caught low numbers of male San José scale in Canterbury and it appears to occur only rarely in this area compared to oystershell scale. Lincoln Plant Health Station has not identified the oystershell scale north of Canterbury. San José scale was unknown in Central Otago until its discovery in the 2 Clyde orchards. It appears that the distribution of the 2 *Quadraspidiotus* species overlaps in the South Island, San José scale being more common in the north, and oystershell scale being more common in the south.

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Growth and development of the oak aphid, *Tuberculoides annulatus* (Homoptera: Aphididae) on excised leaf discs

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Abstract

Development of the 'yellow' and 'green' colour forms of the oak aphid, *Tuberculoides annulatus* (Hartig), was studied using isolated leaf discs of *Quercus* spp. A technique is described which eliminates regular addition of water or nutrient solutions to individual vials and keeps all leaf discs in the same plane. Good leaf disc condition was maintained for more than three weeks. Development was significantly faster in the 'yellow' form of *T. annulatus* than the 'green' form. The growth parameters of length, breadth, and weight for the 'yellow' form were measured daily and all increased in a linear manner against time.

Keywords: Homoptera; Aphididae; *Tuberculoides annulatus; Quercus* leaf disc; colour forms; development rate; growth.

INTRODUCTION

The oak aphid, *Tuberculoides annulatus* Hartig (Homoptera: Aphididae), is common on most of the introduced oak (*Quercus* spp.) in New Zealand. In spite of their abundance, little is known of their biology. High populations of this aphid can occur and their feeding results in copious production of honeydew. Sooty moulds growing on the honeydew can lower the aesthetic appearance of many of the oaks which are primarily specimen trees. This paper reports on biological studies of the oak aphid on isolated leaf discs in the laboratory.

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Laboratory studies of aphids frequently require regular observations. While observation on aphid colonies on whole plants may be more realistic, plant morphology and disturbance of aphids often preclude careful observation. Biological studies of aphids on isolated leaf discs provide an alternative technique, particularly when uniformity of the substrate is desired (Adams & van Emden 1972). Such a technique is generally not suitable for comparative studies on plant resistance (van Emden et al. 1969), but since we were interested in aphid development on a single host, the leaf disc method was thought to be suitable for *T. annulatus*.

Isolated leaf discs have been used for studying aphid biology by several workers (Johnson & Birks 1960; Hughes & Woolcock 1965). Leaf discs were floated on water or a culture solution in glass vials. Disc life is critical, e.g., *Aphis craccivora* Koch was reared on *Vicia faba* L. leaf discs for 2 generations over 2 weeks (Johnson 1965). In contrast leaf discs from Graminae were found to deteriorate rapidly and were not suitable for aphid studies (late A. D. Lowe, pers. comm.).

Young *T. annulatus* feed predominantly on or close to the edge of leaf discs, possibly in response to the higher concentrations of soluble nitrogen in the senescing cells. When methods described previously were used, many *T. annulatus* were drowned when water was added to vials containing excised oak leaf discs. In addition, rapid evaporation often caused discs to adhere to the vial wall rather than maintaining a water barrier to aphid dispersal. The leaf disc technique reported here was designed to overcome some of these problems.

MATERIALS AND METHODS

Support of leaf discs by a single nutrient supply would eliminate variability caused by differential addition of nutrients to vials. Hence a technique was developed to keep many leaf discs in continuous contact with the same nutrient solution and maintain them all at the same plane to facilitate rapid observation of aphid development.

108 24 mm-diameter holes were cut in a rectangular polystyrene board (31 × 28 × 2 cm). Polystyrene proved to be a particularly suitable base since it did not absorb water and was easy to manipulate. The board was placed in a plastic photographic tray (34 × 30 × 3 cm). To keep the upper surface of the board to within 4 mm of the water or nutrient level, 2 steel rods (5 mm diameter) were placed over the board and clipped to the tray. Water was added and maintained at a constant level by a self-watering device. A 650 ml plastic bottle with a short tube in the bottom was placed in one corner. Water outflow was regulated by evaporation at a level below the nozzle releasing water. Water levels could be maintained with minimum disturbance to each leaf disc. Leaf discs were cut by cork borers (21 mm diameter) from mature leaves of *Quercus robur* L. and placed in each cell.

Aphids for the excised leaf disc studies were taken from laboratory cultures reared on seedling *Q. robur* at 22 ± 2°C and 15 h L: 9 h D photoperiod under fluorescent lights. Field observation revealed 2 colour forms, 'green' and 'yellow', and so separate colonies of each were maintained. The 2 colonies kept their colour over several generations (14 months) and maintained parthenogenetic and viviparous reproduction. Comparative studies on development rates were carried out, because the 2 colour forms may be separate subspecies (Mull 1961) or biotypes (Eastop 1973).

Twenty-five and 22 alate viviparous females of the 'yellow' and 'green' forms respectively were transferred by brush to individual leaf discs. On the appearance of 1st instar nymphs, the females and all but 1 nymph were removed from the discs. Aphid growth and development was recorded daily under the 22 ± 2°C and 15 h L : 9 h D experimental conditions.

Growth parameters such as length from the middle of the cauda to the base of the frons (c.f., Muller 1966) and breadth, were measured *in situ* on the 'yellow' form.

Aphids were weighed by carefully transferring them with a fine brush to an electro-microbalance.

RESULTS AND DISCUSSION

Throughout the periods of measurement (up to 28 days), the oak discs remained in good condition and there was no evidence of deteriorating leaf condition adversely affecting oak aphid growth and development. Studies on development of the 2 colour forms could therefore be conducted in standardised conditions.

Instar durations of 'yellow' and 'green' forms are summarised in Figure 1. The 'green' form is clearly slower growing than the 'yellow' form. This is confirmed in Figure 2 summarising the preadult life of both forms. Analysis of individual instar duration using the 't' test revealed that the 2nd, 3rd, and 4th instars and the preadult duration were signficantly longer in the 'green' than in the 'yellow' form (Table 1). This may suggest some evolutionary adaptations in that the 'yellow' form is more clearly detected on the oak leaves than the 'green' form thus increasing the likelihood of predation. Survival of the 'yellow' form of oak aphid was also greater than the 'green' form.

Table 1. Comparison of instar duration and preadult life of the 'yellow' and 'green' forms of oak aphid. Numbers of aphids in parentheses: 't' = t-statistic; N.S. = Not significant; *, **, *** = $P<0.05$, 0.01, 0.001 respectively.

	Duration (Mean Days)		
Stage	Yellow Form		Green Form
1st instar	4.83 (25)		5.23 (22)
't'		1.01 N.S	
2nd instar	3.96 (25)		4.95 (21)
't'		3.45 *	
3rd instar	3.68 (25)		5.05 (19)
't'		8.37 ***	
4th instar	4.61 (23)		5.75 (8)
't'		2.35 *	
Preadult life	17.17 (23)		23.13 (8)
't'		4.21 **	

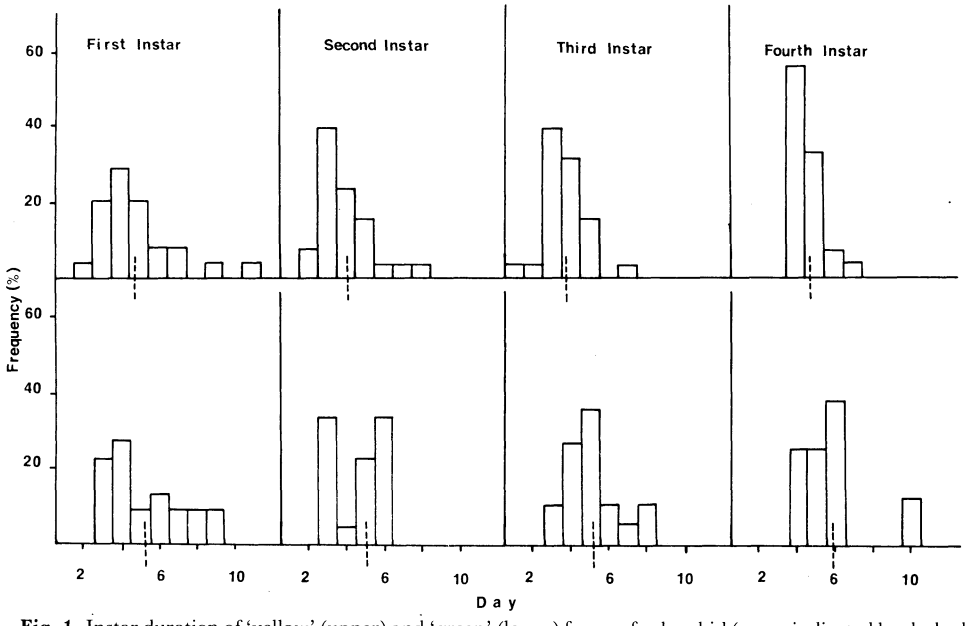

Fig. 1. Instar duration of 'yellow' (upper) and 'green' (lower) forms of oak aphid (mean indicated by dashed line).

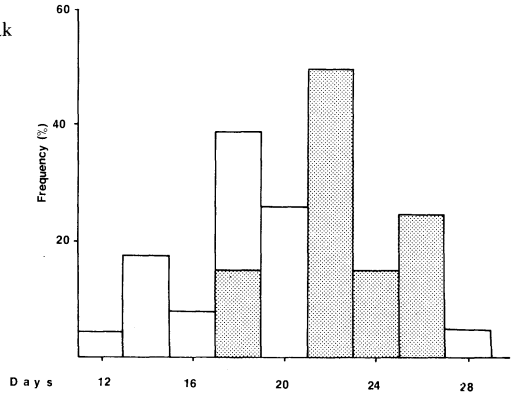

Fig. 2. Duration of preadult life in 2 forms of oak aphid (┌──┐ 'yellow'. ▒▒▒▒ 'green').

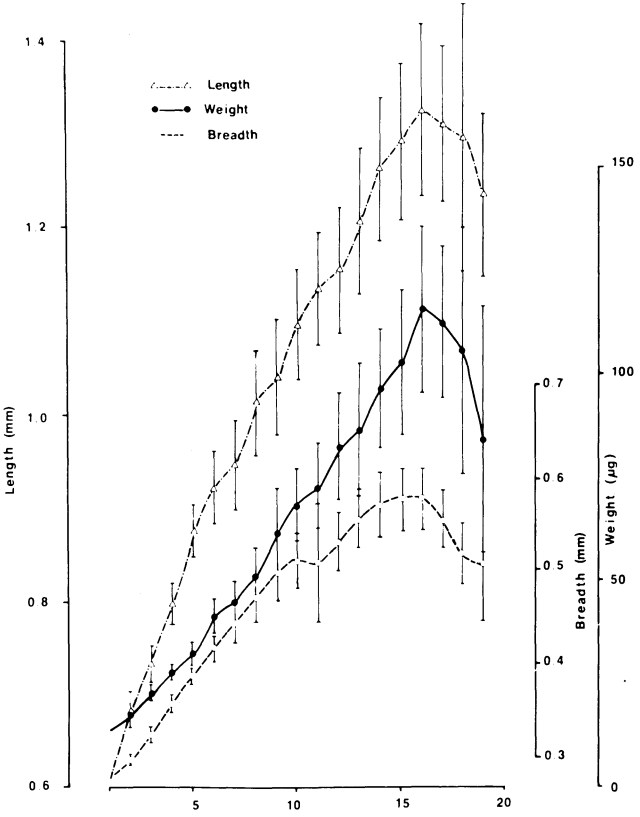

Fig. 3. Growth parameters of length, breadth, and weight of the 'yellow' form of the oak aphid with time.
I = standard error

The faster development rate of the 'yellow' form may compensate for this. Similar differences of development in colour forms have been recorded for pea aphid, *Acyrthosiphon pisum* (Harris), where the 'red' form was more fecund and had a higher migratory potential than the 'green' form (Lowe & Taylor 1964). The 'red' form was also more readily detected by predators.

While true-breeding colonies of each colour form were maintained in the laboratory for 14 months, evidence as to biotype or subspecies designations was not obtained. Muller (1961) indicated that offspring preserving the original colour could be races or subspecies, but further studies will be necessary to clarify the status of these forms in *T. annulatus*. Since the 'yellow' forms were most abundant in the field and time was limited detailed studies of growth and development were confined to that form.

Changes in the growth parameters, length, breadth, and weight are presented in Figure 3. The pooled results do not show sharp changes expected with individual measurements of different instars since there is considerable overlap of instar duration. Linear regression analyses between the growth parameters gave the highest correlation between length and weight with a regression coefficient of 0.61 and a correlation coefficient of 0.98. For the breadth/weight and length/breadth regressions, the regression and correlation coefficients were 0.29 and 0.93, and 15.53 and 0.97 respectively. These data strongly suggest that growth and development proceed in a linear manner up to day 17.

Growth peaked about day 17 with a consistent decline in all parameters in the following days. This may be associated with a period of reduced activity coinciding with the development of reproductive capacity in the juvenile 4th instars. Such a relationship is suggested by the ability of newly emerged adults to begin reproducing almost immediately. Up to 4 nymphs can be produced per adult in the first day of reproductive life.

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Colour polymorphism in the introduced spittlebug *Philaenus spumarius* (Homoptera: Aphrophoridae) in New Zealand

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Abstract

The spittlebug *Philaenus spumarius* is highly polymorphic for colour pattern. Recently it has been introduced into New Zealand, providing a unique opportunity to study the evolution of the colour polymorphism during the occupation of a new geographic area. Many colour forms present in North America and Europe appear to be absent in New Zealand.

Keywords: Homoptera; Aphrophoridae; *Philaenus spumarius*; spittlebug; colour polymorphism.