Inheritance of Body Colors in *Myzus persicae* (SULZER) (Homoptera : Aphididae)¹

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Breeding experiments were carried out to study the inheritance of green-yellow and red colors of *Myzus persicae* (SULZER). The crosses between green-yellow clones yielded only green-yellow hybrid clones, and those between red clones mostly red but occasionally green-yellow hybrid clones. Crosses between green-yellow and red clones yielded both green-yellow and red hybrid clones in most cases; the sum of green-yellow hybrid clones was roughly equal to that of red hybrid clones in a series of parent crosses, the proportions differing according to the crosses. These results suggested that only one pair of alleles, with red dominant, might be involved in producing the color differences. Color changes caused by environmental factors were also discussed.

INTRODUCTION

Green and red forms of aphids caused by the presence of haemolymph pigments (BOWIE et al., 1966) are known in some species (HILLE RIS LAMBERS, 1966; MARKKULA and ROUKKA, 1970). *Myzus persicae* (SULZER) also shows such color variability in virginoparous females. It is known that yellow, green and red forms occur in Japan and that the relative abundance of these forms differs according to season, host plant species and the part of the plant colonized (TANAKA, 1957; SETOKUCHI, 1977; UEDA and TAKADA, 1977). So far as is known, however, no investigation has hitherto dealt with the inheritance of body colors of the aphid. Breeding experiments to study the inheritance of green-yellow and red colors were therefore attempted and the results are herein reported, together with a consideration of the genetic basis and influence of the environment on the control of coloration.

MATERIAL AND METHODS

The origin and body color of 9 parent and 5 F₁ clones used for breeding experiments are shown in Table 1. The clones were reared in autumn at an outdoor insectary to produce sexual morphs, and selected crosses were made. The eggs deposited were preserved under natural conditions until the following spring. The fundatrices which hatched from the eggs were transferred to separate cages just before

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Table 1. ORIGIN AND BODY COLOR OF PARENT AND F₁ CLONES OF *Myzus persicae* USED FOR CROSSES

Clone	Origin (Kyôto)	Color
Parent: URY-0	Radish; Sept., 1971	Green (yellow)
SCY-2	Cabbage; Sept., 1973	Green (yellow)
SCG-1	Cabbage; Sept., 1973	Green
JCG-3	Cabbage; Oct., 1973	Green
SCG-11	Cabbage; Sept., 1974	Green
URR-0	Radish; Sept., 1971	Red
URR-1	Radish; Sept., 1973	Red
JCR-1	Cabbage; Oct., 1973	Red
JRR-1	Radish; Oct., 1973	Red
F ₁ : 14-1	(SCG-1) ♀ × (URY-0) ♂, 1973-74	Green (yellow)
25-2	(JCR-1) ♀ × (URR-0) ♂, 1973-74	Green
24-1	(JCR-1) ♀ × (URY-0) ♂, 1973-74	Red
521-5	(JCR-1) ♀ × (SCG-11) ♂, 1974-75	Red
526-1	(JCR-1) ♀ × (URR-1) ♂, 1974-75	Red

maturity, each giving rise to F₁ or F₂ clones. Most oviparae, males and fundatrices were matured in the same manner as virginoparae on excised leaves of radish (*Raphanus sativus*, race Tokinashi) in small glass tube cages (3.5 × 15 cm). New F₁ and F₂ clones were maintained through at least 5 generations in the outdoor insectary and in a room at 15 hr photoperiod and 20°C (after the third generation) to ascertain their color. Some clones ceased to reproduce at certain stages among the first 5 generations due to an unknown cause. The colors of these clones were recorded based on individuals of the last generation. In the following descriptions on breeding experiments, yellow clones have been included in the same category as the green.

RESULTS AND DISCUSSION

Intraclonal variation

All fundatrices were entirely black just after hatching but became paler with a tinge of red during development. A peculiar body color appeared within this generation or among the subsequent 5 generations, and remained constant thereafter through successive parthenogenetic generations. According to the author's varied experiences with the aphid, however, environmental and nutritional factors, such as temperature, condition of food plant and population density of the aphids, could modify the color. At high temperatures, on senescent leaves or under crowded conditions yellow aphids produced whitish-yellow progeny, green aphids yellowish-green to yellow progeny and red aphids pink, sometimes greenish, progeny. At low temperatures the color became darker, some red aphids becoming rather blackish. Such color changes proved reversible when discolored aphids were transferred to favorable conditions. In the course of rearing 7 different clones on excised leaves of radish at a 15 hr photoperiod and 20°C from 1971 (2 clones) or 1973 (5) to 1981, the color of yellow, green and red aphids never changed for more than 250 generations.

In short-day and low temperature conditions the same apterous viviparae of certain, though not all, yellow and green clones produced progeny of two different

colors: apterous progeny were the same color as the parent, while alatiform progeny were a red shade. Such clone character seems to be genetically determined irrespective of the life-cycle category, and thus also of whether the alatiform progeny become gynoparae or virginoparae. In autumn and winter some green apterous adults in the field were found to be attended by red alatiform larvae.

MATSUMOTO and TSUJI (1979) showed that: (i) green-yellow aphids of *M. persicae*

Table 2. RESULTS OF CROSSING GREEN AND RED CLONES OF *Myzus persicae*

Type of cross	Clones used		Year	No. F ₁ and F ₂ clones		
	♀	♂		Green	Red	Total
Parent × parent:						
Green ♀ × Green ♂	SCG-1	SCG-1	1973-74	2	0	2
	“	“	1975-76	1	0	1
	“	“	1976-77	3	0	3
	SCG-1	URY-0	1973-74	8	0	8
	SCG-1	JCG-3	1975-76	1	0	1
	URY-0	SCG-1	1973-74	4	0	4
Green ♀ × Red ♂	SCG-1	JCR-1	1975-76	3	1	4
	“	“	1976-77	8	2	10
	SCG-1	URR-0	1973-74	0	3	3
Red ♀ × Green ♂	JCR-1	SCG-1	1975-76	5	8	13
	“	“	1976-77	16	17	33
	JCR-1	SCG-11	1974-75	0	10	10
	JCR-1	URY-0	1973-74	0	2	2
	“	“	1974-75	3	5	8
	JCR-1	SCY-2	“	7	5	12
	JRR-1	URY-0	1973-74	0	2	2
	JRR-1	SCG-11	1974-75	4	1	5
Red ♀ × Red ♂	JCR-1	JCR-1	1974-75	2	4	6
	“	“	1975-76	0	5	5
	“	“	1976-77	1	14	15
	JCR-1	JRR-1	1974-75	0	4	4
	JCR-1	URR-0	1973-74	1	1	2
	JCR-1	URR-1	1974-75	0	1	1
F ₁ × F ₁ :						
Green ♀ × Green ♂	14-I	14-I	1975-76	12	0	12
	“	“	1978-79	6	0	6
	“	“	1979-80	13	0	13
	25-2	25-2	1975-76	11	0	11
Green ♀ × Red ♂	14-I	526-1	1978-79	6	11	17
	“	“	1979-80	7	20	27
Red ♀ × Green ♂	24-1	14-I	1975-76	1	4	5
	526-1	14-I	1979-80	2	4	6
Red ♀ × Red ♂	24-1	24-1	1975-76	0	2	2
	526-1	526-1	1979-80	1	6	7
Backcross:						
Green ♀ × Green ♂	SCY-2	14-I	1978-79	1	0	1
Green ♀ × Red ♂	SCG-1	521-5	1975-76	2	0	2
	14-I	JCR-1	1978-79	2	0	2
Red ♀ × Red ♂	JCR-1	521-5	1975-76	1	7	8

chilled at 5°C for 4 to 8 days produced red progeny; (ii) red aphids kept at a temperature of 25°C on cabbages began to produce green-yellow progeny in the second generation and all aphids in the cage became green-yellow after two months. They interpreted these results as evidence that aphid body color does not necessarily depend on the stable character being genetically fixed. An alternative explanation may be possible: (i) they used a green or yellow clone(s) in which the alatiform progeny becomes red at low temperatures, as stated in the previous paragraph. The chilling treatment should have been effective only in production of alatiform progeny. (ii) By the second generation, the culture had become contaminated with some green or yellow clone(s), and rapid replacement took place in subsequent generations. It is apparent that cabbage is a poor host plant for red *M. persicae* (UEDA and TAKADA, 1977; TAKADA, unpublished data).

Breeding experiments

Matings occurred readily between males and oviparae of any clones used, and most of the oviparae subsequently laid their fertilized eggs on the leaves and wall of the cage (average 8 eggs per ovipara). However, the hatching percentage was very low, usually less than 4%, and the larval mortality of fundatrices very high, 30–80%. During the course of these experiments from 1973 to 1980, a total of 154 F₁ clones, 106 F₂ clones and 13 backcross clones was obtained. The body colors of these clones are summarized in Table 2. In all cases crosses within and between green clones yielded only green hybrid clones, even in a cross within a green F₁ clone (25–2), which had been obtained from a cross between two different red clones. The crosses within and between red clones yielded mostly red and occasionally green hybrid clones. The crosses between green and red clones yielded both green and red hybrid clones in most cases, though the proportions of the two colors differed according to the crosses. In the most successful cross, (JCR–1) ♀ × (SCG–1) ♂ in 1976–77, F₁ clones segregated in a ratio which closely approximated 1 : 1. Contrarily, 10 F₁ clones from the cross (JCR–1) ♀ × (SCG–11) ♂ were all red, and F₁ clones from the crosses (SCG–1) ♀ × (JCR–1) ♂ segregated in a ratio of 11 green : 3 red *versus* 21 green : 25 red in the reciprocal crosses.

Genetic interpretation for inheritance

The segregating ratios obtained in a series of crosses of green and red parent clones

Table 3. SUMMARY OF SEGREGATION IN CROSSING GREEN AND RED
PARENT CLONES OF *Myzus persicae*

Type of cross		No. F ₁ clones		X ²
		Green (rr)	Red (Rr) (RR)	
Green × Green (rr) (rr)	Obs.	19	0	—
	Exp.	19	0	
Green × Red (rr) (Rr)	Obs.	46	56	0.49 (0.5 > P > 0.3)
	Exp.	51	51	
Red × Red (Rr) (Rr)	Obs.	4	29	1.81 (0.2 > P > 0.1)
	Exp.	8.25	24.75	

fit the expected segregations of a pair of alleles at a single locus, red (R) being dominant to green (r) (Table 3). Furthermore, the results obtained from the F_1 crosses and backcrosses were essentially consistent with this assumption. All the red parent and F_1 clones used for crossing must be heterozygous because of the production of the green clone at least once in certain crosses, except in the case of the clone (URR-1). Judging from the esterase pattern, however, this clone seems to be the same as (URR-0) (Form-18, TAKADA, 1979).

SHULL (1925) showed that green and red colors in *Macrosiphum solanifolii* (ASHMEAD) (= *M. euphorbiae* (THOMAS)) were dependent upon multiple factors. MÜLLER (1962) proved that in *Acyrtosiphon pisum* HARRIS the inheritance of red was simply dominant to green, a fact which has been confirmed in trials carried out by MARKKULA (1963). Thus the genetic mechanism for inheritance of body colors in *Myzus persicae* may be analogous to that in *A. pisum*.

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