individuals having high activity of the esterase bands. Percentage of individuals with middle and high activities of the esterase bands was only 50% by the selection until 23 generations.

5) From results obtained, the authors consider that the alternate application of malathion and NAC seems to be possible to prevent the development of resistance of the planthopper, and that an application of the mixtures in equivalent of two or three insecticides, such as malathion and NAC, MTMC and fenitrothion, NAC and methomyl also seems to have the same effect.

Biological Effects of Chemosterilants on the Adults of *Musca domestica nebulo* Fabr.

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31. イエバエ *Musca domestica nebulo* Fabr. 成虫に対する化学不妊剤の生物学的効果

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Apholate, tepa, metepa, hempa および hemel の5種の化学不妊剤の生物学的効果が，処理雄と未処理雌，未処理雄と処理雌，処理雄と処理雌それぞれの交配を行なって調べられた．不妊効果は薬剤によって変化するが，一般に雌より雄に対して活性が高い．また雌だけが処理された場合には低濃度ではその他の場合に比べて平均産卵数は減少したが孵化率は高くなった．しかし高濃度では産卵は全く見られなかった．不妊効果は tepa が最も強く，hemel が最も弱いことが認められた．不妊剤の施用量と反比例して雌雄ともに成虫の寿命を短かくする効果が現われた．この効果は処理雌，処理雄の交配において顕著であった．

Introduction

Very little is known regarding the deleterious effects of chemosterilants on insect behaviour. Murvosh *et al.* (1964) conducted experiments to determine the effects of aziridine compounds on the longevity of houseflies and found that metepa and apholate substantially shortened the life span of the fly. The longevity of *Popillio japonica* was also reduced when treated with apholate (Ladd, 1966). Workers at Aligarh, observed a considerable reduction in the life span of both sexes of *M. d. nebulo* when sterilized with apholate or hempa (Raghuwanshi, *et al.*, 1968, Ansari and Khan, 1971). Similar observations have also been recorded by Hafez *et al.* (1969) in the case of *M. d. vicina*. Keeping the view, an attempt has made to observe the effects of apholate, tepa, metepa, hempa and hemel on oviposition and longevity of the housefly, *Musca domestica nebulo*.

Materials and Methods

The flies used during the present studies were obtained from the normal laboratory stock maintained at a temperature of 28±1°C and 60 to 70 percent relative humidity. They were reared on cotton pads soaked in diluted milk. The flies readily oviposited on such pads and observations were taken at interval of twenty four hours.

The samples of chemosterilants were obtained through the courtesy of Dr. A. B. Borkovec, in Charge, Pesticide Chemicals Research Branch, USDA, Beltsville, Maryland.

Individual flies were obtained by isolating the pupae in vials over a plug of moist cotton wool. They were sexed on emergence and those belonging to the same sex were kept in cages 3×3 inches constructed of wire frames covered by mosquito netting. Two groups of each sex were formed. One of these was fed on sugar treated with desired concentrations of a chemosterilant for four days after emergence while the other was given untreated sugar. After treatments single pair reciprocal crosses were established between treated and normal males and females and also between treated males and females by placing the adults in small cloth cages. Fifteen pairs of each type were studied for fecundity and fertility. The observations were carried until the adults died. Eggs obtained from each female were counted under black background of moist black cloth piece and percentage

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hatch of the eggs determined after twenty four hours. Percent sterility and net sterility was calculated by the formulae as described by Hair and Adkins (1964).

Results and Discussion

The results obtained are presented in Tables 1-10. All the chemosterilants tested had a marked effect on the fecundity and fertility of the

Table 1. Effect of apholate on the fecundity and fertility of *Musca domestica nebulo.*

Concentration (%)	Sex treated	Eggs per female		(%) Hatch	(%) Sterility	(%) Net sterility
		Oviposited	Hatched			
0.0078	Males	428.9	232.8	55.8	44.2	28.0
	Females	357.3	238.5	66.7	33.3	13.9
	Both	301.1	140.7	46.7	53.3	39.7
0.0156	Males	231.5	93.5	40.7	59.3	47.4
	Females	191.6	104.4	54.5	45.5	29.6
	Both	225.3	67.9	30.1	69.9	61.1
0.03125	Males	224.0	22.4	10.0	90.0	87.09
	Females	145.0	34.6	23.8	76.2	69.2
	Both	146.7	7.5	5.1	94.9	93.4
0.0625	Males	156.0	2.5	1.6	98.4	97.9
	Females	59.4	2.8	3.7	96.3	95.2
	Both	60.6	0.0	0.0	100.0	100.0
0.125	Males	256.1	0.0	0.0	100.0	100.0
	Females	*	—	—	—	—
	Both	*	—	—	—	—
	Control	452.8	350.8	77.4	22.5	—

* The females did not oviposit.

Table 2. Effect of tepa on the fecundity and fertility of *Musca domestica nebulo.*

Concentration (%)	Sex treated	Eggs per female		(%) Hatch	(%) Sterility	(%) Net sterility
		Oviposited	Hatched			
0.00195	Males	281.5	175.1	62.1	37.9	19.8
	Females	131.6	98.2	74.5	25.5	3.8
	Both	181.5	91.2	50.3	49.3	35.09
0.0039	Males	391.9	68.4	19.4	80.6	75.02
	Females	121.3	38.1	31.4	68.6	59.4
	Both	192.2	21.6	11.2	88.8	85.5
0.0078	Males	241.7	20.5	8.4	91.6	89.1
	Females	79.6	17.0	21.3	78.7	72.5
	Both	174.2	11.1	6.3	93.7	91.8
0.0156	Males	228.4	4.7	2.07	97.93	97.3
	Females	52.3	5.8	11.2	88.8	85.5
	Both	57.0	0.0	0.0	100.0	100.0
0.03125	Males	259.0	0.0	0.0	100.0	100.0
	Females	62.3	0.0	0.0	100.0	100.0
	Both	46.6	0.0	0.0	100.0	100.0
0.0625	Males	80.0	0.0	0.0	100.0	100.0
	Females	*	—	—	—	—
	Both	*	—	—	—	—
	Control	452.8	350.8	77.4	22.5	—

* The females did not oviposit.

Table 3. Effect of metepa on fecundity and fertility of *Musca domestica nebulo.*

Concentration (%)	Sex treated	Eggs per female		(%) Hatch	(%) Sterility	(%) Net sterility
		Oviposited	Hatched			
0.0156	Males	210.4	52.4	41.8	58.2	46.09
	Females	189.8	110.6	58.2	41.8	23.6
	Both	158.3	34.0	39.8	60.2	48.7
0.03125	Males	318.7	32.4	10.1	89.9	86.9
	Females	151.7	78.2	51.6	48.4	33.4
	Both	106.9	10.4	9.7	90.3	87.4
0.0625	Males	198.07	1.2	0.6	99.4	99.2
	Females	85.7	35.3	41.2	58.8	46.8
	Both	106.8	0.15	0.1	99.9	99.8
0.125	Males	199.5	0.0	0.0	100.0	100.0
	Females	52.4	5.6	10.8	89.2	86.06
	Both	46.5	0.0	0.0	100.0	100.0
0.25	Males	342.06	0.0	0.0	100.0	100.0
	Females	*	—	—	—	—
	Both	*	—	—	—	—
	Control	452.8	350.8	77.4	22.5	—

* The females did not oviposity.

Table 4. Effect of hempa on fecundity and fertility of *Musca domestica nebulo.*

Concentration (%)	Sex treated	Eggs per female		(%) Hatch	(%) Sterility	(%) Net sterility
		Oviposited	Hatched			
0.03125	Males	344.6	240.5	69.7	30.3	10.06
	Females	306.8	220.9	71.9	28.1	7.2
	Both	379.4	246.8	65.03	35.07	16.1
0.0625	Males	313.4	177.2	54.7	45.3	29.4
	Females	288.1	183.7	63.7	36.3	17.8
	Both	361.2	157.9	43.7	56.3	43.6
0.125	Males	394.7	120.2	30.4	69.6	60.7
	Females	185.0	89.7	48.5	51.5	37.4
	Both	394.7	103.2	29.8	70.2	61.5
0.25	Males	439.1	91.7	20.9	79.1	73.03
	Females	151.07	41.4	31.6	68.4	59.2
	Both	242.6	34.4	14.1	85.9	81.8
0.5	Males	299.2	10.8	3.6	96.4	95.3
	Females	144.3	22.3	15.4	84.6	80.1
	Both	282.8	5.3	1.9	98.09	97.5
1.0	Males	255.4	0.0	0.0	100.0	100.0
	Females	66.4	0.0	0.0	100.0	100.0
	Both	153.4	0.0	0.0	100.0	100.0
2.0	Males	227.5	0.0	0.0	100.0	100.0
	Females	*	—	—	—	—
	Both	*	—	—	—	—
	Control	452.8	350.8	77.4	22.5	—

* The females did not oviposit.

Table 5. Effect of hemel on fecundity and fertility of *Musca domestica nebulo.*

Concentration (%)	Sex treated	Eggs per female		(%) Hatch	(%) Sterility	(%) Net sterility
		Oviposited	Hatched			
0.125	Males	368.7	192.9	52.1	47.9	32.9
	Females	280.6	203.5	72.6	27.4	6.3
	Both	359.9	185.8	51.6	48.4	33.4
0.25	Males	389.8	134.06	34.3	65.7	55.6
	Females	327.4	231.1	70.5	29.5	9.03
	Both	368.6	116.9	31.7	68.3	59.09
0.5	Males	349.2	54.0	15.4	84.6	80.1
	Females	300.9	200.8	66.7	33.3	13.9
	Both	338.8	43.0	12.6	87.4	83.7
1.0	Males	315.0	20.2	6.4	93.6	91.7
	Females	231.3	143.1	61.8	38.2	20.2
	Both	282.2	12.3	4.3	95.7	94.4
2.0	Males	437.0	0.0	0.0	100.0	100.0
	Females	229.4	136.7	55.6	44.4	28.2
	Both	256.3	0.0	0.0	100.0	100.0
3.0	Males	212.8	0.0	0.0	100.0	100.0
	Females	151.2	31.5	20.8	77.2	70.5
	Both	112.7	0.0	0.0	100.0	100.0
4.0	Males	189.3	0.0	0.0	100.0	100.0
	Eemales	*	—	—	—	—
	Both	*	—	—	—	—
	Control	452.8	350.8	77.4	22.5	—

* The females did not oviposit.

Table 6. Biological effects of apholate with respect to oviposition and longevity of adults.

Concentration tested	Sex treated	Females oviposited (%)	Duration in days			Longevity in days		
			Pre-oviposition period	Oviposition period	Post-oviposition period	Females		Males
						Oviposited	Not oviposited	
0.0078	Males	100.0	6.2	17.2	3.4	26.8	—	21.2
	Females	100.0	7.3	17.4	3.2	27.9	—	23.8
	Both	100.0	7.06	13.3	3.6	24.5	—	22.2
0.0156	Males	100.0	6.8	11.5	4.2	22.5	—	18.4
	Females	100.0	7.2	9.7	4.6	21.5	—	23.8
	Both	100.0	7.3	11.6	3.8	22.7	—	21.8
0.03125	Males	80.0	8.3	8.4	4.8	21.5	10.0	10.3
	Females	73.3	7.5	9.09	4.9	21.4	9.0	17.5
	Both	80.0	7.8	9.08	5.5	22.5	6.6	17.8
0.0625	Males	93.3	6.4	3.5	3.3	13.2	8.0	16.2
	Females	33.3	7.0	2.4	4.8	14.2	12.3	15.7
	Both	33.3	6.3	4.6	6.2	17.1	10.5	11.6
0.125	Males	86.6	6.3	7.5	3.8	17.6	7.5	12.7
	Females	0.0	—	—	—	—	11.9	16.6
	Both	0.0	—	—	—	—	9.7	6.6

Table 7. Biological effects of tepa with respect to oviposition and longevity of adults.

Concentration tested	Sex treated	Females oviposited (%)	Duration in days			Longevity in days		
			Pre-oviposition period	Oviposition period	Post-oviposition period	Females		Males
						Oviposited	Not oviposited	
0.00195	Males	100.0	5.2	13.7	6.3	24.2	—	19.8
	Females	100.0	6.2	8.4	6.6	21.2	—	21.3
	Both	100.0	6.2	8.4	6.6	21.2	—	21.3
0.0039	Males	100.0	6.4	11.8	5.6	23.8	—	19.3
	Females	93.3	8.5	5.2	8.3	22.3	17.0	19.3
	Both	100.0	8.0	10.8	4.0	22.8	—	21.1
0.0078	Males	100.0	6.4	9.5	6.06	21.8	—	17.2
	Females	86.6	8.1	5.6	6.3	20.7	13.5	23.6
	Both	93.3	6.4	8.5	7.3	22.3	13.0	20.5
0.0156	Males	100.0	7.06	9.1	5.2	20.7	—	18.1
	Females	53.3	8.8	1.0	13.0	22.8	14.5	20.1
	Both	33.3	8.6	1.0	12.4	22.0	14.3	22.0
0.03125	Males	93.3	6.5	10.9	4.8	22.2	10.0	20.1
	Females	20.0	9.3	1.0	9.0	19.3	16.0	20.4
	Both	46.6	8.4	1.0	13.8	20.8	13.8	20.6
0.0625	Males	80.0	10.4	4.5	9.3	24.2	17.3	15.6
	Females	0.0	—	—	—	—	16.4	23.5
	Both	0.0	—	—	—	—	15.6	20.3
	Control	100.0	4.3	18.2	5.7	28.2	—	27.8

Table 8. Biological effects of metepa with respect to oviposition and longevity of adults.

Concentration tested	Sex treated	Females oviposited (%)	Duration in days			Longevity in days		
			Pre-oviposition period	Oviposition period	Post-oviposition period	Females		Males
						Oviposited	Not oviposited	
0.0156	Males	93.3	5.3	8.5	7.9	21.7	16.0	18.0
	Females	80.0	8.0	11.08	6.6	25.6	11.0	16.0
	Both	80.0	7.7	11.3	6.4	25.4	9.6	19.9
0.03125	Males	100.0	6.4	13.2	4.9	24.5	—	17.9
	Females	100.0	8.6	10.4	4.9	23.9	—	20.6
	Both	93.3	7.7	11.3	6.4	25.4	9.6	19.9
0.0625	Males	86.6	5.7	8.1	5.6	19.4	9.0	17.5
	Females	86.6	9.1	6.8	6.0	21.9	18.0	19.2
	Both	86.6	7.6	6.6	7.8	22.0	16.5	18.9
0.125	Males	86.6	6.5	7.0	3.6	17.1	11.0	15.3
	Females	60.0	9.2	3.0	8.4	20.6	13.5	12.2
	Both	80.0	8.0	1.6	6.7	18.08	13.0	15.5
0.25	Males	100.0	6.06	13.6	5.6	25.2	—	15.6
	Females	0.0	—	—	—	—	17.06	13.2
	Both	0.0	—	—	—	—	15.4	14.4
	Control	100.0	4.3	18.2	5.7	28.2	—	27.8

Table 9. Biological effects of hempa with respect to oviposition and longevity of adults.

Concentration tested	Sex treated	Females oviposited (%)	Duration in days			Longevity in days		
			Pre-oviposition period	Oviposition period	Post-oviposition period	Females		Males
						Oviposited	Not oviposited	
0.03125	Males	100.0	5.2	16.0	4.08	25.2	—	24.0
	Females	100.0	6.06	15.8	4.6	26.4	—	24.5
	Both	100.0	5.8	14.8	5.2	25.8	—	26.2
0.0625	Males	100.0	5.7	15.4	3.9	25.0	—	21.6
	Females	93.3	6.2	16.0	4.5	27.6	11.0	20.7
	Both	80.0	6.5	18.5	3.2	28.2	8.3	22.1
0.125	Males	100.0	5.9	16.2	3.8	25.9	—	19.5
	Females	86.6	7.1	10.07	4.1	21.2	8.5	20.7
	Both	100.0	7.06	14.8	4.06	25.9	—	24.5
0.25	Males	100.0	6.2	17.3	2.8	26.3	—	18.7
	Females	86.6	7.1	11.8	7.1	26.0	11.5	23.2
	Both	86.6	6.4	14.07	6.3	26.7	10.0	23.1
0.5	Males	93.3	5.9	9.4	8.5	23.8	18.0	20.8
	Females	80.0	6.5	8.1	8.7	23.3	15.0	18.2
	Both	53.3	9.3	13.0	5.5	27.8	10.5	22.8
1.0	Males	100.0	5.9	13.06	4.5	23.4	—	18.6
	Females	60.0	8.5	4.4	13.0	25.9	15.3	22.1
	Both	86.6	8.0	7.3	9.7	25.0	14.5	26.3
2.0	Males	86.6	8.1	7.8	4.5	20.4	13.0	14.8
	Females	0.0	—	—	—	—	13.9	20.8
	Both	0.0	—	—	—	—	19.06	19.6
	Control	100.0	4.3	18.2	5.7	28.2	—	27.8

housefly. Though the effects on males and females were variable with each chemosterilant, a comparison of the minimum effective concentration on each sex shows that males were more susceptible than the females. This has also been observed in *M. d. domestica* with tepa, hempa apholate and metepa (Sacca *et al.*, 1964, Labrecque *et al.*, 1966, Hafez *et al.*, 1969). The normal males when treated with 0.0625, 0.03125, 0.0156 and 0.0078 percent apholate and mated with virgin females induced 97.9, 87.09, 47.4 and 28.0 percent net sterility as against 95.2, 69.2, 29.6 and 13.9 percent net sterility obtained when the females were treated. Similar was the case with tepa, metepa, hempa and hemel. It is apparent from Tables 1-5 that apholate, tepa and hempa are more or less equally effective at a concentration causing approximately 100.0 percent sterility in both sexes. 0.03125 percent tepa induced 100.0 percent net sterility in males and females as against 97.9 and 95.2 percent net sterility in males and females induced by 0.0625 percent apholate. A 100.0 percent sterility was also observed in both sexes when the adults were treated with 1.0 percent hempa. Hemel and metepa had a more pronounced effect on males producing complete sterility at concentrations as low as 1.0 and 0.125 percent. The above findings are partially in agreement with those of Hafez *et al.* (1969) who reported that apholate and tepa were equally effective against *M. d. vicina* but hempa and metepa induced more consistent sterility in males than in females. However, when females were treated with higher concentrations of chemosterilants a complete inhibition of oviposition was observed. In all cases where only females were treated the hatch rate was sufficiently higher but the average number of eggs laid by a female was greatly reduced. This has earlier been observed by Raghuwanshi (1968)

Table 10. Biological effects of hemel with respect to oviposition and longevity of adults.

Concentration tested	Sex treated	Females oviposited (%)	Duration in days			Longevity in days		
			Pre-oviposition period	Oviposition period	Post-oviposition period	Females		Males
						Oviposited	Not oviposited	
0.125	Males	100.0	5.5	19.9	3.1	28.5	—	23.6
	Females	100.0	6.5	18.0	4.2	28.7	—	27.06
	Both	100.0	7.1	18.7	4.06	29.8	—	26.4
0.25	Males	100.0	5.1	15.2	4.1	24.4	—	22.4
	Females	93.3	6.7	15.07	4.7	26.4	14.0	25.4
	Both	100.0	6.2	17.06	3.2	26.4	—	24.4
0.5	Males	100.0	5.2	13.8	4.1	23.1	—	21.1
	Females	100.0	7.2	15.5	3.8	26.5	—	21.4
	Both	100.0	6.6	15.3	3.4	25.3	—	22.2
1.0	Males	100.0	5.0	14.4	4.3	23.7	—	20.5
	Females	86.6	7.7	13.1	4.07	24.8	14.0	25.0
	Both	100.0	8.5	12.6	4.2	25.3	—	22.6
2.0	Males	100.0	5.0	16.6	3.8	25.4	—	19.1
	Females	93.3	9.1	11.5	4.2	24.8	12.0	21.7
	Both	100.0	8.8	12.4	4.0	25.2	—	21.7
3.0	Males	100.0	5.5	9.1	5.1	19.7	—	16.8
	Females	26.6	8.5	7.0	4.7	20.2	12.7	20.0
	Both	46.6	10.1	7.0	4.8	21.9	9.1	17.0
4.0	Males	93.3	6.06	10.07	5.07	21.2	10.0	15.6
	Females	0.0	—	—	—	—	16.8	20.4
	Both	0.0	—	—	—	—	16.0	17.0
	Control	100.0	4.3	18.2	5.7	28.2	—	27.8

in the case of *Culex fatigans* sterilized with apholate, tepa and metepa.

The degree of sterility enhanced when both sexes were treated. This effect was more pronounced in tests with tepa, apholate and hempa but no such effect was observed with metepa and hemel. Females treated with 0.0625, 0.03125, 0.0156 and 0.0078 percent of apholate and mated with normal males induced 95.2, 69.2, 29.6 and 13.9 percent net sterility as against 100.0, 93.4, 61.1 and 39.7 percent net sterility when both sexes were treated. Similarly in case of tepa and hempa, treatment of both sexes enhanced the sterility effect. Complete sterility was observed with 0.0156, 0.0625, 0.125, 1.0 and 2.0 percent of tepa, apholate, metepa, hempa and hemel respectively when both sexes were treated. This shows that alkylating agents were more effective in causing sterility in comparison to the non alkylating agents. Taking net sterility as a criterion, tepa proved to be most promising chemical in inducing sterility in *M. d. nebulo*. Hemel was the least effective of all the chemicals tested. This supports the earlier findings of Murvosh *et al.* (1964) and Hafez *et al.* (1969) who found that tepa was more effective than metepa and apholate when administered in the food of the adults.

In additiion to their sterility effects, chemosterilants have an important bearing on the oviposition and longevity of flies. Preoviposition period was enhanced in tests with all sterilants in the case of crosses between treated males and females and also when only females were treated. However, the preoviposition period was not severely affected when only males were treated. Similarly oviposition period was greatly reduced at higher concentrations when either male or

female or both sexes were treated. The effect on the postoviposition period did not follow any specific pattern.

The longevity of both sexes was adversely affected and was inversely proportional to the concentration tested (Tables 6-10). However, the life span of the flies was not severely affected when treated with non alkylating agents like hempa and hemel. The normal longevity of 27.8 and 28.2 days of the males and females decreased to 6.6 and 9.7, 20.3 and 15.6, 14.4 and 15.4, 19.6 and 19.06 and 17.0 and 16.0 days when the adults were treated with 0.125, 0.0625, 0.25, 2.0 and 4.0 percent of apholate, tepa, metepa, hempa and hemel respectively. Apholate thus caused the most significant reduction in the longevity of adult flies as it reduced the life span of males and females by 76.2 and 65.6 percent respectively. The longevity of normal males and females was adversely affected when either of them were allowed to mate with chemosterilized partners. A reduction of 11.2 and 10.6, 4.3 and 10.9, 14.6 and 3.0, 7.8 and 7.8 and 7.4 and 7.0 days in the longevity of normal males and females was recorded when they mated with partners that had been treated with 0.125, 0.0625, 0.25, 2.0 and 4.0 percent of apholate, tepa, metepa, hempa and hemel respectively. Females which oviposited lived longer than those which did not lay any eggs. This is in conformity with the earlier findings of Ansari and Khan (1971) in the case of *M. d. nebulo.*

Though the reduction in adult longevity caused by these chemosterilants may pose a problem for sterile male release technique in controlling insect pests, it is encouraging in the sense that generally males complete their mating in an early time so the increased mortality after mating with females would not severely affect the success of a control operation.

Summary

Biological effects of chemosterilants were studied by making reciprocal crosses between treated and normal males and females and also between treated males and females in small cloth cages. Fifteen pairs of each type were studied and observations were continued until the adults died. It was found that the sterility effects on both sexes were variable with each chemosterilant. However, a comparison of the minimum effective concentration on each sex showed that males were more suseeptible than the females. It was interesting to note that in all cases where only females were treated the hatch rate was higher but the average number of eggs laid by females was severely reduced. On the other hand oviposition was totally retarded when the females were treated with higher concentrations of any of the chemosterilants. The degree of sterility enhanced when both sexes were treated. Of the five chemicals tested, tepa was found to be the most promising and the hemel was the least in producing sterility.

Besides their sterility effects, apholate, tepa, metepa, hempa and hemel also had deleterious effects on the longevity of flies. The longevity of both sexes was substantially shortened and found to be inversely proportional to the concentration tested. There was also a marked reduction in the life span of both sexes when reciprocal crosses were established. However, this effect was more pronounced with aziridine compounds. Females which oviposited lived longer than those which did not any eggs.

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