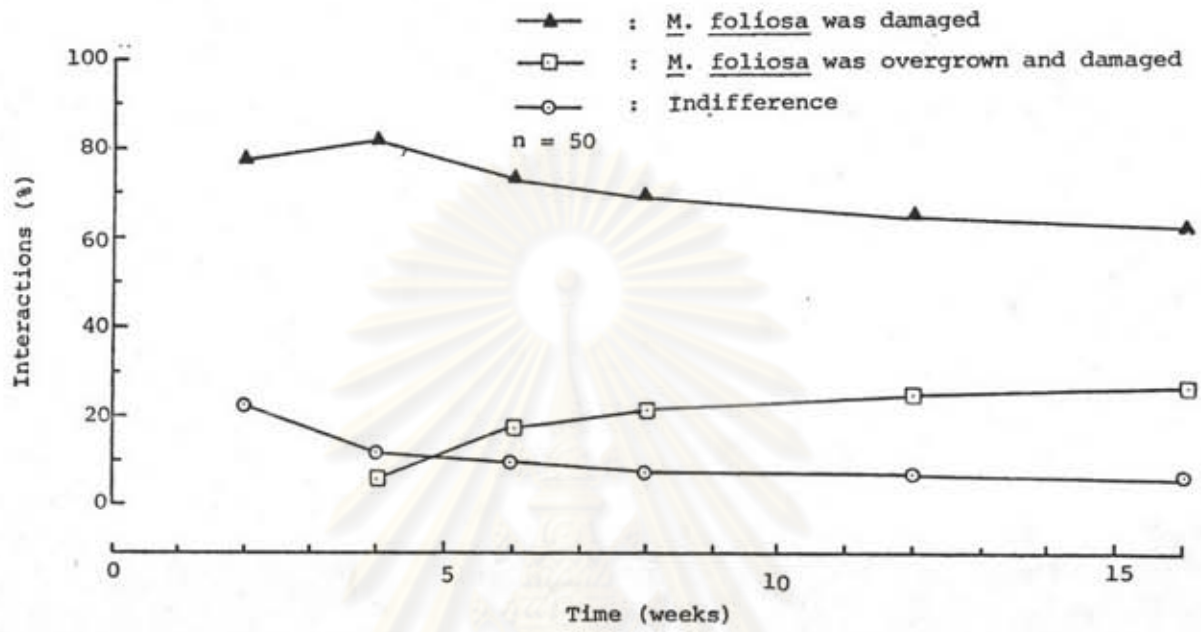


Fig. 4 Interactions through time between M. foliosa and M. ehrenbergii in the field experiments.

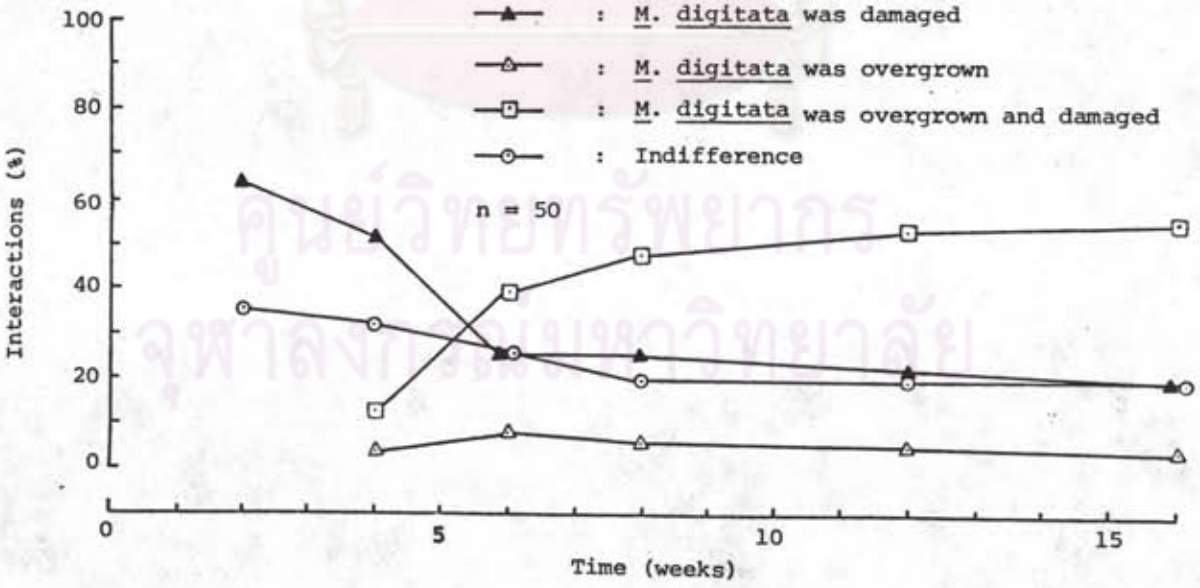


Fig. 5 Interactions through time between M. foliosa and M. digitata in the field experiments.

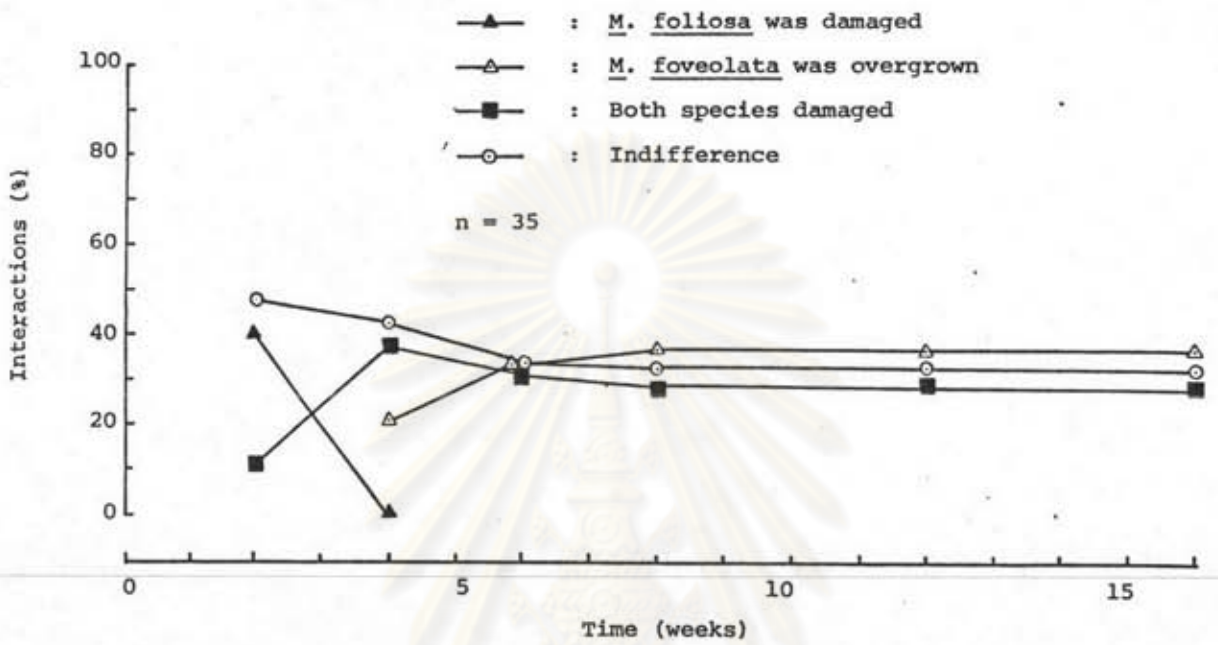


Fig. 6 Interactions through time between M. foliosa and M. foveolata in the field experiments.

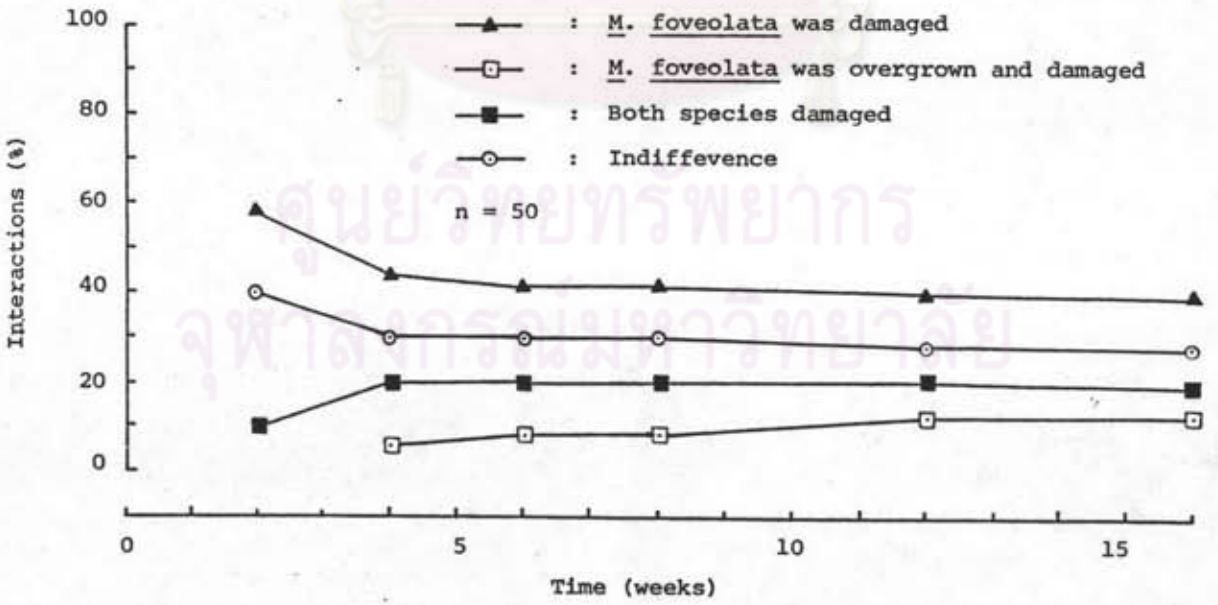


Fig. 7 Interactions through time between M. ehrenbergii and M. foveolata in the field experiment.

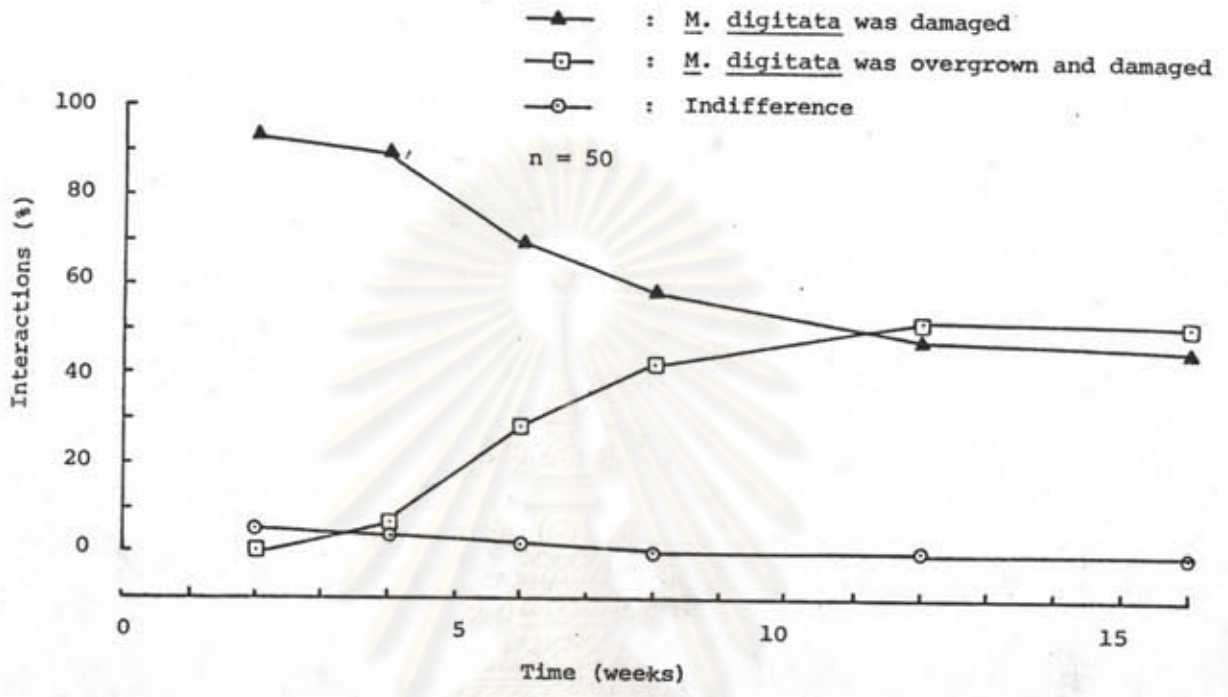


Fig. 8 Interactions through time between M. ehrenbergii and M. digitata in the field experiments.

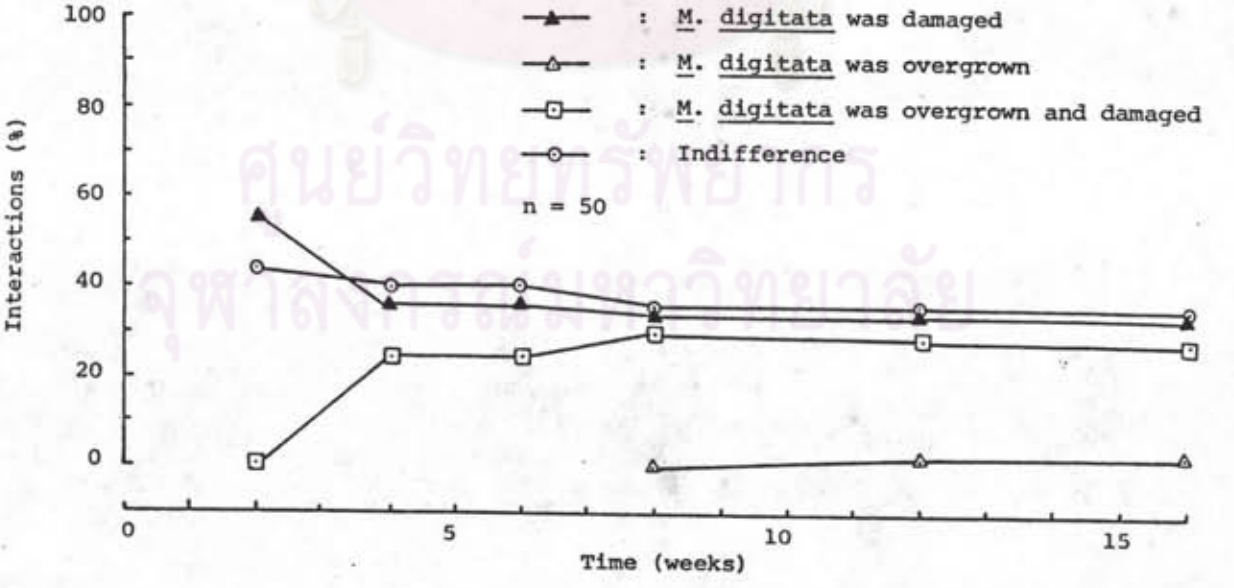


Fig. 9 Interactions through time between M. foveolata and M. digitata in the field experiments.

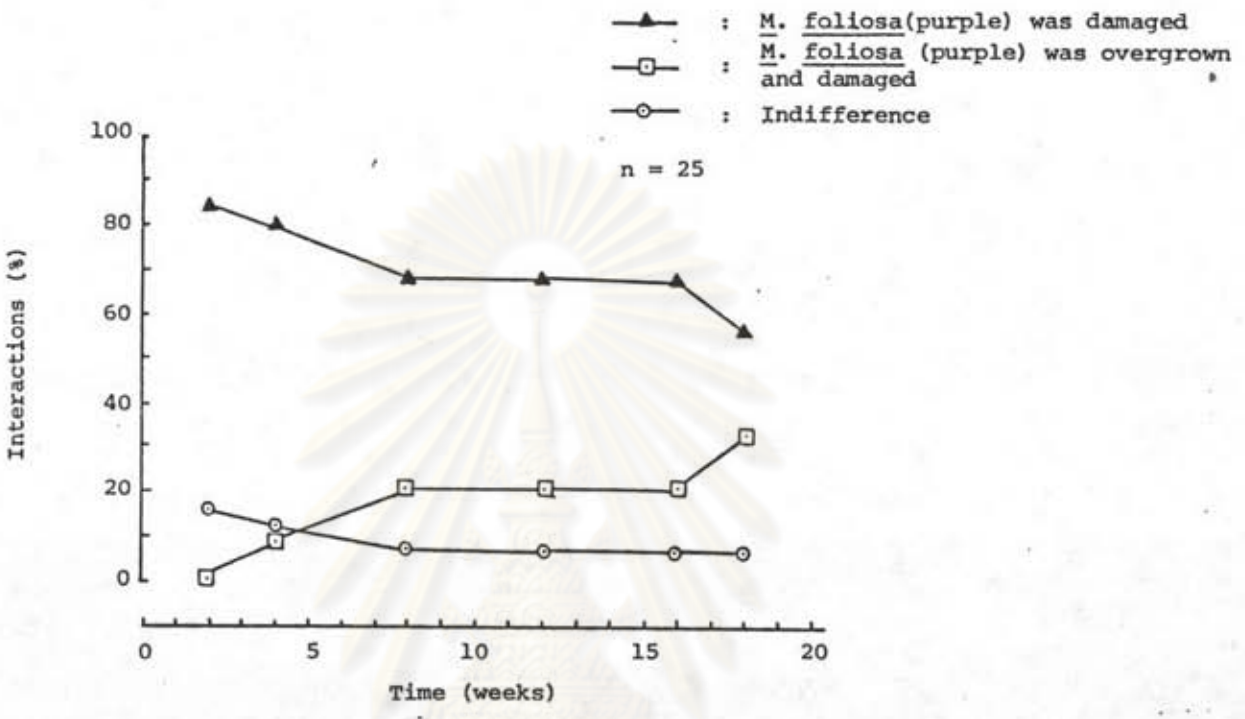


Fig. 10 Interactions through time between M. foliosa (purple) and M. ehrenbergii in the field experiments.

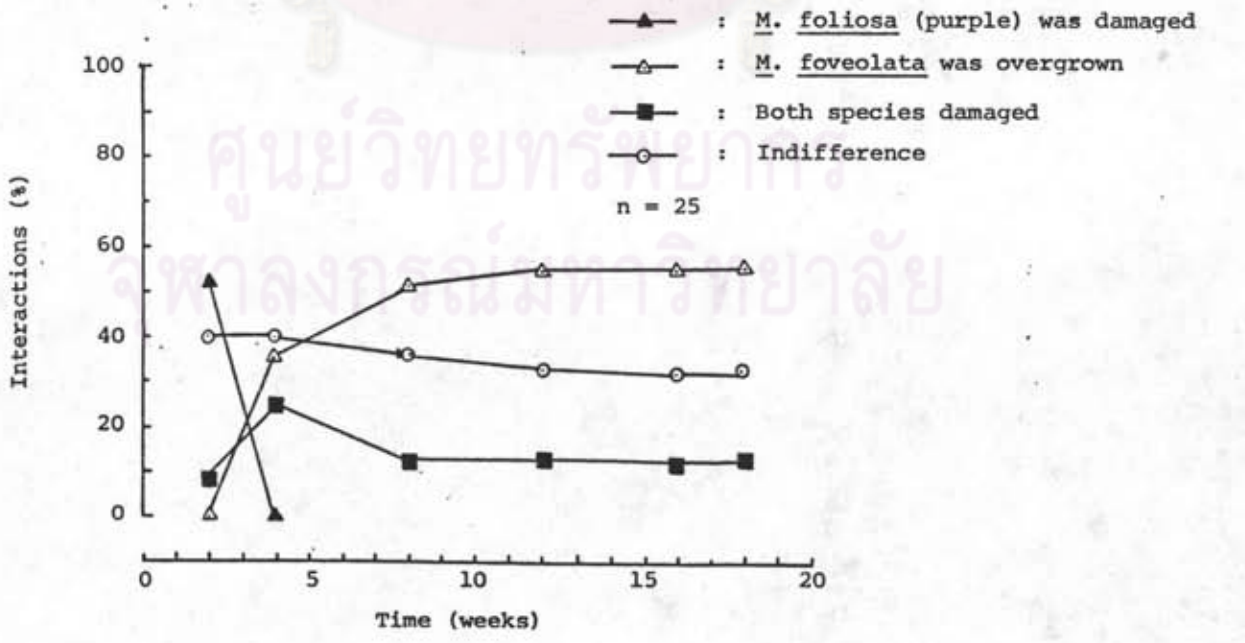


Fig. 11 Interactions through time between M. foliosa (purple) and M. foveolata in the field experiments.

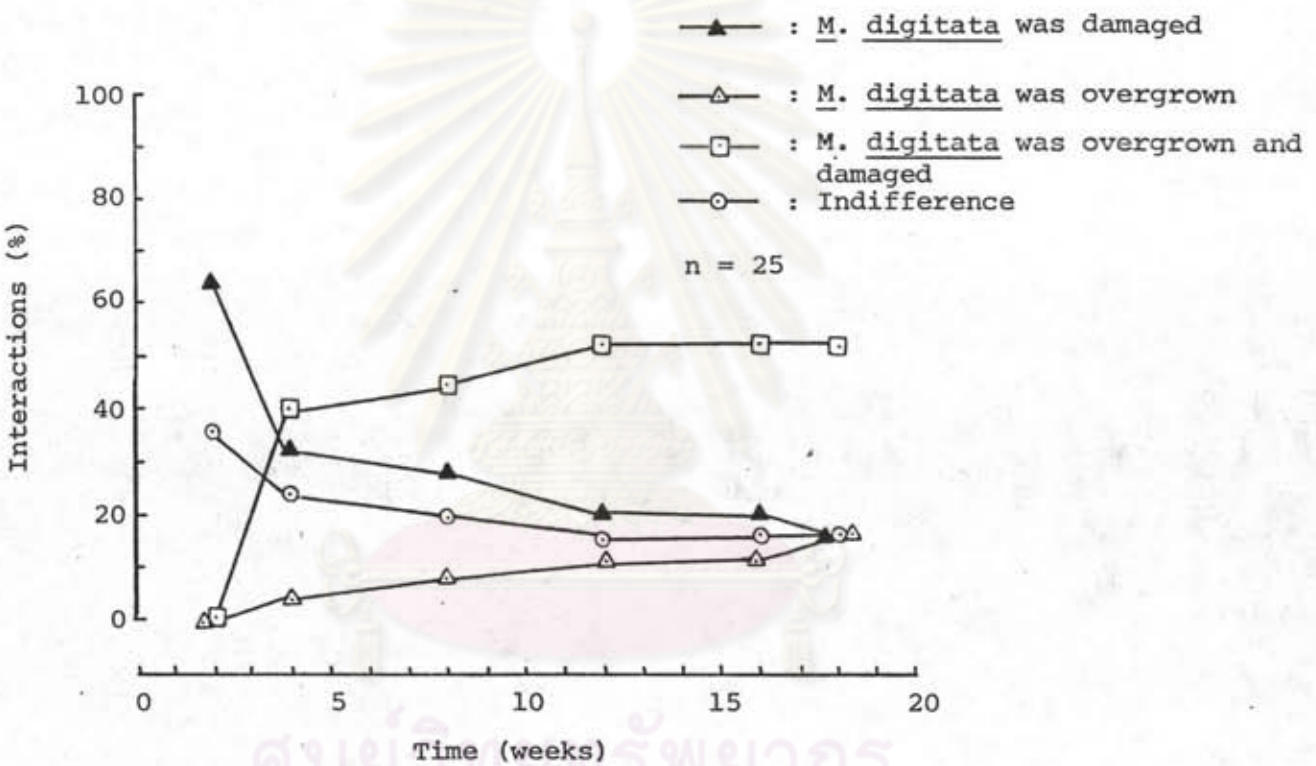
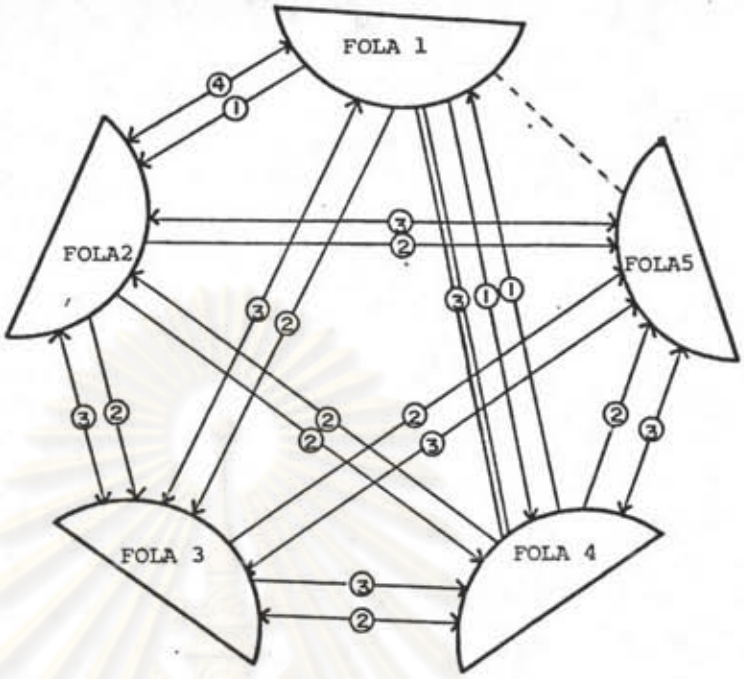


Fig. 12 Interactions through time between M. foliosa (purple) and M. digitata in the field experiments.



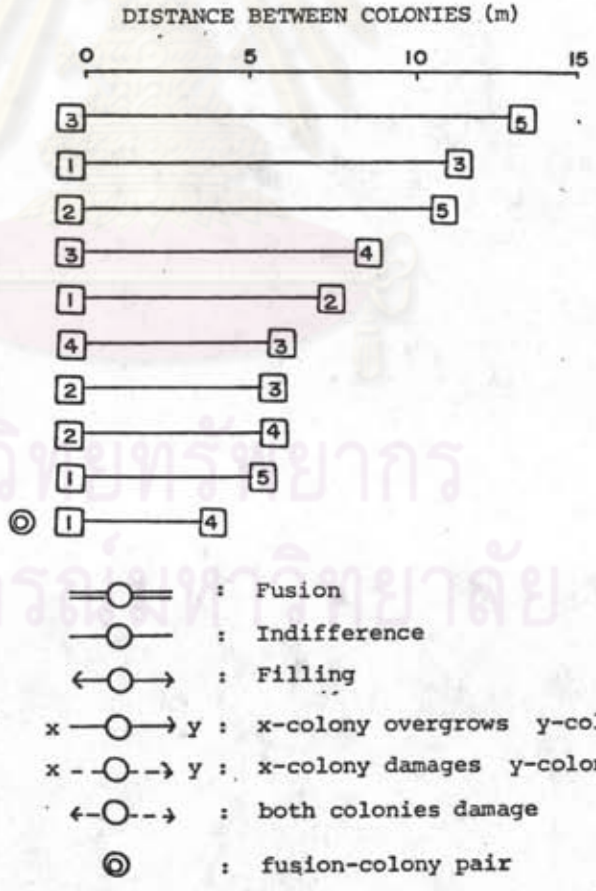
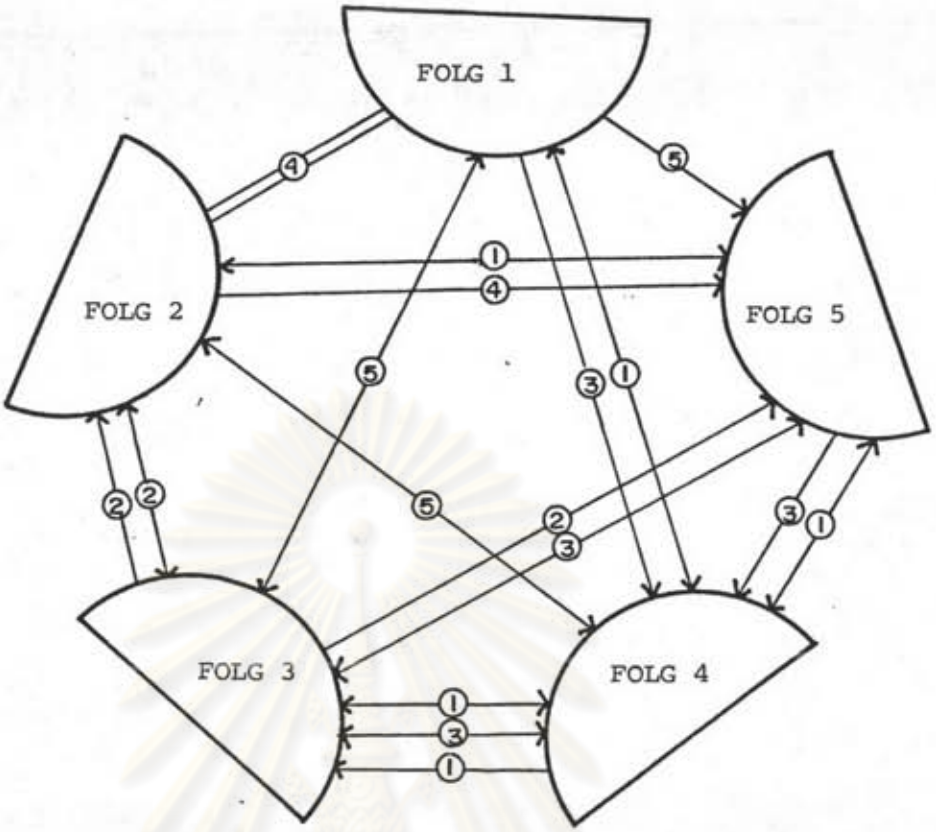


Fig. 13 Intra-reef allografs interactions of M. foliosa collected from the same aggregate area A in the field experiment were found on the end of a 16-week period. Number in the circles indicate number of pairs.



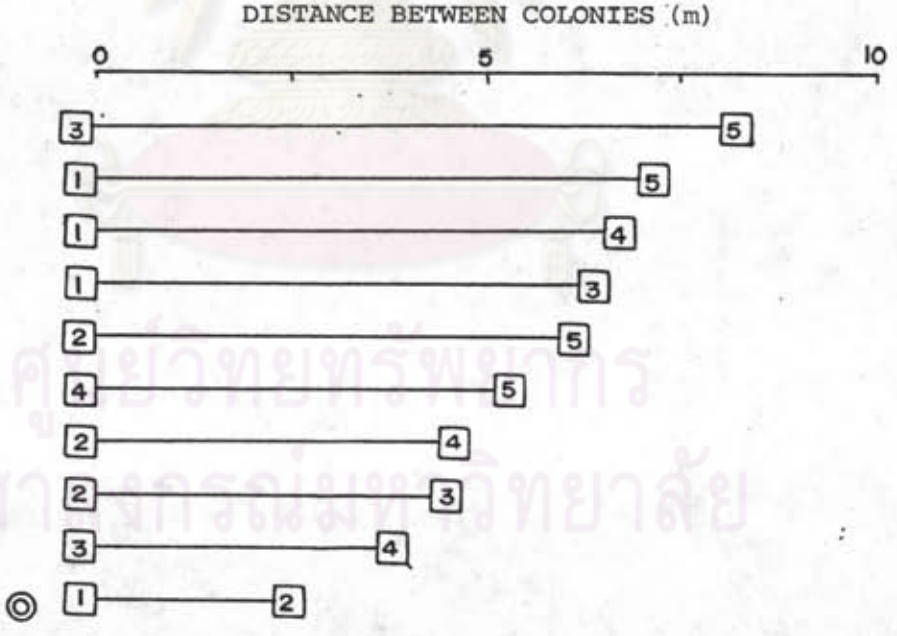


Fig. 14 Intra-reef allografts interactions of M. foliosa collected from the same aggregate area G in the field experiment were found on the end of a 16-week period. Explanation as in Fig. 13

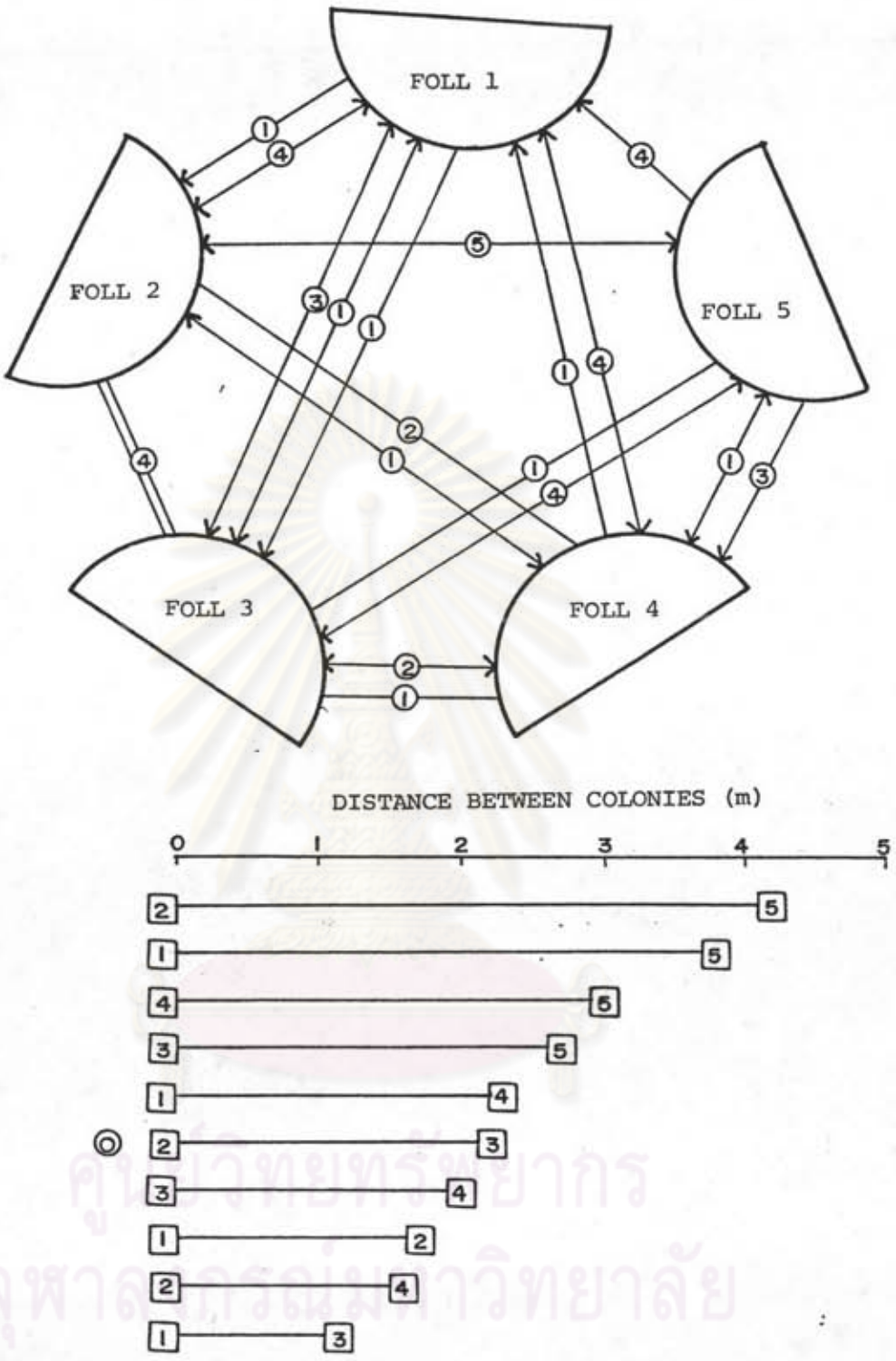


Fig. 15 Intra-reef allograft interactions of M. foliosa collected from the same aggregate area L were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13

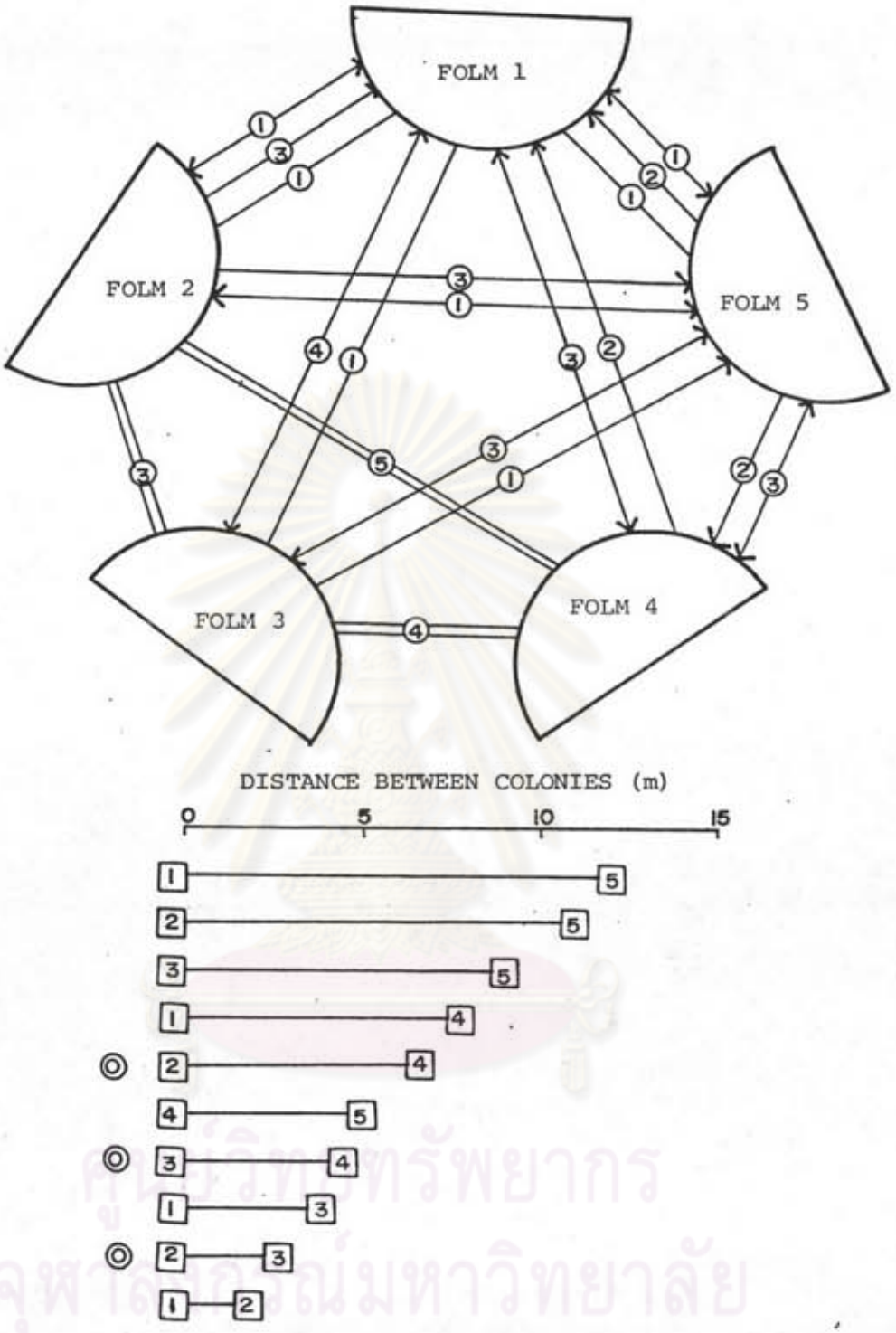
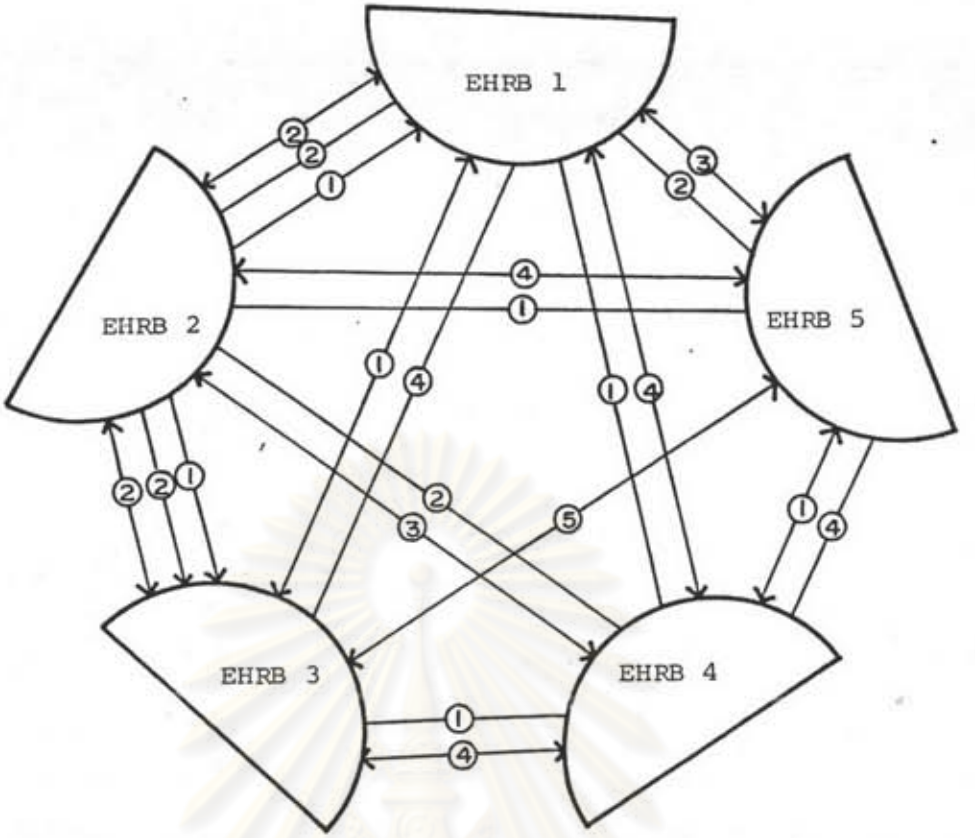


Fig. 16 Intra-reef allograft interactions of M. foliosa collected from the same aggregate area M were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13



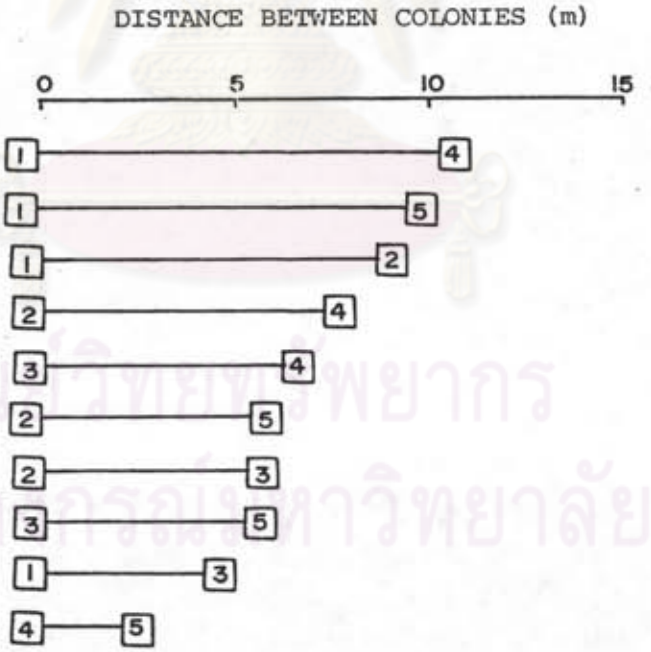


Fig. 17 Intra-reef allografts interactions of M. ehrenbergii collected from the same aggregate area B in the field experiment were found on the end of a 16-week period. Explanation as in Fig. 13

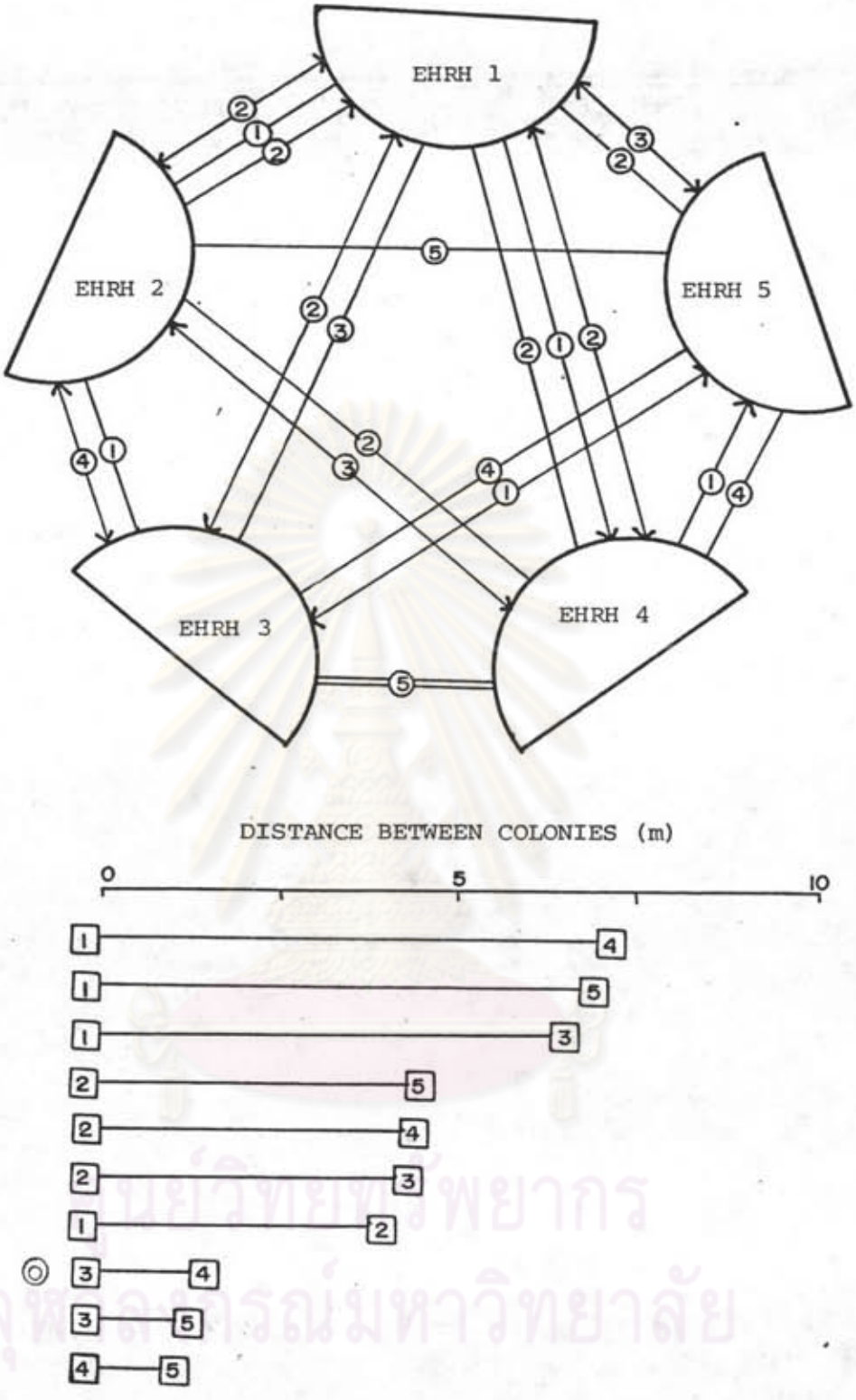


Fig. 18 Intra-reef allografts interactions of M. ehrenbergii collected from the same aggregate area H were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13

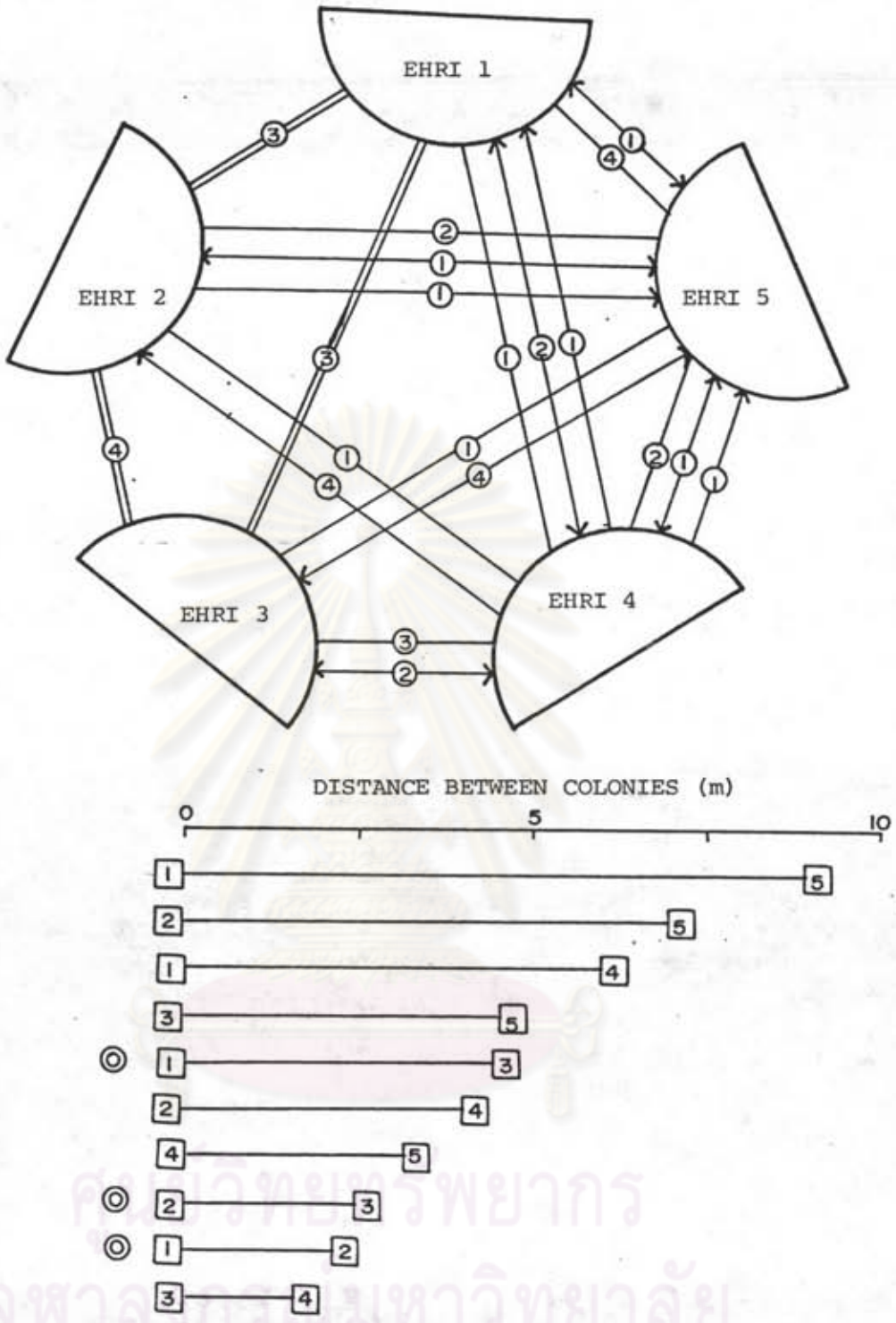


Fig. 19 Intra-reef allografts interactions of M. ehrenbergii collected from the same aggregate area I were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13

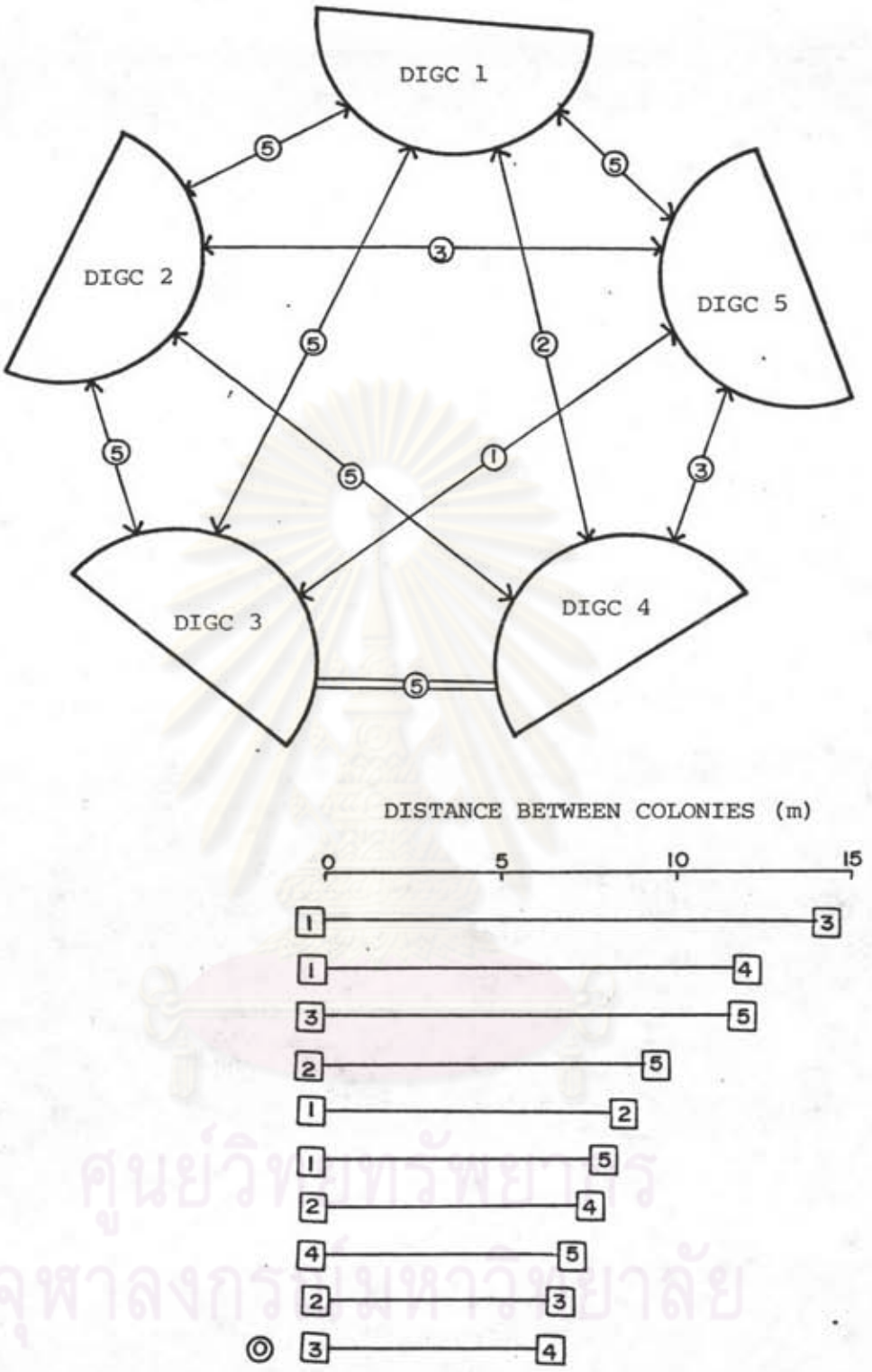


Fig. 20 Intra-reef allograft interactions of M. digitata collected from the same aggregate area C were observed at the end of a 16-week period in the field experiments. Explanation as in Fig. 13.

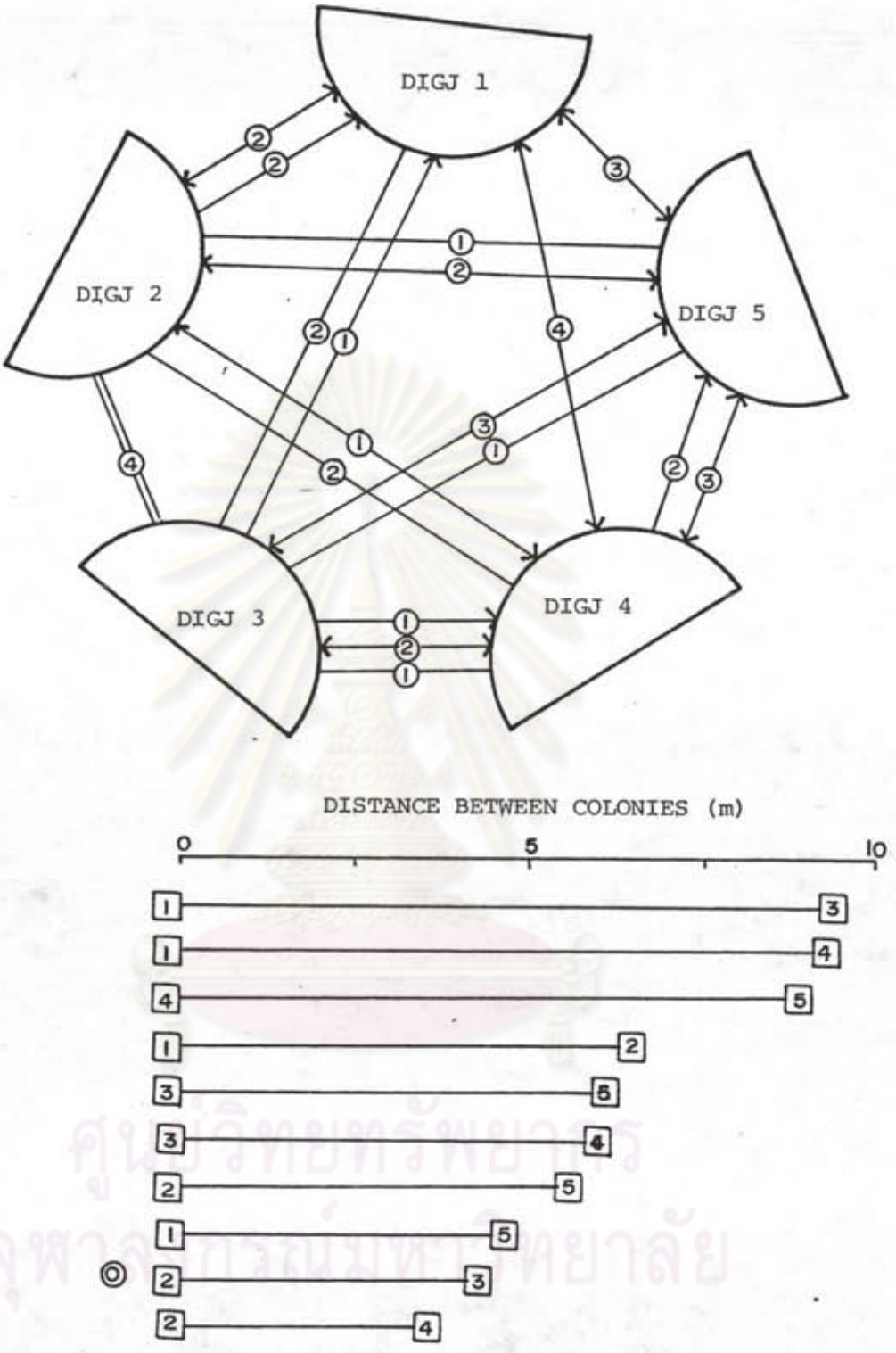


Fig. 21 Intra-reef allograft interactions of M. digitata collected from the same aggregate area J were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13.

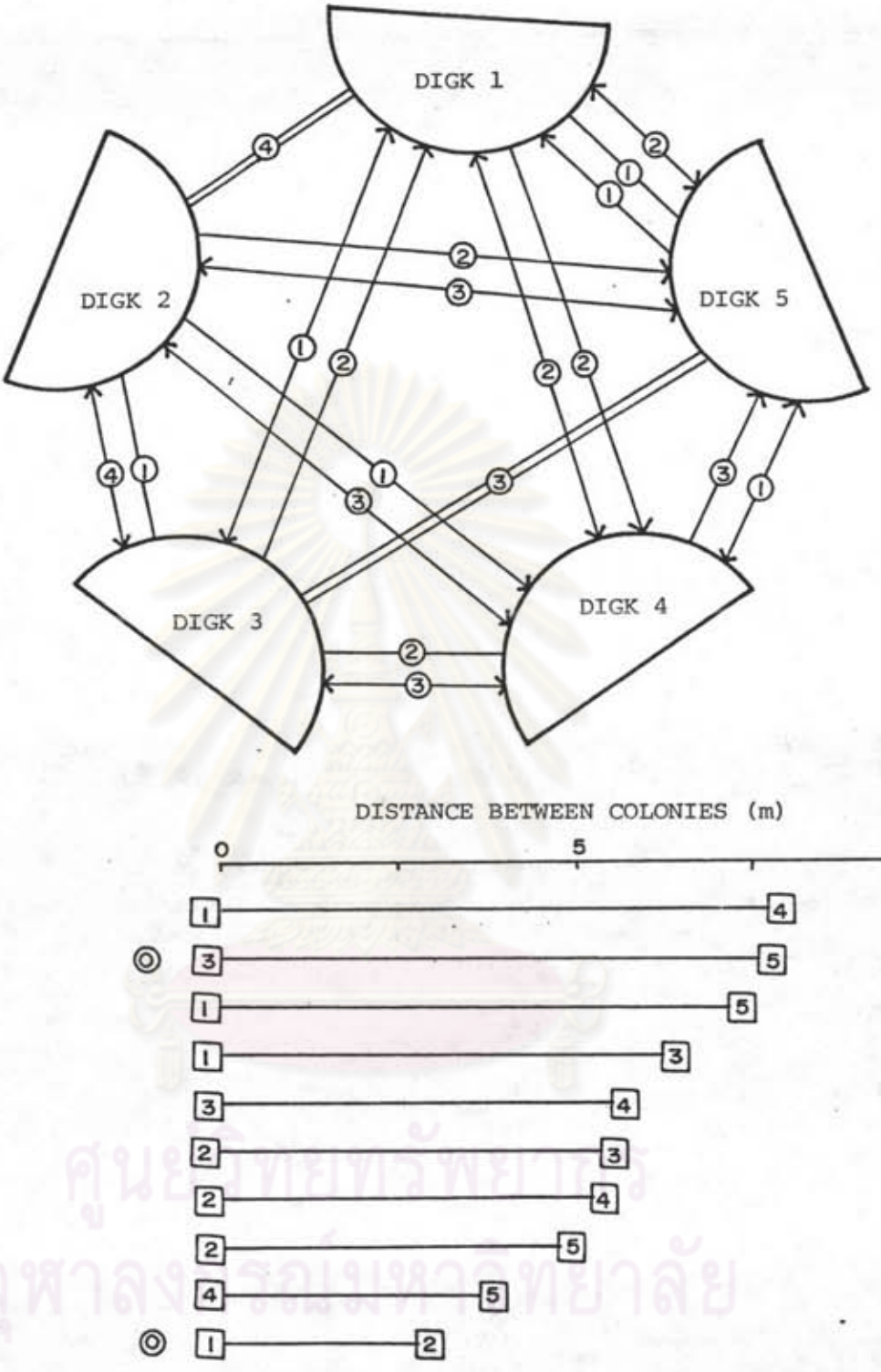


Fig. 22 Intra-reef allograft interactions of M. digitata collected from the same aggregate area K were observed at the end of a 14-week period in the laboratory experiments. Explanation as in Fig. 13.

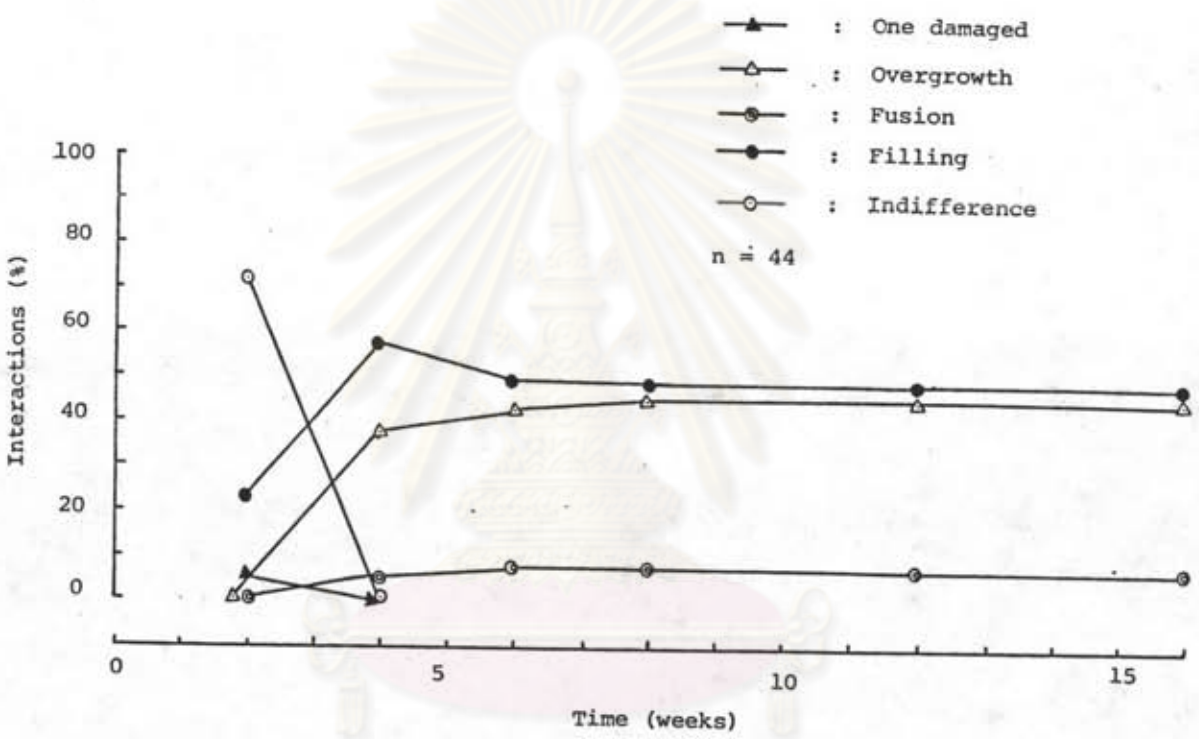


Fig. 23 Intra-reef allograft interactions through time of M. foliosa collected from the same aggregate area A in the field experiments.

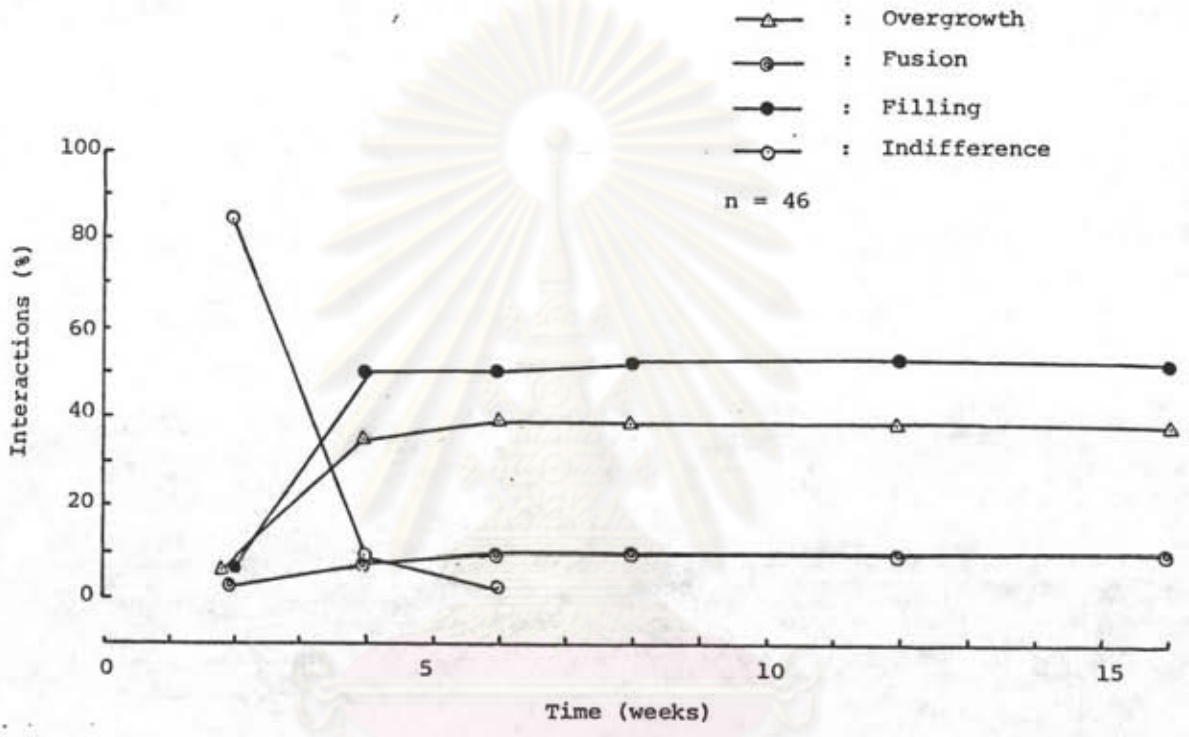


Fig. 24 Intra-reef allograft interactions through time of M. foliosa collected from the same coral aggregate area G in the field experiments.

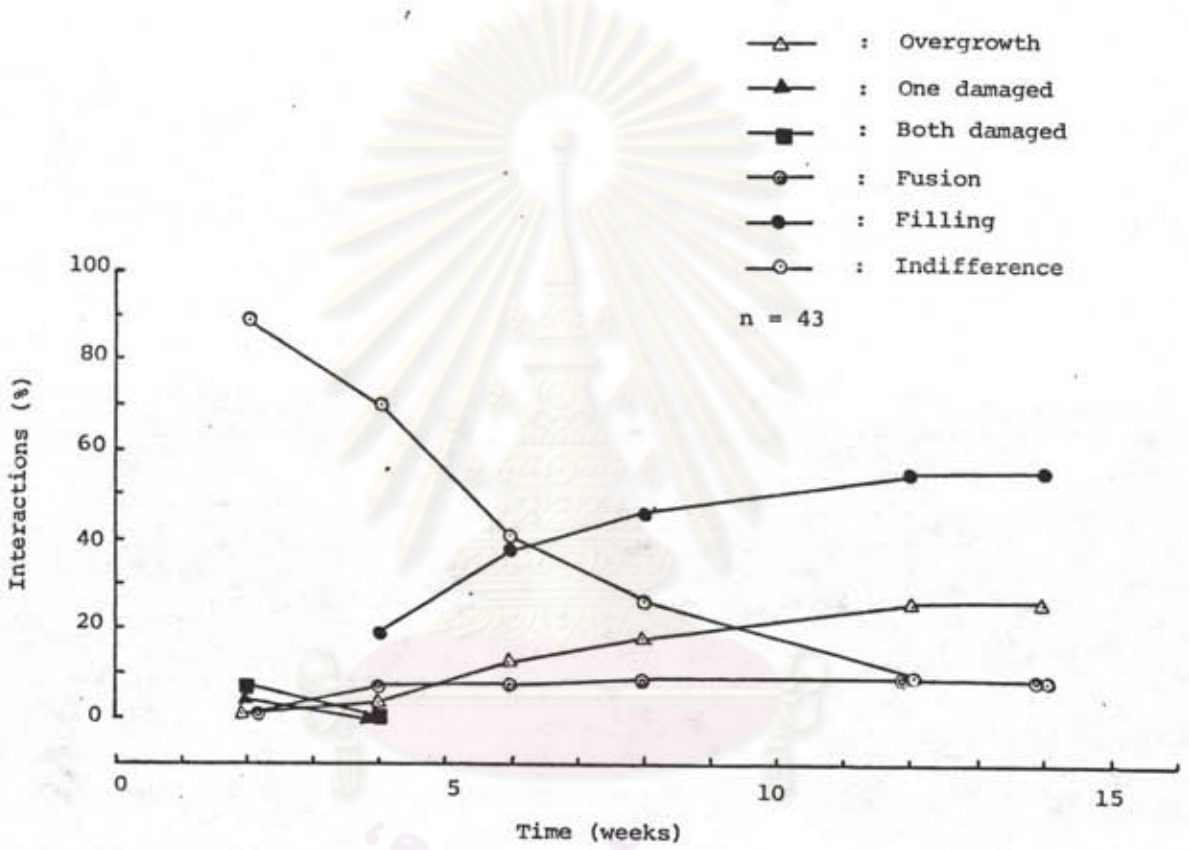


Fig. 25 Intra-reef allograft interactions through time of M. foliosa collected from the same aggregate area L in the field experiments.

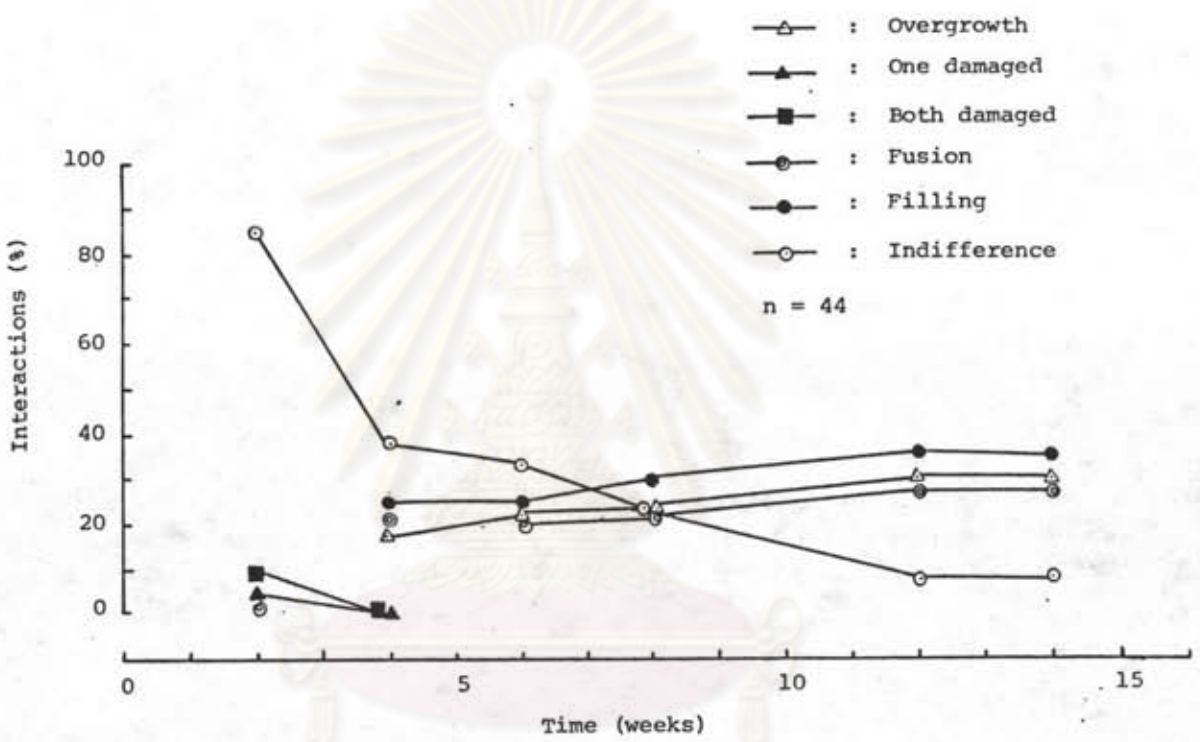


Fig. 26 Intra-reef allograft interactions through time of M. foliosa collected from the same coral aggregate area M in the laboratory experiments.

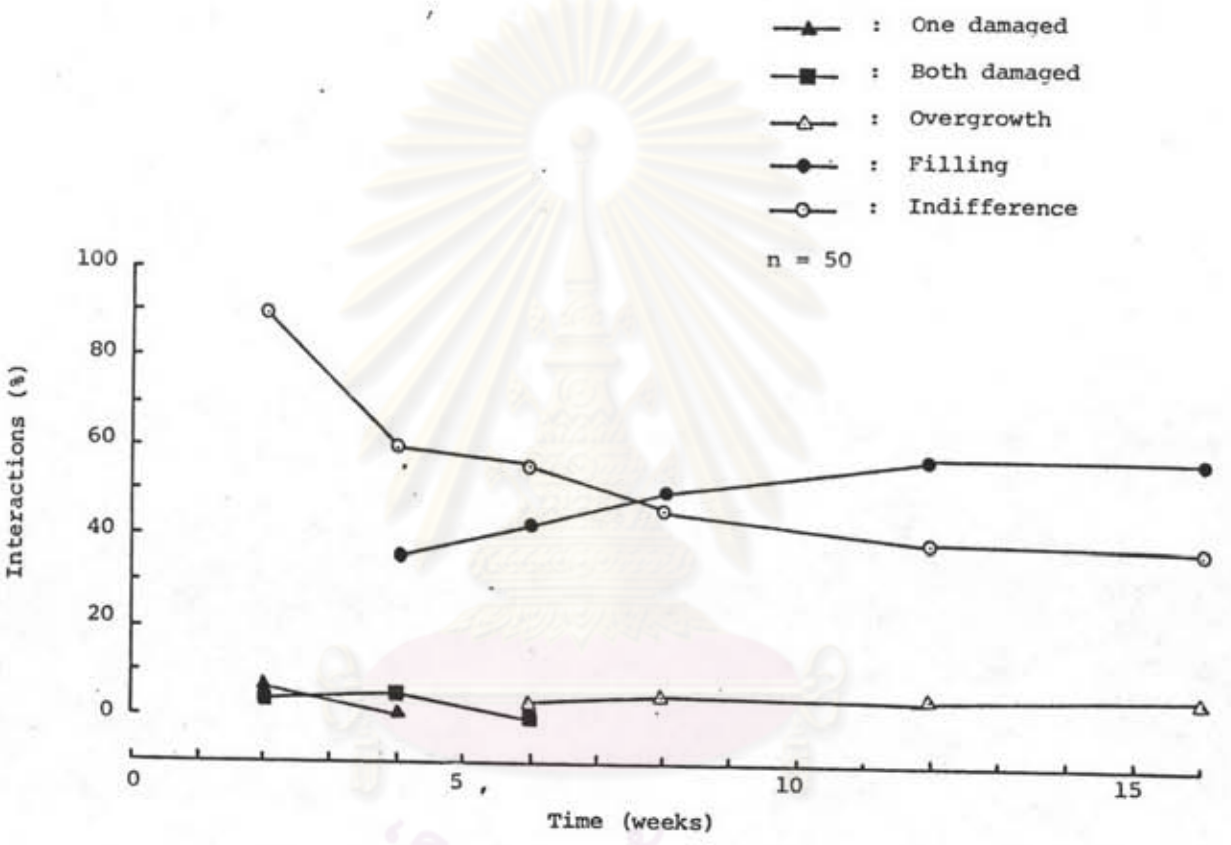


Fig. 27 Intra-reef allograft interactions through time of M. ehrenbergii, collected from the same coral aggregate area B, in the field experiments.

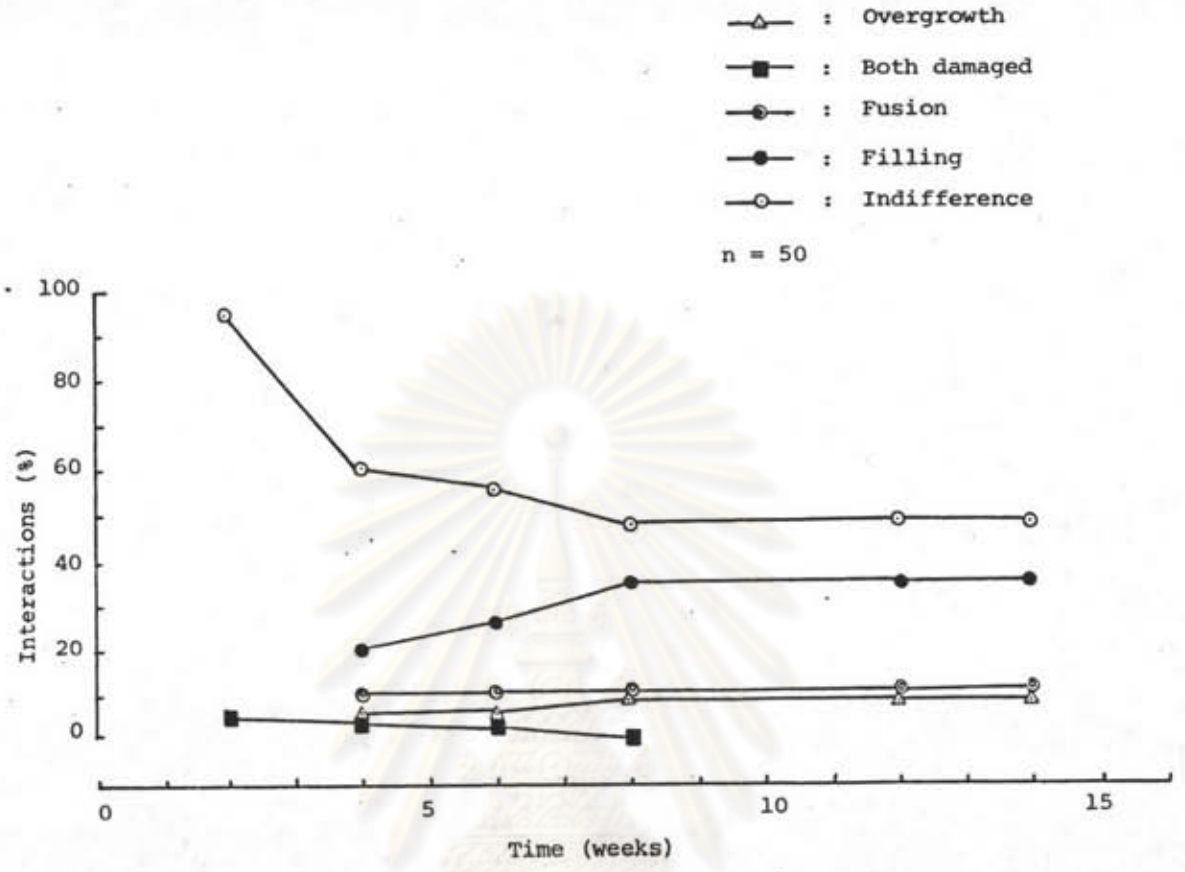


Fig. 28 Intra-reef allograft interactions through time of M. ehrenbergii collected from the same coral aggregate area H in the laboratory experiments.

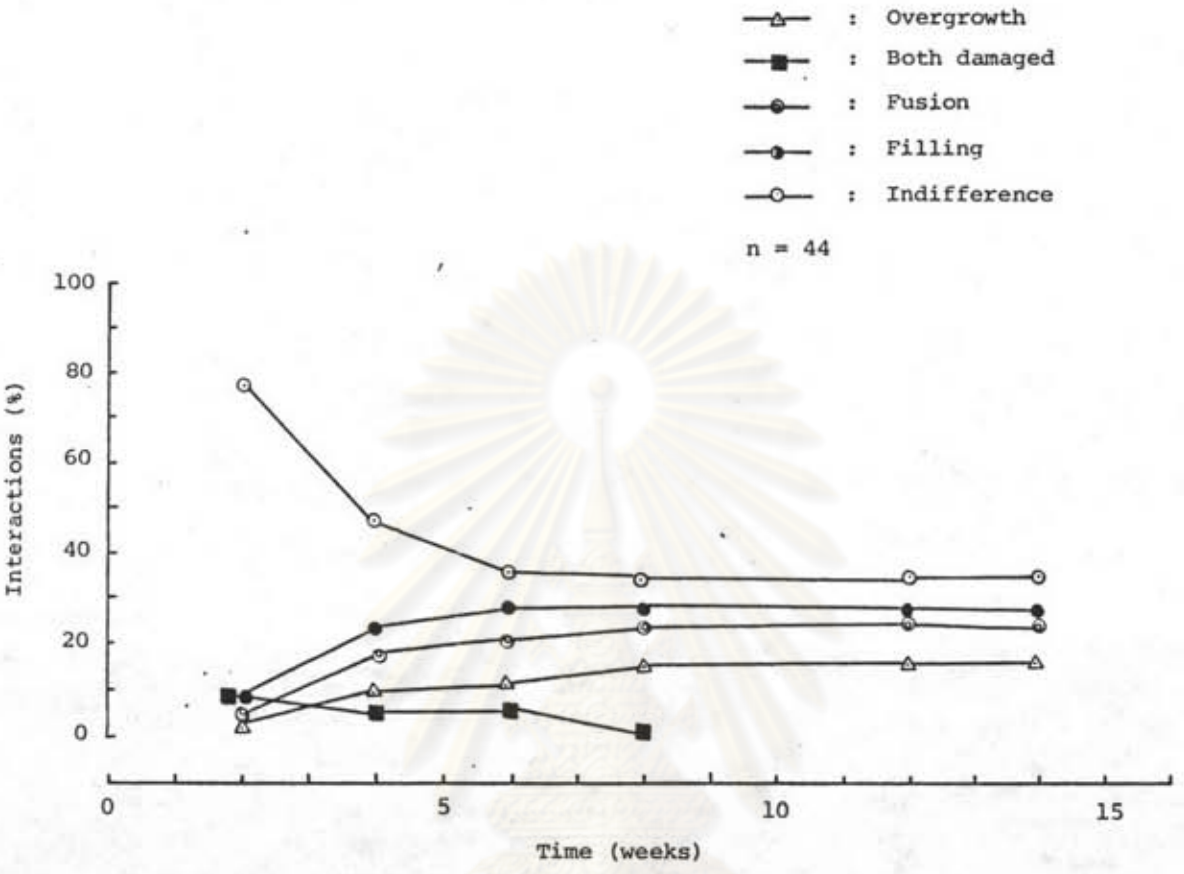


Fig. 29 Intra-reef allografts interactions through time of M. ehrenbergii collected from the same coral aggregate area I in the laboratory experiments.

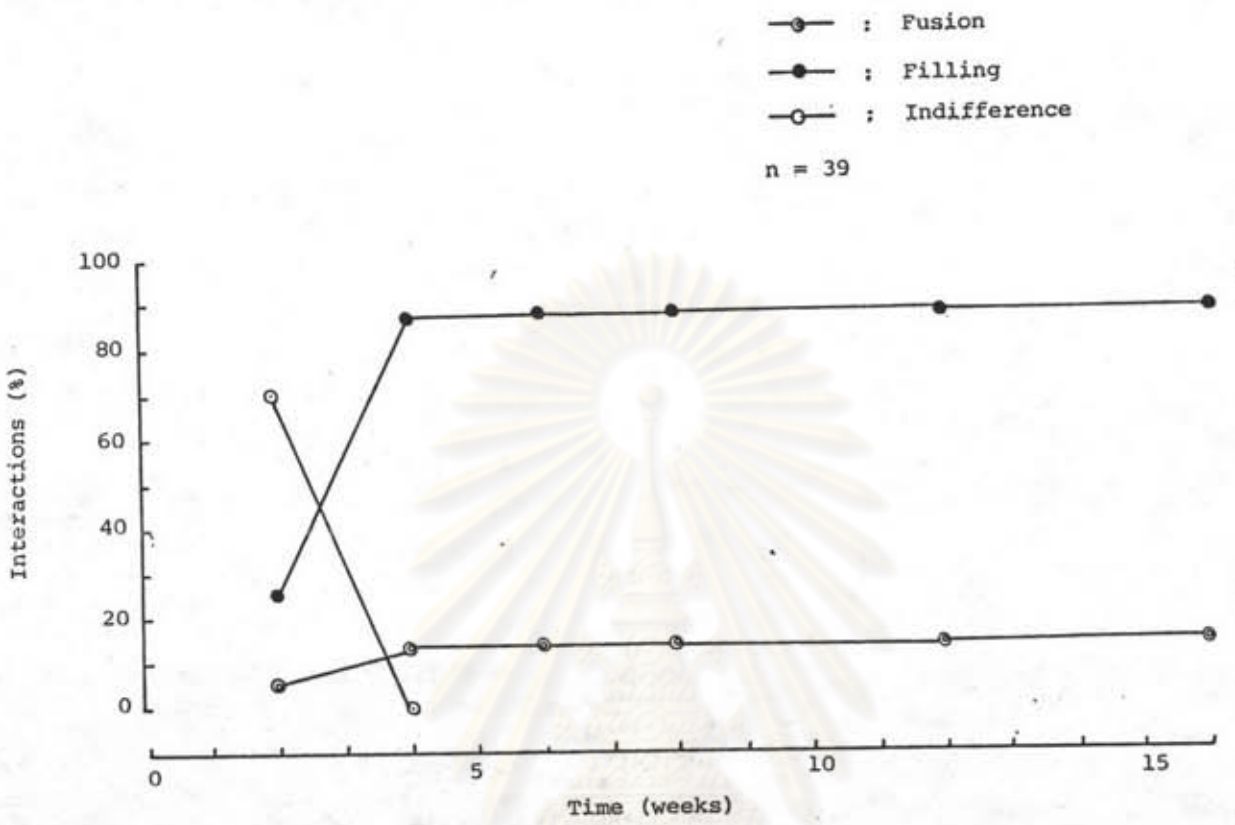


Fig. 30 Intra-reef allograft interactions through time of M. digitata collected from the same coral aggregate area C in the field experiments.

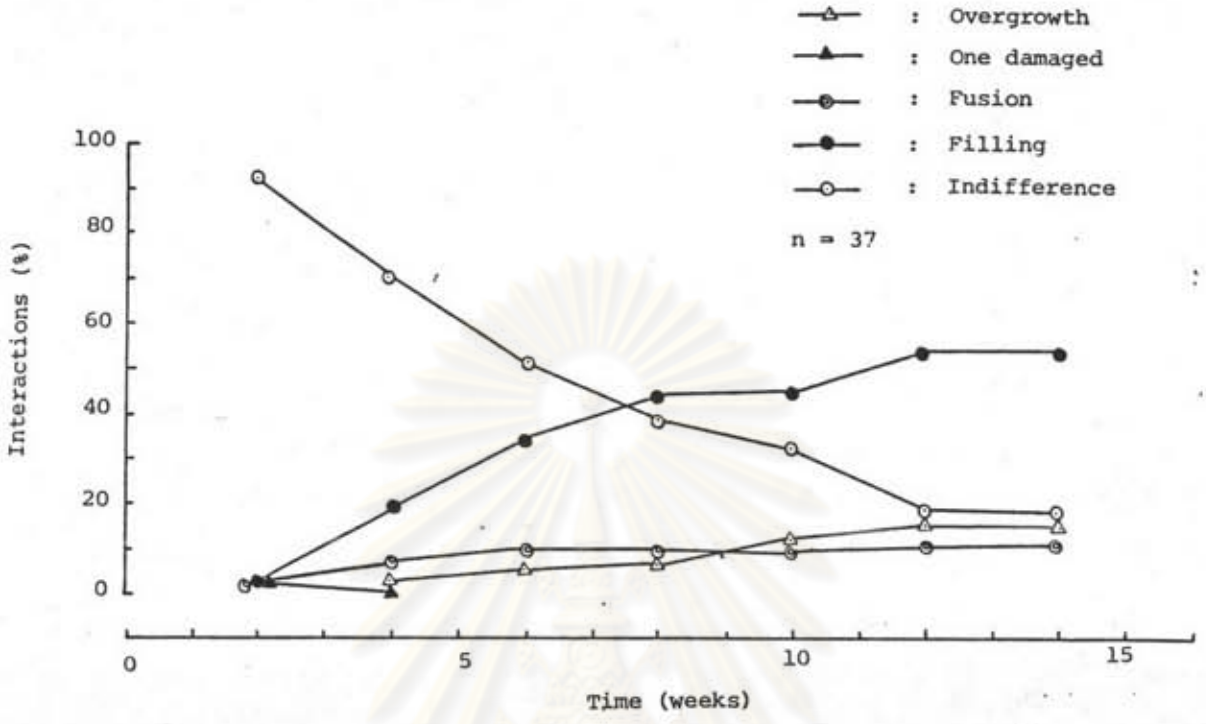


Fig. 31 Intra-reef allograft interactions through time of M. digitata collected from the same coral aggregate area J in the laboratory experiments.

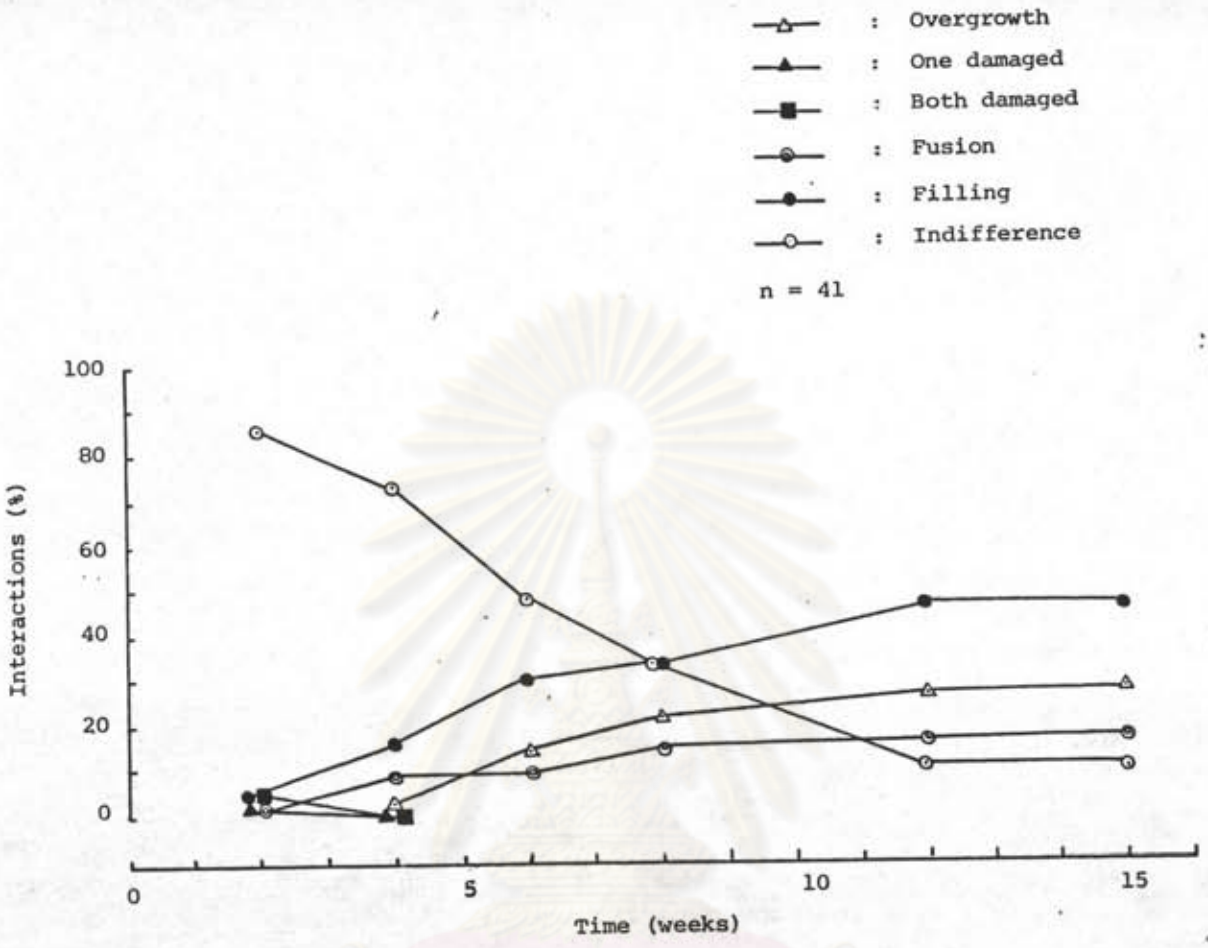


Fig. 32 Intra-reef allograft interactions through time of M. digitata collected from the same aggregate area K in the laboratory experiments.

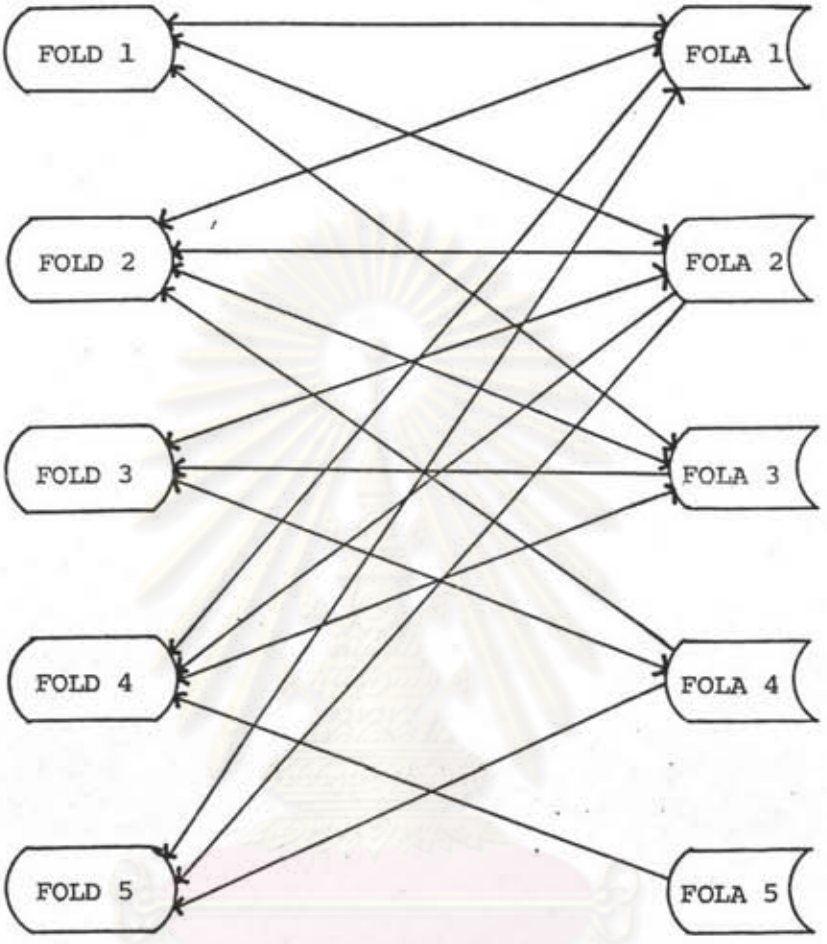


Fig. 33 Inter-reef allograft interactions of M. foliosa collected from the coral aggregate area A and D were observed at the end of a 16-weed period in the field expariments. Symbols show type of interactions as in Fig. 13

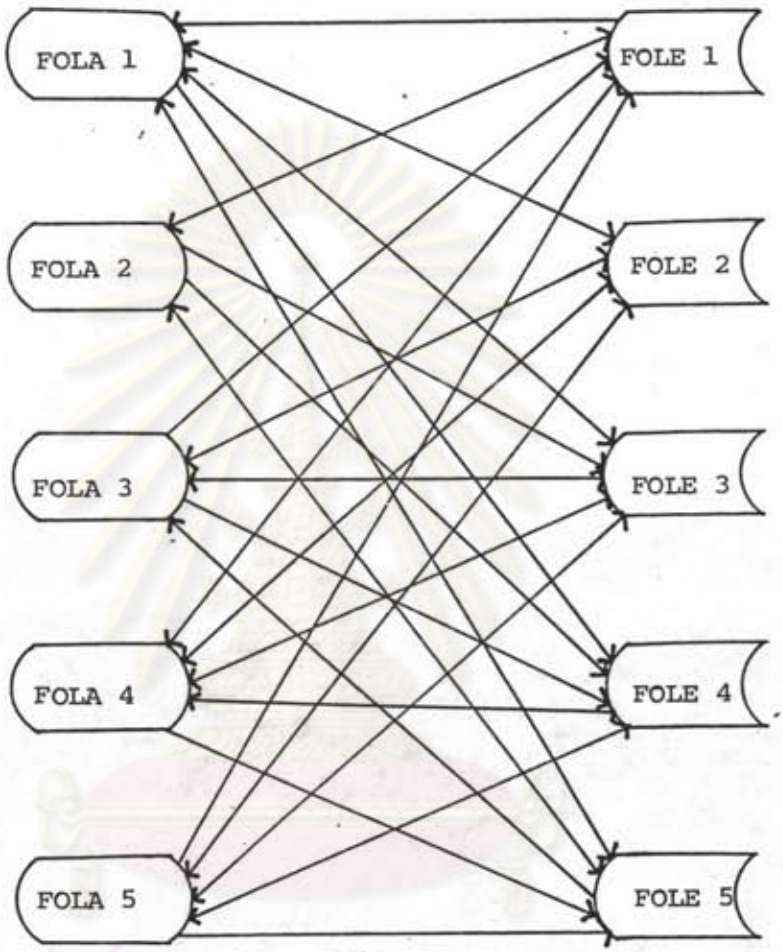


Fig. 34 Inter-reef allograft interactions of M. foliosa collected from the coral aggregate area A and E were observed at the end of a 16-week period in the field experiments. Symbols show type of interaction as in Fig. 13.

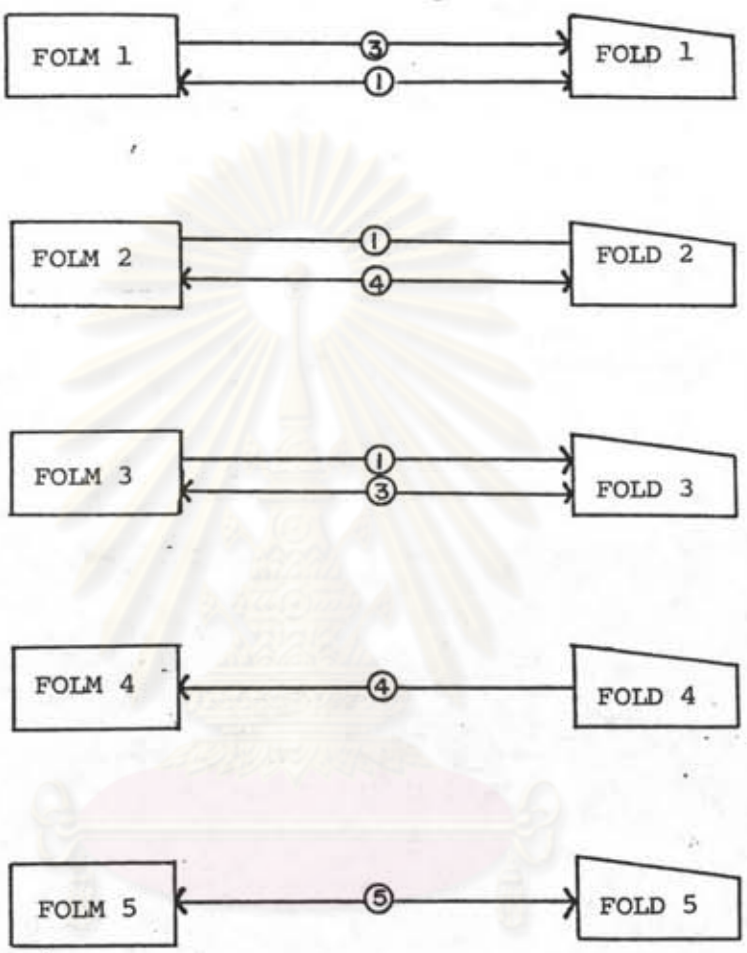


Fig. 35 Inter-reef allograft interactions of M. foliosa collected from the coral aggregate area M and D were observed at the end of a 14-week period in the laboratory experiments. Symbols show type of interactions as in Fig. 13.

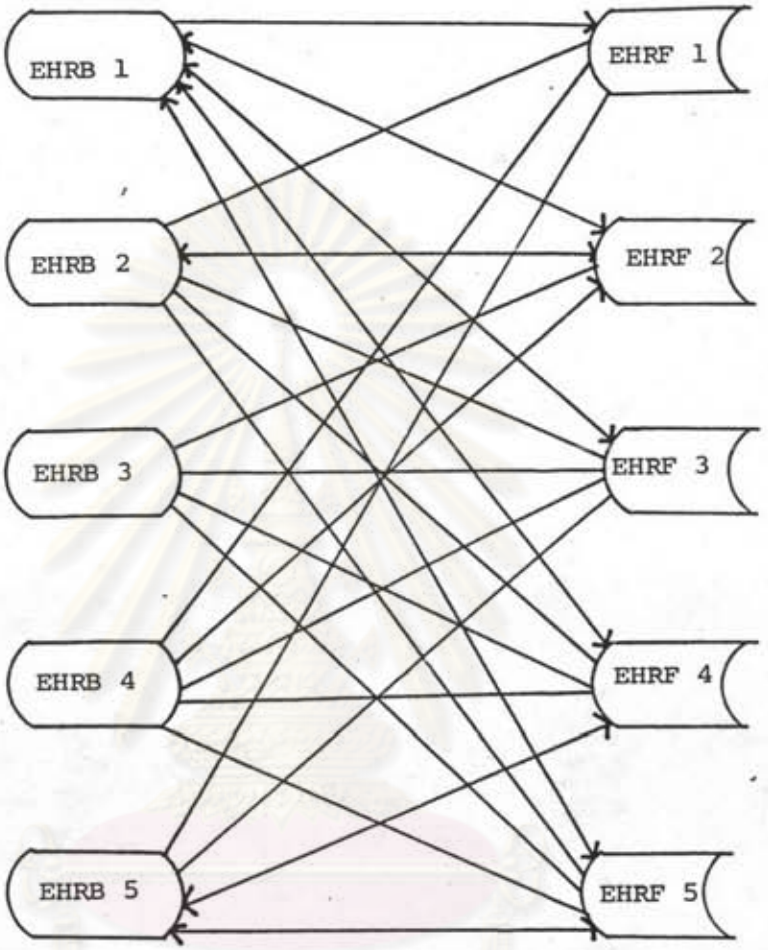


Fig. 36 Inter-reef allograft interactions of M. ehrenbergii collected from the coral aggregate area B and F were observed at the end of a 16-week period in the field experiments. Symbols show type of interactions as in Fig. 13.

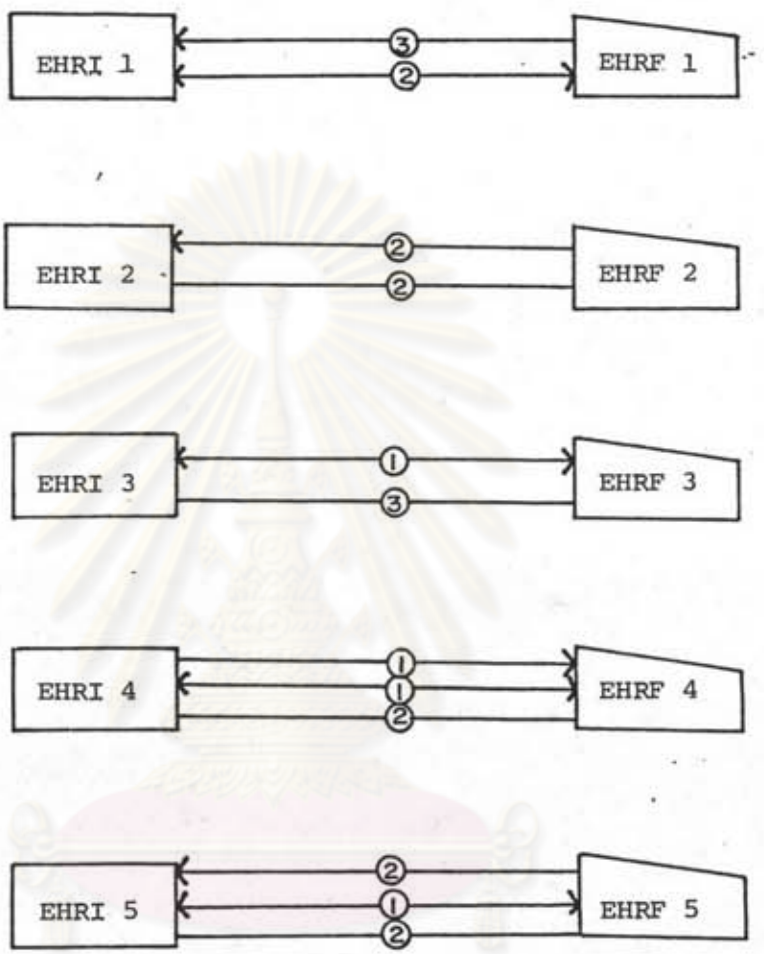


Fig. 37 Inter-reef allograft interactions of M. ehrenbergii collected from the coral aggregate area I and F were observed at the end of a 14-week period in the laboratory experiments. Symbols show type of interactions as in Fig. 13.

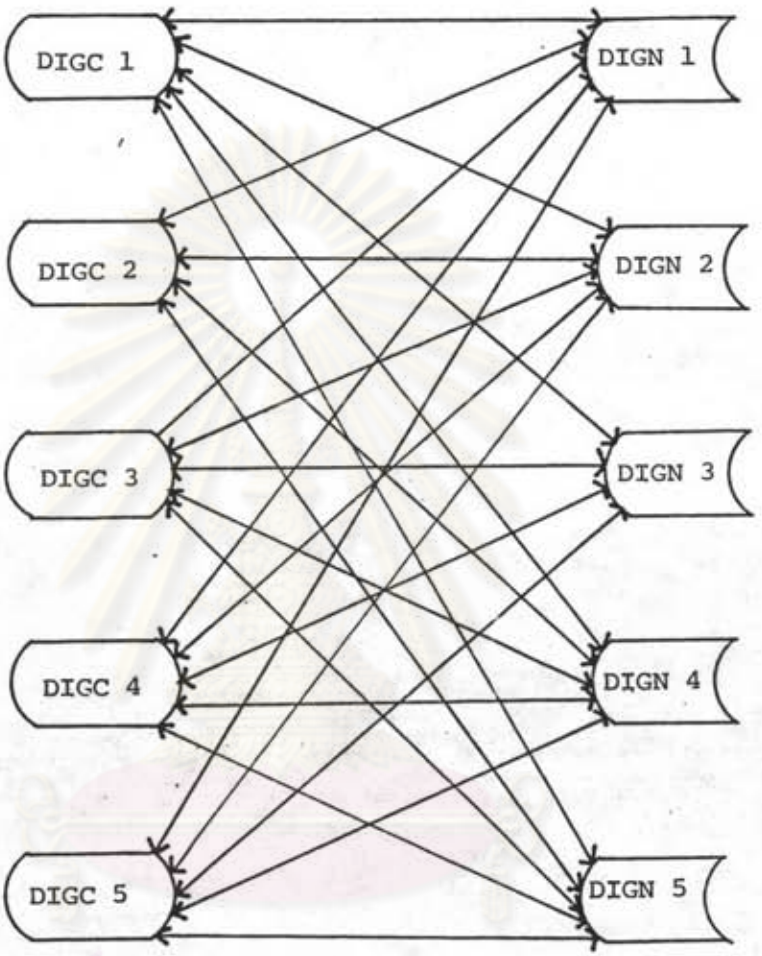


Fig. 38 Inter-reef allograft interactions of M. digitata collected from the coral aggregate area C and N were observed at the end of a 16-week period in the field experiments. Symbols show type of interactions as in Fig. 13.

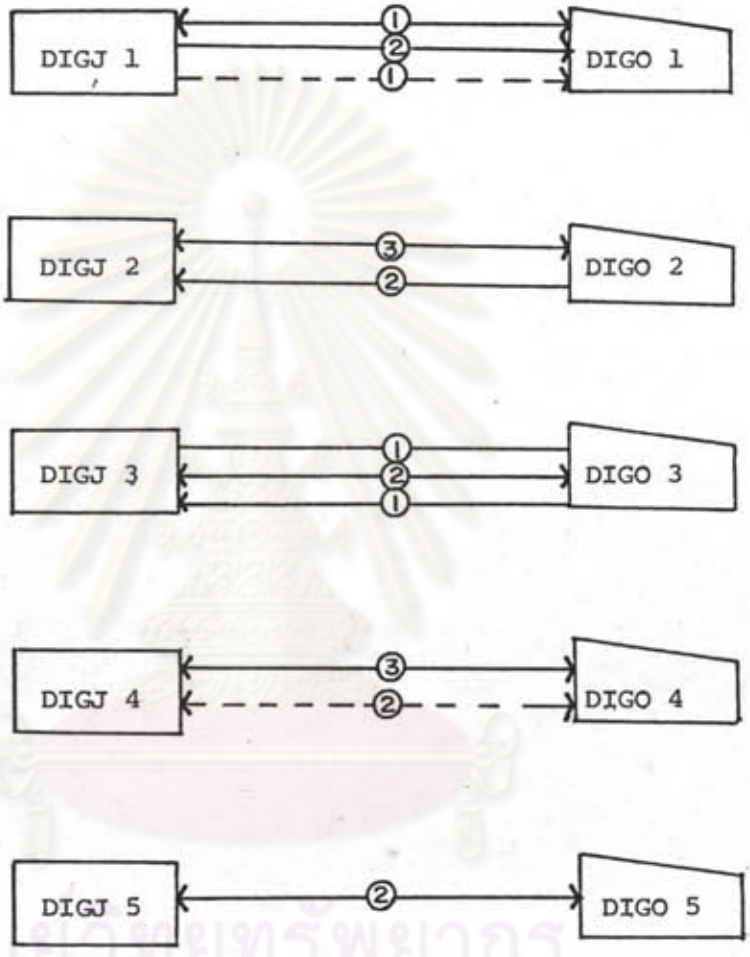


Fig. 39 Inter-reef allograft interactions of M. digitata collected from the coral aggregate area J and O were observed at the end of a 14-week period in the laboratory experiments. Symbols show type of interactions as in Fig. 13.

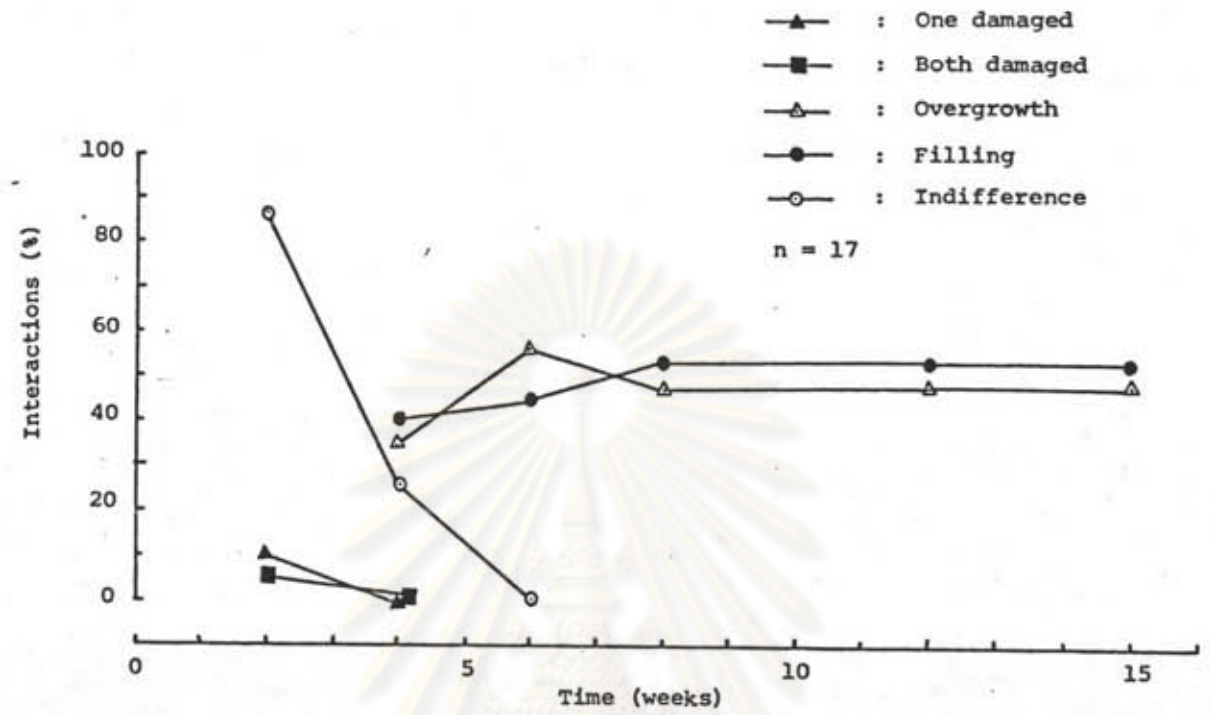


Fig. 40 Inter-reef allograft interactions through time of M. foliosa collected from the coral aggregate area A and D in the field experiments.

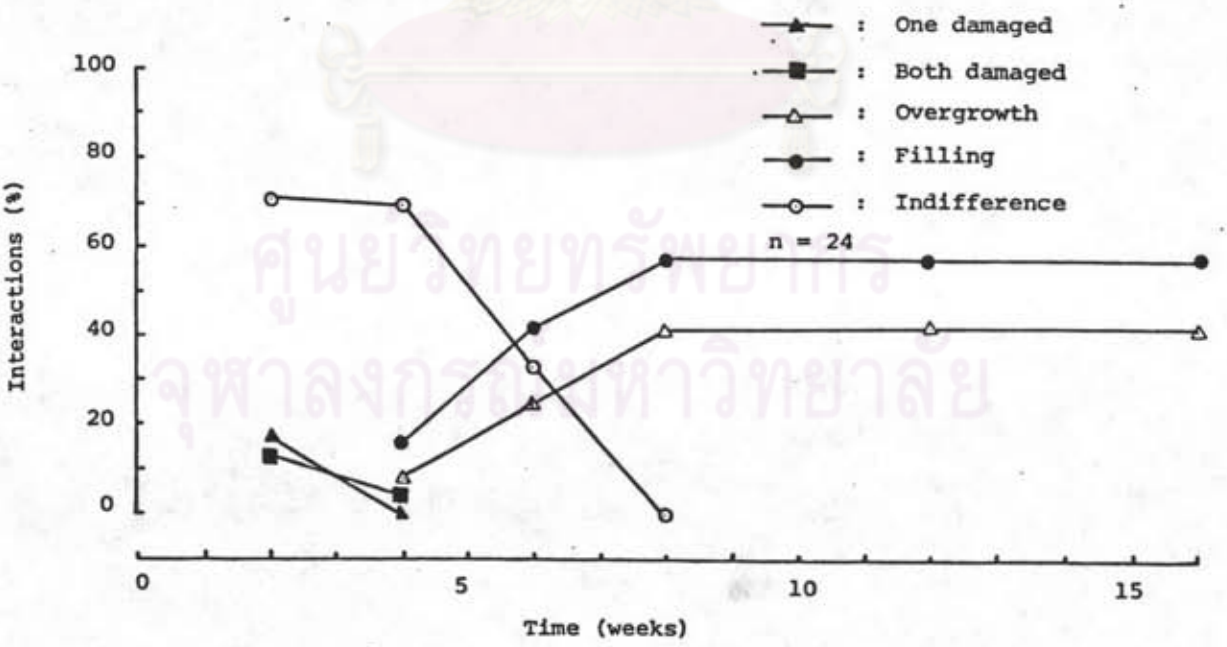


Fig. 41 Inter-reef allograft interactions through time of M. foliosa, collected from the coral aggregate area A and E in the field experiments.

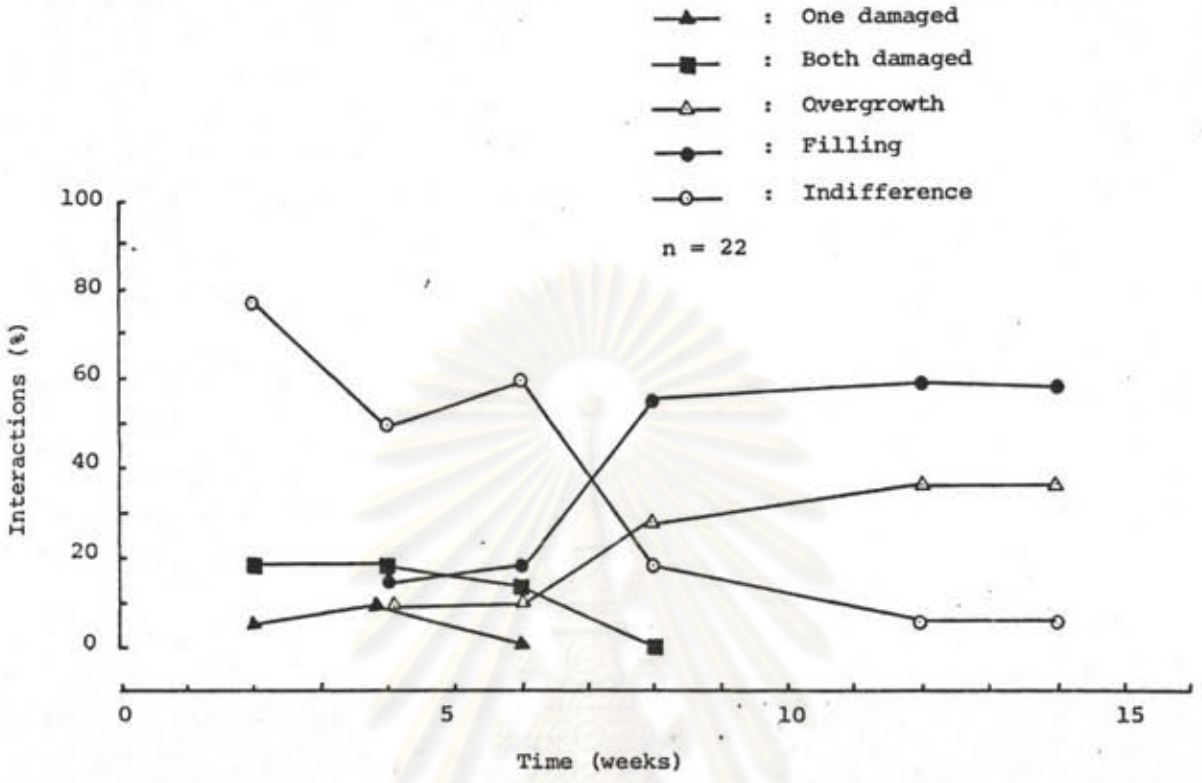


Fig. 42 Inter-reef allagraft interactions through time of M. foliosa collected from the coral aggregate area D and M in the laboratory experiments.

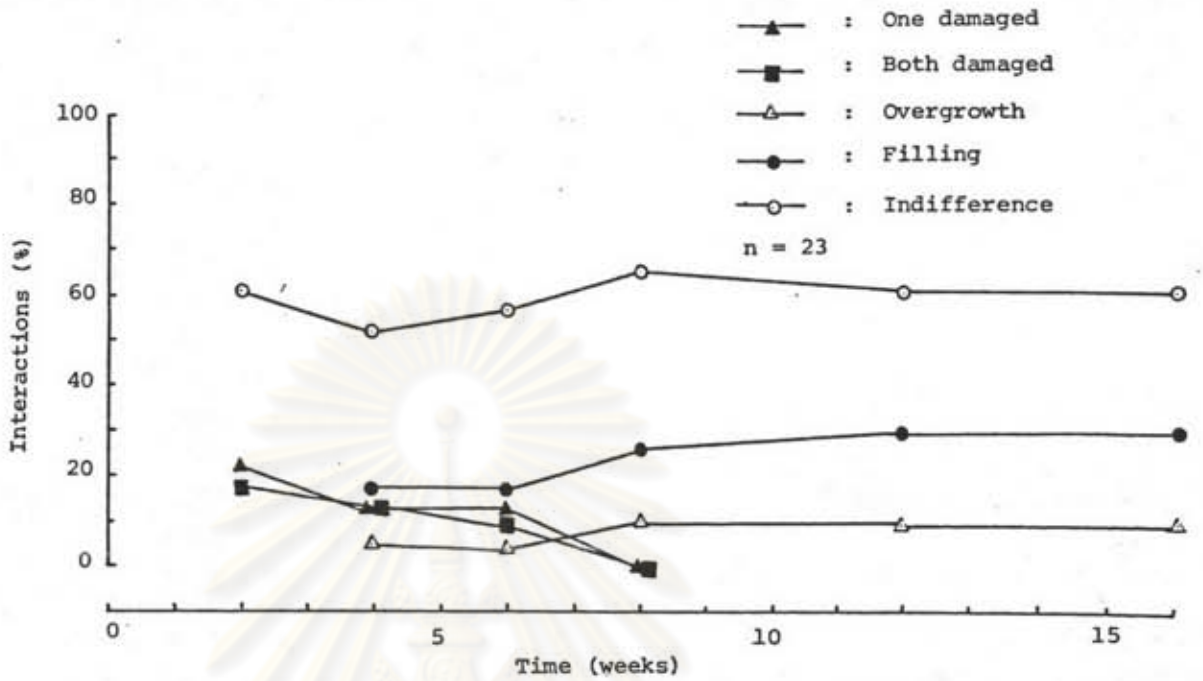


Fig. 43 Inter-reef allograft interactions through time of M. ehrenbergii collected from the coral aggregate area B and F in the field experiments.

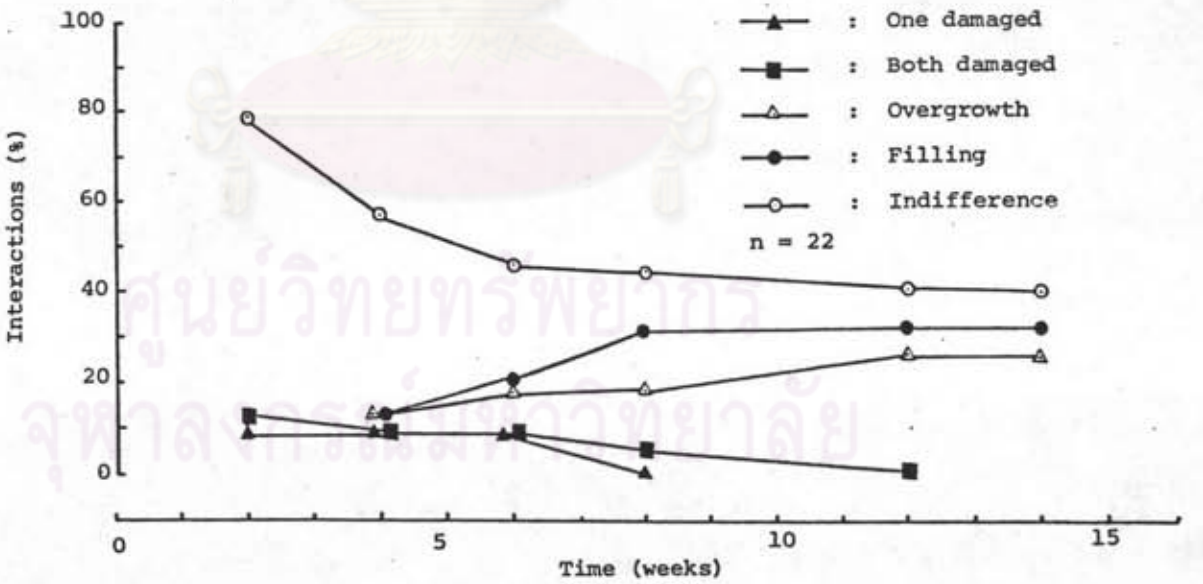


Fig. 44 Inter-reef allograft interactions through time of M. ehrenbergii collected from the coral aggregate area I and F in the laboratory experiments.

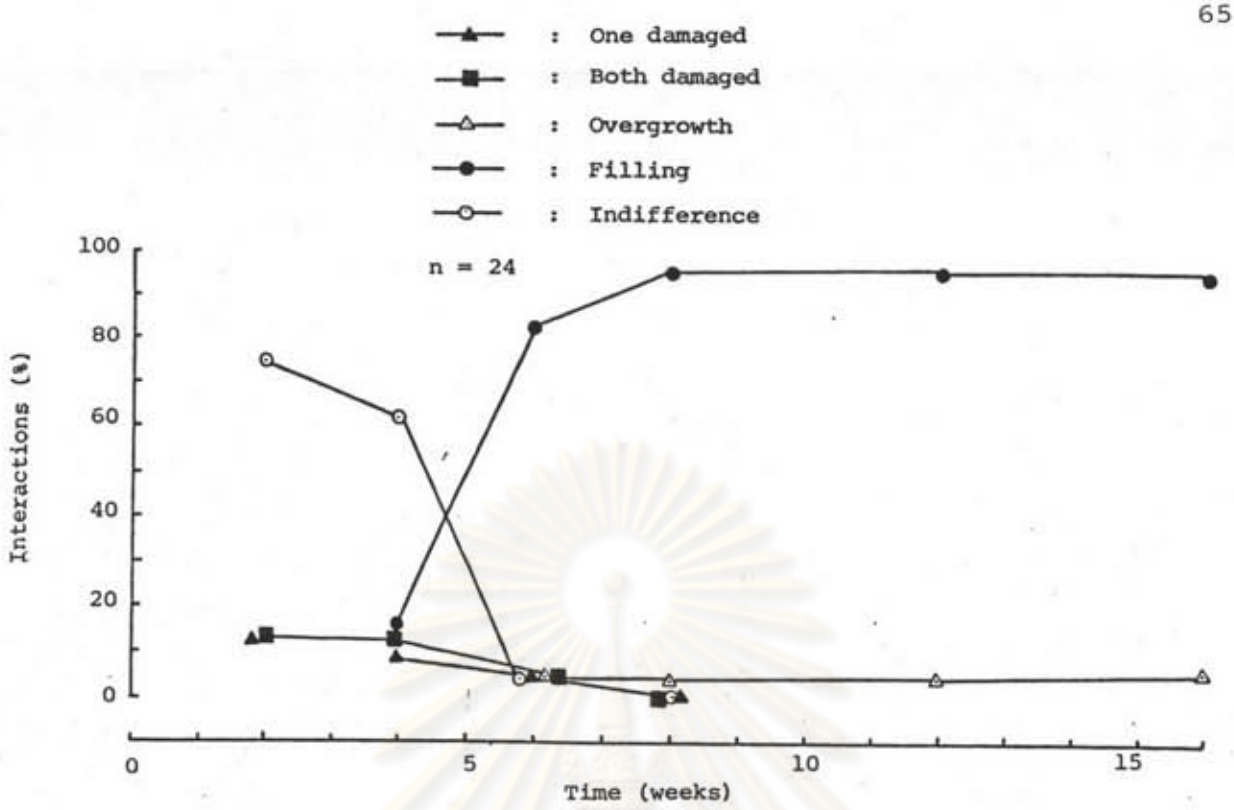


Fig. 45 Inter-reef allograft interactions through time of M. digitata collected from the coral aggregate area C and N in the field experiments.

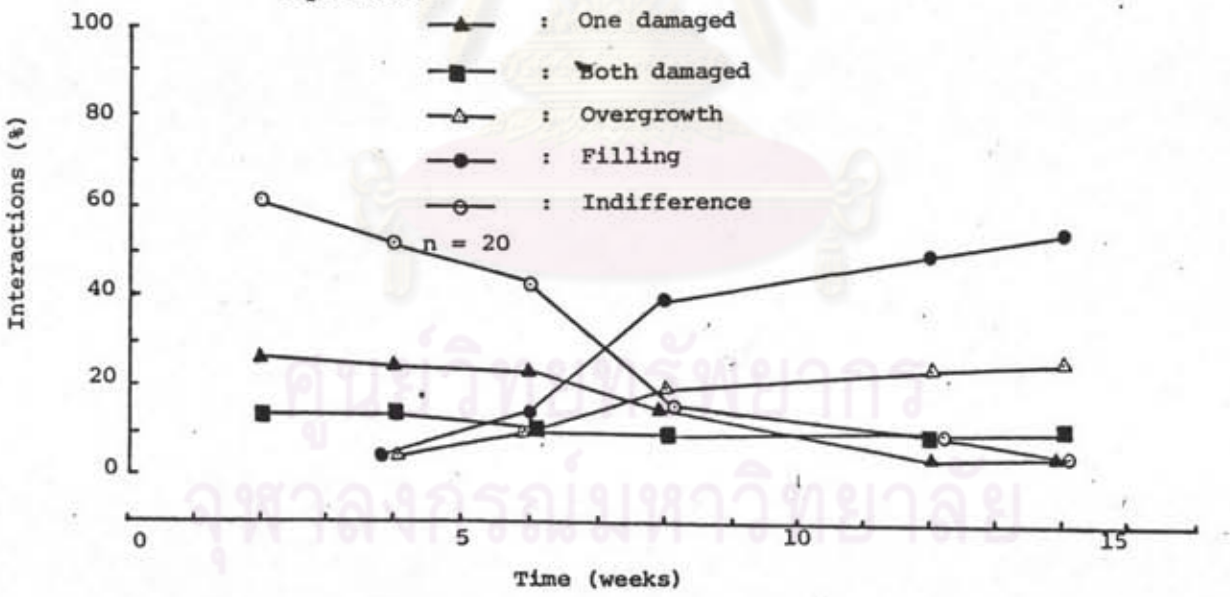


Fig. 46 Inter-reef allograft interactions through time of M. digitata collected from the coral aggregate area J and O in the laboratory experiments.

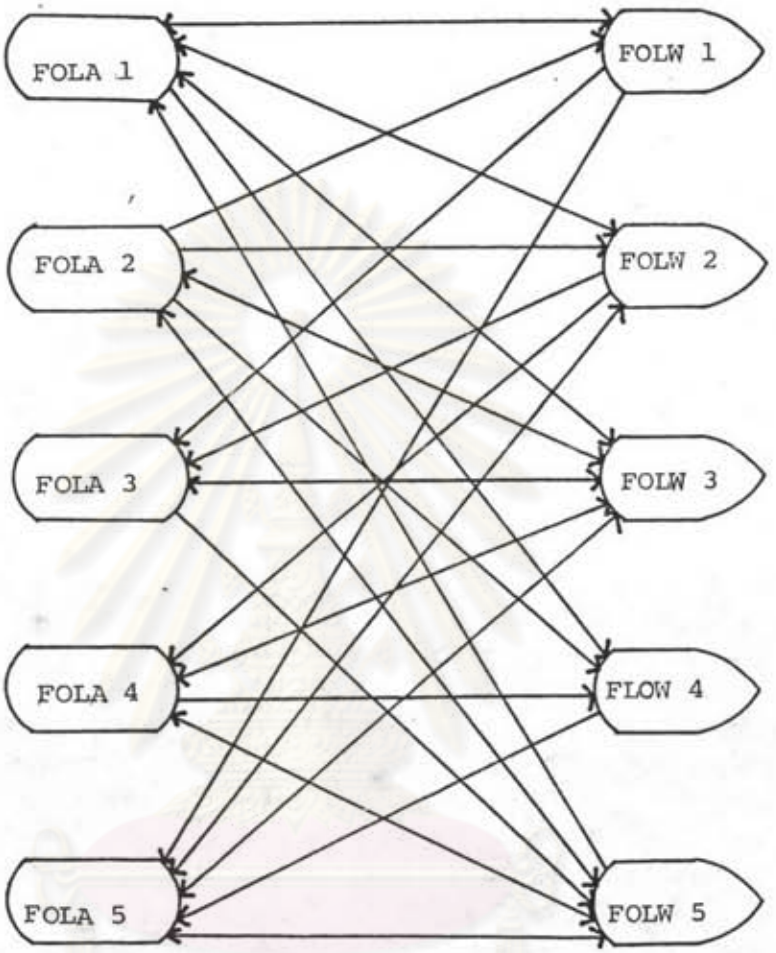


Fig. 47 Across-island allograft interactions of M. foliosa collected from the coral aggregate area A and western coast of Sesoko Island, were observed at the end of a 16-week period in the field experiments. Symbols show type of interactions as in Fig. 13.

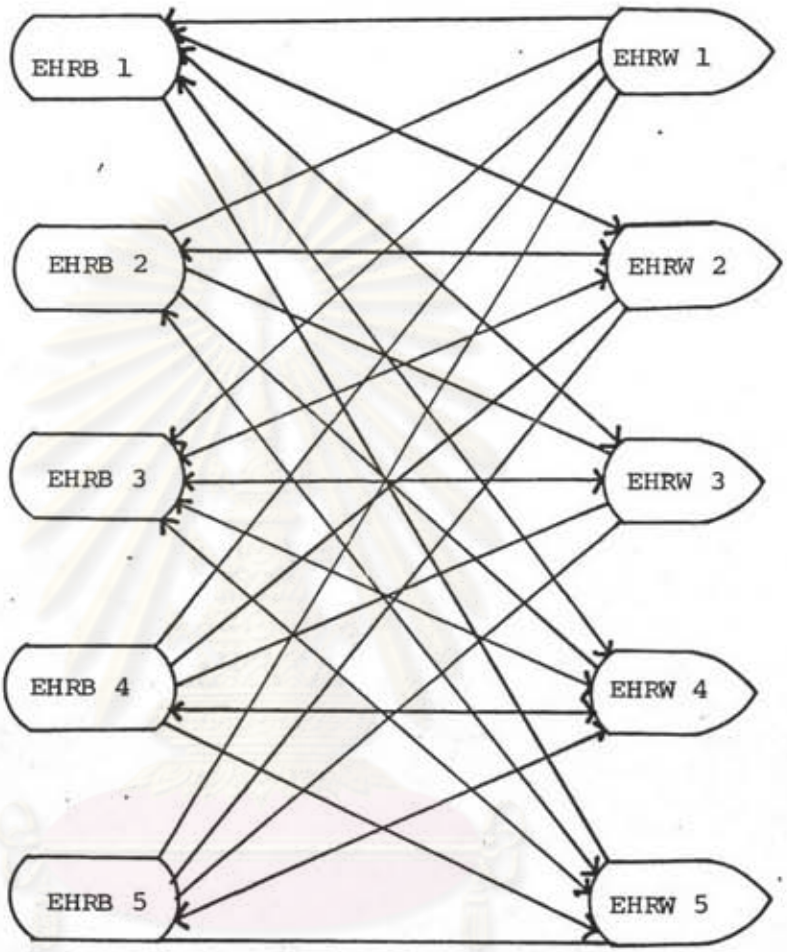


Fig. 48 Across-island allograft interactions of M. ehrenbergii collected from the coral aggregate area B and western coast of Sesoko Island, were observed at the end of a 16-week period in the field experiments. Symbols show type of interactions as in Fig. 13.

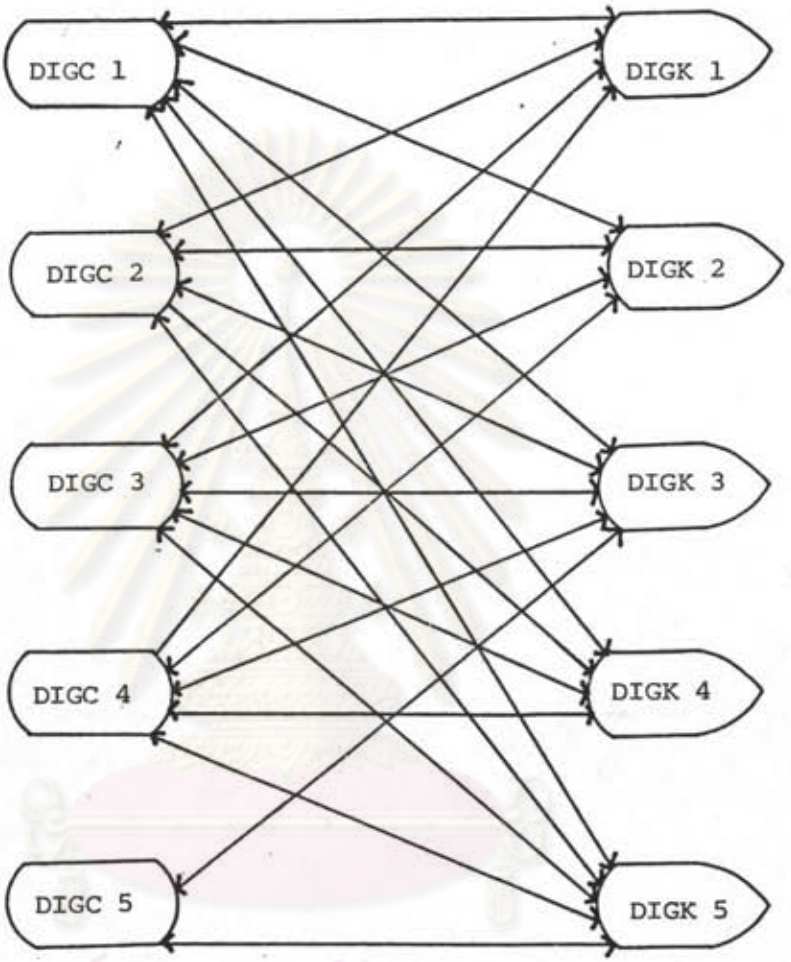


Fig. 49 Across-island allograft interactions of M. digitata collected from the coral aggregate area C and K were observed at the end of a 16-week period in the field experiments. Symbols show type of interactions as in Fig. 13.

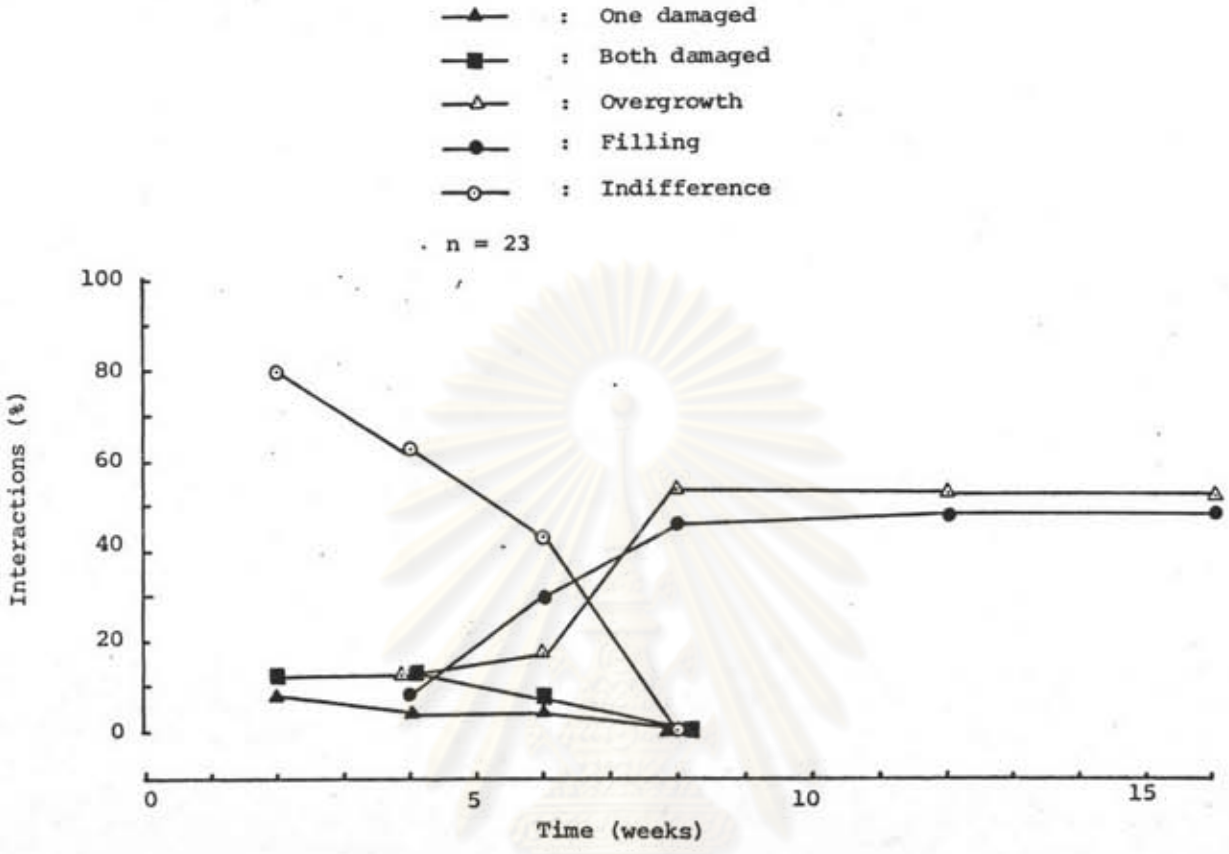


Fig. 50 Across-island allograft interactions through time of M. foilosa collected from the coral aggregate area A and western coast of Sesoko Island, in the field experiments.

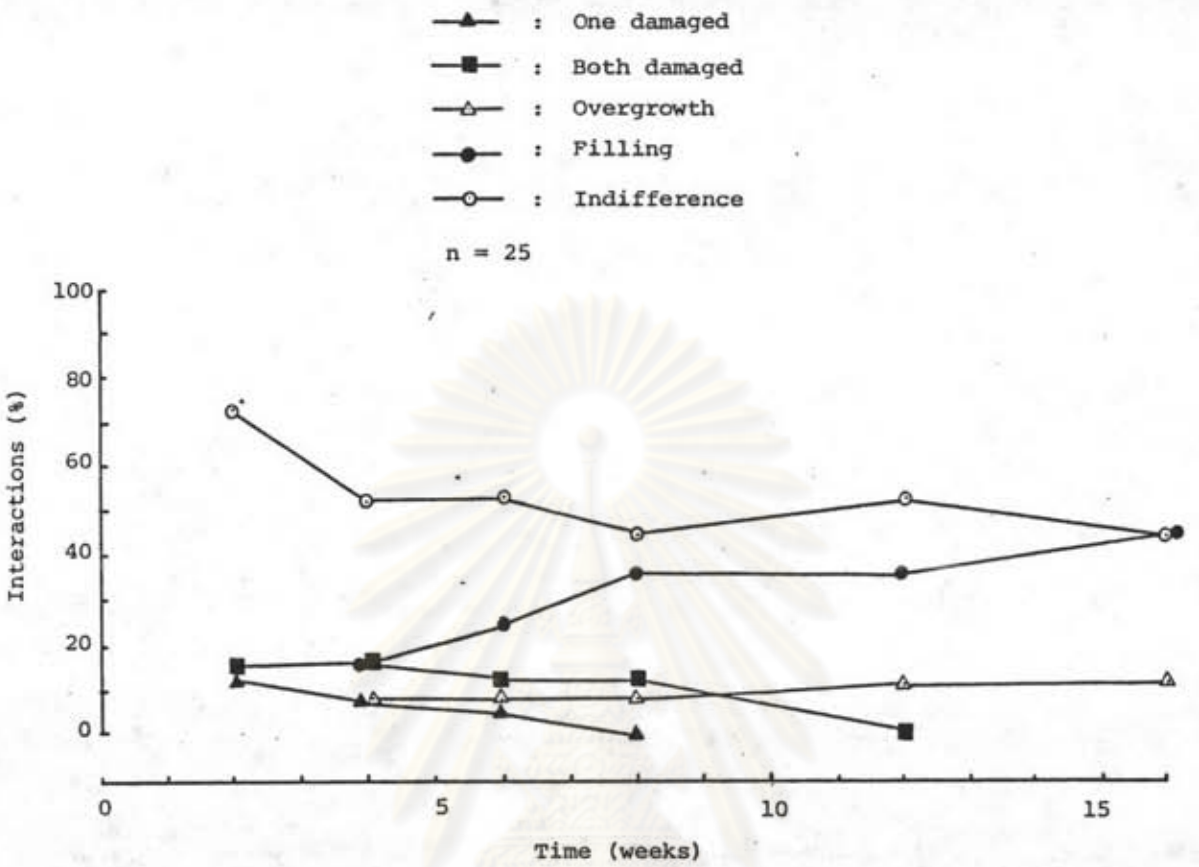


Fig. 51 Across-island allograft interactions through time of M. ehrenbergii collected from the coral aggregate area B and western coast of Sesoko Island, in the field experiments.

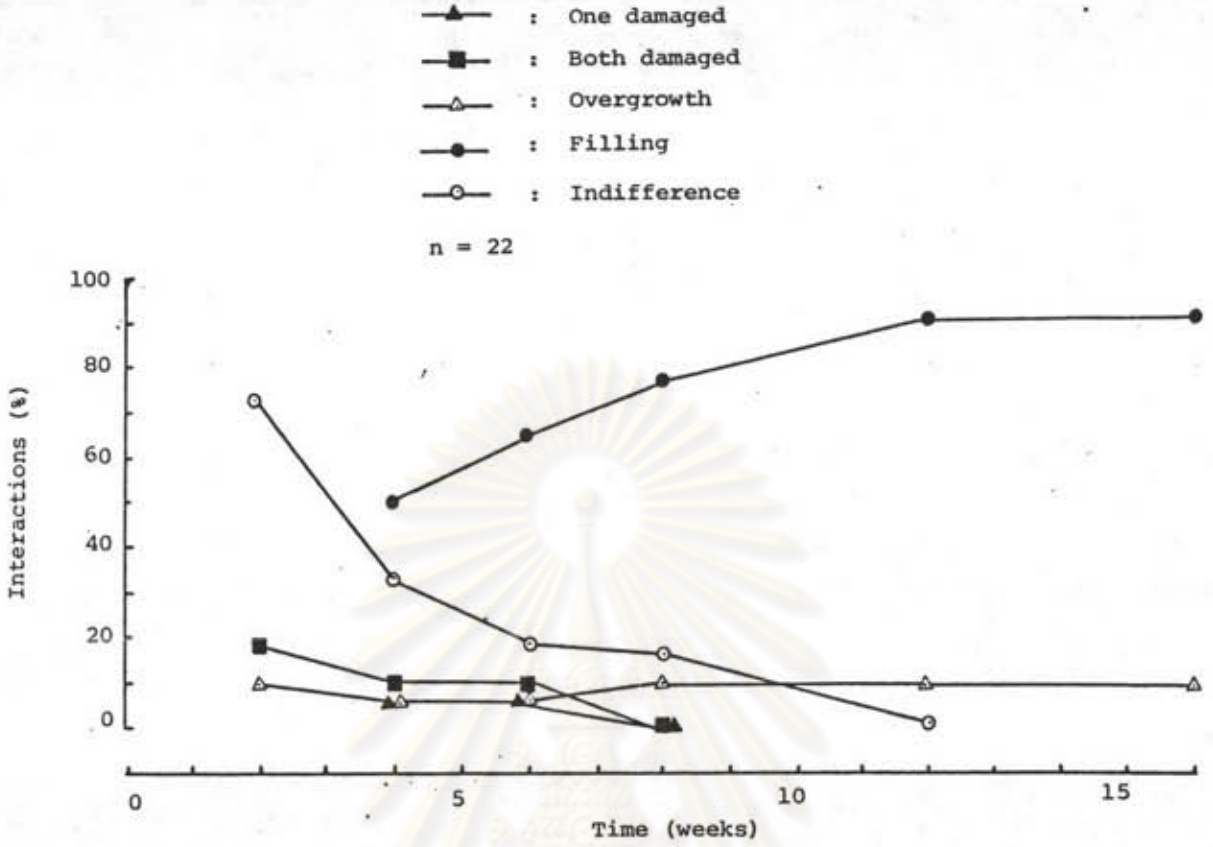


Fig. 52 Across-island allograft interactions through time of M. digitata collected from the coral aggregate area C and K in the field experiments.

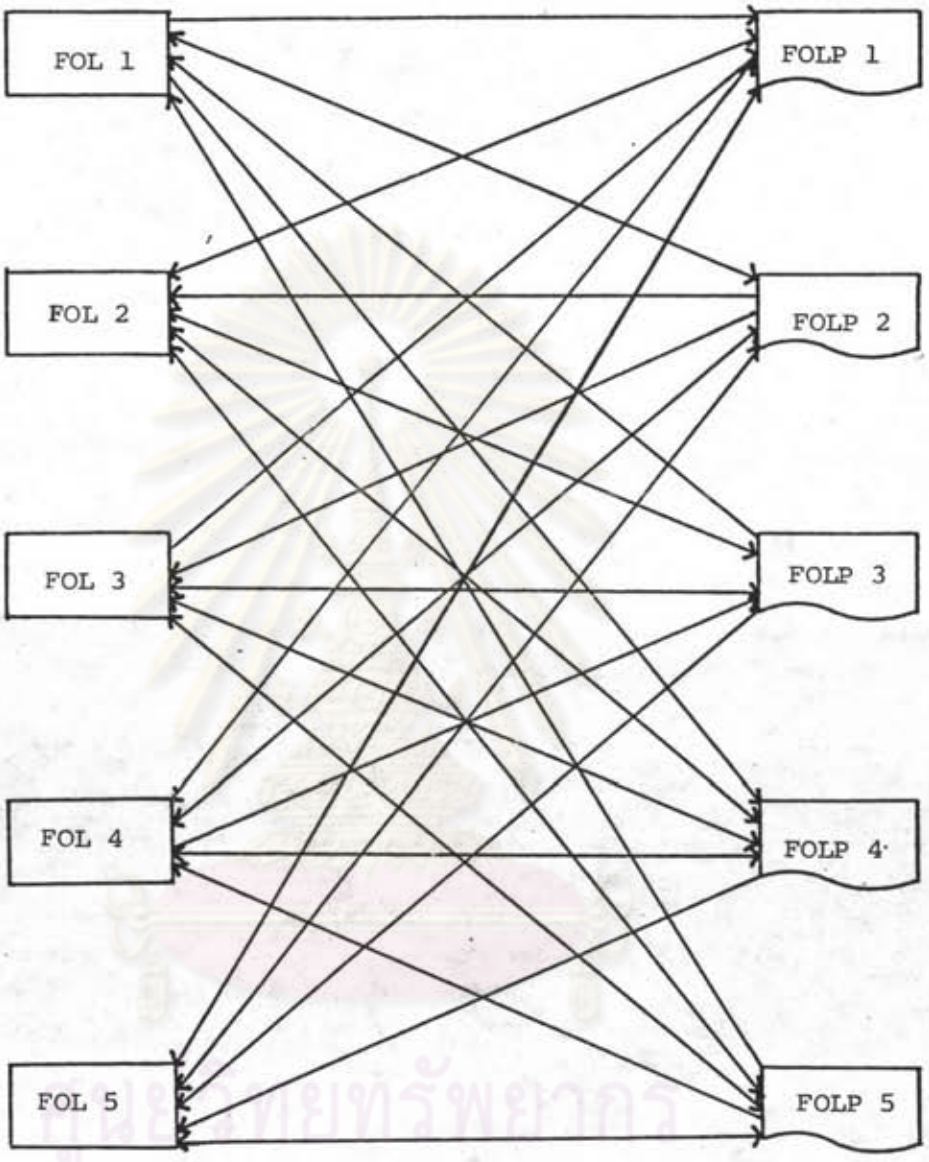


Fig. 53 Inter-morph allograft interactions of M. foliosa were observed at the end of a 18-week period in the field experiments. Symbols show type of interactions as in Fig. 13.
FOL : M. foliosa, FOLP : M. foliosa (purple)

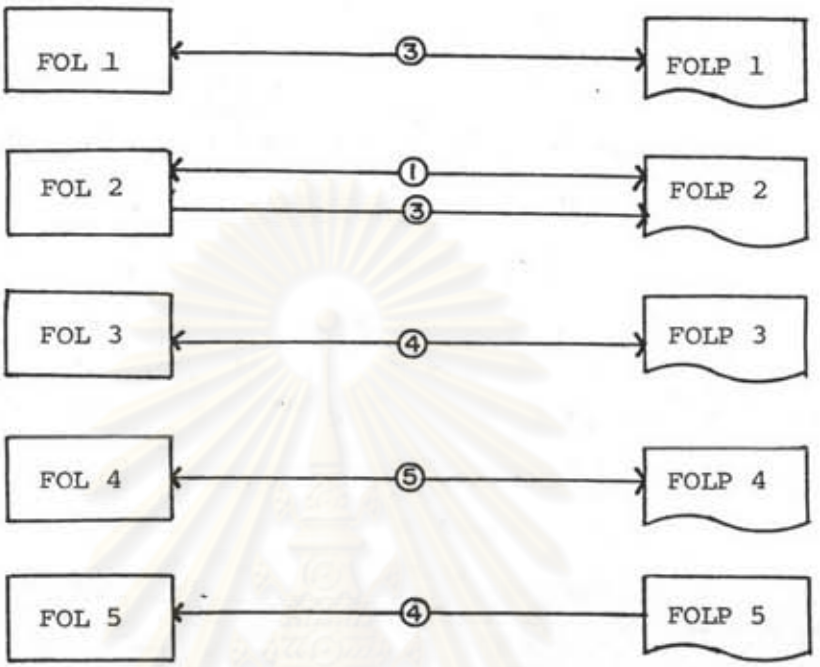


Fig. 54 Inter-morph allograft interactions of M. foliosa were observed at the end of a 14-week period in the laboratory experiments. Symbols show type of interactions as in Fig. 13.
FOL : M. foliosa; FOLP : M. foliosa (purple)

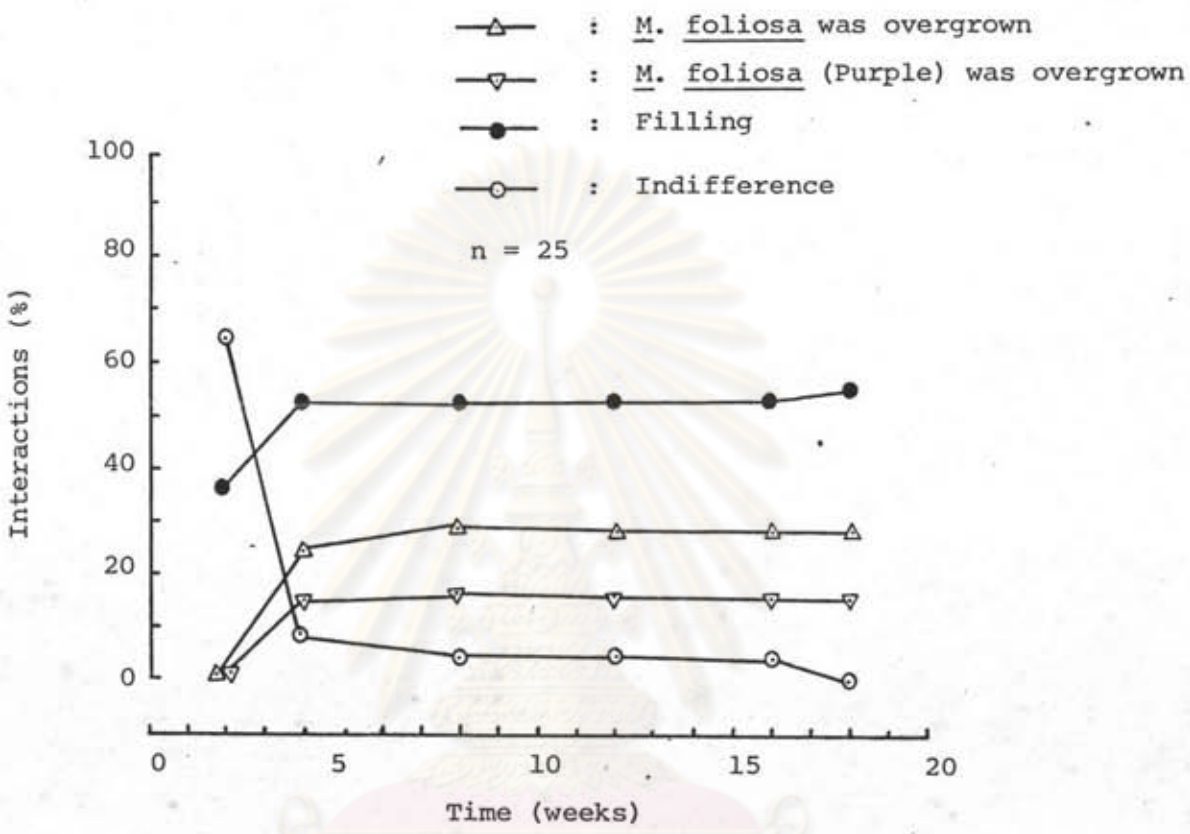


Fig. 55 Inter-morph allograft interactions through time of M. foliosa in the field experiments.

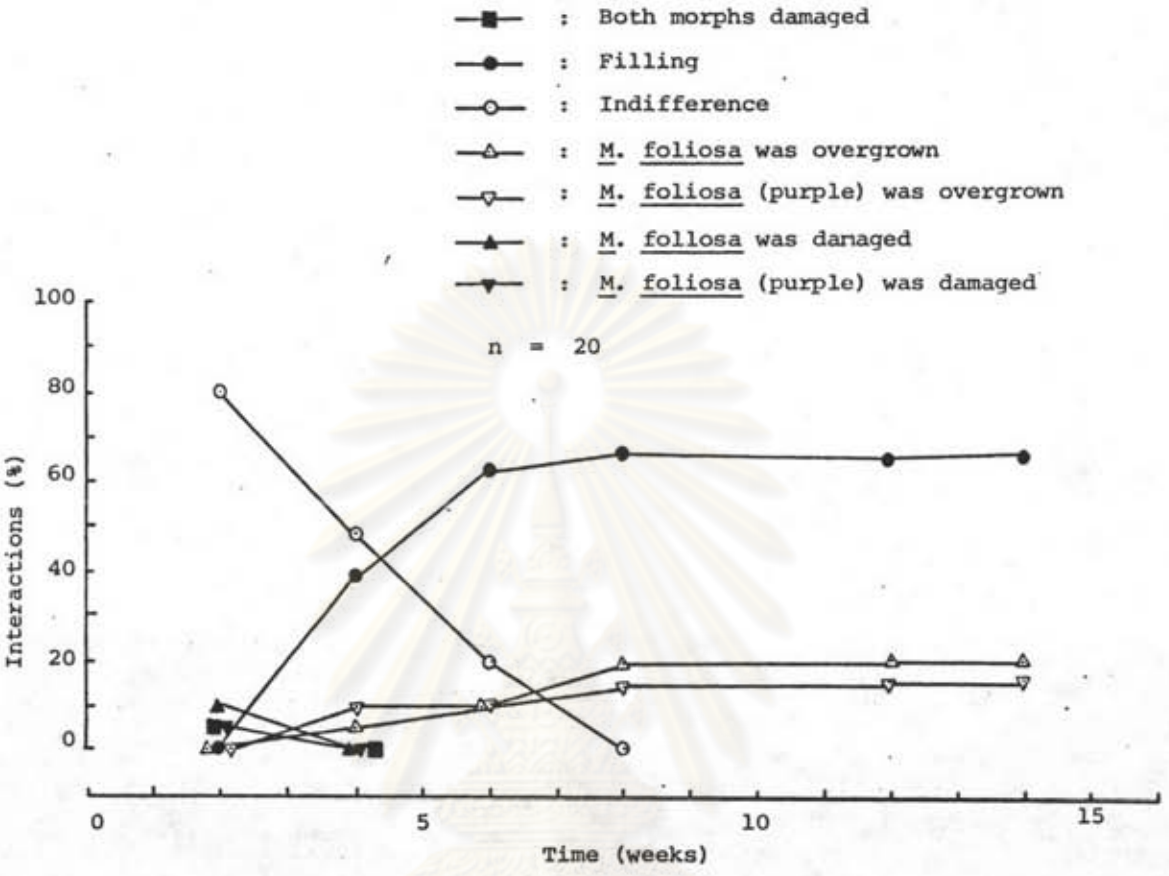


Fig. 56 Inter-morph allograft interactions through time of Montipora foliosa in the laboratory experiments. Number of pairs (n) indicates number of pairs observed at the end of the experiments.

3. Field observations

Data on the distribution and abundance of the four Montipora species, M. foliosa, M. ehrenbergii, M. digitata and M. foveolata, in the area of 1000-m^2, perpendicular to shoreline in front of Sesoko Marine Science Center, Okinawa are given in Table 8 and Fig. 57. The results obviously indicate that M. foliosa is a dominant species in terms of both poulation density and coverage area, while M. foveolata is a rare species. The distribution of all four species are limited at the 65-m on the transverse line (Fig. 57). In M. foliosa normal type (brown colony) is more significantly abundant than the purple colony edge type. In the shallow water, M. ehrenbergii are found more frequently. All four species are distributed densely at 40 - 60 m on the transverse line.

Table 9 shows the frequency of interspecific interactions for each species of the four Montipora species with other corals including Hydrocoral and Lobophytum crassum in the 1000 m^2 - study area. Number of colonies in contacts of M. foliosa and M. digitata are higher (34.6% and 34.3% respectively). M. foliosa and M. ehrenbergii seem to overgrow and damage other corals frequently while M. digitata is overgrown and damaged. Frequency of intra-specific interactions for the four species of Montipora in the study area are given in Table 10. In M. foliosa, the intraspecific interactions show the major types of interactions as overgrowth (52.4%) and filling (39.7%). Fusions between the two morphs of M. foliosa could not be detected by this field observations. Moreover, the distribution and abundance of living coral fragments of Montipora in the study area is presented in Fig. 58. The

fragments of both morphs of M. foliosa and M. digitata were found during this observation but those of M. ehrenbergii and M. foveolata were not found. The distribution pattern of fragments seems to correspond with the distribution pattern of parent colonies.

The clarify the naturally occurring interactions within and between the four Montipora species, observations by random diving had veen done for many hours. Table 11 shows interspecific interactions of the four Montipora species with other corals and Table 12 presents the data on interspecific interactions among the four Montipora species. Surprisingly, M. ehrenbergii overgrows and damages Faviid corals frequently. The four Montipora species are obviously superior to Porites lutea (Table 11). Ranking of competitive ability among four speceis of Montipora is presented in Fig. 59. This hierarchy is consistent with that of the long-term grafting experiments.

Table 8 Distribution and abundance of the four Montipora species in the study area.

Figures indicate number of colonies with coverage ($m^2/50\ m^2$) in the parentheses.

Distance on the transverse line from shoreline (m)	Species				
	M. foliosa	M. foliosa (purple)	M. ehrenbergii	M. digitata	M. foveolata
0 - 5	0	0	0	0	0
5 - 10	0	0	0	0	0
10 - 15	0	0	0	0	0
15 - 20	0	0	0	0	0
20 - 25	1 (.0025)	0	8 (.12)	0	0
25 - 30	1 (.01)	0	15(.1925)	0	0
30 - 35	9 (.17)	3 (.095)	6 (.07)	0	0
35 - 40	14(.455)	16(1.1825)	7 (.105)	4(.075)	0
40 - 45	30(1.06)	10(.04)	18(.5525)	22(.425)	1(.005)
45 - 50	70(1.725)	30(.905)	21(.455)	26((.34)	1(.045)
50 - 55	48(1.17)	16(.6825)	19(.21)	31(.2975)	1(.01)
55 - 60	31(.6225)	1 (.005)	28(.355)	18(.1475)	7(.045)
60 - 65	9 (.1275)	0	16(.16)	7 (.06)	2(.015)
65 - 70	0	0	0	0	0
70 - 75	0	0	0	0	0
75 - 80	0	0	0	0	0
80 - 85	0	0	0	0	0
85 - 90	0	0	0	0	0
90 - 95	0	0	0	0	0
95 - 100	0	0	0	0	0
0 - 100	213(5.3425)	76(2.91)	138(2.22)	108(1.345)	2(0.12)

Table 9 Frequency of interspecific interactions for each species of the four Montipora species with scleractinian corals, hydrocorals and soft corals in the study area. Number in parentheses indicate percentage. OVG : overgrows, ovg : is overgrown; DAM : damages; dm : is damaged; O&D : overgrows and damages; o&d : is overgrown and damaged; Fil : filling; Ind : indifference. Distance on the transverse line at 0 - 20 m and 65 - 100 m no apparent colonies of the four Montipora species were observed.

Species	Distance on the transverse line (m)	No. of colonies	No. of colonies in contact	No. of interactions								Total No. of interactions
				OVG.	ovg.	DAM	dam	O&D	o&d	Fill	Ind	
M. foliosa (1)	20 - 25	1	0	0	0	0	0	0	0	0	0	0
	25 - 30	1	0	0	0	0	0	0	0	0	0	0
	30 - 35	9	0	0	0	0	0	0	0	0	0	0
	35 - 40	14	7	0	0	0	0	7	0	0	0	7
	40 - 45	30	16	2	0	0	3	12	0	0	1	18
	45 - 50	70	29	4	0	0	0	29	0	0	1	34
	50 - 55	48	15	4	0	1	0	12	0	0	0	17
	55 - 60	31	13	1	0	0	0	13	0	0	0	14
	60 - 65	9	1	1	0	0	0	0	0	0	0	1
	20 - 65	213 (100)	81 (38.0)	12 (13.2)		1 (1.1)	3 (3.3)	73 (80.2)	0	0	2 (2,2)	91 (100)
M. foliosa (purple) (2)	20 - 25	0	0	0	0	0	0	0	0	0	0	0
	25 - 30	0	0	0	0	0	0	0	0	0	0	0
	30 - 35	3	0	0	0	0	0	0	0	0	0	0
	35 - 40	16	3	1	0	0	0	2	0	0	0	0
	40 - 45	10	3	1	0	0	0	2	0	0	0	0
	45 - 50	30	6	1	0	0	0	6	0	0	0	0
	50 - 55	16	7	3	0	0	0	4	0	0	0	0
	55 - 60	1	0	0	0	0	0	0	0	0	0	0
	60 - 65	0	0	0	0	0	0	0	0	0	0	0
	20 - 65	76 (100)	19 (25.0)	6 (30.0)	0	0	0	14 (70.0)	0	0	0	20 (100)
(1) + (2)	20 - 65	289 (100)	100 (34.6)	18 (16.2)	0	1 (0.90)	3 (2.7)	87 (78.4)	0	0	2 (1.8)	111 (100)

Table 9 (cont.)

Species	Distance on the transverse line (m)	No. of colonies	No. of colonies in contact	No. of interactions								Total No. of interactions
				OVG.	ovg.	DAM	dam	O&D	o&d	Fill	Ind	
M. ehrenbergii	20 - 25	8	0	0	0	0	0	0	0	0	0	0
	25 - 30	15	3	1	0	0	0	1	0	1	0	3
	30 - 35	6	2	2	0	0	0	0	0	0	0	2
	35 - 40	7	1	0	0	0	0	1	0	0	0	1
	40 - 45	18	2	0	0	1	0	1	0	0	0	2
	45 - 50	21	8	0	0	0	0	8	0	0	0	8
	50 - 55	19	4	0	0	1	0	3	0	0	0	4
	55 - 60	28	3	1	0	0	0	2	0	0	0	3
	60 - 65	16	5	0	0	0	1	5	0	0	0	6
	20 - 65	138	28	4	0	2	1	21	0	1	0	29
		(100)	(20.3)	(13.8)		(6.5)	(3.4)	(72.5)		(3.4)		(100)
M. digitata	20 - 25	0	0	0	0	0	0	0	0	0	0	0
	25 - 30	0	0	0	0	0	0	0	0	0	0	0
	30 - 35	0	0	0	0	0	0	0	0	0	0	0
	35 - 40	4	2	0	0	0	0	0	2	0	0	2
	40 - 45	22	7	0	0	0	0	0	7	0	0	7
	45 - 50	26	15	0	1	0	1	0	15	0	0	17
	50 - 55	31	7	0	1	0	1	0	5	0	0	7
	55 - 60	18	5	0	0	0	0	3	1	0	1	5
	60 - 65	7	1	0	0	0	1	0	0	0	0	1
	20 - 65	108	37	0	2	0	3	3	30	0	1	39
		(100)	(34.3)		(5.1)		(7.7)	(7.7)	(76.9)		(2.6)	(100)
M. foveolata	20 - 25	0	0	0	0	0	0	0	0	0	0	0
	25 - 30	0	0	0	0	0	0	0	0	0	0	0
	30 - 35	0	0	0	0	0	0	0	0	0	0	0
	35 - 40	0	0	0	0	0	0	0	0	0	0	0
	40 - 45	1	0	0	0	0	0	0	0	0	0	0
	45 - 50	1	1	0	0	0	0	1	0	0	0	1
	50 - 55	1	0	0	0	0	0	0	0	0	0	0
	55 - 60	7	1	0	1	0	0	0	0	0	0	1
	60 - 65	2	1	0	0	0	1	0	0	0	0	1
	20 - 65	12	3	0	1	0	1	1	0	0	0	3
		(100)	(25.0)		(33.3)		(33.3)	(33.3)				(100)

Table 10 Frequency of intraspecific interactions for the four species of Montipora in the study area. Number in parentheses indicate percentage. Ovg : overgrowth; Fill : filling; Fus : fusion; Ind : indifference.

Species	Distance on the transverse line (m)*	No. of colonies	No. of colonies in contact	No. of interactions				Total No. of interactions
				Ovg.**	Fill	Fus	Ind	
M. foliosa (1)	20 - 25	1	0	0	0	0	0	0
	25 - 30	1	0	0	0	0	0	0
	30 - 35	9	0	0	0	0	0	0
	35 - 40	14	2	0	1	0	0	1
	40 - 45	30	8	3	0	1	0	4
	45 - 50	70	22	9	3	1	0	13
	50 - 55	48	11	1	5	0	0	6
	55 - 60	31	10	1	4	0	1	6
	60 - 65	9	2	1	0	0	0	1
	20 - 65	213 (100)	55 (25.8)	15 (48.4)	13 (41.9)	2 (6.5)	1 (3.2)	31 (100)
M. foliosa (purple) (2)	20 - 25	0	0	0	0	0	0	0
	25 - 30	0	0	0	0	0	0	0
	30 - 35	3	0	0	0	0	0	0
	35 - 40	16	2	1	0	0	0	1
	40 - 45	10	0	0	0	0	0	0
	45 - 50	30	17	3	5	2	0	10
	50 - 55	16	0	0	0	0	0	0
	55 - 60	1	0	0	0	0	0	0
	60 - 65	0	0	0	0	0	0	0
	20 - 65	76 (100)	19 (25.0)	4 (36.4)	5 (45.4)	2 (18.2)	0	11 (100)
M. foliosa - M. foliosa (purple) (Inter-morph) (3)	20 - 25	1 - 0	0 - 0	0	0	0	0	0
	25 - 30	1 - 0	0 - 0	0	0	0	0	0
	30 - 35	9 - 3	0 - 0	0	0	0	0	0
	35 - 40	14 - 16	2 - 2	0	2	0	0	2
	40 - 45	30 - 10	2 - 2	← 2	0	0	0	2
	45 - 50	70 - 30	10 - 10	← 7, → 1	3	0	0	11
	50 - 55	48 - 16	5 - 4	← 3	2	0	0	5
	55 - 60	31 - 1	1 - 1	→ 1	0	0	0	1
	60 - 65	9 - 0	0 - 0	0	0	0	0	0
	20 - 65	213-76 (100) (100)	20 - 19 (9.4) (25.0)	← 12, → 2 (57.2)	7 (9.5)	0 (33.3)	0	21 (100)
(1) + (2) + (3)	20 - 65	289 (100)	103 (35.6)	33 (52.4)	25 (39.7)	4 (6.3)	1 (1.6)	63 (100)

Table 10 (cont.)

Species	Distance on the transverse line (m)*	No. of colonies	No. of colonies in contact	No. of interactions				Total No. of interaction
				Ovg.**	Fill	Fus	Ind	
M. ehrenbergii	20 - 25	8	0	0	0	0	0	0
	25 - 30	15	2	0	0	0	1	1
	30 - 35	6	0	0	0	0	0	0
	35 - 40	7	0	0	0	0	0	0
	40 - 45	18	2	0	1	0	0	1
	45 - 50	21	2	0	1	0	0	1
	50 - 55	19	0	0	0	0	0	0
	55 - 60	28	0	0	0	0	0	0
	60 - 65	16	0	0	0	0	0	0
	20 - 65	138 (100)	6 (4.3)	0	2 (66.7)	0	1 (33.3)	3 (100)
M. foveolata	20 - 65	12	0	0	0	0	0	0
M. digitata	20 - 65	108	0	0	0	0	0	0

* Distance on the transverse line at 0 - 20 m and 65 - 100 m. no apparent colonies of the four Montipora species were observed

** —— : M. foliosa overgrown

—— : M. foliosa (purple) overgrown

Table 11 Interspecific interactions of the four Montipora species with scleractinian corals, hydrocorals and soft corals. Data compiled from observations in the study area and random diving. Horizontal arrows indicate dominance of species in left hand column over those in the top column, vertical arrows indicate the opposite. O : overgrowth; OD : overgrowth with damage; D : damage F: Filling; I : indifference. Figures in the right-hand of squares indicate the frequency of interactions

	Psammocora contigua	Pocillopora damicornis	Seriatopora hystrix	Stylophora pistillata	Montipora sp.	Acropora sp.	Porites lobata	Porites lutea	Porites solida	Porites rus	Porites sp. 2	Favia pallida	Favites sp.	Goniastrea aspera	Platygyra lamellina	Hydnophora rigida	Hydnophora microconos	Cyphastrea sp.	Echinopora lamellosa	Galaxea fascicularis	Merulina ampliata	Millepora sp.	Lobophytum crassum
M. foliosa	O → 28 D ↓ 1	O → 1	O → 5 I 1	O → 5 D ↓ 5	O → 3	O → 15 D ↓ 1	OD 1	OD → 28	OD 122 O → 1	O → 6	OD 15	D 3	D 2	D 1	D 1	D 1	D 1	D 1	O 1	OD 5	O → 3 D ↓ 5 OD → 3	OD 2	O 22 OD → 9 D ↓ 1	O 12 I ↓ 2
M. foliosa (purple)	O → 4			D ↓ 1	O → 1	O → 1		OD 3	OD 4 O → 3	OD 1	OD 5	D 3								O → 1 D ↓ 4		O 3	O ↓ 1
M. ehrenbergii	OD → 1			D → 1 OD ↓ 2		D 1		OD 4	OD 4	O 1	OD 3	O 8 D 3 OD 13	O 2 D 6 OD 12	O 4 OD 2 F 1								O 1 OD → 1	O 1
M. digitata			I 1	D ↓ 3 I 1				D → 2 OD 1	D → 19	I 1		D ↓ 2	D ↓ 1	D ↓ 1								D ↓ 1 OD 2	O ↓ 4
M. foreolata				OD → 1				O → 1				F 1								D ↓ 2			

Table 12 Interspecific interactions among the four species of Montipora observed in the study area and random diving. Figures indicate number of interactions. L, R : left and species in the column of "Combinations" respectively.

Combinations	Type of interactions						Total
	in the study area			random diving			
	Overgrowth L → R, R → L	Damage L → R, R → L	Overgrowth & Damage L → R, R → L	Overgrowth L → R, R → L	Damage L → R, R → L	Overgrowth & Damage L → R, R → L	
M. foliosa M. ehrenbergii		1		1	3	2	7
M. foliosa (purple) M. ehrenbergii							0
M. foliosa M. digitata		1	20	17		63	101
M. foliosa (purple) M. digitata	1		5			18	24
M. foliosa M. foveolata	1			1			2
M. foliosa (purple) M. foveolata							0
M. ehrenbergii M. digitata			2		3	4	9
M. ehrenbergii M. foveolata							0
M. digitata M. foveolata			1				1

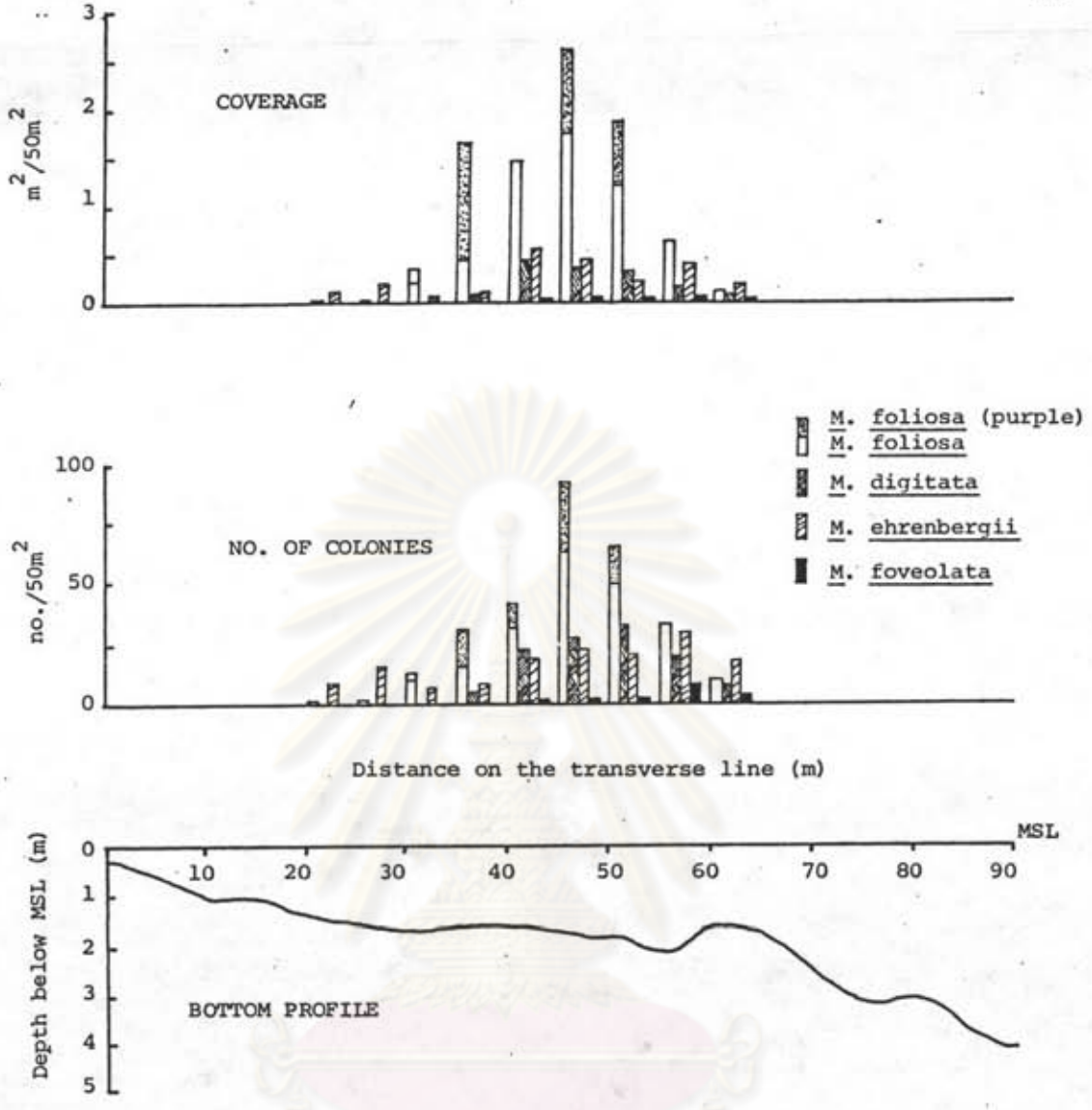


Fig. 57 Distribution pattern of the four species of Montipora in the study area in front of Sesoko Marine Science Center, Okinawa.

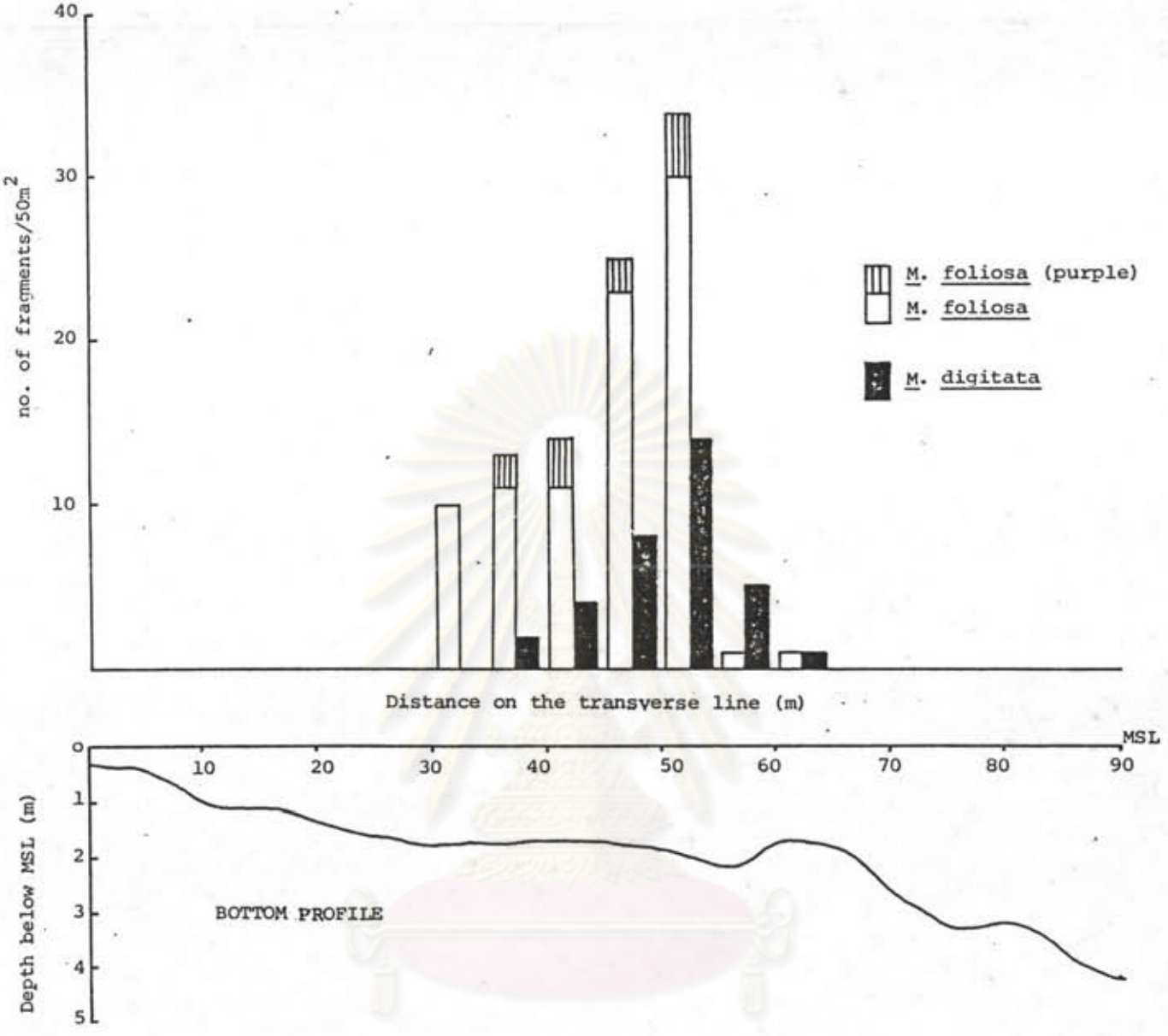


Fig. 58 Distribution and abundance of living coral fragments of Montipora in the study area.

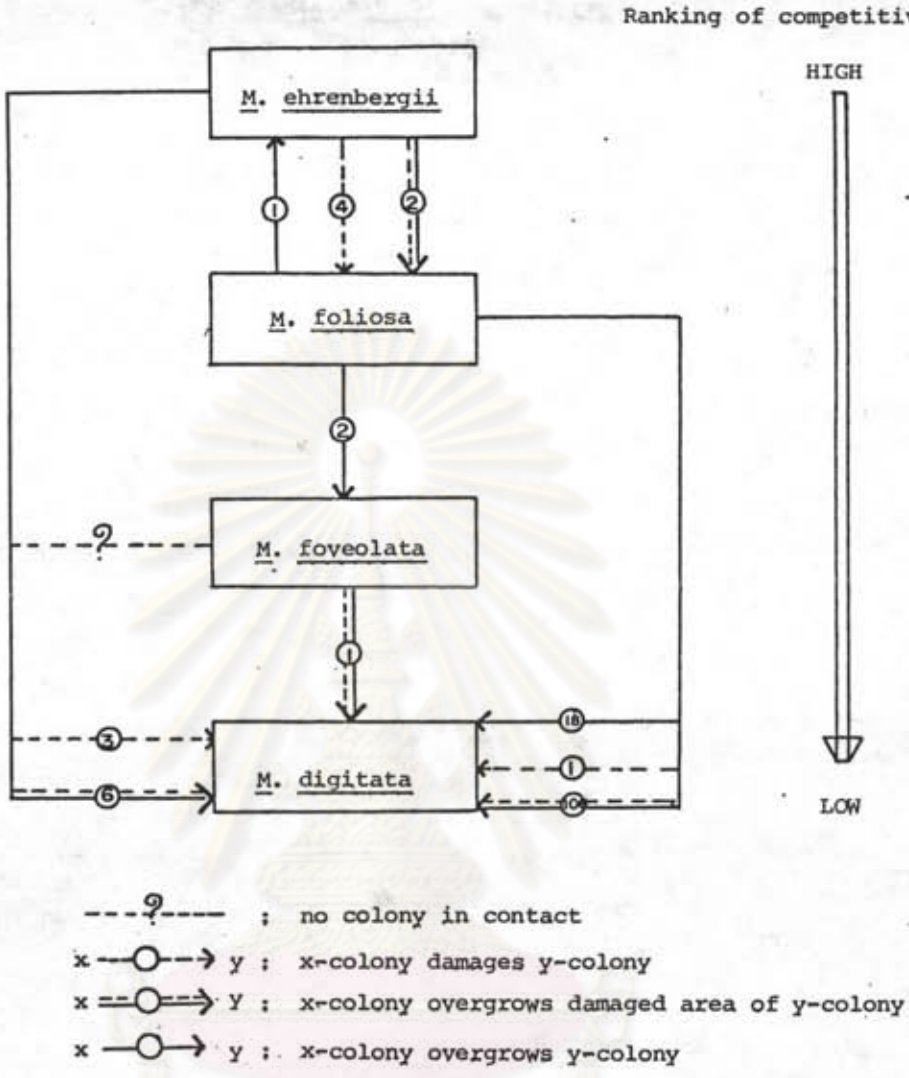


Fig. 59 Interspecific interactions among four species of Montipora in the natural reefs. Data compiled from observations in the study area and random diving. Number in circles indicate number of events.