STABLE AGE DISTRIBUTTIONS OF LUCERNE APHID POPULATIONS IN SE-TASMANIA

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Abstract

Stable agé distributions of lucerne aphid populations were investigated in the field at Penna and Campania in SE-Tasmania, Australia, commencing in 1986 and terminating in 1989. At Campania, it was observed that on 14 of 37 sampling occasions the blue green aphid (BGA) did not exhibit a stable age distribution and unstable conditions were related to high population densities rather than low. Mowing of the lucerne did not affect the stable age condition of the BGA. With respect to the seasonal effect, it was found that age distributions of the BGA populations at Campania were stable in summer, autumn and winter with the exception of spring. At Penna, the results showed that on 7 of 21 sampling occasions for the pea aphid (PA) and 5 of 14 occasions for the BGA, the age distributions were not stable. Unstable conditions were associated with high opoulation levels as at Campania. Grazing management did not affect the stable age distribution of these aphid species. It was found that both PA and BGA were not stable in spring but were stable in subsequent seasons. ie. summer, autumn and winter confirming the result at Campania.

1. Introduction

Fluctuation in numbers of most aphid species is normally related to the summed effects of environmental components which may be favourable for one species but unfavourable for another. Kitching and Jones [1] reported that many regulatory factors e.g. weather, host plant conditions, natural enemies, fungal diseases etc. play a significant role in governing the abundance of aphid populations. In reality, the regulatory processes associated with natural control are complex as these regulatory factors act in an integrated manner to affect aphid populations. Hughes, [2] reported that when aphid populations have overlapping generations, the reproductive rate will steady. The frequency of distribution of numbers of the first three nymphal instars will stabilize and the increase of these instars will conform to a geometric series.

Thus the objective of the present study is to investigate the effect of environmental complexity on the distribution of the age structure of lucerne aphids in the south-castern part of Tasmania.

2. Materials and methods

Twenty stems of lucerne plants were randomly selected from the fields on alternative weeks at Penna and Campania in SE-Tasmania, commencing in 1986 and terminating in 1989. The samples were brought back to the laboratory and the aphids were extracted from the stem using 70% alcohol. Then these aphids were counted in separated instars using a microscope.Based on preliminary observations on the development of immature stages, the nymphal instars of the blue green aphid (BGA) and the pea aphid (PA) were simply identified using the following criteria;

(i) BGA: The first and second instar nymphs have 5 antennal segments whereas the third and the fourth instars have 6 segments. The proportions of the caudal length to the width of its base were 0.33, 0.50, 0.75 and 1.00 for the first, second, third and fourth instars respectively.

(ii) PA: Only the first instar has 5 antennal segments whereas the other immature stages have 6 segments. The proportions of the caudal length to the width of its base were 0.50, 0.75, 1.00 and 1.25 respectively.

The calculation procedures to test for the existance of stable age distributions of lucerne aphids are indicated below;

(a) Calculation of potential increase (e^{λ}): This value provides a multiplication factor for each instar and is given by [2]:

$$e^{\lambda} = \frac{\text{Nos. aphids in instars } 1+2}{\text{Nos. aphids in instars } 2+3}$$

(b) Calculation of expected numbers: The expected numbers of the first three instars in a geometric series are calculated as follows [2];

$$\text{Expected nos. of term } 1(3^{rd} \text{ instar}) = \frac{(\text{Sum of aphid nos. in instars 1, 2 and 3})(e^{\lambda}-1)}{(e^{\lambda})^{3}-1}$$

If (e^{λ}) < 1, e^{λ}-1 and $(e^{\lambda})^3$-1 are replaced by 1-e^{λ} and 1- $(e^{\lambda})^3$ respectively. The expected numbers of term 2 (2^{nd} instar) and 3 (1^{st} instar) were obtained by multiplying the first term by e^{λ} and $(e^{\lambda})^2$ respectively. To determine whether the aphid populations were of stable age or not, chi-square (1df) was calculated for the fit of observed numbers to the expected series. If the chi-square value was less than 3.84 then the null hypothesis that a stable age distribution exists is accepted.

3. Results

i. Stable age distribution at Campania

Investigation was conducted using the aphid sampling data from the WL 318 lucerne stand at Mallow farm, Campania (1986-1989). BGA was the only lucerne aphid species found at high densities on this cultivar whereas other species were essentially absent. Thus the results relate to the BGA only.

The rate of potential increase (e^{λ}) and the chi-square value (X^2) are presented in Table 1. Any value of the calculated X^2 greater than 3.84 with 1 df would lead to the rejection of the null hypothesis that the aphid had a stable age distribution [2] It was found that on 14 of 37 occasions the BGA did not exhibit a stable age distribution and these unstable conditions were normally associated with high population densities rather than low. Mowing of the lucerne did not affect the stable age condition. Calculation of total X^2 (Gilbert, N. per. comm. 1989) was conducted to assess the stable age distribution of the BGA with respect to seasons. The results indicated that age distributions of the BGA populations at Campania were stable in summer, autumn and winter with the exception of spring (Table 1).

ii. Stable distribution at Penna

The calculation was conducted using population study data obtained from Hunter River lucerne stand 4 at Flexmore farm, Penna (1986-1989).

In table 2 are shown the values of rate of potential increase (e^{λ}) and chi-square (X^2) for goodness of fit to a stable age distribution. The results showed that on 7 of 21 sampling occasions for the PA and 5 of 14 occasions for the BGA, the age distributions were not stable. The unstable conditions in both aphid species were mainly associated with high population levels rather than low as at Campania. Grazing management did not affect the stable age distribution of these aphid species (Table 2).

However, the total chi-square value of each season did indicate that both PA and BGA were not stable in spring but were stable in subsequent seasons ie. summer, autumn and winter confirming the result at Campania (Table 3).

4. Discussion

The present work demonstrated that cutting and grazing of lucerne were not likely to have great influence on disturbing a stable age distribution of lucerne aphids because on most occasions after either grazing or cutting, the lucerne aphid populations exhibited a stable condition. This indicates that such practices affected all aphid stages equally rather than the specific elimination of only certain stages eg. adult or specific nymphal instars ie. density and stage independent mortality.

At both Penna and Campania, the chances that lucerne aphid populations were unstable varied within the range of 33-38 percent for both PA and BGA (Table 1, 2) and this occurred mainly in spring. The use of total chi-square (X^2) as suggested by Gilbert (pers. comn. 1989) to assess a stable age distribution of these lucerne aphids in separate seasons within a three year period (1986-1989) demonstrated that spring was the only time when BGA and PA populations were not stable. Instability could arise from either of two possibilities;

i. The emigration of alatae: Spring climate conditions favoured rapid increase of both BGA and PA in Tasmania. The crowding condition created severe density dependent effect on aphid populations resulting in rapid development of alate populations to emigrate from lucerne fields. Results of the study on the effect of densities on emigration of BGA indicated that BGA was very sensitive to crowding and both alate nymphs and adults formed rapidly at high population densities. Thus drastic reduction of adult stages within populations partly explains why lucerne aphid populations were not stable particularly in spring.

ii. Precipitation effect: A high incidence of precipitation in spring could eliminate specific stages of lucerne aphids. Maelzer [3] reported that in Macrosiphum rosae (L) most adults and old nymphal stages were killed by rain leaving young nymphal stages which required time to become adult and reproduce young nymphs in the population again. This effect was not observed in this work.

Thus alate emigration is likely to be the major reason why lucerne aphid populations were unstable in spring in Tasmania. However, Carter et al., [4] argued that the use of the Hughes method is not sensitive enough to test a stable age distribution. Gilbert (pers. comn. 1989) also pointed out that in biological research, there is always some heterogeneity involved leading to a less sensitive use of chi-square to test a stable age distribution of aphids. Thus the result concluded from the three year-field studies would be more realistic and sensitive than those trying to simulate and interpret population performance by using short term field data to support theoretical models.

Table 1 The number of BGA and the potential increase rate (e^{λ}) and X^2 (1df) for goodness of fit of expected numbers from a geometric series for a stable instar distribution to observed numbers of BGA in instars one to three on WL 318 lucerne, Mallow, Campania (1986-1989)

Sampling dàte	Season	Managenent	No.BGA counted	(e^{λ})	X^2
2.10.86	Spring		23	0.762	8.892**
16.10.86	Spring		73	4.643	13.949***
30.10.86	Spring		184	2.388	1.309
14.11.86	Spring		158	2.446	1.981
	Spring	Cutting	-	-	-
6.1.87	Summer		9	0.571	0.332
	Summer	Cutting	-	-	-
4.2.87	Summer		9	0.625	0.890
18.2.87	Summer		9	1.600	0.890
4.3.87	Autumn		25	0.895	1.328
	Autumn	Cutting	-	-	-
31.3.87	Autumn		4	0.500	1.249
15.4.87	Autumn		26	3.571	0.245
29.4.87	Autumn		232	2.253	0.052
12.5.87	Autumn		1392	1.788	6.054*
	Autumn & Winter	Long grazing period	-	-	-
15.9.87	Spring		154	1.538	0.017
29.9.87	Spring		2158	1.812	46.125***
13.10.87	Spring		5268	1.820	57.972***
27.10.87	Spring		3133	0.811	0.442

Table 1 (cont)

Sampling date	Season	Managenent	No.BGA counted	(e^{λ})	X^2
	Spring	Cutting	-	-	-
11.11.87	Spring		76	1.075	4.515*
26.11.87	Spring		218	1.916	0.580
9.12.87	Summer		201	1.674	7.655*
21.12.87	Summer		23	1.200	1.179
	Summer	Cutting	-	-	-
20.1.88	Summer		12	0.900	3.444
2.2.88	Summer		3	0.300	0.371
	Summer	Cutting	-	-	-
2.3.88	Autumn		7	0.429	1.521
15.3.88	Autumn		78	1.098	0.550
28.3.88	Autumn		981	1.748	3.344
11.4.88	Autumn		372	0.825	8.125**
26.4.88	Autumn		347	0.621	0.110
	Autumn & Winter	Long grazing period	-	-	-
22.6.88	Winter		22	1.583	1.149
	Winter	Long grazing period	-	-	-
1.9.88	Spring		73	0.877	6.020*
14.9.88	Spring		96	2.081	5.949*
27.9.88	Spring		419	1.464	5.871*
12.10.88	Spring		5074	1.769	111.375***
25.10.88	Spring		4519	1.252	16.897***
9.11.88	Spring		3987	1.775	89.471***
	Spring	Cutting	-	-	-
21.12.88	Summer		10	0.444	0.670
5.1.89	Summer		10	0.857	0.430
	Summer	Cutting	-	-	-
16.2.89	Summer		13	0.875	1.874

* Significant at 5% level of confidence.
** Significant at 1% level of confidence.
*** Significant at 0.1% level of confidence.

Table 2. The number of lucerne aphids and the potential increase rate (e^{λ}) and X^2 (1df) for goodness of fit of expected numbers from a geometric series for a stable instar distribution to observed numbers of aphids in instars one to three on Hunter River (stand 4), Penna (1986-1989)

Sampling date	Season	Managenent	Aphid species					
			PA			BGA		
			No. counted	(e^{λ})	X^2	No. counted	(e^{λ})	X^2
25.9.86	Spring		155	1.808	0.596	-	-	-
8.10.86	Spring		209	2.128	0.128	48	3.067	1.083
23.10.86	Spring		625	1.131	193.263***	27	1.600	2.671
5.11.86	Spring		305	0.758	9.790**	44	0.477	12.810***
	Spring	Grazing	-	-	-	-	-	-
30.12.86	Summer		10	0.300	0.982	-	-	-
14.1.87	Summer		13	0.692	9.236***	-	-	-
	Summer	Grazing	-	-	-	-	-	-
11.3.87	Autumn		10	0.778	3.580	-	-	-
25.3.87	Autumn		16	0.375	2.561	-	-	-
9.4.87	Autumn		12	0.727	4.025*	-	-	-
	Autumn & Winter	Long grazing period	-	-	-	-	-	-
25.8.87	Winter		11	1.167	1.123	61	1.400	0.950
8.9.87	Spring		12	0.600	0.050	41	2.050	12.073***
22.9.87	Spring		53	1.452	3.607	152	1.957	5.452*
6.10.87	Spring		73	1.447	24.476***	542	1.188	92.474***
20.10.87	Spring		40	1.833	0.109	124	1.268	0.487
	Spring	Grazing	-	-	-	-	-	-
16.12.87	Summer		7	1.250	0.590	-	-	-
30.12.87	Summer		-	-	-	-	-	-
	Summer	Grazing	-	-	-	-	-	-
9.2.88	Summer		-	-	-	-	-	-
22.2.88	Summer		-	-	-	-	-	-
	Autumn & Winter	Long grazing period	-	-	-	-	-	-
14.7.88	Winter		15	1.091	2.736	80	1.213	0.318
27.7.88	Winter		13	0.727	1.244	302	0.714	1.636
10.8.88	Winter		68	0.979	1.247	305	1.590	0.321
25.8.88	Winter		19	0.933	3.217	678	0.754	2.613
8.9.88	Spring		68	1.415	6.270*	1.532	1.680	1.240
21.9.88	Spring		142	1.124	9.142**	1.711	1.247	6.550*

* Significant at 5% level of confidence.
** Significant at 1% level of confidence.
*** Significant at 0.1% level of confidence.

Table 3. Seasonal effects on stable instar distributions of lucerne aphids in WL 318 lucerne stand (Mallow, Campania) and Hunter River lucerne stand (Flexmore, Penna), 1986-1989.

Season	Campania(W1318)		Penna (Hunter River)			
	BGA		BGA		PA	
	X^2	df	X^2	df	X^2	df
Spring	371.365***	16	134.840***	9	247.431***	10
Summer	17.735	10	0.910	1	12.941	7
Autumn	22.578	10	-	-	10.166	3
Winter	1.583	1	5.838	5	9.567	5

*** Significant at 0.1% level of confidence.

5. References

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