

SOME EFFECTS OF WEATHER ON APHIDS IN CROPS AND PASTURES IN CANTERBURY, NEW ZEALAND

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INTRODUCTION

Pest insects are frequently held in check by natural means. The level of this control is influenced by the supply of food, the activity of parasitic organisms, including entomophagous insects and disease pathogens, and weather. Any enquiry into the importance of weather in insect ecology must include an examination of the effects of temperature (including freezing), humidity, wind (direction and velocity), precipitation (rate and amount), light (intensity and duration), and evaporation. The effects of these factors are interrelated and all react on other controlling influences. The importance of weather in this connection is well illustrated by the work of Andrewartha and Birch (1954). In a 14-year census of thrips in a garden in Adelaide they showed that 78 per cent. of the variation in annual peak numbers was correlated with meteorological variations.

The investigation of aphid ecology in New Zealand has reached the stage where hypotheses about general and detailed effects of weather can be made, but these still need confirmation by controlled experiment. Weather appears to be an important factor, and this paper reports some of the preliminary findings, and relates these to overseas hypotheses of aphid behaviour.

Aphids are small, soft-bodied, polymorphic insects capable of doing damage in their own right. They are also important because of their ability to spread virus diseases between and within crops.

Seventy-three species have been recorded in New Zealand mainly by Cottier (1953) compared with New York State which has 303 (Leonard 1963), Israel, 207 (Bodenheimer and Swirski 1957), and Britain, 500 (Johnson, 1962). Approximately 2,700 species have been described throughout the world.

The aphid life-cycle is involved and consists of a number of generations annually. Alate (winged) forms which undertake dispersal flights are regularly produced, with peaks of

flight in mid-spring and late autumn. Sampling of the air-mass with traps and the study of individual aphid species on their host-plants in replicated plots are methods used in aphid studies. Both have been employed in an ecological study carried on at several sites in Canterbury over the last seven years. In trapping, 42 species have been captured, nine being taken in considerable numbers in all seasons and at all sites where traps have been maintained. Seven of these are known to be important vectors of crop viruses. The crops affected are potatoes, brassicas, cereals, legumes, and carrots. Species may have a limited or a wide range of hosts, and it is important ecologically to note that present agricultural and horticultural practices provide an unbroken continuity of crops which the economically important species colonise.

EFFECT OF THE PHOTOPERIOD-TEMPERATURE INTERACTION

The "classical" life-cycle of aphids has been described from Europe. It includes the production of sexual forms in autumn followed by an egg stage in winter. Lees (1964) determined that the stimulus leading to production of sexual forms is the onset of short days with low temperatures. New Zealand's latitude is such that this does not occur in most economically important species. The aphids survive the winter as apterae in sheltered positions on their host plants. It is this continuous viviparous parthenogenicity within populations of introduced species that is the dominant effect of climate on aphids under New Zealand conditions.

The cabbage aphid (*Brevicoryne brassicae* (L.)) and the cereal aphid (*Rhopalosiphum padi* L.) may be regarded as typical of those

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thus affected. Other types of aphid life-cycles known in New Zealand are summarised, with examples, in Fig. 1. Against this general pattern detailed effects of weather can be studied.

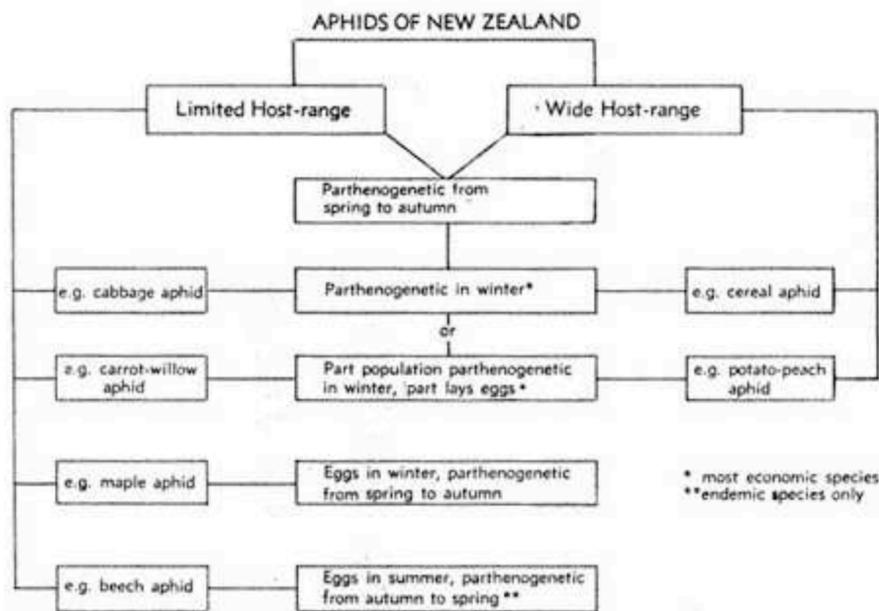


FIGURE 1. Diagram showing the main cycles of aphid behaviour in New Zealand.

EFFECTS OF TEMPERATURE, HUMIDITY, AND RAINFALL ON POPULATION PATTERN AND FLIGHT IN TWO SPECIES

Population pattern

A detailed study of the relationship of the cabbage aphid to its host plants has been undertaken at several sites in Canterbury. This species colonises all brassicas and a typical population pattern on plants is shown in Fig. 2 (A), taken from Lamb and Lowe (1961). Figure 2 (B) shows the numbers of alates developing on the same plants, and Fig. 2 (C) the number of alates taken on traps located within the study plots. There is a relationship within these three sets of results and between them and the weather. At present this relationship can be stated only in general terms pending further analysis, but the pattern runs chronologically under field conditions as follows: A spring population begins to develop on seed-crops of chou moellier as the temperature rises in about mid-July, the population increase becoming apparent after 3-4 weeks. Within this population alates begin to appear in early September and increase in proportion to the whole population from then onwards.

These alates fly to emerging seedling brassicas in late spring, and before the chou moellier plants dry off in early December, farmers' sowings of rape, turnips, and swedes have emerged to receive an initial colonisation. Alates give birth to live wingless nymphs and a population of apterous forms develops as a result of favourable temperature. The upward trend in numbers is regularly interrupted by a stable period or a slight decline in autumn, when day-temperatures rise beyond the upper threshold of development—62°F. (Lamb 1961). Lamb interpreted this figure—surprisingly low for an upper threshold—as evidence that other factors were operating in the field to reduce the suitability of the host plant as a food source for aphids. These factors in turn were related to the low humidity and rainfall at this time, causing high evaporation and transpiration rates.

As temperatures fall and autumn rain allows increased plant growth, the upward trend in aphid numbers resumes and a population peak

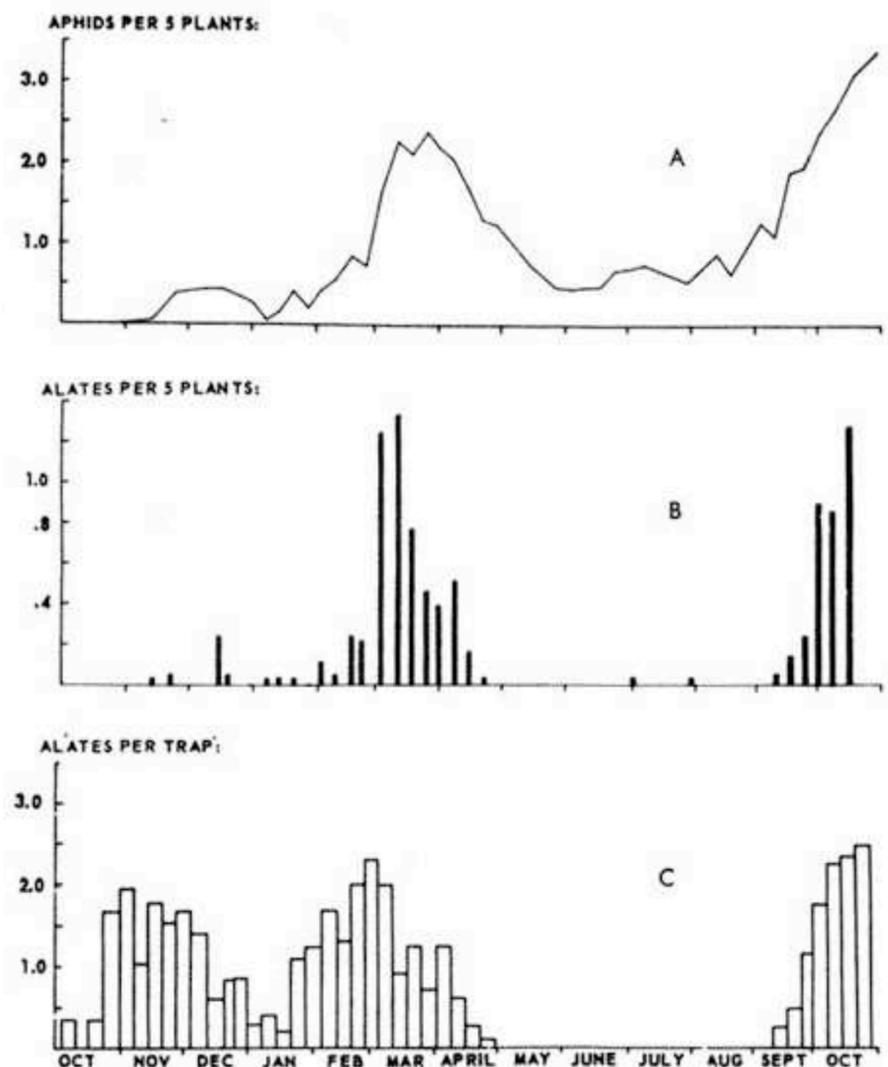


FIGURE 2. Seasonal trends at Lincoln in mean numbers of the cabbage aphid: (A) and (B) on plants, (C) on traps, all as log (n + 1), 1958-59 season. After Lamb and Lowe (1961).

is usually reached in March or April. The decline in numbers from this peak is rapid, due to a complex of factors. High autumn humidities favour propagation and growth of fungous diseases, and *Entomophthora aphidis* Hoffman can be epidemic at this stage. Temperatures then drop towards the lower threshold for development in aphids (approximately 45°F.) which restricts the aphid populations to low levels during the winter. Under experimental conditions the whole process takes place on the one plant from initial sowing in October to seeding and ripening in December of the following year.

The reactions of various species of aphids to weather are quite distinct, and comparison of the above trends in cabbage aphid populations with those in populations of the cereal aphid reveals specific differences. The temperature relationships of the cereal aphid have been studied under controlled conditions by Villaneuva and Strong (1964) and some of their data are shown in Table 1. These indicate temperature effects similar to those already shown as typical of the cabbage aphid. There is an unbroken succession of host-crops available to both species. The notable differences between field populations of these two aphids are (1) the very low numbers of the cereal aphid present during the summer-autumn period of high temperatures, possibly caused by a relatively low upper temperature threshold, and (2) the almost total absence of disease as a controlling factor in populations of the cereal aphid (see below).

An unexplained phenomenon occurs in the relationship of autumn and spring numbers of cereal aphids trapped in Canterbury during six years (Fig. 3). Alate cereal aphids fly in late autumn on to seedling wheat crops, and give birth to nymphs which become the nucleus for spring populations. Data for the years 1963 and 1964 showed large differences in

survival rates between autumn and spring. Sampling gave no evidence of biological control and meteorological records failed to show differences in mean temperatures between the two winters. Rainfall records, however, were negatively correlated with aphid survival rates, and this strongly suggests weather plays a part.

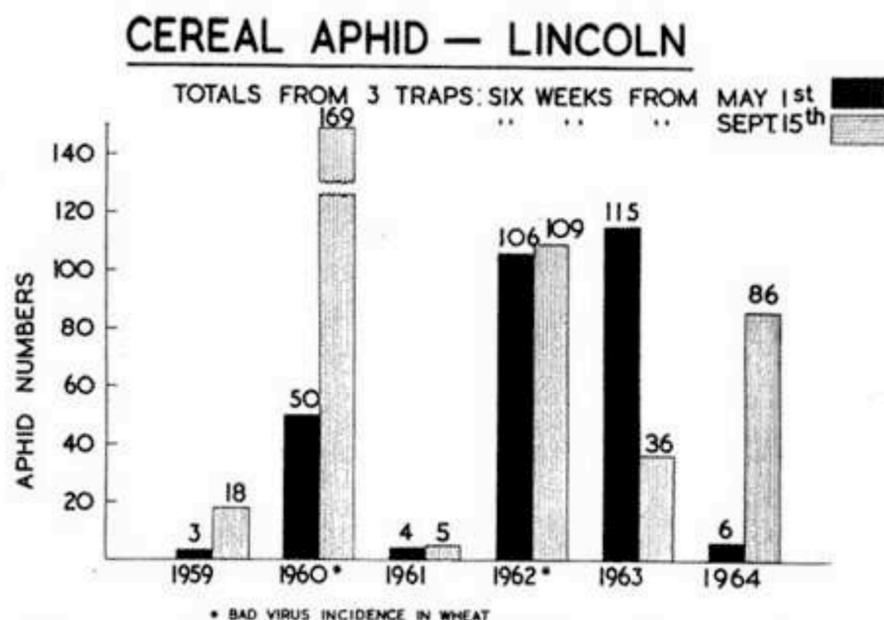


FIGURE 3. Total cereal aphids taken on 3 traps at Lincoln at the end of autumn and the beginning of spring flights, 1959-64.

Flight

The production of winged forms in a population is of prime importance in dispersal of aphids and hence in the spread of virus diseases. Recent work (Johnson 1965) has confirmed that tactile stimuli lead to the production of alates. Once they have developed, take-off and dispersal is almost entirely a matter of suitable weather. After moulting to the winged stage, alate aphids go through a brief period of maturation on the plant. The right combination of temperature and low wind speed leads to take-off after which the alate is strongly attracted to ultra-violet-blue light and deliberately flies upward. It is then carried involuntarily on wind currents. During

TABLE 1. Effect of temperature on generation time, total life span, and fecundity of the cereal aphid on barley in the laboratory. After Villaneuva and Strong, 1964.

Temperature (°F.)	Lowest threshold for development = 46°F.		Highest threshold for development = 78.8°F.	
	Generation time (days)	Life Span (days)	Young per female	Number of Aphids tested
55.4	21.7 ± 1	44.9 ± 16.6	30.5 ± 13.4	12
73.4	6.6 ± 0.7	20.5 ± 4.5	42 ± 17.5	29
78.8	5.2 ± 0.4	18.3 ± 5.9	50.4 ± 9.8	22
86	5.8 ± 0.7	13.7 ± 3.7	10.9 ± 4	16

flight biochemical changes take place and induce a landing response. Flight then becomes deliberate again, the aphids are attracted to green-yellow light, and land on fresh green plants. Johnson (1962) showed that there is a diurnal bi-modal peak (Fig. 4) in the flight pattern and interpreted the first peak as take-off of aphids which moult overnight and receive the stimulus to fly early in the day. He regarded the second peak as being caused by an accumulation of aphids moulting during the day but not flying until they had gone through a maturation ("teneral") period, even though the flight stimulus may be present all day. He states "As the population grows, successive batches of winged aphids come straight into migration. . . . These are not seen because they are usually taken high into the air. On calm days, especially when there are temperature inversions, these immense populations become concentrated in the lower layers of air, and that is when we usually see them." This has been deduced from the results of trapping on a vertical transect, with segregation of the catch at hourly intervals. The pattern appears to be directly applicable to Canterbury where population peaks coincide with the occurrence of Föhn winds and relatively shallow temperature-inversion layers.

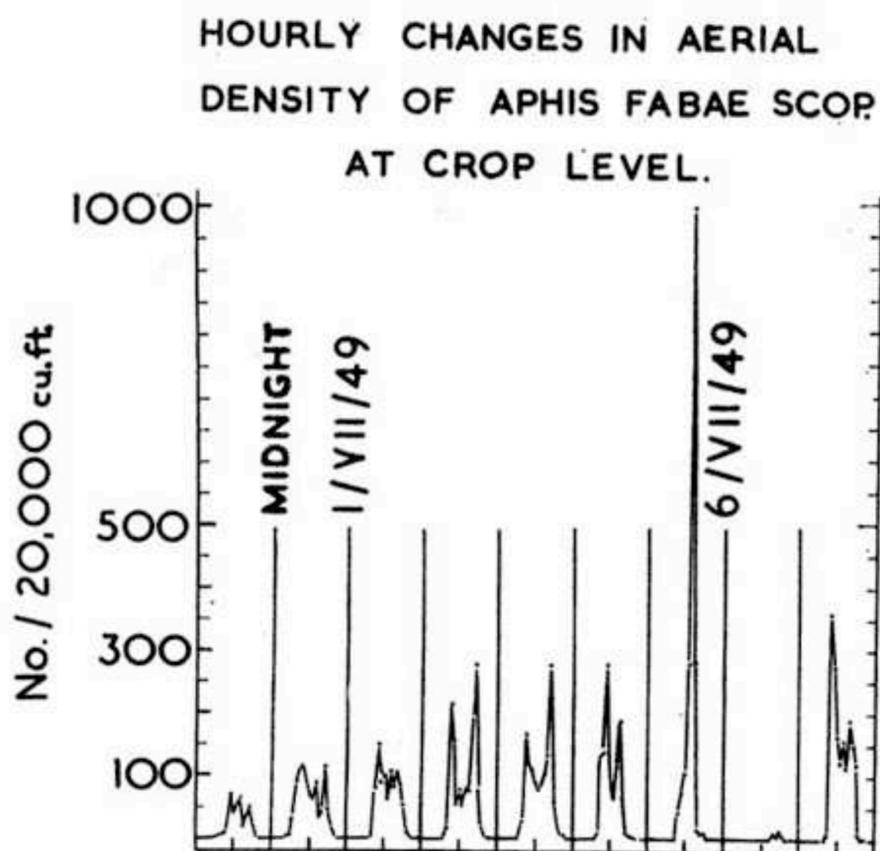


FIGURE 4. Daily flight curves of *Aphis fabae*, showing bi-modal peak. After Johnson, C. G. (1962).

Local data on the cereal aphid reveal both sustained and short flights. With other species, it has been taken in moderate numbers more than 100 miles off-shore by ships sailing to the Antarctic (Gressitt *et al.* 1961). It will also colonise, presumably by short flights, paddocks adjacent to a known source (Lowe 1964). Both types of flights are reflections of weather suitable for take-off—in the first instance for sustained flight, in the second for early landing.

Take-off in the cabbage aphid occurs at temperatures in the crop of from 58°F. upwards and at wind-speeds of under 7 m.p.h.

Such flights may be affected by heavy rain, which sometimes virtually destroys the alate population just before flights or directly after landing, causing failure of the species to disperse or to establish on fresh crops.

SOME INDIRECT EFFECTS OF WEATHER

The indirect effects of weather on aphid ecology are manifold. No local studies have been made of those arising from soils and plants, except insofar as they are correlated with weather. However, in studies of brassicas susceptible and resistant to colonisation, the cabbage aphid and the green peach aphid, which colonise these plants, have been shown to increase at different rates on leaves of different age. The green peach aphid shows a marked preference for aging, yellow leaves but the cabbage aphid prefers fresh leaf growth. Where yellowing, and hence change of leaf constituents, is a result of weather adverse to plant growth (as in drought), differential population growth in the two aphid species is in turn a reflection of weather operating through host-plant condition.

The entomophthoraceous fungus mentioned as the main cause of a drop in autumn populations of the cabbage aphid, is directly affected by autumn weather. Under similar conditions no such control appears to be exerted on populations of the cereal aphid, though the disease is present in an incipient form. Plant structure in the different host crops may play a part in the modification of the macro-climate, and the consequent behaviour of the fungus. The micro-climate of these crops would probably repay further study.

An understanding of the effects of weather on aphids in crops and pastures is incomplete without a knowledge of the relationship of meteorological factors to the biology and ecology of associated entomophagous insects. Our knowledge of these relationships is limited at present. An example of effect of temperature is found in the predaceous ladybird *Coccinella undecim-punctata* L. This insect appears as an adult later in the spring than the start of population growth of the cabbage aphid. The latter begins in mid-July when mean temperatures are in the upper forties. The aphid has a distinct advantage in being able to increase to pest numbers early in the growing season when free from this predator. Further knowledge of this kind may give a reliable guide to suitable beneficial insects for aphid control in crops.

THE COLLECTION AND ANALYSIS OF DATA

What methods are to be employed to analyse the data have yet to be decided. For instance, several effects of temperature on the cabbage aphid have been noted as facts observable in the field. Outside the generally accepted thresholds (45–75°F.) within which multiplication takes place, little is known about upper and lower lethal thresholds, or about the cumulative effects of temperature. A question of obvious economic significance in Canterbury is the effect of frost on aphids. This is related to the lower lethal temperature of the species involved as well as to the micro-climate of the individual host crop and cannot at present be answered. Normal meteorological values expressed as daily or weekly means are too general to permit detailed analysis. Continuous records of temperature though easily obtained represent a Herculean task in analysis if cumulative effects on different species in different seasons or sites are studied. This is only one aspect of the effect of weather on a species. Weather has a marked influence on population fluctuations, and evaluation of all effects, direct and indirect, on the several species involved will require many years of data collection and experimental analysis.

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