

THE RELATIONSHIP BETWEEN *DROSOPHILA* OCCURRENCE AND MOULD ABUNDANCE ON ROTTING FRUIT

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Some species of *Drosophila* belong to a functional guild of species which are detritivores of rotting fruit. This guild includes mammals and birds, a variety of invertebrates and a number of species of micro-organisms. Therefore, *Drosophila* may have to compete with a number of other species, from a wide range of taxa, for access to their resource. These potential competitors include species of mould which grow on the surface of the decomposing fruit. Janzen (1977) suggested that some characteristic qualities of rotten fruit are a 'deliberate' strategy of fungi to make the resource unattractive to higher animals, a form of interspecific interference effect. Moulds are often a pest of *Drosophila* cultures in the laboratory and the use of fungicides or the maintenance of high larval density are often needed to restrain fungal growth (Demerec, 1950; Ashburner & Thompson, 1978). On more natural resources the performance of *D. immigrans* and *D. melanogaster* has been shown to be reduced by the presence of *Penicillium* on citrus fruits (Atkinson, 1981).

The aim of this paper is to examine the occurrence of *Drosophila* and the extent of mould growth on pieces of fruit left out in the field. It is hoped that this may give some further insight into whether mould/*Drosophila* interactions are of general significance to the structure of the communities in which these taxa occur.

METHODS

Association between mould and Drosophila on pieces of fruit

Experiments were carried out at two field sites. The first site, Hendon (NZ403559), an urban district of Sunderland in north east England, consisted of an urban garden containing a few herbaceous plants. Populations of *Drosophila* had been observed in the garden in a previous year's pilot study, centred mainly around a small compost heap. The local area consists mainly of urban terraced housing with some nearby parkland.

The second site used was at West Learmouth (NT386638), near to Cornhill-on-Tweed on the English-Scottish border. The site consisted of a small patch of woodland adjacent to a road verge. The woodland had once been part of a cottage garden and contained apple, cherry and elder trees. Thus there were a number of naturally occurring breeding resources for *Drosophila*.

To examine the distribution of moulds and *Drosophila*, pieces of banana (≈ 20 g) were placed in plastic cups (open end 60 mm diameter) with screw-on plastic lids. Nine holes (4 mm) were drilled through the lids to allow entry of flies. The baits were left exposed in the field for six days and then returned to the laboratory. The plastic cups were then fitted with lids with air-holes covered with fine nylon gauze. The pieces of fruit, along with any *Drosophila* eggs or larvae, were maintained at 25°C in an insect room, with relative humidity at 45–55% and a 16/8 hour light/dark cycle. The fruit was retained for 21 days and a note was made of whether the growth of mould on the fruit covered the entire exposed surface (100% cover). A record was also made of which pieces of bait gave rise to emergent adult *Drosophila*. Eighty

pieces of bait were left exposed in the field on each of three occasions: twice at West Larmouth (July & August 1993) and once at Hendon (September 1993).

Effects of the presence of Drosophila larvae upon fungal growth

In an intensive study of the biogeography of Catalonian *Drosophila*, Monclus (1964) suggested that the coastal basin near to Barcelona is one of the most diverse in terms of number of species. Therefore, a more detailed examination of the effects of *Drosophila* larvae on the growth of moulds was performed in Calella del Mar on the northern Mediterranean coast of Spain (2° 40' longitude, 41° 36' latitude) in May/June 1994. Trapping of *Drosophila* was carried out in a pine woodland, consisting mainly of aleppo pines, stone pines and cork oaks, near to the El Faro lighthouse. Strawberries which had first been topped were placed into plastic-cup traps (described above) and were left exposed in the field for up to 3 weeks. In total 45 traps were used, distributed at random throughout a patch of woodland approximately 20 by 20 m.

The traps were examined each day at around 4.00 p.m. and the percentage cover of moulds on the surface of the fruit was estimated. The presence or absence of *Drosophila* larvae on each piece of fruit was recorded. Larval identification was carried out by comparison with specimens of known taxa and, for further assurance, some larvae were allowed to complete their development and the adults identified on emergence (from work on adult *Drosophila* in the same area the most common species were *D. subobscura* Collin, *D. immigrans* Sturtevant and *D. simulans* Sturtevant).

RESULTS

Association between mould and Drosophila

The collecting period for this experiment was poor in terms of numbers of *Drosophila*, with *Drosophila* adults emerging from less than 15% of fruit baits (mainly *D. subobscura* Collin). There were generally more than one species of mould present on the fruit, such as *Penicillium*, *Aspergillus* and *Mucor* species. However, for the purposes of this investigation moulds were not separated into distinct taxa. The classification of fruit pieces was analysed using a chi-square (χ^2) procedure to examine for association (Table 1). The data were validated as suitable for pooling and then analysed using Cochran's method for calculating χ^2 suitable for data which gives rise to some low expected values (Zar, 1984, Table 1d).

Overall, there was a highly significant negative association between *Drosophila* emergence and complete fungal cover ($\chi_c^2 = 217.2$, for 1 d.f., $P < 0.001$). When there was complete fungal cover of the surface of the fruit there were very few cases of *Drosophila* emergence. Conversely, when the fungal cover was less than 100% *Drosophila* adults emerged in every case. It appeared, therefore, that there was a complementary distribution of complete fungal cover of the fruit surface and the emergence of *Drosophila*.

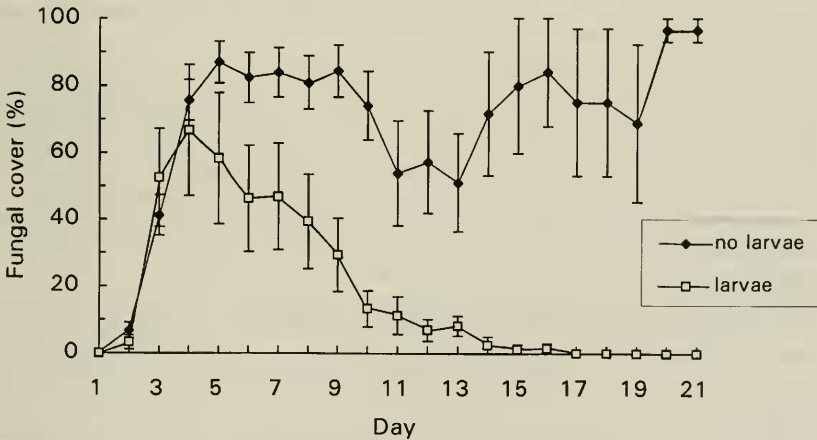
Effects of the presence of Drosophila larvae upon fungal growth

The development of fungal growth on the surface of the strawberries is illustrated in Figure 1. Again, there was a mixture of fungal species present which were pooled

Table 1. Contingency tables for association between *Drosophila* emergence and complete fungal cover of fruit.

(a) July 1993— West Learmouth				(b) August 1993— West Learmouth			
		Complete fungus cover				Complete fungus cover	
		Yes	No			Yes	No
<i>Drosophila</i>	Present	0	8	<i>Drosophila</i>	Present	0	16
	Absent	72	0		Absent	64	0
$\chi^2 = 79.2, P < 0.001.$				$\chi^2 = 79.8, P < 0.001.$			

(c) September 1993— Hendon, Sunderland				(d) Pooled data			
		Complete fungus cover				Complete fungus cover	
		Yes	No			Yes	No
<i>Drosophila</i>	Present	2	11	<i>Drosophila</i>	Present	2	35
	Absent	67	0		Absent	203	0
$\chi^2 = 64.9, P < 0.001.$				$\chi^2_c = 217.2, P < 0.001.$			

Figure 1. The pattern of fungal growth on strawberries with and without *Drosophila* larvae (mean \pm SE).

and treated as a single taxon. The data on percentage fungal cover of the fruit pieces were analysed using the generalized linear interactive modelling system (GLIM; Baker & Nelder, 1978), defining the fungal cover as binomial (i.e. a proportion of 100%). The 'repeated measures' nature of the data was compensated for to some extent by including 'time' as a factor in the analyses. A significant statistical interaction was found to occur between the age of the fruit and the presence of *Drosophila* larvae in their effects on fungal growth ($F_{20, 380} = 2.43, P < 0.01$).

Fungal cover rapidly increased on all pieces of fruit for the first 4 days. By the fifth day the trends for fungal growth on pieces of fruit which contained *Drosophila* larvae and those which were unoccupied began to diverge, the fungal growth on the surface of pieces of fruit which contained *Drosophila* larvae being reduced. At the end of the investigation pieces of fruit which had contained *Drosophila* larvae tended to have no fungal cover on the surface whereas fruits which were assumed to have contained no larvae had virtually complete cover.

DISCUSSION

The complementary distributions of complete fungus cover and *Drosophila* emergence may be taken as evidence for negative interspecific effects; complete fungus cover debarring *Drosophila* development and/or the presence of *Drosophila* larvae in the resource preventing absolute cover by mould. There are potential mechanisms which could give rise to these effects. Some fungi produce mycotoxins which have a deleterious affect on insect performance (e.g. Keller & Zimmermann, 1989) and *D. melanogaster* has been shown to be negatively affected by at least one of these mycotoxins (aflatoxin) produced by the fungus *Aspergillus flavus* (Matsumura & Knight, 1967). In laboratory cultures mould infection can cause serious reductions in *Drosophila* population size (Demerec, 1950; Ashburner & Thompson, 1978). Conversely, some insects are known to feed on the hyphae of fungi growing on the shared resource and thus reduce the fungal standing crop (e.g. Wicklow & Yocom, 1982; Lussenhop & Wicklow, 1985).

However, there is a danger in using distributional data to infer competitive mechanisms (Connell, 1975; Schoener & Adler, 1991; Stone & Roberts, 1992) especially when the distributions are biased to certain classes (Wright & Biehl, 1983). Differences in qualitative aspects of the habitat may produce complementary distributions, regardless of any interactions which may occur. For example, fruit suitable for *Drosophila* emergence may be unsuitable for rapid fungal growth and conversely fruit which promotes fungal growth may be unsuitable for *Drosophila* development. Even if negative effects are inferred there is no indication of any causal mechanisms.

However, the data from Calella gives some indication that there is at least one negative effect occurring between the two taxa. The growth of mould on the surface of the strawberries is reduced if *Drosophila* larvae are present. There was no suggestion that the larvae were feeding on the mould, thus reducing its standing crop by trophic means. The mechanism of the fungal reduction appeared to be one of physical interference. Larvae were observed feeding on, or just under, the surface of the fruit and the movement of the larvae had a mixing effect on the fruit substance. This behaviour tended to undermine and churn up the fungal mat so causing a decrease in fungal cover. A similar effect has been observed in dung systems where fungus-gnat larvae have been observed to have a mixing effect on the substrate and decrease the density of fungal hyphae (Lussenhop *et al.*, 1980; Lussenhop & Wicklow, 1985).

As nearly all pieces of rotting fruit will have some mould growth then the likelihood of *Drosophila* ever encountering mould-free fruit will be extremely scarce. Mould contamination is known to reduce *Drosophila* populations size in the laboratory and the results presented here suggest that interactions between moulds and *Drosophila* may also be important in determining the local community structure of a resource patch in the field.

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REFERENCES

- Ashburner, M. & Thompson, J. N. 1978. The laboratory culture of *Drosophila*. In: Ashburner, M. & Wright, T. R. F. (Eds) *The genetics and biology of Drosophila* Vol. 2a. Academic Press, London.
- Atkinson, W. D. 1981. An ecological interaction between citrus fruit, *Penicillium* moulds and *Drosophila immigrans* Sturtevant (Diptera: Drosophilidae). *Ecol. Ent.* 6: 339–344.
- Baker, R. J. & Nelder, J. A. 1978. *The GLIM system. Release 3.77*. Royal Statistical Society, Oxford.
- Connell, J. H. 1975. Some mechanisms producing structure in natural communities. In: Cody, M. L. & Diamond, J. M. (Eds) *Ecology and evolution of communities*. Harvard University Press, London.
- Demerec, M. 1950. *Biology of Drosophila*. Wiley, Chapman & Hall, New York.
- Janzen, D. H. 1977. Why fruits rot, seeds mold and meat spoils. *Am. Nat.* 111: 691–713.
- Keller, S. & Zimmerman, G. 1989. Mycopathogens of soil insects. In: Wilding, N., Collins, N. M., Hammond, P. M. & Webber, J. F. (Eds) *Insect fungus interactions*. Academic Press, London.
- Lussenhop, J., Kumar, R., Wicklow, D. T. & Lloyd, J. E. 1980. Insect effects on bacteria and fungi in cattle dung. *Oikos* 34: 54–58.
- Lussenhop, J. & Wicklow, D. T. 1985. Interaction of competing fungi with fly larvae. *Microbial Ecol.* 11: 175–182.
- Matsumura, F. & Knight, S. G. 1967. Toxicity and chemosterilizing activity of aflatoxin against insects. *J. Econ. Ent.* 60: 871–872.
- Monclus, M. 1964. Distribucion y ecologia de drosofilidos en España. *Génetica Ibérica* 16: 143–165.
- Schoener, T. W. & Adler, G. H. 1991. Greater resolution of distributional complementarities by controlling for habitat affinities: a study with Bahamian lizards and birds. *Am. Nat.* 137: 669–692.
- Stone, L. & Roberts, A. 1992. Competitive exclusion, or species aggregation? *Oecologia* 91: 419–424.
- Wicklow, D. T. & Yocum, D. H. 1982. Effect of larval grazing by *Lycoriella mal* (Diptera: Sciaridae) on species abundance of coprophilous fungi. *Trans. Br. Mycol. Soc.* 78: 29–32.
- Wright, S. J. & Biehl, C. C. 1983. Empty sites and the analysis of presence-absence data. *Am. Nat.* 122: 833–834.
- Zar, J. H. (1984) *Biostatistical analysis*. Prentice-Hall, London.

SHORT COMMUNICATIONS

***Cicones undata* Guér.-Mén. (Coleoptera: Colydiidae) still common under sycamore bark in south-east London.**—Since I first found this pretty beetle under sycamore bark in Nunhead Cemetery in October 1991 (Jones, 1992, 1993), I have frequently examined dead sycamores killed by the sooty bark disease, an ascomycete fungus *Cryptostroma corticale* Ell. & Ev., and I am happy to report that the beetle continues to thrive in the area. Nunhead Cemetery (TQ3575; VC17, Surrey) has a large number of dead standing sycamore trees and the *Cicones* is without doubt the commonest beetle under their bark. It is often possible to find 10 to 20 specimens within a few minutes of searching on each tree. Specimens have been found on several BENHS field meetings to the cemetery, and on many other occasions during the last 5 years.