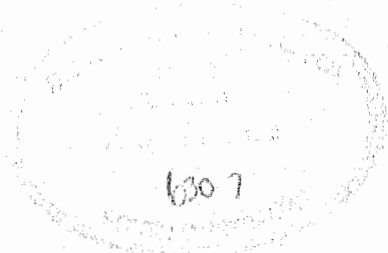


DEPARTMENT OF AGRICULTURE AND FISHERIES, SOUTH AUSTRALIA

Agronomy Branch Report

A SURVEY OF THE LITERATURE ON THE BLUE-GREEN APHID

Acyrtosiphon kondoi SHINJI



by

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1. ORIGINS, DISTRIBUTION AND SPREAD

The blue-green aphid (BGA), *Acyrtosiphon kondoi* Shinji originated in Asia (Dickson, 1975; Passlow, 1977; Sharma *et al.* 1975) though the exact location is still unknown. There seems to be some confusion because BGA is very similar in appearance to the closely related species, *Acyrtosiphon caraganae* (Cholodkovsky) and *A. loti* (Theobald), whose range extend much further than that of BGA (Gonzalez *et al.* 1978). Gonzalez *et al.* (1978) believe BGA originated in Central Asia. The most likely areas are in China or Russia, but unfortunately these areas are now closed to investigation.

BGA was first described from Manchuria by Shinji and Kondo in 1938. The original specimens were destroyed in World War II and so it was later re-described by Takahashi in 1965. It has since been described by Eastop in 1971.

The present distribution of BGA is from Iran (the most westerly locality) to Afghanistan, Japan, India, United States, New Zealand and Australia. Gonzalez *et al.* (1978) are of the opinion that it will continue to spread west across Europe and Northern Africa wherever the host plants occur.

In Japan BGA is found on all three main islands (Gonzalez pers. comm.) and flourishes on cultivated lucerne under a wide range of climatic conditions. In spring it is the most common aphid on lucerne (Dickson, 1975).

BGA was found in India in 1974 (David & Ghorpade, 1974). It is also widespread in the United States. It was first found in Arizona in February 1975 and by late 1975 was well established in all the major lucerne growing areas of that state (Nielson and Kodet, 1975). In California it was first collected in 1974 but was not identified until March 1975 when an outbreak occurred (Sharma *et al.* 1976). It was soon generally distributed throughout California from the southern hot, desert valleys (Imperial County) northwards, including the cool mountain areas (Kono, 1975). BGA has also been found in Utah, Nevada, (Nielson *et al.* 1976), Nebraska, Oregon, (Anon. 1977 (b) and (c)) and Kansas (Anon. 1976) as well as in Mexico and in Argentina (Gonzalez *et al.* 1978).

The first recording of BGA in New Zealand was in October 1975 (Cox, 1976; Cox and Dale, 1977). It spread rapidly throughout the north island and in 1976-77 was a major pest of lucerne in the Marlborough, Nelson and Canterbury districts in the south island (Batey and Trought, 1977; Cox, 1976). It is now widespread in the south island (Batey and Trought, 1977).

BGA was first discovered in Australia in Queensland in May 1977 (Anon., 1977 (a); Passlow, 1977). Later it was found in New South Wales and by September had been recorded in Victoria (G. Berg and P. Ridland, pers. comm.). The first recordings in South Australia were from Loxton in November 1977 but it was not recorded elsewhere in the state until April 1978 (Cordingley, in preparation). BGA was first recorded in Tasmania late in 1977 (Anon., 1978) and within 6 months had spread to all lucerne growing areas in that state (R. Brieze - Stegeman, pers. comm.).

2. IMPORTANCE

Considerable losses in lucerne production have been attributed to damage by BGA in the United States, New Zealand and Australia.

In the United States, Sharma *et al.* (1975) claim that complete harvests have been lost. In New Zealand losses in hay production have ranged from 25% at Canterbury over 1976-77 to 85% at Nelson (Batey and Trought 1977). In one study in the north island, production losses ranged from 16% to 62% (Gaynor *et al.* 1978). Losses under grazing management have been as high as 20% (Batey and Trought, 1977) and Kain *et al.* (1976) report a 15% reduction in plant density. In crops such

as white clover there may be up to 20% loss in seed yield if BGA numbers build up on the seed heads (Batey and Trought, 1977). In Australia BGA have significantly affected production of both lucerne and other pasture legumes in almost all areas (Turner and Franzmann, 1978).

The economic threshold levels for damage to crops by BGA are unknown (Henderson, 1977) and opinions differ as to the level of infestation before control is necessary. However according to Summers (1975(a)) there are indications that BGA is capable of causing damage at lower population levels than those normally considered to be an economic infestation of an aphid. Recommendations to spray range from a mean number of 0.25 aphids/plant (Wynn-Williams and Burnett, 1977) to greater than 5 per stem (Kain *et al.* 1977) to 10 per stem (Kain, pers. comm.).

3. DAMAGE

The time of aphid attack is very important in determining the amount of damage that occurs. Early infestations have more effect than late because plant growth is reduced and the longer feeding period means more damage. Also, high rates of infestation cause more damage than low rates (Wynn-Williams and Burnett, 1977). Thus damage is a function of both the number of aphids, the length of time they are feeding on the crop (Kain *et al.* 1977) and the time of year when the infestation occurs.

Aphid damage in autumn, winter and spring, when the growth of BGA populations is rapid and the growth of lucerne slow, can lead to high losses in production (Gaynor *et al.* 1978; Kain *et al.* 1976; Kain *et al.* 1977; Wynn-Williams and Burnett, 1977). Damage occurring in summer is less severe because aphid numbers are usually low and the lucerne growth rate rapid. Thus lucerne is most susceptible to attack in the period when it is least productive. Damage in early autumn can be carried through into late autumn and to the following winter and spring with a loss of production of up to 72% in late autumn, 47% in winter and 27% in the following spring (Kain *et al.* 1977).

Damage by BGA is first apparent as circular patches of yellow, wilting plants scattered throughout the crop. Another sign of aphid presence is the white masses of shed aphid skins which remain adhering to the plant, sometimes giving the impression of a much higher level of aphid infestation than is actually present (Cox, 1976).

Damage to individual plants causes retarded growth, characterized by small, misshapen leaves and short internodes. Chlorosis and leaf curling are also common symptoms. In severe cases premature leaf drop occurs (Clarke, 1976; Nielson and Kodet, 1975; Sharma *et al.* 1976; Wynn-Williams and Burnett, 1977). On seedling lucerne even low populations of aphids cause twisted foliage, stunting and eventually death of the plants (Batey and Trought, 1977). Observations also suggest that root growth in damaged plants is reduced in proportion to top growth (Wynn-Williams and Burnett, 1977). Reduced root growth means reduced nitrogen fixation and reduced nutrient uptake (Gaynor *et al.* 1978).

Many of the above symptoms, such as short internodes, yellowing and deformed and misshapen leaves suggest that the aphid may inject a toxin into the plant during feeding (Clarke, 1976; Dickson, 1975; Lehman *et al.* 1975; Sharma, 1978; Sharma *et al.* 1975; Summers, 1975(a); Dunbier *et al.* 1977). Sharma *et al.* (1975) state that a virus may also be involved. Feeding damage by BGA or damage by the toxin seems to affect cell expansion much more than cell division and differentiation because affected plants do not increase in height (Wynn-Williams and Burnett, 1977).

4. HOST RANGE

The main host plant of BGA is lucerne, *Medicago sativa*, but it also attacks annual medics, clovers and a variety of other legumes (Higushi and Miyazaki, 1969; Eastop, 1971; Dickson, 1975). A list of the known host plants is given in Appendix 1.

There are differences of opinion as to which are the "preferred" hosts. Sharma *et al.*, (1975) claim lucerne is preferred. Miyazaki (in Dickson, 1975) states that BGA prefers lucerne to white clover, *Trifolium repens* and white clover to red clover, *T. pratense*. Nielson and Kodet (1975) state BGA prefers other legumes to lucerne.

5. BIOLOGY

The most comprehensive studies on the biology of BGA have been done by Henderson (1977). The discussion below is based on his work unless otherwise acknowledged.

There are four nymphal instars + the adult stage. First and second instars can be distinguished from each other by the cornicles, which are blunter in the first instar, and by the relative lengths of the antennae which often do not reach the proximal end of the cornicles in the first instar but extend almost to the distal end in the second instar. Second and third instar apterae can be separated by the presence of an additional antennal segment in the third instar. Third and fourth instars can be distinguished by antennal segments III and IV which are of similar length in the third instar but in the fourth instar, segment IV is longer than III.

Alatae and apterae can be distinguished as early as the third instar because the wing buds (although internal at this stage) are visible as bulges in the dorsal region of the thorax.

No sexual morphs have been found. Reproduction is by parthenogenic viviparous females.

The development of BGA on lucerne can be summarized as follows. Henderson (1977) says that Hughes (1977) states that the lower threshold of development is approximately 4°C. However the existence of this reference is in doubt. Milne (pers. comm.) gives the lower threshold for development on lentils as approximately 5°C.

There is some confusion as to the upper threshold, Clarke (1976) states it as being 32°C while Lowe (pers. comm.) gives it as being around 24°C. Present studies (Cordingley, in preparation) have shown that development still occurs at 33°C. Probably BGA can withstand much higher temperatures provided it is not subject to water stress (Henderson, 1977). It is also able to develop in areas where there are frosts (Kain, pers. comm.). In general the rate of development increases with temperature, with optimum development occurring at 18°C (Clarke, 1976; Cox, 1976; Summers, 1975(b)).

Henderson (1977) gives the duration of development in terms of day-degrees. He states that, assuming fourth instar development takes 1.2 times the average time for the first three instars, then fourth instar apterae will have an instar duration of 65.75 day-degrees and the duration of first, second and third instars will be 58.83, 54.13 and 51.75 day-degrees respectively. Taking the pre-reproductive period of the adult as 24 hours at 23°C, the generation time (i.e. birth → birth) is 253 day-degrees.

Longevity decreases with increase in temperature. Maximum longevity at 7.2°C is 124 days (mean 68 days) while the maximum at 27°C is 13 days (mean 5 days) (Summers, 1975 (b)).

Fecundity increases with temperature up to 25°C (15°C according to Summers, 1975 (b)), then decreases (Clarke, 1976). The optimum temperature for reproduction is 15-21°C. Summers (1975(b)) states there is no reproduction above 27°C.

Alatae are smaller and less fecund than apterae (Henderson, 1977). At 20°C Hughes and Snowball (pers. comm.) state up to 4 young are produced/female/day while Cox (1976) states 12 or more are produced/female/day.

The biology of BGA on annual medics is summarized below (from Pearson, 1976).

Hosts ¹⁾	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Pre-reproductive Period ²⁾	7	7	8	8	7
Reproductive Period ²⁾	21	27	12	18	24
Post-reproductive Period ²⁾	3	3	0	2	8
rm/female/female/day)	.274	.232	.048	.196	.263
Ro (female/female/generation)	48.4	29.2	2.0	18.5	39.2
Generation Time ²⁾	14.2	14.5	13.8	14.9	14.0
Doubling Time ²⁾	2.53	2.98	14.28	3.53	2.64

1) Hosts:	1 <i>M. tormata</i>	cv	Tornafield
	2 <i>M. littoralis</i>	cv	Harbinger
	3 <i>M. rugosa</i>	cv	Paragosa
	4 <i>M. truncatula</i>	cv	Hannaford
	5 <i>M. polymorpha</i>	cv	Vulgaris

2) In Days.

rm = intrinsic rate of increase.

Henderson (1977) divides the BGA population cycle up into five phases:

- (1) Initial build up
- (2) rapid increase in numbers
- (3) maximum abundance
- (4) decrease
- (5) low numbers until next build up.

His studies indicate that populations can develop at almost any time (see later). The differences in numbers at different sites at any one time i.e. high numbers in one area and very low numbers close by, may simply be due to the two populations being at different stages in the population cycle. The occurrence of population cycles is not limited by weather conditions but weather does have an effect on the maximum size of the cycles.

An experienced observer can estimate the approximate age of a BGA colony by noting the position of the colony on the plant and the distribution of aphids in the colony. Young developing colonies are found on the growing tips of the lucerne plant. As the colony grows it extends further down the main stem and at maximum size the upper part of the stem is encrusted with aphids. As the population cycle continues, numbers decline, the inter-aphid distance increases and the aphids become less concentrated on the main growing tip and more dispersed over the plant. The size of the aphids decreases as the colony ages and the number of alates produced increases. This is a "spontaneous" decline (Henderson, 1977; Richardson, 1977).

Spontaneous declines are partly due to interactions between aphids. They can be independent of predators, parasites, fungi and weather conditions. They are also partly due to a decline in plant condition and/or some mechanism by which the aphid anticipates the plant condition declining. Low numbers between cycles are also partly due to poor plant condition. Poor plant condition leads to a decrease in numbers because the fecundity and reproductive rates decline and increasing numbers of alates are produced. (The rate of population decline is slower in winter than in spring). Wynn-Williams and Burnett (1977) state that aphid numbers increase according to the amount of plant material available i.e. population growth is closely tied in with the growth cycle of lucerne.

In New Zealand there are two main periods of high population numbers - one in winter and one in spring. The apparent difference in maximum size between winter and spring populations is due to the higher growth rate of the population in spring. This may reflect the fact that lucerne grows faster in spring and can therefore sustain population growth for a longer period of time. The rate of population growth slows as the winter peak is reached and could indicate that climate and plant condition become limiting factors.

BGA numbers can build up very quickly (from 10-500/shoot in a few weeks (Batey and Trought, 1977)), because:-

- (1) reproduction is parthenogenic i.e. fertilization is unnecessary.
- (2) nymphs are born live.

(Cox, 1976). Numbers can range from less than 10/stem to well over 80/stem (McClellan and Weinberger, 1977). For example in New Zealand, at Rangiora the spring peak in population numbers was 222 aphids/stem and that in the following autumn 57/stem (Thomas, 1977).

Crop management practices, such as grazing and cutting considerably reduce numbers (Henderson, 1978).

BGA, supposedly a "cool-weather" aphid, is present in greatest numbers in autumn, winter and spring (i.e. April to December in the southern hemisphere). (Batey and Trought, 1977; Summers, 1975(a)). However as stated earlier it can be found in lucerne all year round and can build up to high numbers at any time (Richardson, 1977), though in general numbers are very low in summer (Nielson and Kodet, 1975; Summers, 1975(a)).

Both Henderson (1977) and Richardson (1977) have evidence to show that high temperatures do not control BGA populations. For example in one area in New Zealand the peak in BGA numbers coincided with a peak in summer temperatures and in winter, population numbers increased while the temperature decreased. Thus the pattern of population cycles is not determined by either low or high temperatures alone. Henderson (1977) noted that increases in population numbers continued up to maximum when daily maximum temperatures were within the range 18.6-21°C. (The population expanded most rapidly when the average maximum temperature was 15.7°C). After this, numbers declined. In general Henderson's findings agree with those of Richardson (1977) that there is no strong correlation between BGA numbers and weather conditions although there are geographical differences in early spring and late autumn.

There is also no clear correlation between aphid flight and weather. Peak flights occur in spring and autumn (with numbers higher in spring). These flights correspond to peaks in population numbers and coincide with decreases in the number of aphids on the plant.

There is evidence to suggest that alates are produced as the aphid population density on the plants increases (see Henderson, 1977). In general, unwinged forms (apterae) occur when conditions are favourable and winged forms (alatae) occur in adverse conditions e.g. weakening of the food plant or over-crowding (Cox, 1976). Population increase declines prior to wing formation which suggests fecundity is reduced either with density or with plant condition. The variation in numbers of aphids/stem suggests plant condition is the most likely factor in causing reduced fecundity (Hughes and Snowball, pers. comm.).

6. PARASITES

The literature concerning the parasites of BGA is limited mainly because BGA has only recently been recognized as a pest (it first reached pest status in the United States in 1975 (Sharma *et al.* 1976)). However there is a considerable amount of literature on some of the species as parasites of other aphids. A list of the known and potential parasites of BGA is given in Appendix 2. Many of these will attack BGA in the laboratory but their effectiveness in the field has yet to be investigated. Most are also parasites of the closely related pea aphid, *Acyrtosiphon pisum* and may prefer this species as a host. For example, Gonzalez *et al.* (1975) evaluated *Aphidius ervi* and *A. smithi* as parasites of BGA and found that while both readily attack BGA, they also readily attack the pea aphid.

Gonzalez *et al.* (pers. comm.) conducted a search for BGA parasites in Japan. They found only four: *Aphidius ervi*, *A. gifuensis*, *Ephedrus nacheri* and *Praon dorsale*. They found however, that *A. gifuensis* from Japan would not parasitize the American forms of BGA which indicated that the American forms differed racially from the Japanese. Laboratory rearings of *Ephedrus nacheri* on BGA were very successful indicating a well established relationship between these two species. (*A. gifuensis* is a main parasite of *Myzus persicae*. *E. nacheri* and *Praon dorsale* are both polyphagous parasites (Gonzalez *et al.*, pers. comm.)).

Gonzalez *et al.* (1978) conducted a survey for BGA and its parasites in areas of Afghanistan, Belgium, Czechoslovakia, Greece, Iran, Israel and Maroc where *Medicago* sp. were cultivated. Their aim was to collect parasites from different geographical areas and evaluate their effectiveness in controlling BGA in different climatic zones in California. They collected *A. ervi* from 14 areas, *A. urticae* from 10 areas, *Praon barbatum* from 5 areas, *A. smithi* from 4 areas and another *Aphidius* sp. (near *pisivorus*). *A. ervi* was the most abundant and widely distributed parasite. It was found in various climatic areas, from high plateaus to coastal and desert regions. *A. urticae* was less abundant and less widely distributed than *A. ervi*. *P. barbatum* and *A. smithi* were present only in relatively few areas.

In laboratory trials, Gonzalez *et al.* (1978) found that *A. ervi* and *P. barbatum* readily parasitized and reproduced on BGA (grown on lentils) but that *A. smithi* and *A. urticae* oviposited but did not complete development on BGA. They concluded that *A. ervi* had the greatest potential for the biological control of BGA in California.

Several species of parasites have been introduced into New Zealand to control BGA. These are:

Aphidius ervi
A. smithi
A. urticae
Ephedrus plagiator
Praon barbatum

As in California, *A. smithi* and *A. urticae* did not develop on BGA (Cameron *et al.* 1978). The situation in New Zealand is complicated by the fact that these parasites all parasitize the pea aphid, which is present in New Zealand. Thus it is difficult to establish the success of the parasites in becoming established on, and reducing the numbers of BGA.

In New Zealand a native parasite, *Aphelinus* sp. (? *semiflavus*) was found to parasitize BGA (Thomas, 1977; Cameron *et al.* 1978). Henderson (1977, 1978) found it present in glasshouse cultures but it has seldom been recorded in the field.

Parasites of BGA were first introduced into Australia in October 1977. These were:

Ephedrus plagiator (Japanese strain)
Aphidius ervi (Japanese strain)
A. smithi (from California).

A. smithi did not parasitize BGA here although in California it did under laboratory conditions (Snowball and Lukins, pers. comm.). The other two species have been released in Queensland, New South Wales, Victoria, Tasmania and South Australia but there has been no evidence of their establishment (Forrester, Snowball and Lukins, pers. comm.).

In Tasmania, a naturalized Aphidid parasite, later identified as *Aphidius ervi*, was found. It has since been discovered in a number of areas in low numbers (Brieze - Stegeman, pers. comm.).

7. PREDATORS

Predators of BGA include ladybirds, lacewings, syrphid larvae, nabid bugs, hoverflies, midges, mites and spiders (Cox, 1976; McClellan and Weinberger, 1977; Kain *et al.* 1976; Henderson, 1977). A list is given in Appendix 3.

Ladybirds, (*Coccinellidae*) are particularly important predators because although their rate of reproduction is much slower than that of the aphid, the larvae are very voracious (Cox, 1976). For example, prey consumption trials in New Zealand with *Harmonia dimidiata*, *Coccinella septempunctata* and *C. undecimpunctata* gave the following results:

	No. of BGA eaten	
	given 100	given 200
<i>H. dimidiata</i>		
adults (pairs)	74-96	112-157
3rd & 4th instar larvae	91-100	142-200
<i>C. septempunctata</i>		
adults (pairs)	60-98	-
<i>C. undecimpunctata</i>		
adults (pairs)	30-32	-

(from Thomas, 1977)

H. dimidiata, from Pakistan, has great potential as a predator of BGA. It can survive in the field for 18 months or more. However it is polyphagous and hibernates in conifers in winter (Thomas, 1977). Thus the closeness of hibernation sites would be important in the establishment of this species. Similarly *Coccinella undecimpunctata* requires conifers for hibernation sites. Of the many predator species imported into New Zealand, only *H. dimidiata* and

C. septempunctata show promise of becoming established. The Australian ladybirds, *Coelophora inequalis* and *Platyomus lividigaster* were introduced into New Zealand accidentally but have become established there (Thomas, 1977).

Even though some predators are quite common e.g. *Micromus tasmaniae* in New Zealand and *C. repanda* in Australia, the general opinion is that predators alone have little hope in controlling aphid population numbers because predator numbers usually lag behind those of the aphids i.e. there are too few predators present early in the development of aphid populations to prevent outbreaks occurring. In some cases the predator does not appear until aphid numbers are past their peak (Henderson, 1978). However predators are important as part of an integrated control system.

8. DISEASE

Several species of *Entomophthora* fungi have been found infecting BGA in the United States (Clarke, 1976), New Zealand (Thomas, 1977) and Australia. Turner and Franzmann (1978) mention three species attacking BGA in New Zealand: *E. planchoniana*, *E. thaxteriana* and *E. virulenta*. These had significant effects on aphid populations in winter and spring.

Henderson (1977, 1978) mentions that the highest incidence of fungus attack by *E. planchoniana* occurred about the time of the aphid population peak but this did not prevent a buildup of aphids. The critical aphid density required for the fungus to spread occurred just before the crash in population numbers when the aphid density was already above the economic threshold.

In Australia six species of *Entomophthora* have been found attacking BGA (Milner, pers. comm.). These are:

- E. aphidis*
- E. nr. exitialis*
- E. virulenta*
- E. ignobilis*
- E. sphaerosperma*
- E. planchoniana*

Of these *E. nr. exitialis* and *E. ignobilis* are the most common. A 40-90% kill is reported to have occurred in wet conditions in the Hunter Valley of New South Wales (Walters, pers. comm.).

9. CHEMICAL CONTROL

Batey and Trought (1977) state that in general if aphid numbers are 5-10/shoot then some form of control is necessary.

A summary of insecticides used in trials for the control of BGA, the application rates and general remarks about effectiveness is given in appendix 4. Studies in the U.S.A. (Sharma *et al.* 1976) and in New Zealand (Kain *et al.* 1976; Sharpe and MacDiarmid, 1976) have shown that BGA is easily killed by most insecticides, although some give better control than others and for a longer period of time. Initially it seems there are no differences in control between contact and systemic insecticides but in the long term, systemic insecticides are less effective (Kain *et al.* 1976). East *et al.* (1977) state that while it was possible to control BGA with granular applications of systemic insecticides, much higher application rates were necessary than with foliar sprays to achieve the same amount of control. Crop height appears to be an important factor in the effectiveness of insecticides (Kain *et al.* 1976).

Despite the ease with which BGA is killed by insecticides, the re-infestation rate is often very rapid, particularly when alates are present (Kain *et al.*, 1976; Trought, 1977).

It is difficult to assess which is the most effective insecticide overall because different workers have used different insecticides in their trials and different rates of application. The results of some of the trials are as follows. Kain *et al.* (1976) compared pirimicarb, carbofuran, methomyl, permethrin, mevinphos, chlorpyrifos, diazinon and thiometon. They found that 7 days after application all the insecticides gave good control irrespective of the type of insecticide (i.e. contact or systemic) and rate of application. After 14 days only permethrin gave good control. After 28 days the insecticides had no effect. They concluded that permethrin maintained significantly lower aphid numbers than carbofuran and diazinon, 14 and 28 days after application. They also claimed excellent control in trials with maldison, mevinphos, chlorpyrifos, demeton-s-methyl and thiometon.

East *et al.* (1977) state that all rates of thiometon gave better control than maldison or chlorpyrifos 6, 17 and 24 days after application.

Sharma *et al.* (1975) state that of mevinphos, methidathion, methomyl, maldison, carbofuran and diazinon, the last three gave the highest kill and provided control for a longer period of time than the others.

East *et al.* (1977) showed that it was possible to control BGA with lower rates of insecticides than previously reported. They state that while almost all the chemicals they tested (appendix 5) gave good initial knockdown, cypermethrin, thiometon, demeton-s-methyl, pirimicarb, omethoate, dicrotophos, acephate and dimethoate reduced numbers and gave control for longer periods than the other insecticides.

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APPENDIX 1.HOST PLANTS OF A. kondoi

- Aeschynomene falcata* (o)
Astragalus cicer (j) (l)
A. hamosus (l) (d)
A. mexicanus (j)
A. pomonensis (b) (locoweed)
A. rubyi (j)
Caragana arborescens (g) (j)
C. decorticans (j)
Centrosema pubescens (o)
Coronilla varia (l) (Crown vetch)
Desmodium heterophyllum (o)
D. intortum (o)
D. uncinatum (o)
Dorycnium sp. (b)
Glycine wightii (o)
Hedysarum coronarium (c) (French honeysuckle)
Lens culinaris (i) (Lentils)
L. esculenta (g)
Lespedeza (f) (bush clover)
L. stipulacea (o)
L. striata (o)
Leucaena leucocephala (o)
Lotononis bainesii (o)
Lotus arabicus (j)
L. corniculatus (b) (f) (g) (j) (l) (bird's foot trefoil)
L. pedunculatus (l)
L. scoparius (b) (deer weed)
Lupinus sp. (c)

Macroptilium atropurpureum (n) (o) (d)
M. lathyroides (o)
Macrotyloma uniflorum (o)
Medicago sp. (Annual medics) (a) (k) (d)
Medicago sativa (b) (f) (j) (Lucerne)
Melilotus hispida (f) (burr clover)
M. indicus (b) (sour clover)
M. officinalis (e) (f)
Onobrychis vicifolia (h) (l)
Ornithopus compressus (n) (d)
O. sativus (l)
Pueraria phaseoloides (o)
Stylosanthes guyanensis (o)
S. hamata (o)
S. humilis (o)
S. scabra (o)
Tephrosia virginiana (f) (goat's rue-vetch)
Trifolium sp. (c) (l) (d)
Trifolium hybridum (f)
T. incarnatum (f) (l) (Italian or crimson clover)
T. pratense (b) (f) (red clover)
T. repens (b) (e) (f) (m) (white clover)
T. semipilosum (o)
Trigonella foenum-graecum (c) (fenugreek)
Vicia atropurpurea (l) (purple Vetch)
V. dasycarpa (l) (n) (d)
V. sativa (l)
Vigna hosei (o)
V. luteola (o)

- a = Anon (1977, (a))
- b = Dickson (1975)
- c = Fletcher & Wilson (pers. comm.).
- d = Franzmann *et al.* (1979)
- e = Gonzalez *et al.* (1975)
- f = Gonzalez *et al.* (pers. comm.).
- g = Gonzalez *et al.* (1978)
- h = Henderson (1977)
- i = Milne (pers. comm.)
- j = Nielson and Kodet (1975)
- k = Passlow (1977)
- l = Taylor (pers. comm.)
- m = Trought (1977)
- n = Turner & Franzmann (1978)
- o = Turner & Ostrowski (pers. comm.)

APPENDIX 2.

PARASITES OF *A. kondoi*

- * *Aphelinus* spp. (a) (f) (g) (h)
- * *Aphidius ervi* (a) (b) (c) (d) (e)
- * *A. gifuensis* (d)
- A. nigrips* (c)
- A. picipes* (c)
- * *A. spp.* (near *pisivorus*) (e)
- A. pulcher* (c)
- A. rosae* (c)
- * *A. smithi* (c) (e)
- * *A. urticae* (a) (e)
- Binodoxys angelicae angelicae* (c)
- Ephedrus californicus* (c)
- * *E. nacheri* (d)
- * *E. plagiator*(a)
- Monoctonus paulensis* (c)
- Praon aguti* (c)
- * *P. barbatum* (a) (e) (h)
- * *P. dorsale* (d)
- P. occidentale* (c)
- P. pequodorum* (c)
- P. simulans* (c)
- Toxares detiger* (c)

- * = known definitely to parasitize BGA (at least in the laboratory)
- a = Cameron et al, (1978)
- b = Clarke (1976)
- c = Gonzalez et al. (1975)
- d = Gonzalez et al. (pers. comm.).

- e = Gonzalez et al. (1978)
- f = Henderson (1977)
- g = Henderson (1978)
- h = Thomas (1977)

APPENDIX 3.PREDATORS OF A. kondoiCOCCINELLIDAE

- Adalia bipunctata* (e) (j)
- x *Cleobora mellyi* (a)
- Coccinella arcuata* (l)
- C. leonina*(j)
- * *C. punctata* (h)
- x *C. repanda* (a) (l)
- * *C. septempunctata* (j)
- x * *C. undecimpunctata* (b) (c) (d) (e) (f) (j)
- + *Coelophora inequalis* (j)
- x *Diomus notescens* (a) (g)
- * *Harmonia dimidiata* (b) (j)
- Hippodamia convergens* (j)
- x *Leis conformis* (a) (g)
- * *Oenopia sauzeti* (j)
- + *Platyomus lividigaster* (j)
- x *Verania frenata* (a)

SYRPHIDAE

- Melanostoma fasciatum* (e) (b) (d) (j)
- Melangyna novaezealandiae*(d) (e) (j)
- x *M. vividiceps* (g)
- * *Scaeva pyrastris*(j)
- Simosyrphus grandicornis* (k)
- Sphaerophoria* sp. (k)
- x * *Syrphus* spp. (j)
- * *S. confrater* (j)

CHAMAEMYIIDAE

- * *Leucopis nigricornis* (j)
- * *L. obscura* (j)
- * *L. puncticornis* (j)

CECIDOMYIIDAE (j)CHRYSOPIDAE

- * *Chrysopa carnea* (j)
- x *C. signata* (k)

HEMEROBIIDAE

- Boriomyia maorica* (d) (e)
- Drepanacra binocula* (j)
- * x *Micromus tasmaniae* (b) (d) (e) (f) (h) (j)

NABIDAE

- Nabis capsiformis* (j)
- N. conformis* (l)
- N. maoricus* (d)
- x *N. tasmanicus* (k)

PENTATOMIDAE

- Oechalia schellenbergii* (l)

MIRIDAE

- Creotiader dilutus* (l)

PHALANGIIDAE

- Phalangium opilio* (j)

MITES

- Anystis baccharum* (d) (e)
- * = introduced into New Zealand
- + = Australian species accidentally introduced into New Zealand
- x = species occurring in Australia.

- a = Brieze-Stegeman (pers. comm.)
- b = Cameron *et al.* (1978)
- c = Cox (1976)
- d = Henderson (1977)
- e = Henderson (1978)
- f = Kain *et al.* (1976)
- g = Ridland & Berg (pers. comm.)
- h = Rohitha (1977)
- i = Summers (1975 (b))
- j = Thomas (1977)
- k = Ting, Swincer and Walden (pers. comm.)
- l = Turner and Franzmann (1978)

APPENDIX 4.INSECTICIDES FOR CONTROL OF BGA

Chemical	Rate kg/ha	Remarks	Ref.
Acephate	0.125	good control up to 4 weeks	a, b.
	0.375	excellent control for at least 6 weeks	c
azinphos-ethyl	0.44	not effective at this rate	g
bromophos	0.28-0.4	good control over 7 days. For flowering crops with bees at risk	a, m
carbøfuran	0.25-0.75	good control but may affect parasites and predators	c, e
chlorpyrifos	0.05-0.4	good control.	a, c, f, g, l
cypemethrin	0.025	good control for up to 4 weeks	c
demeton-s-methyl	0.125-0.75	good control for 4-6 weeks. 0.75 is recommended rate in New Zealand	a, c, g, n
diazinon	0.5-0.8	good control for up to 21 days at the lower rate	g, j, k, l
dichlorvos	0.42	good initial control but rapid buildup after 5 days. For flowering crops with bees at risk.	m
dicrotophos	0.125	good control for short periods	c
disulfoton	1.00	good control for up to 6 weeks on seedling lucerne when sown with cover crop. Not good on established lucerne	g, i
ethiophencarb	0.50	specific to aphids but slow action and excessive phytotoxicity	g

Chemical	Rate kg/ha	Remarks	Ref.
fenitrothion	0.3	good control for short periods	c
Furadan	0.55	good control	j, k
Malathion	0.15-0.75	poor results	c, e
(Maldison)	1.75	good control (but not at lower rates)	j, i
methamidophos	0.60	good control	g
methomyl	0.125-0.55	good control	c, j, k
mevinphos	0.125	good control for short periods	c
omethoate	0.15-0.58	good control (for up to 3 weeks at lower rate). Not phytotoxic	c, g
oxamyl	0.125	good control for short periods	c
parathion	0.40	good control for short periods	c
pennacp	0.43	good control	j, k
permethrin	0.25-0.75	better control than pirimicarb or carbofuran	e
phosdrin	0.20	good control	j, k
pirimicarb	0.05-0.25	gives up to 5 weeks control at lower rates. Better control with rates of 0.1 kg/ha and above	a, c e, h
prothiophos	0.50	not effective at this rate	g
quinalphos	0.3	rate too low for effectiveness after 39 days	g
Supracide	0.55	good control	j, k

Chemical	Rate kg/ha	Remarks	Ref
thiometon	0.1-0.5	excellent control	a, b, c
	0.375	recommended rate in New Zealand	d, e, n

- a = Batey and Trought (1977)
b = Cliffe (1977)
c = East et al. (1977)
d = Kain (1977)
e = Kain et al. (1976)
f = Kain et al. (1977)
g = More (1977)
h = O'Connor and Hart (1977)
i = Palmer (1977)
j = Sharma et al. (1976)
k = Sharma et al. (1977)
l = Sharpe and MacDiarmid (1976)
m = Trought (1977)
n = Turner and Franzmann (1978)

APPENDIX 5INSECTICIDES TESTED BY EAST *et al.* (1977) FOR CONTROL OF BGA

acephate
carbofuran
chlorpyrifos
cypermethrin
demeton-s-methyl
diazinon
dicrotophos
dimethoate
fenitrothion
maldison
methomyl
mevinphos
omethoate
oxamyl
parathion
permethrin
pirimicarb
thiometon