

**Environmental factors and morphological discrimination between spring and summer migrants of the grain aphid, *Sitobion avenae* (Homoptera: Aphididae)**

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**Aphids, *Sitobion avenae*, morphology, spring and summer migrants, phenotypic variability**

**Abstract.** The morphology of spring and summer migrants of *Sitobion avenae* (F.) from several different environmental conditions were compared using analysis of variance and canonical variate analysis. Both between morph and within morph differences were found for a range of morphometric features and ratios. When aphids of both morphs and from a range of conditions were considered together any morph differences were obscured by phenotypic variability. Similarly canonical variate analysis indicated that differences due to environmental variability were greater than those due to morph.

INTRODUCTION

The grain aphid *Sitobion avenae* (Fabricius) is a monoecious (non host alternating) species that is found on various members of the Gramineae, including cereal crops, throughout the year (Carter et al., 1980; Dixon, 1987). It can overwinter either parthenogenetically (anholocyclically) or as an egg (holocyclically). The proportion of aphids that overwinter anholocyclically and holocyclically in different regions is not well known but would be very useful in predicting the size and timing of the spring migration into cereal crops. If some morphological difference could be found between winged individuals produced early in the year by holocyclic populations (spring migrants) and by asexually overwintering populations ('summer' migrants), it would be possible, by examining suction trap catches, to gain a measure of the relative importance of the two types of overwintering.

Several studies have tried to distinguish spring and summer migrants of various aphid species in terms of morphology (Börner, 1951; Elliot, 1969; Woodford & Lerman, 1977; Bird et al., 1979; Hand, 1986; Newton, 1986; Simon et al., 1991).

Newton (1986) found evidence that there were differences between the two morphs in *Sitobion avenae* but her study was not conclusive because she only used one clone and the results indicated that environmental conditions had a marked effect on morphology.

The aim of this study was to investigate the morphology of spring and summer migrants of *Sitobion avenae* and to determine whether they can be distinguished when a number of clones are reared at different temperatures and on different host plants.

MATERIALS AND METHODS

Nymphs hatched from eggs were used to initiate clonal cultures and were placed individually on: wheat seedlings at 15°C and 20°C, *Poa annua* seedlings at 15°C and 20°C; and on excised wheat leaves in rearing units (Austin et al., 1991). All the nymphs were allowed to become adult and reproduce and were

then removed. Their offspring (second generation) were allowed to reproduce and also removed. Any winged individuals were preserved in lactic acid alcohol (Eastop & Van Emden, 1972). Winged aphids from the third generation were also preserved in the same way if no winged morphs had been produced by the same clone in the second generation. The preserved individuals were the spring migrants. *S. avenae* shows a peak in winged morph production in the second and third generation after which this migrant production declines (unpublished results).

Summer migrants were collected from five parthenogenetic clonal cultures, which had been maintained on wheat seedlings and in rearing units for many generations in the same conditions (15°C and 20°C) as the spring migrants.

Preserved aphids were examined under a dissecting microscope and 13 different measurements were taken per aphid. These were the lengths of: AS3 (3rd antennal segment); AS4 (4th antennal segment); AS5 (5th antennal segment); ASB (base of 6th antennal segment); ASPT (processus terminalis); ROST (ultimate segment of the rostrum); TARSUS (2nd segment of the hind tarsus); FEM (hind femur); TIB (hind tibia); BODY (body length: frons to base of cauda); WING (forewing); SIPH (siphunculus); CAUDA (cauda).

Seven ratios were calculated from these variables. They were chosen because of their previous use in studies to distinguish spring and summer migrants of other aphid species. The ratios were as follows: AS4/TARSUS (Stroyan, 1984; Taylor et al., 1984; Simon et al., 1991); AS4/ROST (Stroyan, 1984; Taylor et al., 1984; Simon et al., 1991); ROST/TARSUS (Stroyan, 1984; Simon et al., 1991); SIPH/FEM (Woodford & Lerman, 1977); AS3/AS4 (Bird et al., 1979); SIPH/ROST (Elliot, 1969); and AS3/ROST (Stroyan, 1984).

Analysis of variance and canonical variate analysis (CVA) were used to compare spring and summer migrants both in terms of the 13 morphometric variables and the seven ratios. The statistical package Genstat (Lane, Galway & Alvey, 1987; Payne et al., 1987) was used to carry out the CVA.

## RESULTS

Aphids of the same morph but from different conditions were found to show differences both in the variables and the ratios (Table 1). The largest aphids were from rearing units and the smallest from either wheat at 20°C or *Poa annua* at 15°C.

TABLE 1. The difference in size variables and ratios between aphids of the same morph in different conditions.

a) Spring migrants						
Variable/ratio	Wheat 20°C	Wheat 15°C	Rearing unit 15°C	<i>Poa annua</i> 15°C	F	p
AS3	0.569 (.010)	0.720 (.011)	0.722 (.014)	0.544 (.013)	58.19	p < 0.001
TARSUS	0.147 (.001)	0.158 (.002)	0.157 (.002)	0.142 (.001)	18.69	p < 0.001
FEM	0.783 (.015)	0.928 (.012)	0.968 (.021)	0.780 (.015)	34.24	p < 0.001
BODY	2.172 (.046)	2.502 (.077)	2.567 (.059)	2.157 (.015)	16.05	p < 0.001
AS4/TARSUS	2.713 (.063)	3.385 (.073)	3.785 (.083)	2.919 (.053)	51.55	p < 0.001
ROST/TARSUS	0.723 (.007)	0.715 (.008)	0.732 (.010)	0.766 (.009)	5.96	p < 0.01
b) Summer migrants						
Variable/ratio	Wheat 20°C	Wheat 15°C	Rearing unit 15°C		F	p
AS3	0.583 (.016)	0.649 (.008)	0.710 (.010)		25.44	p < 0.001
TARSUS	0.144 (.007)	0.145 (.002)	0.146 (.001)		0.42	ns
FEM	0.787 (.015)	0.835 (.011)	0.933 (.014)		29.03	p < 0.001
BODY	2.114 (.035)	2.227 (.033)	2.625 (.040)		49.75	p < 0.001
AS4/TARSUS	2.951 (.066)	3.307 (.057)	3.731 (.060)		37.57	p < 0.001
ROST/TARSUS	0.781 (.009)	0.761 (.009)	0.799 (.010)		3.9	p < 0.05

All measurements in mm. Standard error in parenthesis.

When aphids of different morph but from the same conditions were compared they were also found to show differences (Table 2). The differences were not as consistent as differences between conditions, but on wheat seedlings at 15°C spring migrants were larger (Table 2b). In the other treatments spring migrants were not significantly larger but mean values were often higher than those for summer migrants. The lack of consistency between treatments and the considerable influence of environmental conditions on aphid morphology meant that when aphids from a range of conditions were considered there were no consistent differences that could be used to separate the morphs. This was true for both measured variables and ratios.

TABLE 2. The difference in size variables and ratios between aphids of different morph but in the same conditions.

Variable/ratio	Spring migrants	Summer migrants	F	p
a) Wheat 20°C				
AS3	0.569 (.010)	0.583 (.016)	0.43	ns
TARSUS	0.147 (.001)	0.144 (.001)	3.74	ns
FEM	0.783 (.015)	0.787 (.015)	0.03	ns
BODY	2.172 (.046)	2.114 (.035)	1.02	ns
AS4/TARSUS	2.713 (.063)	2.951 (.066)	6.60	p < 0.05
ROST/TARSUS	0.723 (.007)	0.781 (.009)	24.58	p < 0.001
b) Wheat 15°C				
AS3	0.720 (.011)	0.649 (.008)	24.3	p < 0.001
TARSUS	0.158 (.002)	0.145 (.002)	23.67	p < 0.001
FEM	0.928 (.012)	0.835 (.011)	27.34	p < 0.001
BODY	2.502 (.077)	2.227 (.033)	15.06	p < 0.001
AS4/TARSUS	3.385 (.073)	3.307 (.057)	0.66	ns
ROST/TARSUS	0.715 (.008)	0.761 (.009)	10.18	p < 0.01
c) Rearing unit 15°C				
AS3	0.722 (.014)	0.710 (.010)	0.52	ns
TARSUS	0.157 (.002)	0.146 (.001)	17.14	p < 0.001
FEM	0.968 (.021)	0.933 (.014)	2.08	ns
BODY	2.567 (.059)	2.625 (.040)	0.63	ns
AS4/TARSUS	3.785 (.083)	3.371 (.060)	0.27	ns
ROST/TARSUS	0.732 (.010)	0.799 (.010)	21.99	p < 0.001

All measurements in mm. Standard error in parenthesis.

Ratios, although often considered to be independent of size were found to vary significantly between aphids of the same morph from different conditions (Table 1), indicating that ratios may be size related. In order to see if this was the case the seven ratios were correlated with size and all were found to show a significant relationship (Table 3), although the correlation coefficients for ROST/TARSUS and AS3/AS4 were very small. There is no indication that AS3/AS4 can distinguish spring and summer migrants but ROST/TARSUS has been used for this purpose by Simon et al. (1991). Due to the apparent taxonomic value of the latter ratio a further 89 spring and summer migrants were cleared, mounted and measured at a higher magnification ( $\times 150$ ) in order to verify the correlation with size. A significant and higher correlation was found ( $r = -0.40$ ,  $p < 0.001$ ). In

addition the mean value of this ratio for the various groups, measured under higher magnification, did not separate the morphs of *S. avenae*.

TABLE 3. Correlation with size of the seven ratios used in the comparison of spring and summer migrants.

Ratio	r	Probability	Variance accounted for (in %)
AS4/TARSUS	0.80	p < 0.001	63
AS4/ROST	0.83	p < 0.001	69
ROST/TARSUS	-0.16	p < 0.05	2
SIPH/FEM	0.45	p < 0.001	20
AS3/AS4	-0.20	p < 0.01	4
SIPH/ROST	0.88	p < 0.001	78
AS3/ROST	0.81	p < 0.001	66

Similarly, when morphs from one set of conditions were compared using CVA the groups showed quite good separation (Fig. 1), which was better when morphometric variables were used. When CVA was carried out on all spring and summer migrant groups, considerable overlap occurred when both morphometric variables (Fig. 2a) and ratios (Fig. 2b) were used. In both cases spring and summer migrants were not separated by the analysis but tended to be grouped together according to environmental conditions, suggesting that the influence of environment on morphology is greater than any differences that may occur between the morphs.

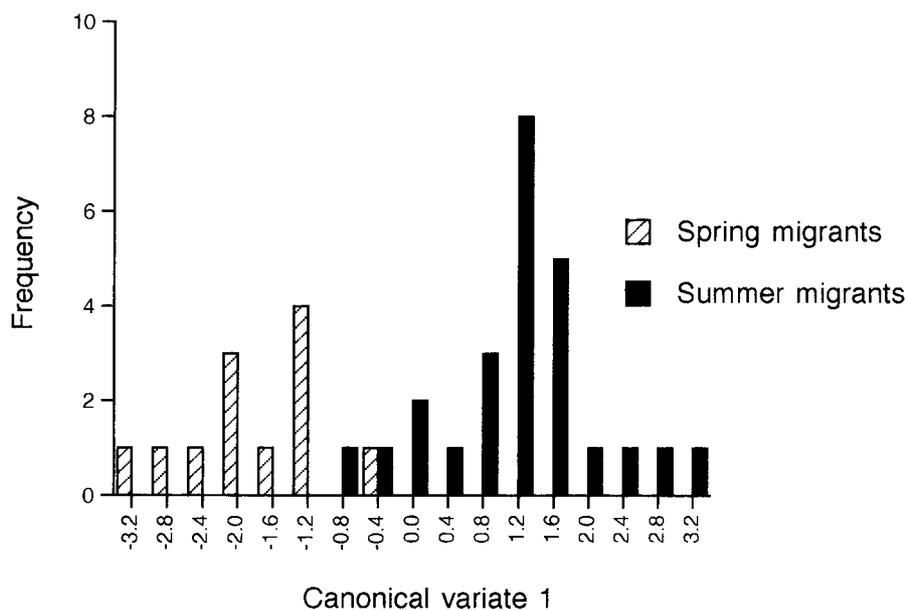


Fig. 1. Canonical variate analysis of spring and summer migrants of *Sitobion avenae* from wheat at 15°C, using 13 morphometric variables.

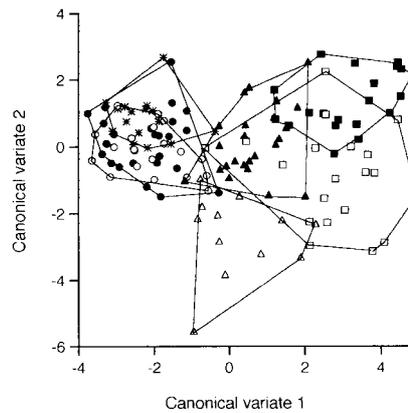
## DISCUSSION

It is clear from both this and previous studies (Müller, 1966; Murdie, 1969; Shaw, 1973; Tsitsipis & Mittler, 1976; Woodford & Lerman, 1977; Dixon et al., 1982; Hand, 1986; Damsteegt & Voegtlin, 1990) that environmental factors have a great effect on aphid size and morphology. The effects of this phenotypic plasticity means that any differences between spring and summer migrants of *S. avenae*, which may occur when reared in the same conditions, are obscured when aphids from a range of conditions are considered.

Phenotypic plasticity not only affects the morphological measurements but also the ratios because they are correlated with size. In consequence it was also not possible to use ratios to separate morphs.

In other aphid species such as *Rhopalosiphum padi* (L.) there is good evidence that when reared in the same conditions, spring and summer migrants are morphologically different (Rogerson, 1947; Simon et al., 1991). These differences in *R. padi* have been applied to field caught aphids to determine spatial differences in the relative abundance of the two morphs and have given some useful results that are in agreement with other work (Simon et al., 1991). However, previous studies have used aphids from a limited range of environmental conditions and so from a narrow range of size and ratio values. It would be interesting to know how phenotypic variability of both morphs would affect their separation, as environmental variability in the field, which is considerable and which has been shown to influence aphid size (Way & Banks, 1967; Shaw, 1973), is likely to at least reduce if not prevent their discrimination.

a) Morphometric variables



b) Ratios

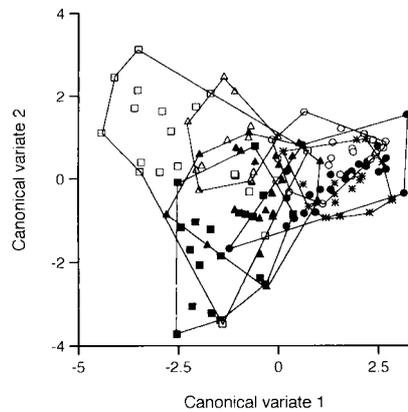


Fig. 2. Canonical variate analysis of spring and summer migrants of *Sitobion avenae* using: a) 13 morphometric variables; and b) seven morphological ratios. Spring migrants from wheat at 15°C ( $\Delta$ ) and 20°C ( $\circ$ ), from rearing units at 15°C ( $\square$ ), and from *Poa annua* at 20°C ( $*$ ). Summer migrants from wheat at 15°C ( $\blacktriangle$ ) and 20°C ( $\bullet$ ), and from rearing units at 15°C ( $\blacksquare$ ). (Lines connect the outer points of each group.)

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