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The influence of climate on melanism in the Two-Spot ladybird, *Adalia bipunctata,* in central Italy

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SUMMARY

1. The frequency of black forms of the Two-Spot ladybird, *Adalia bipunctata*, progressively decreases with increasing altitude, inland from Viareggio and Pisa; it increases again, though not to the same extent, to the north east of the Apennines.
2. Probably temperature is an important selective agent, though air pollution may also have some effect.

INTRODUCTION

Samples of the Two-Spot ladybird, *Adalia bipunctata* (L.) (Coccinellidae), usually contain some individuals in which the elytra are mainly red with black spots or patterning, and others which have black elytra with two or more red spots. Although a number of recognisably different forms are involved, the commoner ones are controlled by a single locus with the basically black ones dominant to the red ones (Lus, 1928, 1932). In parts of continental Europe and in Britain, the black forms occur most frequently in large urban areas, particularly where there is much industry (Lusis, 1961; Creed, 1968, 1971). Frequencies of up to 95% are found in heavily industrialised areas, compared with less than 10% in extensive rural areas. Furthermore, Creed (1971) found that there was a strong positive association between melanic frequency and the mean levels of smoke pollution; this was confirmed by multiple regression analysis of melanic frequencies against 14 environmental variables including air pollution, temperature, rainfall and a number of biological parameters that might influence crypsis on tree trunks (Lees *et al.*, 1973). Although there is no supporting evidence from British collections, Lusis (1961) suggested that a higher melanic frequency occurs in places with a maritime humid climate.

Fiori (1928) recorded a sample of 263 individuals collected in Bologna, of which 40% were black varieties. Bologna is a large industrialised urban area with relatively high air pollution levels (a mean SO_2 level of 600 μgm^{-3} was recorded for November to March in 1964–65 and 1965–66; Damilano, 1966). It was therefore of interest to determine the extent of variation in melanic frequency in this part of Italy, and to see whether there was any correlation with environmental gradients.

RESULTS

A sample of 95 ladybirds caught in Pisa in 1968 contained 74·7% melanic forms. Between 1972 and 1974 many more samples were collected along a broad transect running inland from the coast between La Spezia and Pisa, towards Bologna and crossing the Apennine Mountains. Details of the samples are given in Table 1, and their position is shown on the map (fig. 1).

Table 1. Details of collections of *Adalia bipunctata* in central Italy. The majority of the insects were collected in July as adults and pupae, except for Pisa (1968), in May; and Pisa (1972) and Metato (1973) which were hibernating adults. Mean annual rainfall and temperature figures are for 1966–70 and are extracted from the *Annali Idrologici*, Part 1, Istituto Poligrafico dello Stato, Roma

		Number				Mean		
	Year	Red	Black	Total	% Black	temp. (°C)	Altitude (m)	Rainfall (mm)
Arcola*	1974	25	75	100	75·0	13·7	14	1400
Viareggio	1972	5	36	41	87·8	15·2	1	1000
San Rossore	1972	11	46	57	80·7		4	950
Pisa	1968	24	71	95				
	1972	12	23	35				
	Total	36	94	130	72·3	15·1	6	1000
Metato	1973	9	25	34	73·5		6	1000
Lucca	1974	31	33	64	51·6	14·8	19	1250
Piano della Rocca†	1974	20	10	30	33·3	13·1	110	1800
San Marcello Pistoiese	1972	25	5	30				
	1974	72	22	94				
	Total	97	27	124	21·8	11·9	625	1650
Prunetta	1972	75	20	95				
	1974	5	1	6				
	Total	80	21	101	20·8		958	2000
Le Piastre‡	1972	14	4	18				
	1974	26	6	32				
	Total	40	10	50	20·0	9·6	741	2250
Pievepelago	1972	37	2	39				
	1974	59	4	63				
	Total	96	6	102	5·9		735	1550
Pavullo	1974	84	8	92	8·7	9·0	682	850
Bologna	1974	14	18	32	56·3	13·6	51	700
Modena	1974	22	14	36	38·9	13·5	35	750
Ozzano Taro	1972	16	11	27				
	1974	13	16	29				
	Total	29	27	56	48·2		134	900

* Temperature and rainfall data for Sarzana.
† Temperature data for Castelnuovo Garfagna.
‡ Temperature data for Pracchia.

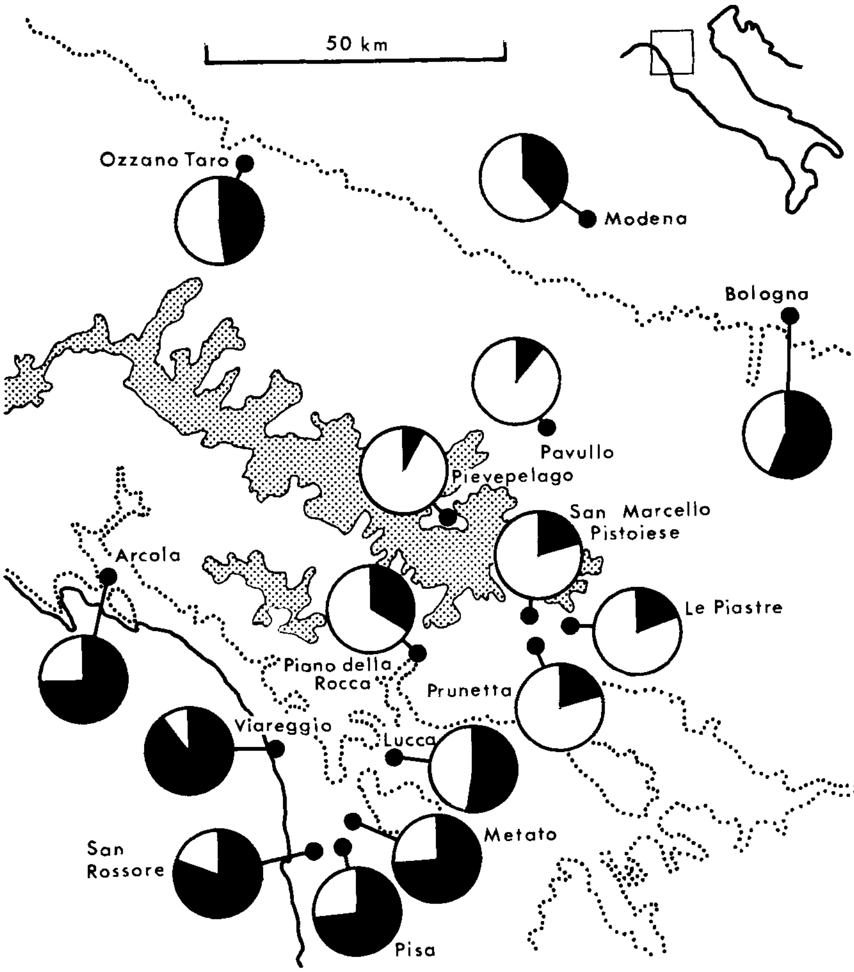

Fig. 1. Map showing location of collecting sites and melanic frequency (black segments) at each; at top right is shown the relationship of this area to Italy as a whole. Dotted contour is at 100 m above sea level; ground over 1000 m is stippled.

DISCUSSION

Only 32 individuals were collected from Bologna. Their melanic frequency of 56% is not significantly different from the 1926 sample ($\chi^2_{(1)} = 3{\cdot}13$; $0{\cdot}1 > P > 0{\cdot}05$), though it suggests that melanics may have increased in the intervening period, possibly due to increased pollution levels. However, the use of different collecting sites might indicate a spatial rather than a temporal change in frequency.

Clearly there is a steep cline in melanic frequency from over 70% near to the coast, at Arcola, Viareggio and Pisa, to 6% at Pievepelago, a distance of 45 km inland, and 9% at Pavullo; further to the east and north, at Bologna, Modena and Ozzano Taro, the frequency rises again. The highest melanic frequencies are found at sites near to sea level, whereas the samples from the greatest altitudes have the lowest frequency

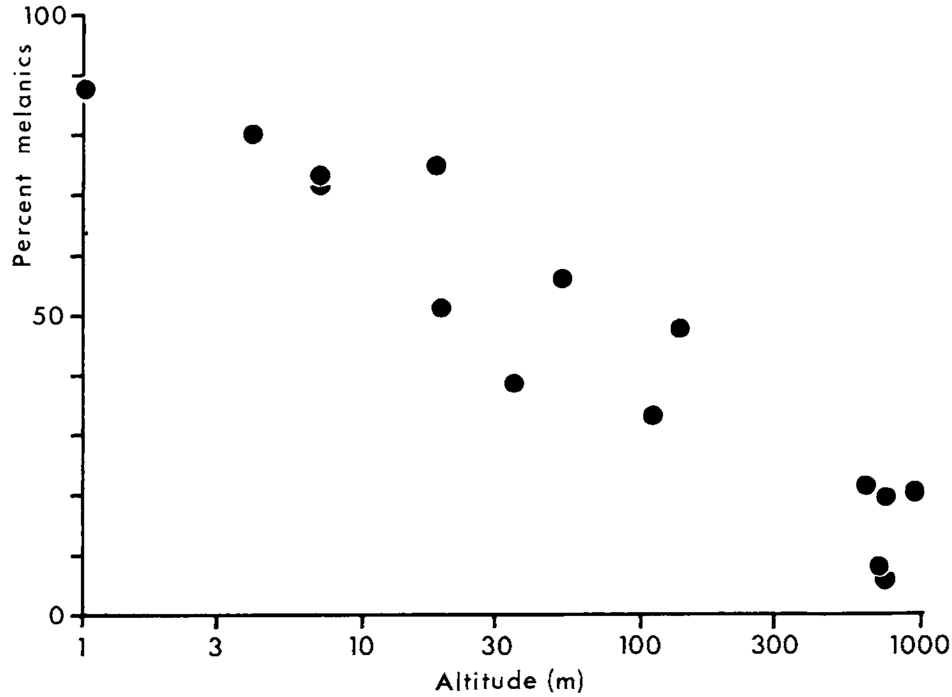

Fig. 2. Relationship between melanic frequency and altitude, plotted on a logarithmic scale, for all 15 sites. $r = 0{\cdot}96$; $y = 96{\cdot}57 - 12{\cdot}13 \log_e x$.

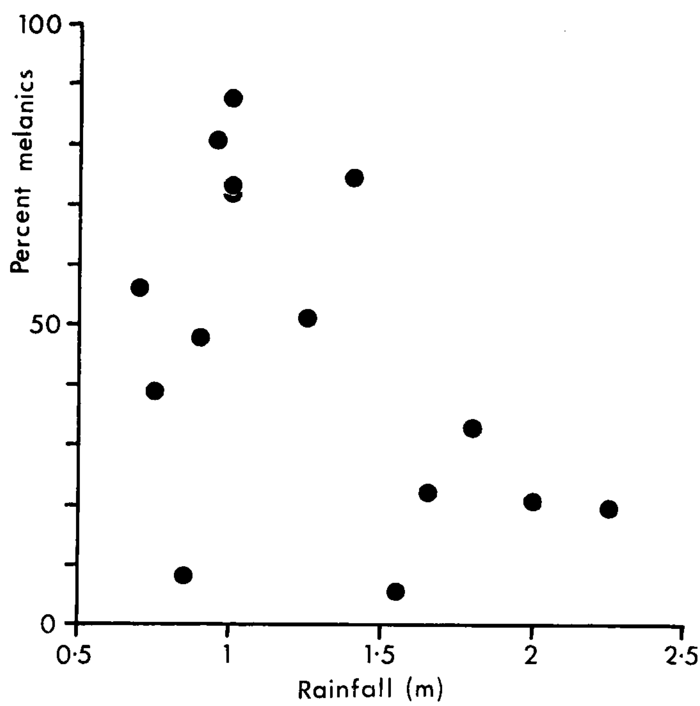

Fig. 3. Relationship between melanic frequency and mean annual rainfall. $r = 0{\cdot}47$.

(see fig. 2). However, it seems extremely unlikely that altitude *per se* is exercising a selective influence; rather it is likely to be some environmental factor which itself varies with altitude.

Rainfall tends to be greater with increasing altitude. There is thus a negative correlation between rainfall, and presumably therefore, humidity, and melanic frequency (see fig. 3), though there is a considerable range of frequencies at sites with low rainfall. This correlation is the reverse of the situation found by Lusis (1961) elsewhere in Europe, and together with the evidence from Britain, must therefore cast doubt on the importance of humidity as a selective agent. Similarly, the collecting sites in the mountains have fewer hours of sunshine per year than do the coastal sites; this conflicts with the suggestion of Benham *et al.* (1974) that a decrease in the amount of sunshine favours melanic individuals at the expense of red ones.

Air pollution levels will clearly be lower in the more mountainous areas than in the more populated, low-lying coastal and inland areas. However, the considerably greater melanic frequency near to the coast than at Bologna would imply a much higher general level of air pollution at the coast; this seems most unlikely. By contrast, there is evidence that potential atmospheric pollutants, including hydrocarbons and alkyl benzene sulphonate, are present in large quantities in the coastal waters of this part of the Mediterranean, and that an aerosol of these is harmful to vegetation inland (Lapucci *et al.*, 1972). Hydrocarbons also occur in smoke, though there is at present no evidence that they are the component of smoke responsible for any selective effect.

Timofeeff-Ressovsky (1940) found the mortality rate of black *Adalia bipunctata* in

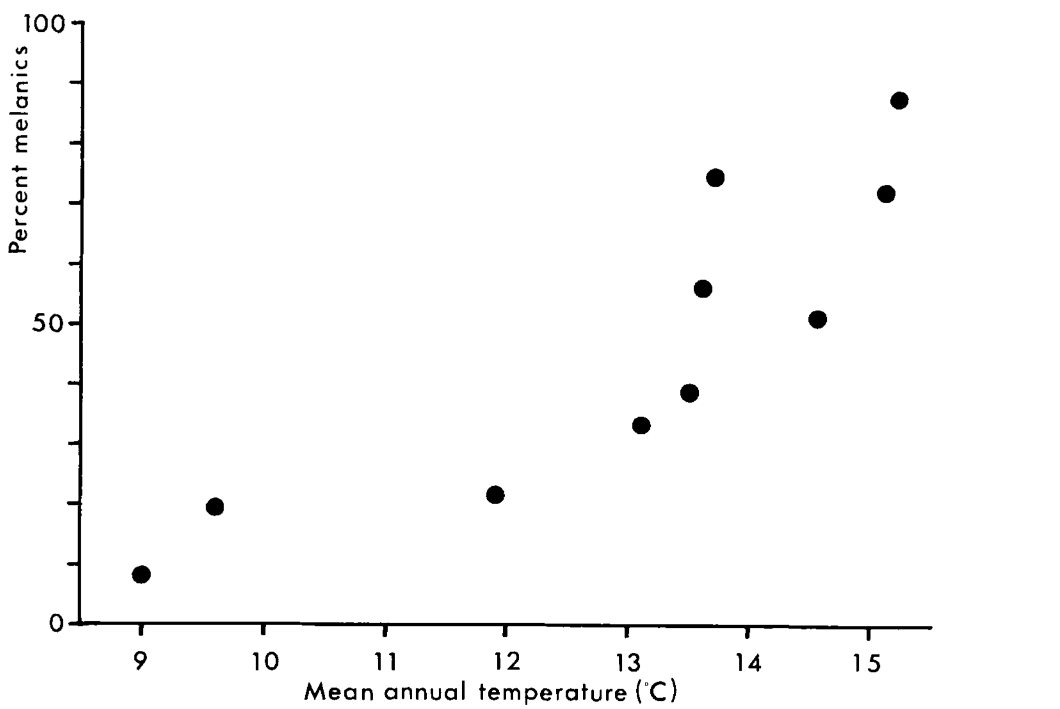

Fig. 4. Relationship between melanic frequency and mean annual temperature at 10 sites for which temperature data are available. $r = 0{\cdot}88$; $y = 10{\cdot}85x - 93{\cdot}22$.

Berlin to be higher than that of the red individuals during hibernation; their frequency made a compensatory recovery during the summer months. Perhaps the black forms have a higher mortality rate than the red forms throughout the year, and also a higher fecundity. However, it appears more likely that the black individuals are more vulnerable than the red ones to cold conditions; conversely, Marriner (1926) observed that the black insects were better able to withstand high temperatures. This suggests that the low temperatures associated with increased altitude would favour the red morphs, and vice versa. In figure 4 melanic frequency is plotted against mean annual temperature; this has been chosen because low winter temperature might be expected to favour red individuals, whereas high summer temperature should favour black ones. Weighting the points according to sample size, the correlation coefficient $(r) = 0{\cdot}88$; $P < 0{\cdot}001$. There is some indication that the relationship is not linear, with melanic frequency increasing more rapidly at higher temperatures. Log transformation of the melanic frequencies increases the value of r to 0·91, but this has little obvious biological relevance, and the same regression constants for the relationship between melanic frequency and mean annual temperature do not apply throughout the insect's range in Europe.

It could be argued that we should use some measure which combines mean minimum temperature in winter with mean maximum temperature in summer. For instance, although Pisa has a consistently lower mean monthly minimum temperature than Viareggio, which should theoretically favour red individuals, its mean maximum temperatures in summer are the higher and should thus favour black individuals. However, the data presented in this paper are not extensive enough for valid conclusions to be drawn from a more complicated model in which selection coefficients during summer and winter are separate functions of temperature (Creed, 1975).

Although it is impossible to rule out other environmental variables which are themselves related to altitude, we conclude that in this part of Italy, as in Berlin, some aspect of temperature is almost certainly influencing the melanic frequencies. The possible effects of air pollution, including highly photo-reactive radicals, cannot be excluded as contributory factors. In the less extreme Atlantic climate of Great Britain, local differences in melanic frequency seem to be predominantly the effect of smoke pollution; temperature appears to be of little importance except in so far as the observation that the mean annual temperature over much of the country is similar to the high altitude Italian sites and that the melanic frequency in relatively unpolluted British areas is correspondingly low.

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