Biological Control of Leaf-roller on Wine Grapes in Gisborne

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Executive summary

The biological control of leafroller was studied in four Gisborne vineyards. Leafroller were well controlled by two species of wasp in the unsprayed vineyard and the two vineyards that had received a spring application of Tokuthion/oil for mealy bug control. The beneficial wasp species appeared to have been destroyed in the vineyard sprayed with Lorsban in January. Leafrollers were able to complete development in this vineyard free from the attentions of the wasps. Gisborne grape-growers should monitor their vines in autumn and make the decision to spray or not to spray in spring for mealybug control based on the results of this examination.
The wasp species most useful in effecting control of the leafroller were *Dolichogenida tasmanica* and *Goniozus jacintae.* *Glyptapanteles demeter* was of dubious value and no contribution was seen from *Ancistrocerus gazella.*
Further evidence was collected showing that large outbreaks of disease were independent of the presence of leafrollers.

Introduction

The New Zealand Wine industry has set a direction toward environmentally friendly production of wine with the adoption of the phrase that its products are the "riches of a clean, green land". The Integrated Wine-grape Program (IWP) makes maximum use of non-chemical control systems such as leaf-plucking to reduce the use of fungicides. IWP seeks to replace the remaining chemical sprays with products of low toxicity and/or natural origin or with bio-control systems.
This project seeks to measure the contribution that beneficial wasp species can make toward the biological control of leafrollers on wine-grapes in Gisborne. Initial results have suggested that this contribution may be substantial.
Accurate association of disease with its cause is also important. A TBG program hosted by the Millton organic vineyard provided information that leafrollers were not the prime cause of Sour rot and Botrytis infections. More data on this relationship was sought.

Material and Methods

Four vineyards were selected for study during the 1999/2000 growing season. The vineyards taking part in this research included a vineyard that planned to make no use of insecticidal sprays and three that were to make sparing use if necessary. Vineyard A had not used insecticides for the past 5 seasons. Vineyards B and D had made early season use of Tokuthion/Oil for mealybug control (18th September for vineyard B and 21st September and 5th October for vineyard D). Vineyard C had used Lorsban for the same pest on 30th January. No insecticides targeted for leafrollers were used in the experimental vineyards in the current season.

Vineyards A and B were located on the "Golden Slope" along the Back Ormond road. The blocks selected contained Muller Thurgau (rows 24-48 in vineyard A and 3-35 in vineyard B) and Mendoza Chardonnay (rows 95-127 in vineyard A and 49-81 in vineyard B). Vineyard C was inland and vineyard D was coastal. Rows 15-31 (Merlot) and 39-87 (Clone 15) were selected for study in vineyard C. Blauberger grapes (right-hand rows 4-36 and left-hand rows 36-44) and Cabernet sauvignon (rows 12-28) were measured in Vineyard D.

A total of 30 vines in each vineyard were examined on the 3-4th December 1999, 19-20th January 2000, 16-18th February and 23-25th March. The sample was stratified, with a vine in the mid-third and two end-thirds of each row. Sample rows were separated by seven un-sampled rows.

The sample included all life stages of leafroller(eggs, caterpillars, pupae and pupal exuviae and adult moths). Empty leaf shelters and empty excavations were counted as a measure of the insects activity. The activity measure is a record of the recent behavior of the caterpillars. The silken constructions on the leaf and the silk-ways in the bunches remain available for collection for some time. Caterpillars are a more fleeting part of the vine ecology, being removed by parasitiods, predators, birds and lost by being dislodged by strong winds and rain. Parasitiod cocoons were collected and noted whether empty or full.

Collected caterpillars were placed in plastic tubes part-filled with artificial diet. The end was tightly plugged with cotton wool and the tubes placed in a cool place in the laboratory. The tube was labeled with the date of collection, the row number and the place of collection(bunch, leaf etc.). The tube was examined at one, two and three weeks after collection and the outcome recorded. If a leafroller pupae was produced, the pupae was removed from the tube and placed in a larger vial to allow room for the new moth to spread its wings. Properly expanded wings improved the likelihood of a correct identification. If a parasitiod cocoon was produced, the tube was regularly examined till the adult wasp emerged, then identified and recorded.

Results

All stages of the life of leafrollers were collected. Egg-batches were tightly glued to leaf surfaces. They are blue-green in colour and appear as a small patch of scales on the leaf surface. Once hatched, the silvery appearance of the empty shells was much more easily seen. The caterpillars were found on all parts of the vine. The overlap of the back of a vine leaf, the ridge formed by the central vein on the leaf, touching portions of two adjacent leaves, the bunch of forming leaves at a growing tip all sheltered leafrollers. The presence of a leafroller in a bunch was often signaled by a "raisin". The raisin was a berry with a strongly wrinkled surface. It often retained the usual (green) colour of the berry but could also be brown. The skin was unbroken and the berry firm. When the bunch was dissected, the leafroller had chewed all the green cortical tissue of the berry stalk of the raisin. The reduction of fluid flow to the berry caused the raisin wrinkling. Leafroller spin silk-ways through the area occupied. The silk-way is a silken tube that acts as a pathway for the caterpillar. The tube is held in place with silk strands between the tube and the grape bunch.

All vineyards showed a low level of activity (fig.'s 1-4) with the maximum level of activity between 20-25 records during the growing season from a sample of 30 vines. The

level of activity and the number of caterpillars steadily increase in parallel as the season progresses in Vineyard D (fig.4). Both measures show a stable, low population of leafrollers in Vineyard B (fig.2). The only vineyard that was sprayed with insecticide during the measurements was C (fig. 3). No live leafrollers were collected in February, only dead caterpillars and beneficial wasps were recorded. The activity record drops from a peak in February to very low levels in March. The number of live leafrollers is stable and low in Vineyard A (fig.1). Activity decreases from a peak in January.

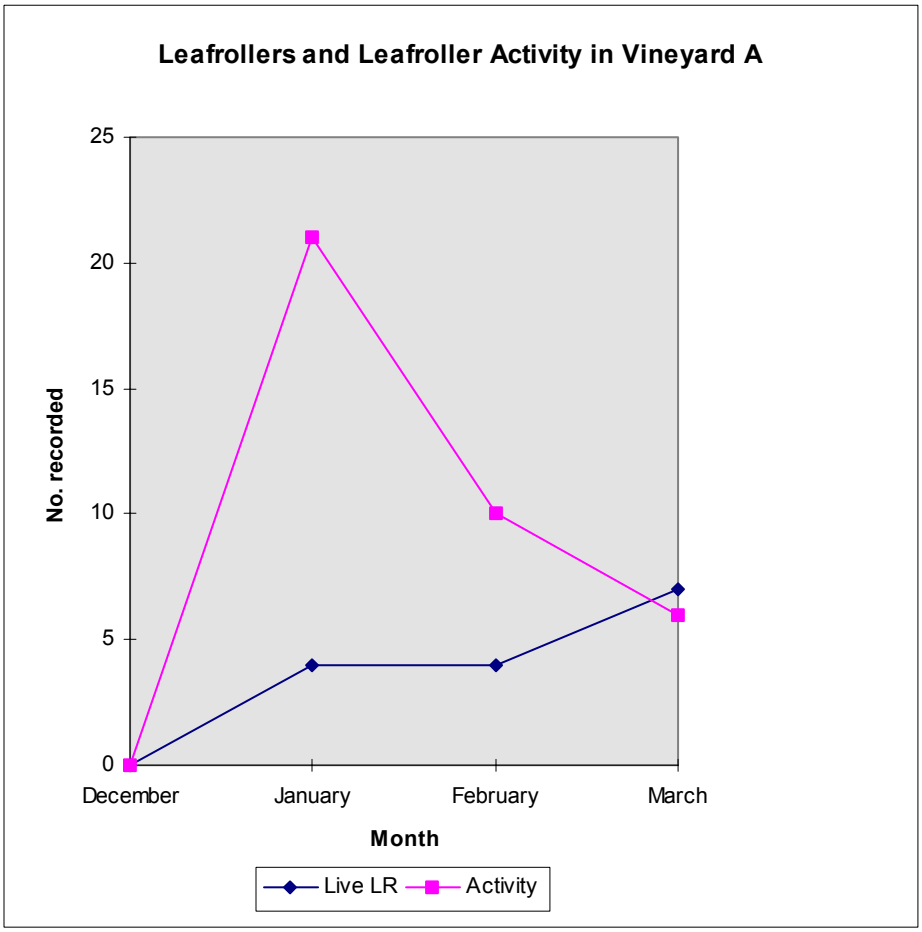

Fig.1 Live leafroller caterpillars were collected from leaves and bunches of 30 vines during 4 monthly samples (December 1999 to March 2000) from Vineyard A. Activity is the sum of empty leaf shelters and empty excavations in grape bunches. All grapes were picked when the last sample was taken so this measure is an underestimate of the activity in March.

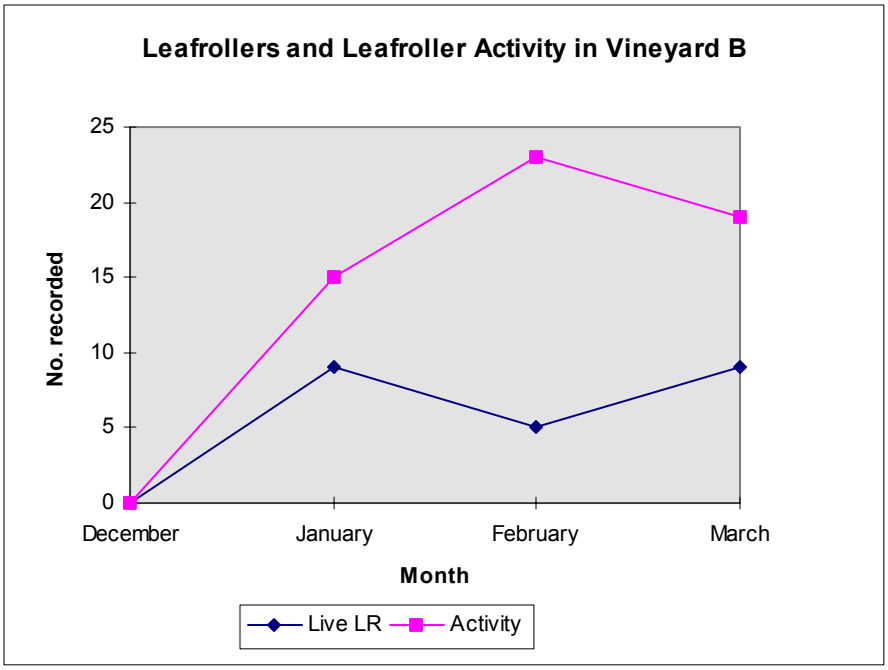

Fig.2 Live leafroller caterpillars were collected from leaves and bunches of 30 vines during 4 monthly samples (December 1999 to March 2000) from Vineyard B. Activity is the sum of empty leaf shelters and empty excavations in grape bunches. All grapes were picked when the last sample was taken so this measure is an underestimate of the activity in March.

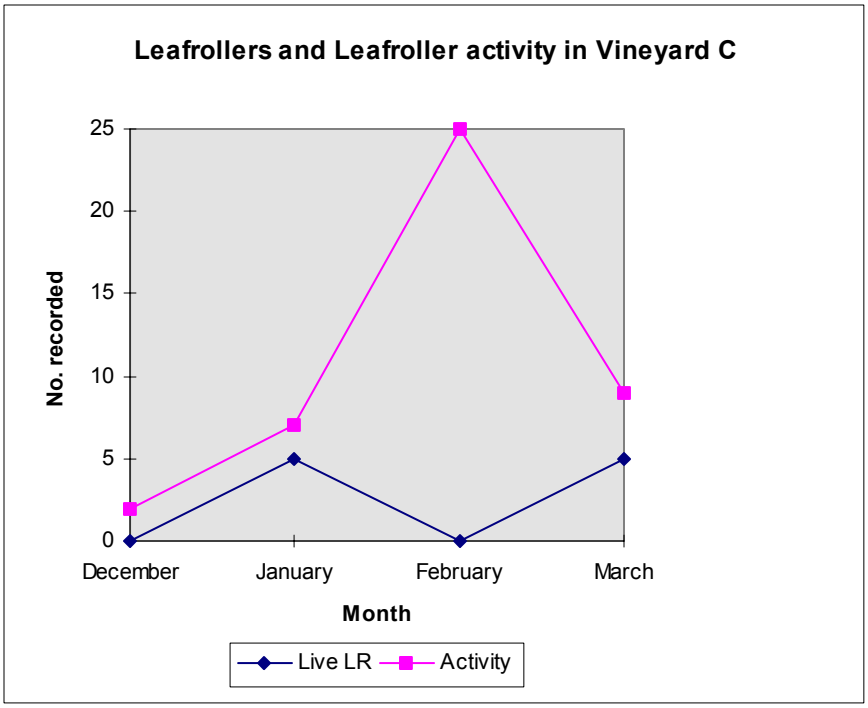

Fig.3 Live leafroller caterpillars were collected from leaves and bunches of 30 vines during 4 monthly samples (December 1999 to March 2000) from Vineyard C. Activity is the sum of empty leaf shelters and empty excavations in grape bunches. The grapes were still present when the last sample was taken so this measure is a good estimate of the activity in March.

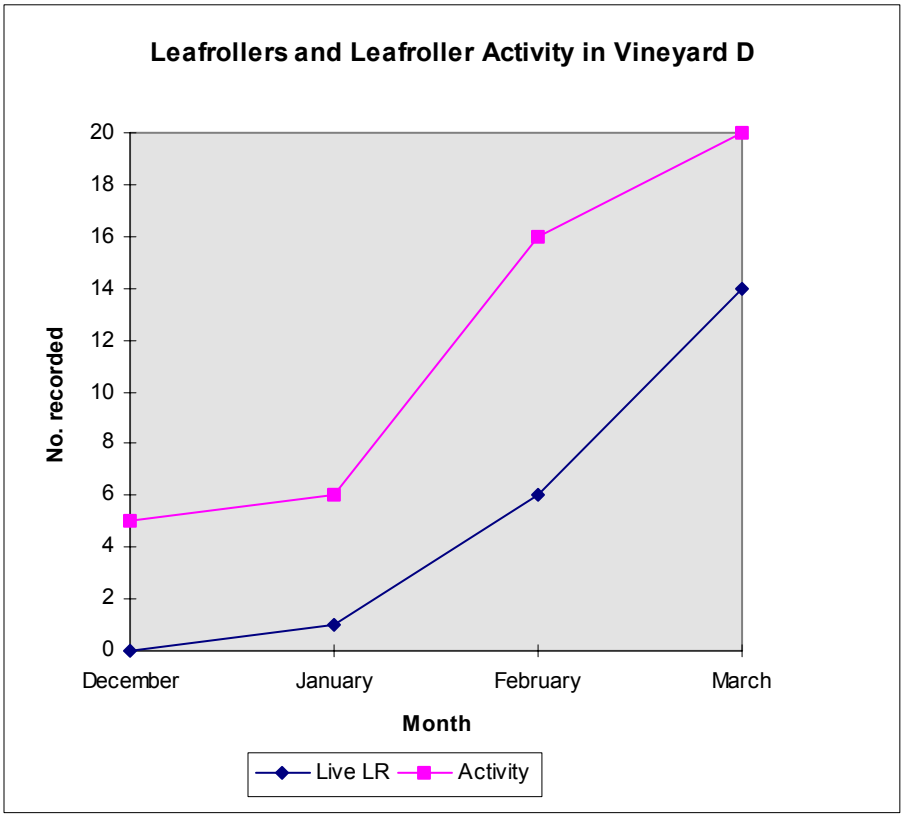

Fig.4 Live leafroller caterpillars were collected from leaves and bunches of 30 vines during 4 monthly samples (December 1999 to March 2000) from Vineyard D. Activity is the sum of empty leaf shelters and empty excavations in grape bunches. Two thirds of the grapes were picked when the last sample was taken so this measure is an underestimate of the activity in March.

Population structure and percentages of different age-classes of the leafroller

Human populations have different proportions of the age classes in different regions. For example human populations north of the Mediterranean sea have larger percentages of older retired people, south of the sea the percentage of younger people is higher. Leafroller populations also show differently structured populations and these differences can provide information on events that have affected the species during the year. All leafroller individuals begin life as a fertilized egg, hatch and feed and grow through a series of moults. The addition of a little more silk weaving transforms the feeding arena into shelter for the pupae. When pupal development is complete, the pupal skin splits to allow the emergence of the adult moth. The shell remaining is known as the exuviae. Pupal exuviae are long lasting, remaining inside the pupal shelters for weeks probably

months. Because of the longevity of the empty shell, the exuviae numbers provide an over-representation of the pupal life-stage. On the other hand, absence of exuviae in a collection from the vines provides good evidence that few individuals make it that far.

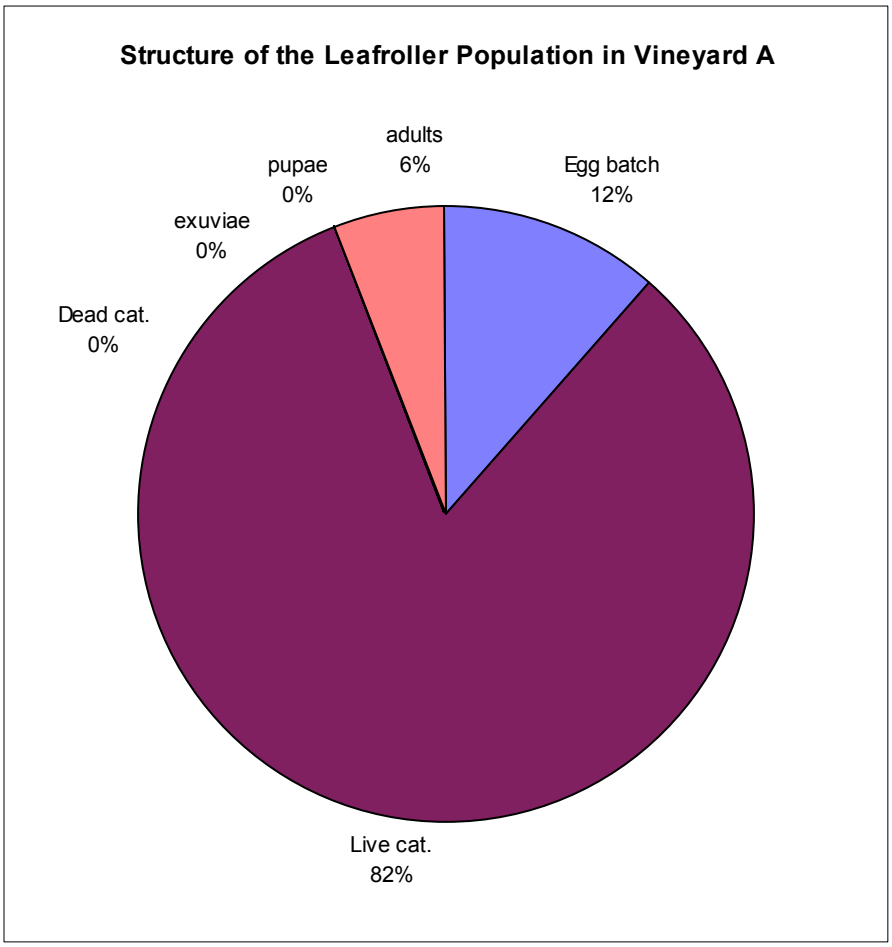

Fig.5 Structure of the leafroller population in Vineyard A. This graph illustrates the proportion of each life-stage of a leaf-rollers existence that was collected from the field. The results from all monthly collections were summed. Early life stages are capitalised, later with lower case letters.

The life stages of the leafroller collected from three of the Vineyards show a very similar structure (fig.'s. 5,6 and 8)……more than 80% of the leafrollers collected are live caterpillars. The only vineyard with dead caterpillars collected is Vineyard C (fig. 7). This vineyard contains many later life stages (pupae and pupal exuviae) that show that wild leafrollers are completing development and emerging as adults.

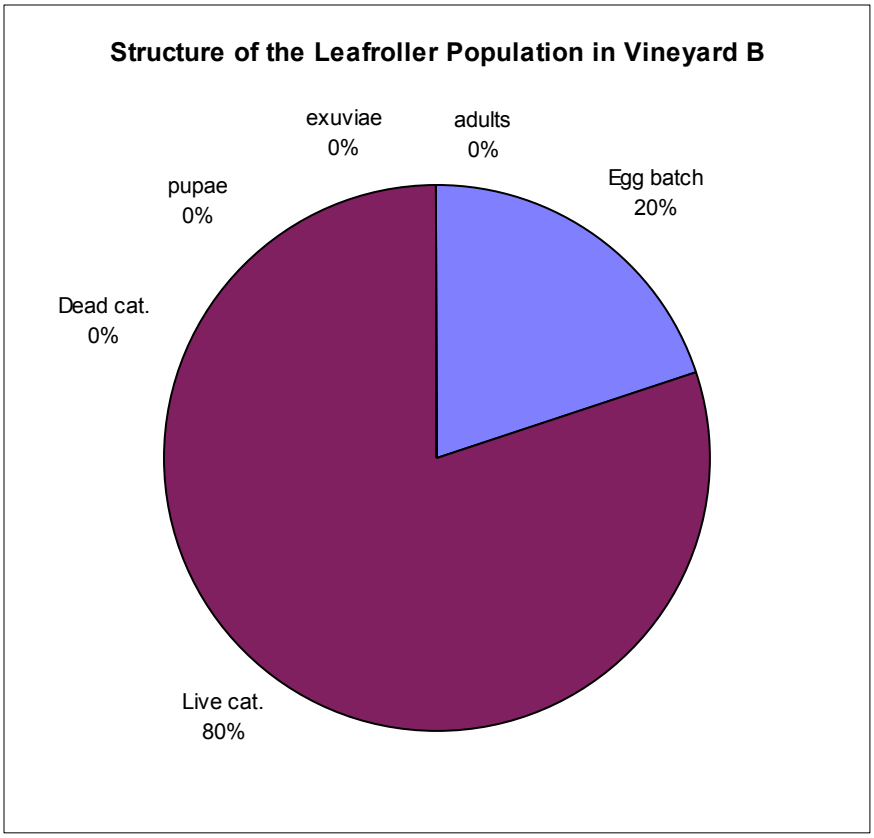

Fig.6 Structure of the leafroller population in Vineyard B. This graph illustrates the proportion of each life-stage of a leaf-rollers existence that was collected from the field. The results from all monthly collections were summed. Early life stages are capitalised, later with lower case letters.

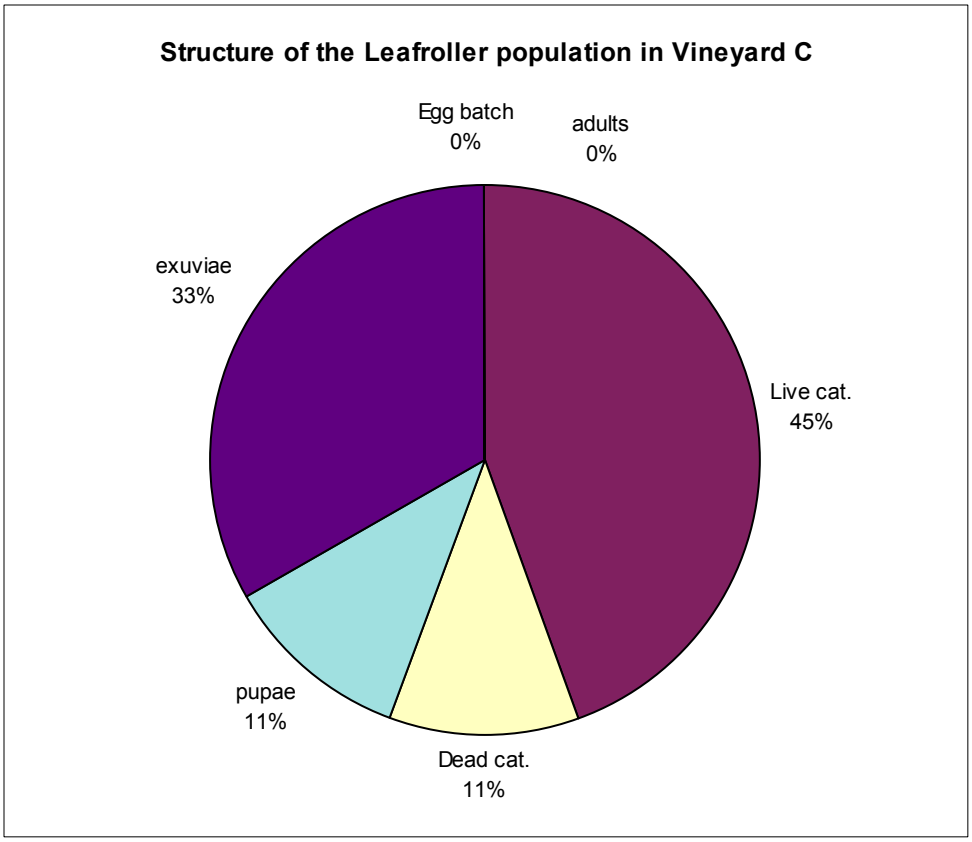

Fig.7 Structure of the leafroller population in Vineyard C. This graph illustrates the proportion of each life-stage of a leaf-rollers existence that was collected from the field. The results from all monthly collections were summed. Early life stages are capitalised, later with lower case letters.

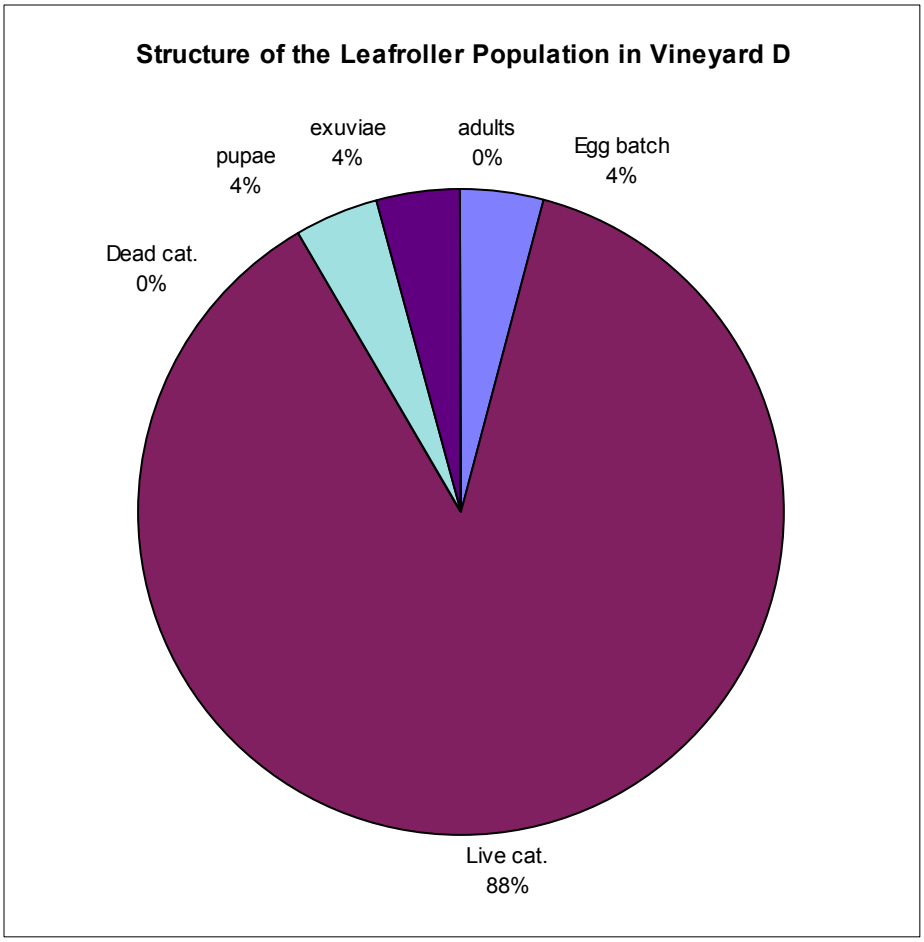

Fig.8 Structure of the leafroller population in Vineyard D. This graph illustrates the proportion of each life-stage of a leaf-rollers existence that was collected from the field. The results from all monthly collections were summed. Early life stages are capitalised, later with lower case letters.

The probability of a collected leafroller caterpillar surviving to adulthood

The likelihood of a leafroller living in a plastic diet tube surviving to become an adult is dependant on the ecology of the vineyard from which it came. Many caterpillars appear to be healthy when collected but have a wasp grub feeding within. These grubs reveal themselves by burrowing through the wall of the caterpillar body and spinning up silken cocoons.

The percentage of the leafrollers collected in January varies greatly between the vineyards, ranging from 0% to 100% (fig. 9). This is in part due to the very small numbers of caterpillars collected in this month. No reared leafrollers succeeded in completing development in February. In Vineyards A, B and D this was because all leafrollers produced a parasitiod (the majority) or died. In vineyard C, all found

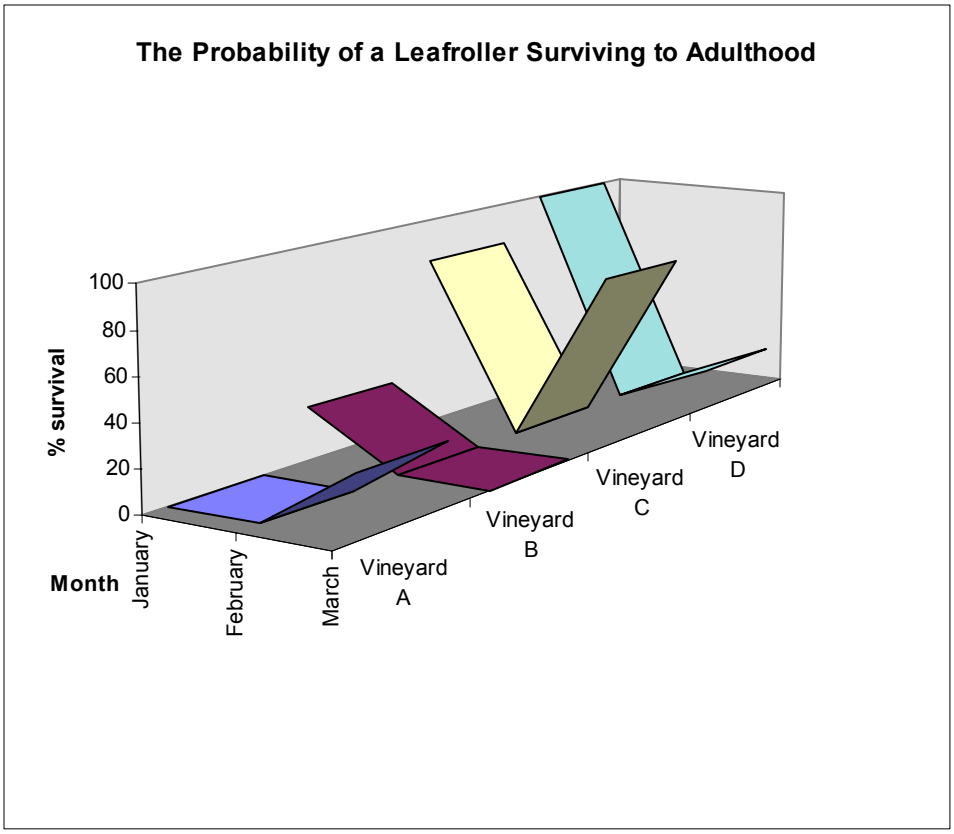

Fig.9 The caterpillars collected from each vineyard were placed on diet and reared until a parasitiod cocoon was produced or a leafroller pupae and adult emerged. The percentage that succeed in emerging as an adult from the diet tubes was taken as an indication of the probability that a wild leafroller would have similarly been successful in living to adulthood on the vines.

leafrollers were dead. No March-collected leafrollers succeeded in Vineyard B. Though numbers of leafroller collected from Vineyard C in March were not large, 80% succeeded in completing development. Lower proportions completed in Vineyards A and D.

Because a leafroller is protected from many dangers within the walls of the diet tube and fed nutritious diet, its chances of living to adulthood in the laboratory are increased. The only leafrollers that emerged from the March collection from Vineyard A were collected as very small, newly hatched second instars. These caterpillars may not have lived in the vineyard A for long enough to attract the attention of the parasitiods. In contrast, several of the leafroller from Vineyard C were collected as pupae, i.e. they had survived wild conditions for most of their lifespan.

Parasitoid Numbers, Increase with Time and Distribution Within the Vineyard

Most of the mortality of the leafroller population is due to the activity of the beneficial wasp population. Two species (*Dolichogenida tasmanica* and *Goniozus jacintae*) were collected from the vineyards A and B as adults and reared from collected caterpillars (fig.

10). *D. tasmanica* is reared in similar numbers from caterpillars collected from leaves as from bunches. *G. jacintae* is only found in bunches in these vineyards. The former species is solitary, producing one new wasp for every caterpillar consumed. The latter species may produce one or more wasps depending on the size of the caterpillar (fig.11).

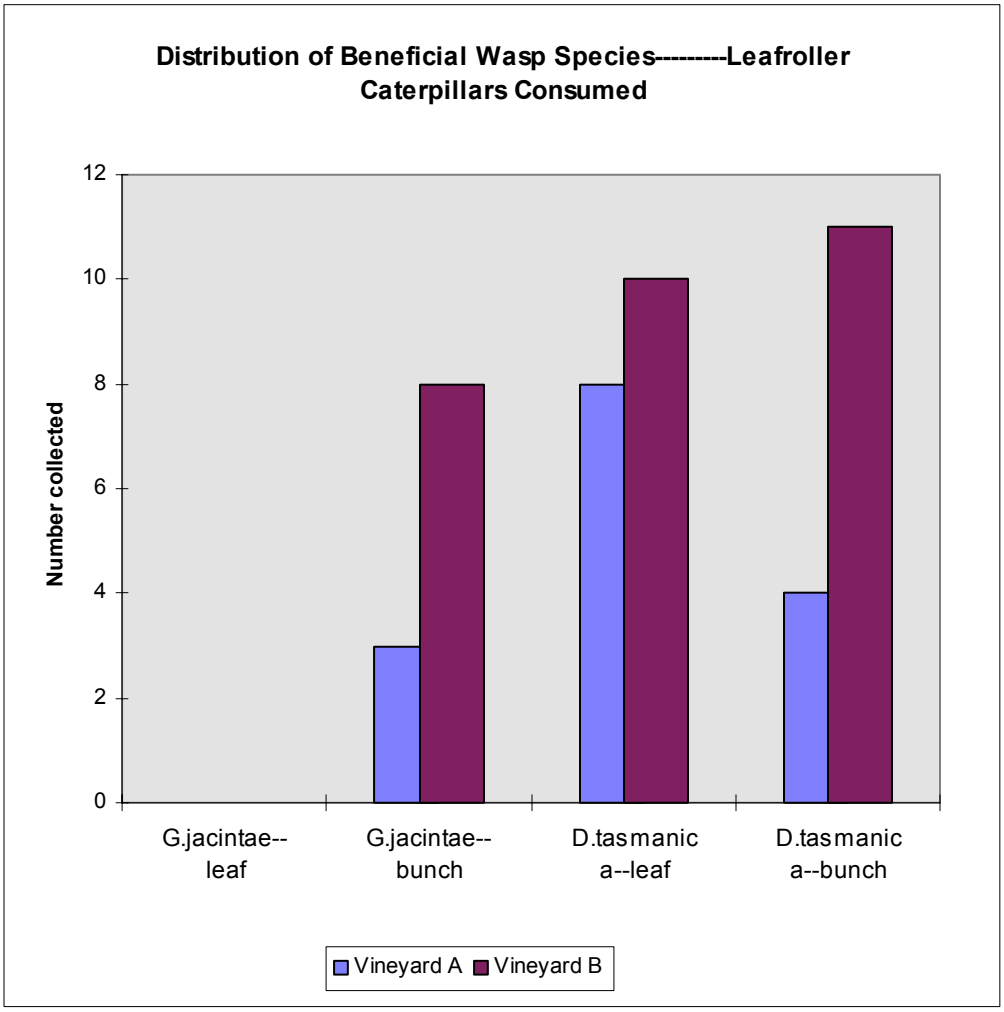

Fig.10 This distribution is made up of field collected wasps and wasp cocoons and wasps that emerged from reared caterpillars collected from vineyards A and B. This graph illustrates the number of caterpillars consumed

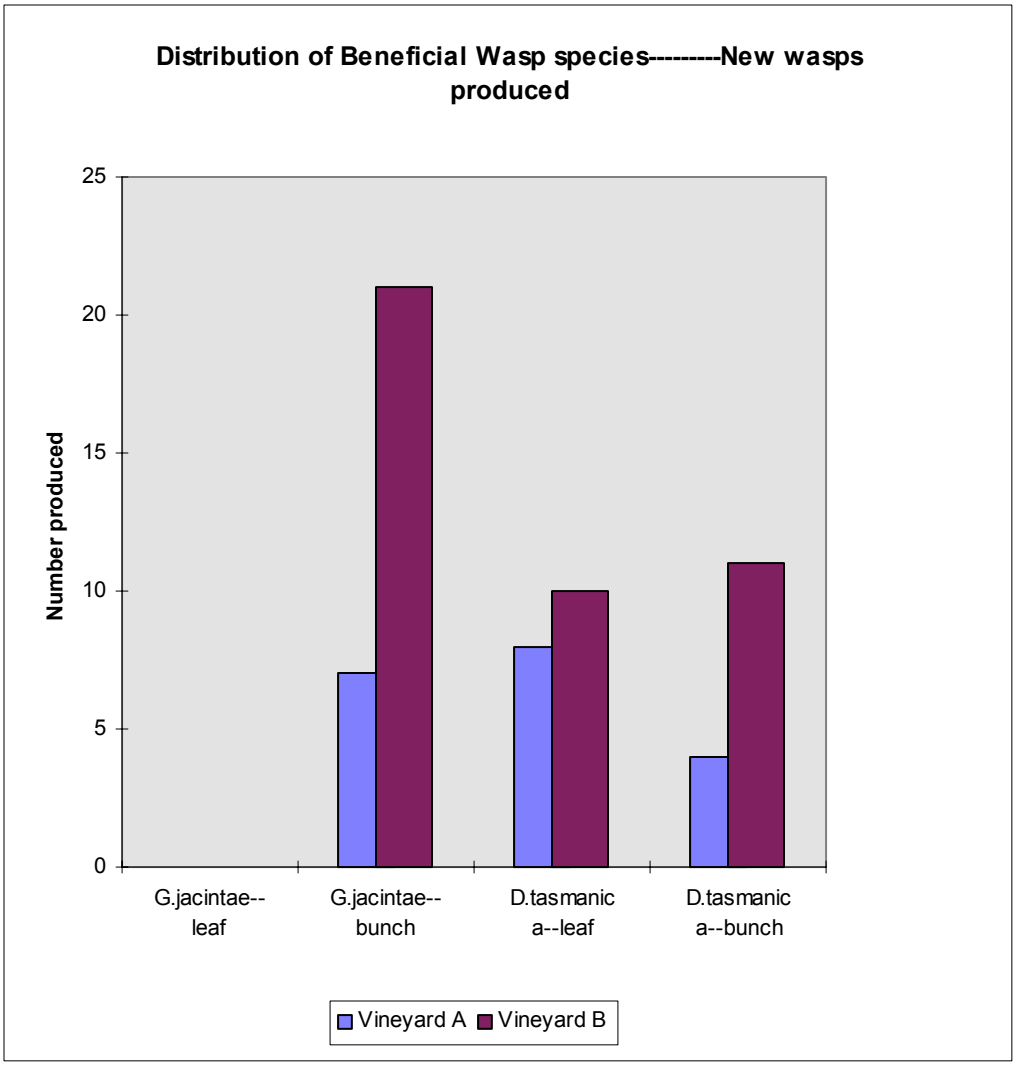

Fig.11 This distribution is made up of field collected wasps and wasp cocoons and wasps that emerged from reared caterpillars collected from vineyards A and B. This graph illustrates the number of new wasps produced.

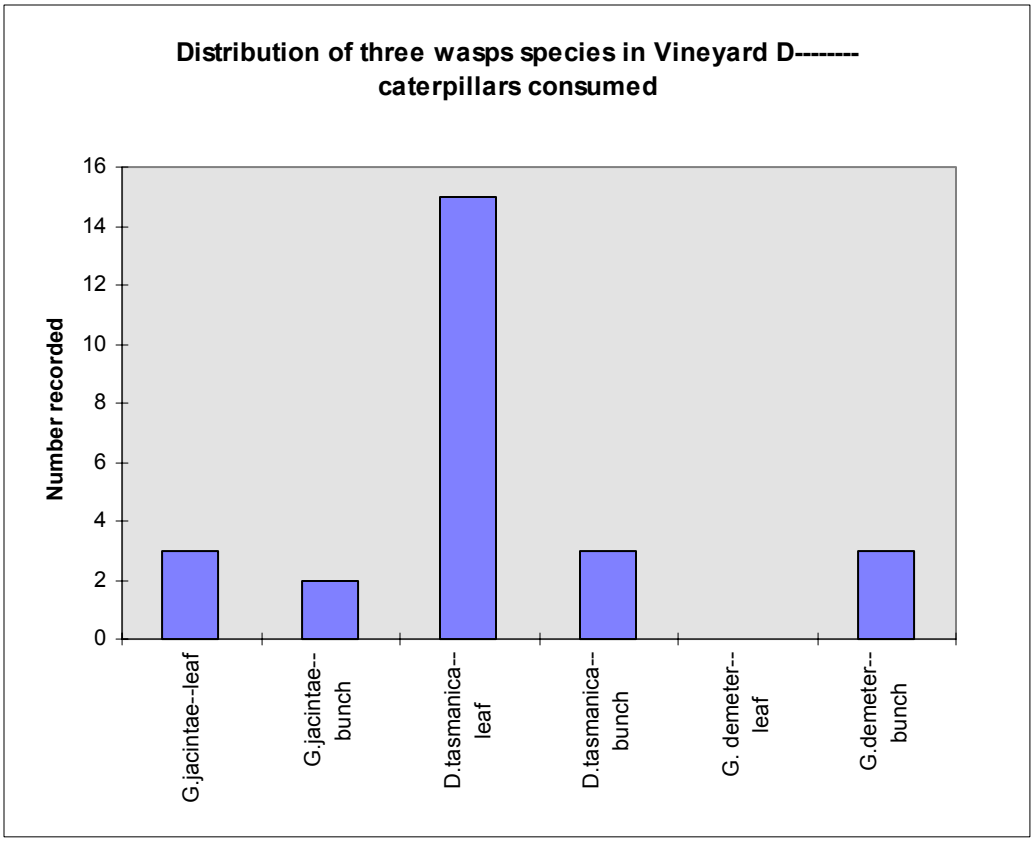

Fig.12 This distribution is made up of field collected wasps and wasp cocoons and wasps that emerged from reared caterpillars collected from vineyard D. This graph illustrates the number of caterpillars consumed.

D. tasmanica is the dominant species on leaves in Vineyard D (fig.12). Small numbers of *D. tasmanica, G. jacintae* and a new species *Glyptapanteles demeter* are found from caterpillars taken from bunches. This new species is a relative of *D. tasmanica* . It largely differs in its ability to produce large numbers of new wasps from a large caterpillar. *G. jacintae* is also found in similar small numbers on the leaves. This behavior differs from that seen in Vineyards A and B.
Insufficient wasps were collected from Vineyard C for the distribution to be worth plotting.

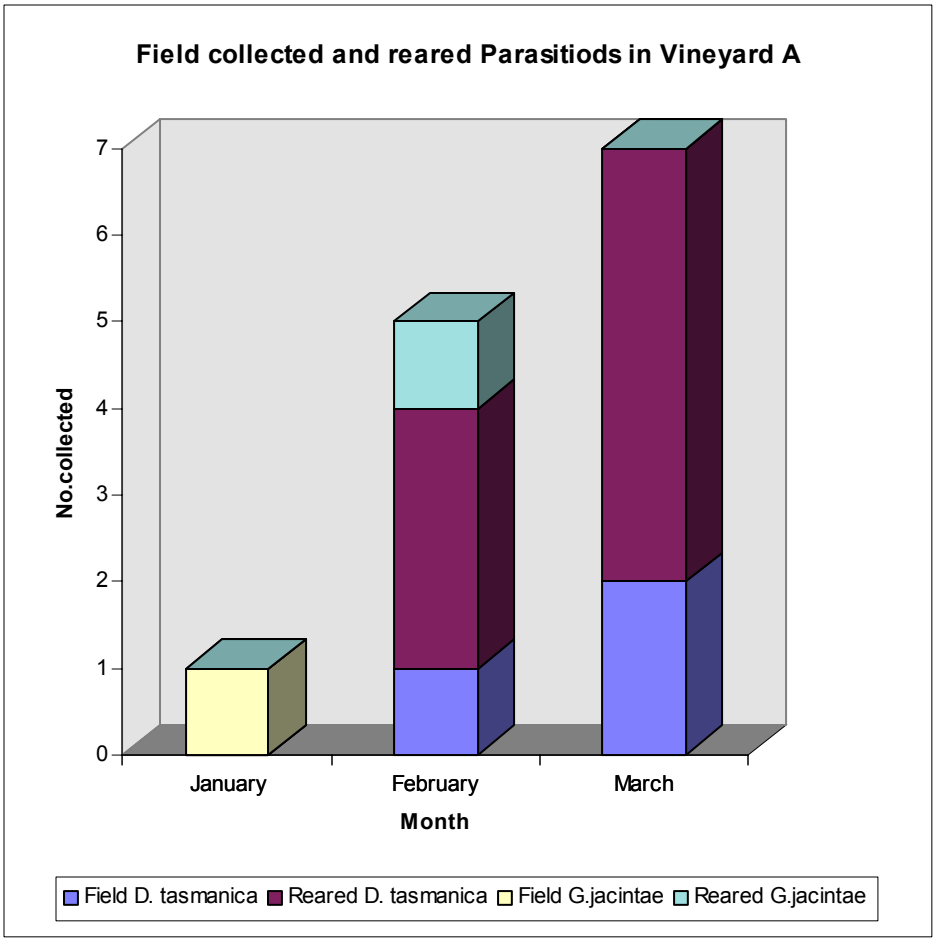

Fig.13. Wasps collected from Vineyard A, either as cocoons from the field or reared from captured caterpillars. This vineyard contains *G. jacintae* and *D. tasmanica.*

The dominant species in vineyard A is *D. tasmanica* making up most of the collection in February and all of March. The reared portion of the population is larger. Numbers of parasitiods increase with time in vineyards A and D (fig.'s 13 and 16) and remain in stable numbers in vineyard B (fig.14). Too few are collected from vineyard C to provide any indication of direction in vineyard C (fig. 15). *D. tasmanica* is the most common species overall.

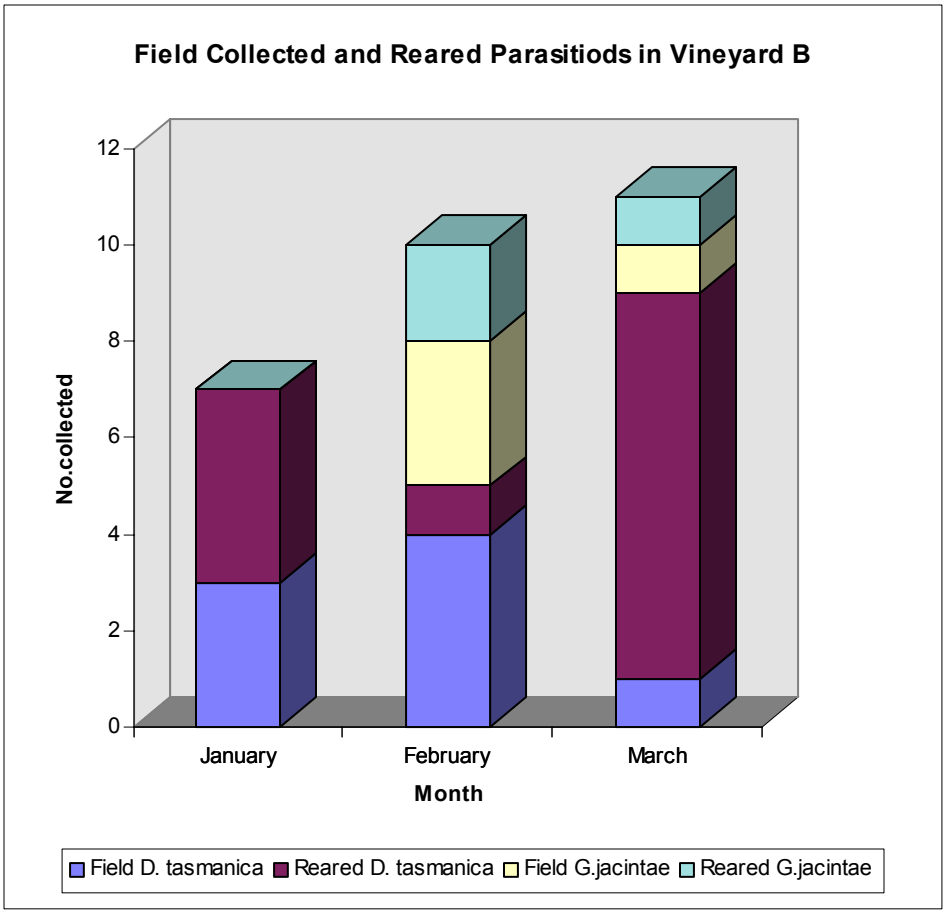

Fig.14. Wasps collected from Vineyard B, either as cocoons from the field or reared from captured caterpillars. This vineyard contains *G. jacintae* and *D. tasmanica*

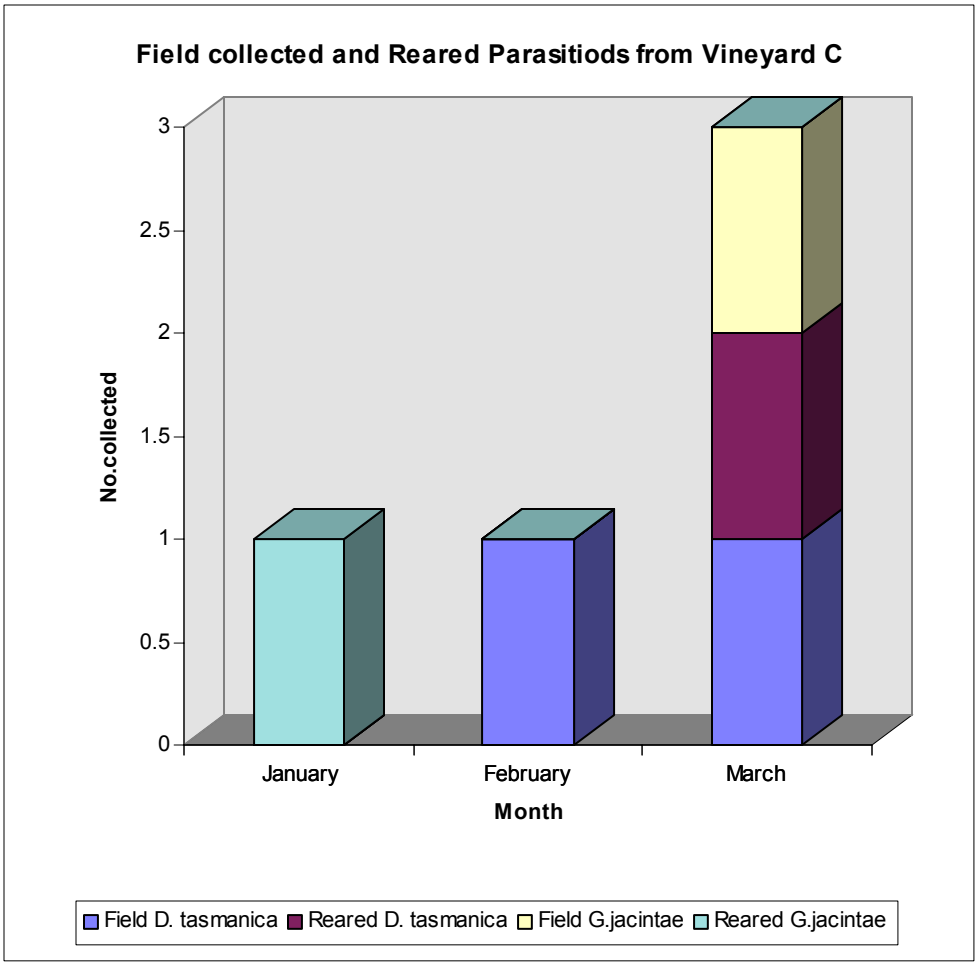

Fig.15. Wasps collected from Vineyard C, either as cocoons from the field or reared from captured caterpillars. This vineyard contains *G. jacintae* and *D. tasmanica*

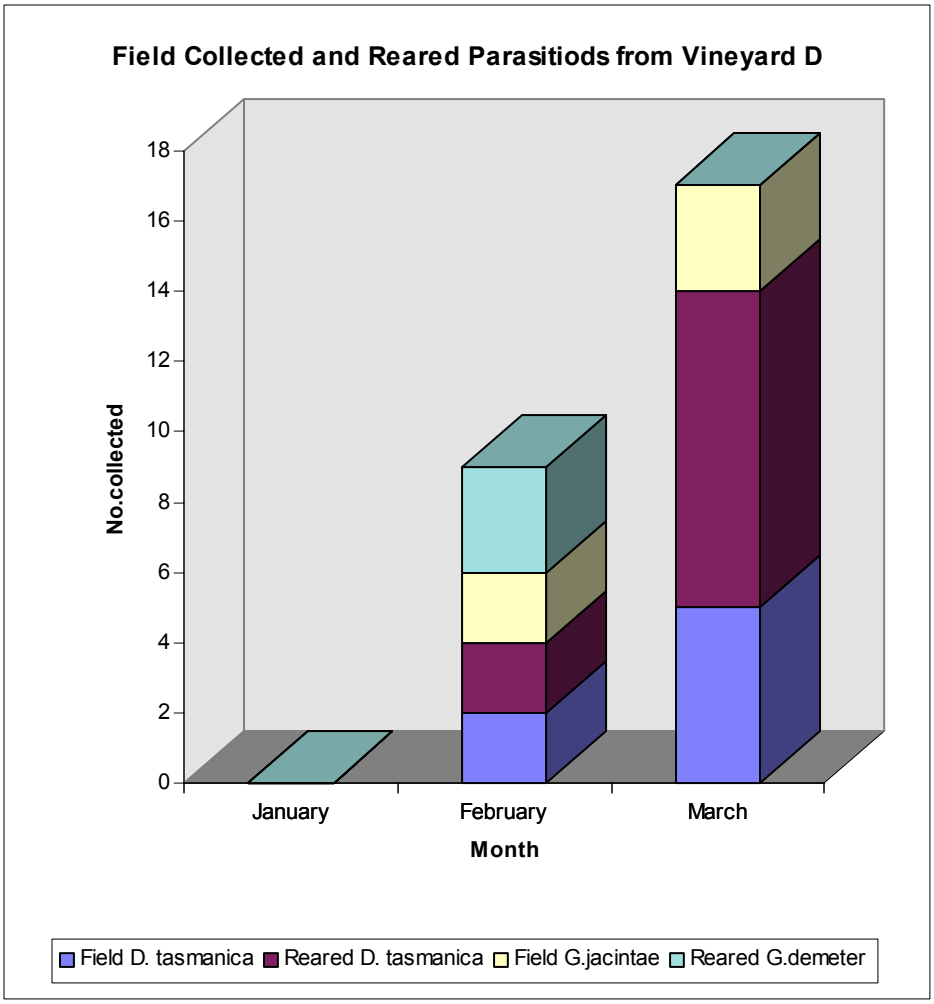

Fig.16. Wasps collected from Vineyard D, either as cocoons from the field or reared from captured caterpillars. This vineyard contains *G. jacintae, Gl. demeter* and *D. tasmanica.*
No filled cells were found in the "Hotels" in either of the two vineyards that contained them. No activity of any kind was observed from *Ancistrocerus gazella.*

Impact of the leafrollers on the grapes.
Very little evidence of Sour rot or Botrytis was found in vineyard A in January (fig.17). The excavations found in grape bunches were all clean and dry. The caterpillars appear to prefer to eat the green cortical layers of the stems of the grape bunch. Where they had fed on the berry, the surface of the berry had healed and was covered with hard brown scar tissue. Twenty per cent of the leafrollers in this vineyard were found in association with Botrytis infested berries in February. This was a small loss, two bunches with Botrytis from 30 vines.

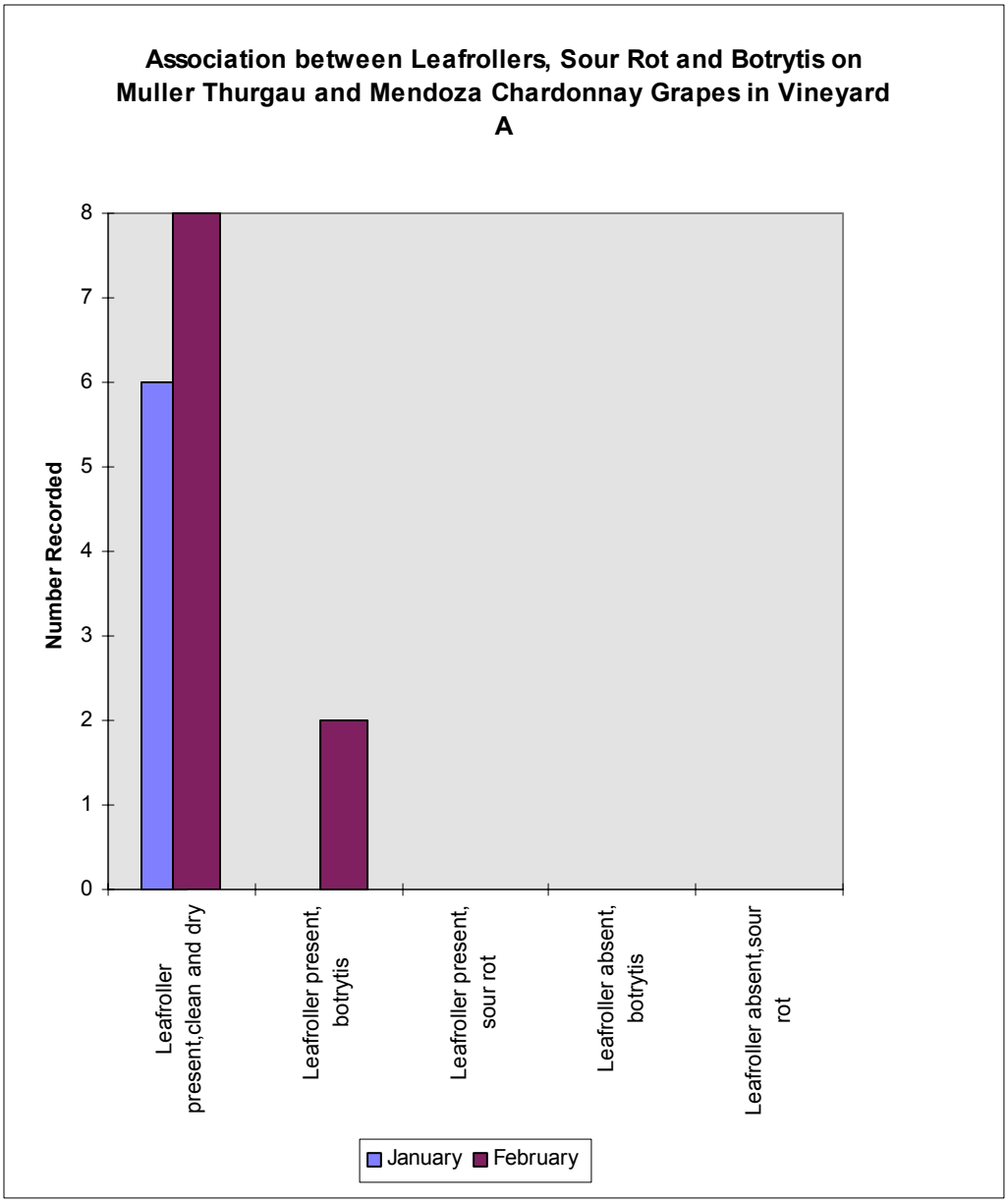

Fig.17 All the bunches from 30 vines were sampled from Vineyard A in December, January and February. All the bunches had been harvested when the March sample was made. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

The same two varieties in vineyard B produced somewhat different results (fig.'s 18 and 19). More leafroller activity and more Botrytis were found in the Muller Thurgau grapes (note the different Y-axis scale in these two fig.s).

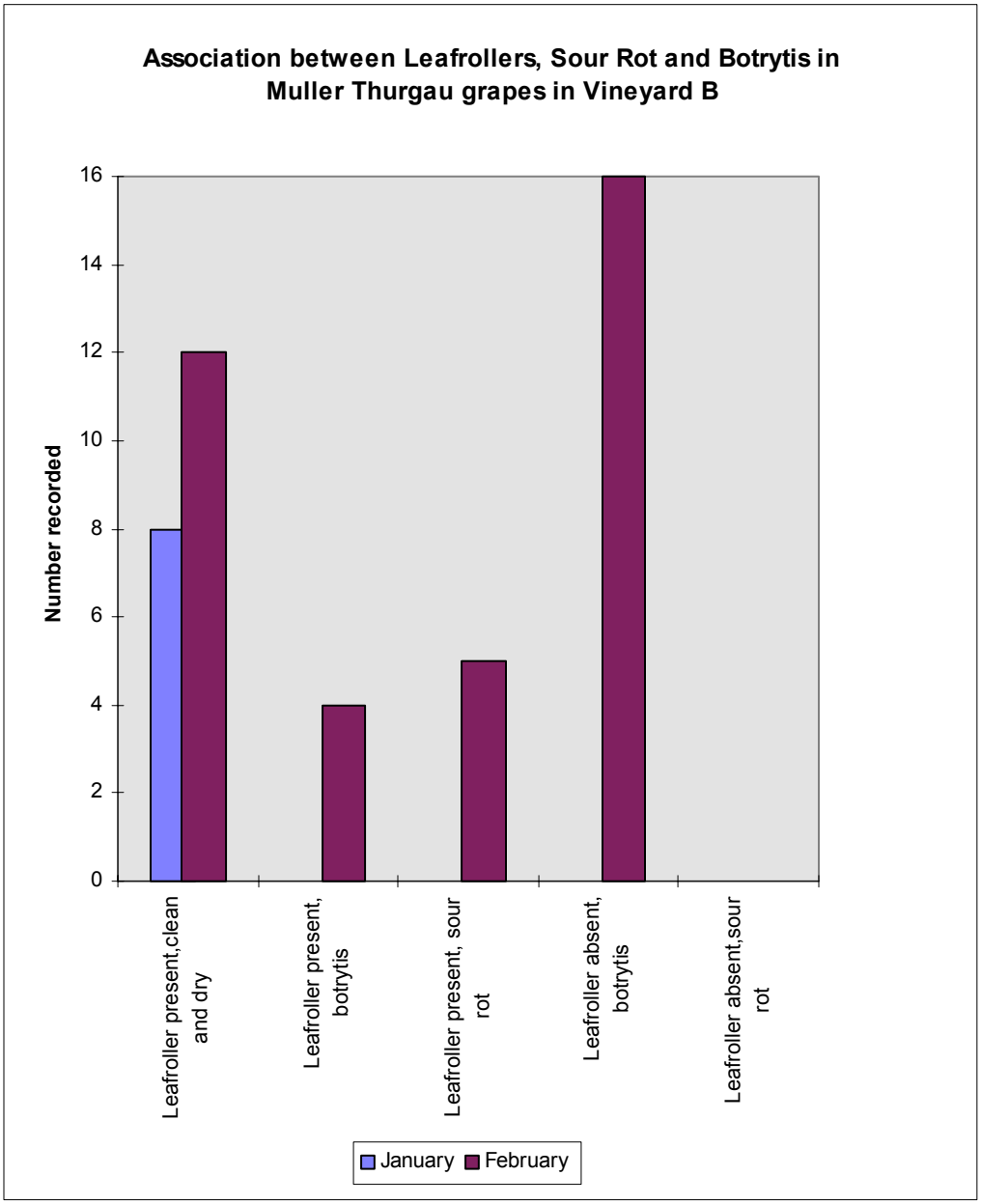

Fig.18 All the bunches from 15 Muller Thurgau vines were sampled from Vineyard B in December, January and February. All the bunches had been harvested when the March sample was made. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the

bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

None of the leafroller activity in January was associated with disease (fig.18). Twenty bunches with Botrytis were collected in February, 4 (20%) with a leafroller present. Five bunches with sour rot all had leafrollers present. This is a small amount of damage from 15 vines.

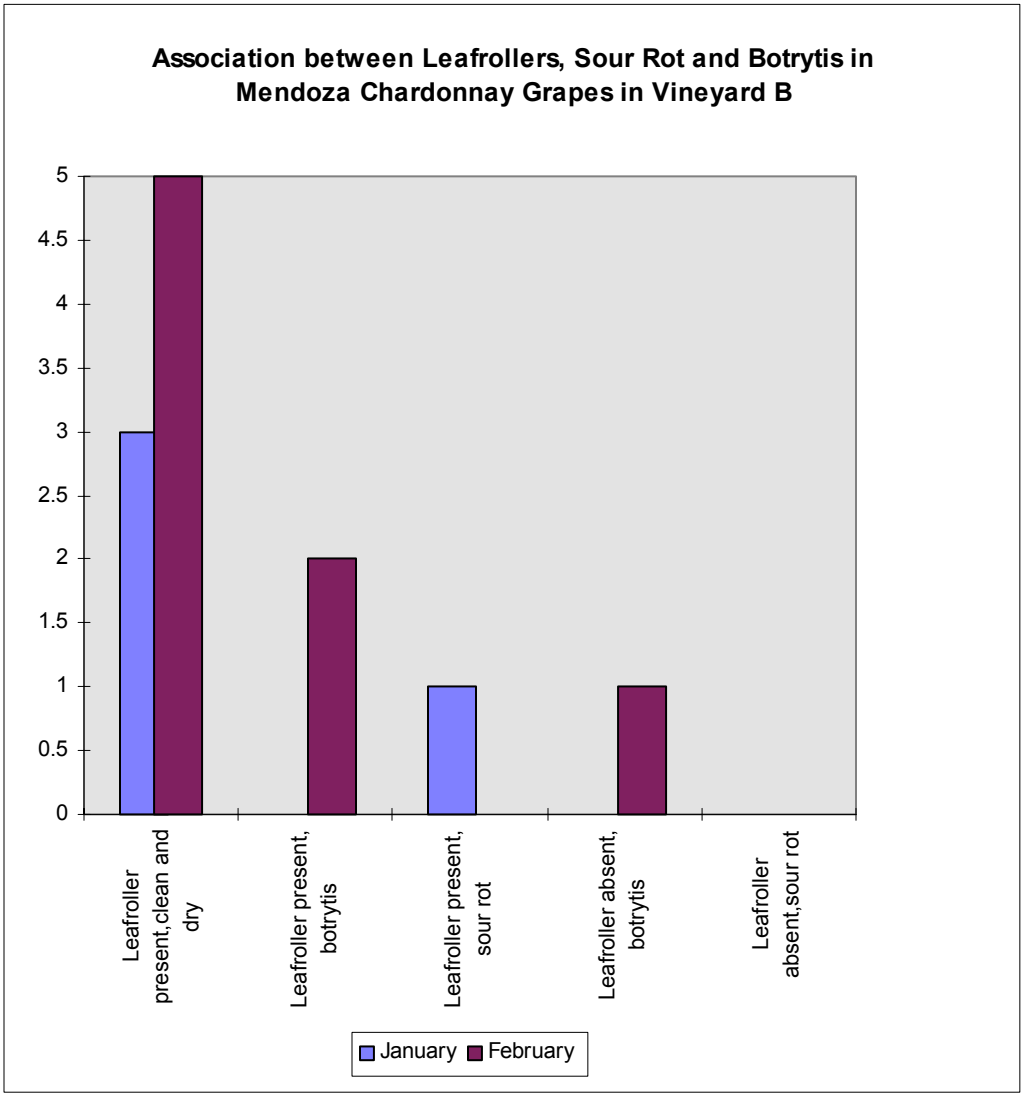

Fig.19 All the bunches from 15 Mendoza Chardonnay vines were sampled from Vineyard B in December, January and February. All the bunches had been harvested when the March sample was made. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

Fewer leafroller and diseased bunches were recorded from the Mendoza Chardonnay grapes (fig.19). Three bunches with Botrytis were found, two with leafroller present. The only sour rot bunch had a leafroller present.

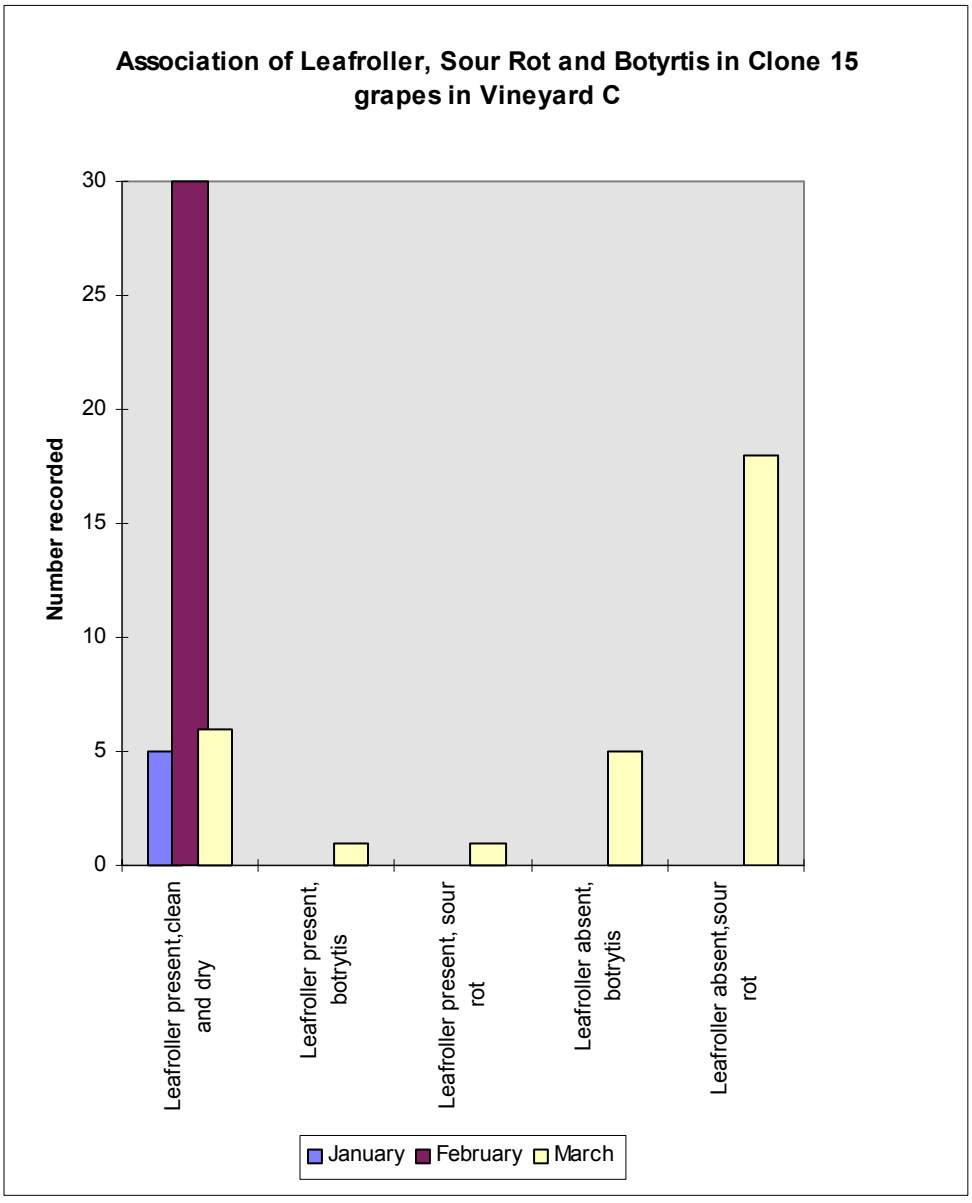

Fig.20 All the bunches from 15 Clone 15 vines were sampled from Vineyard C in December, January, February and March. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

Leafrollers are active in Vineyard C each of the three months from January to March but disease is recorded only in March (fig.20). Most leafroller activity was recorded in February.

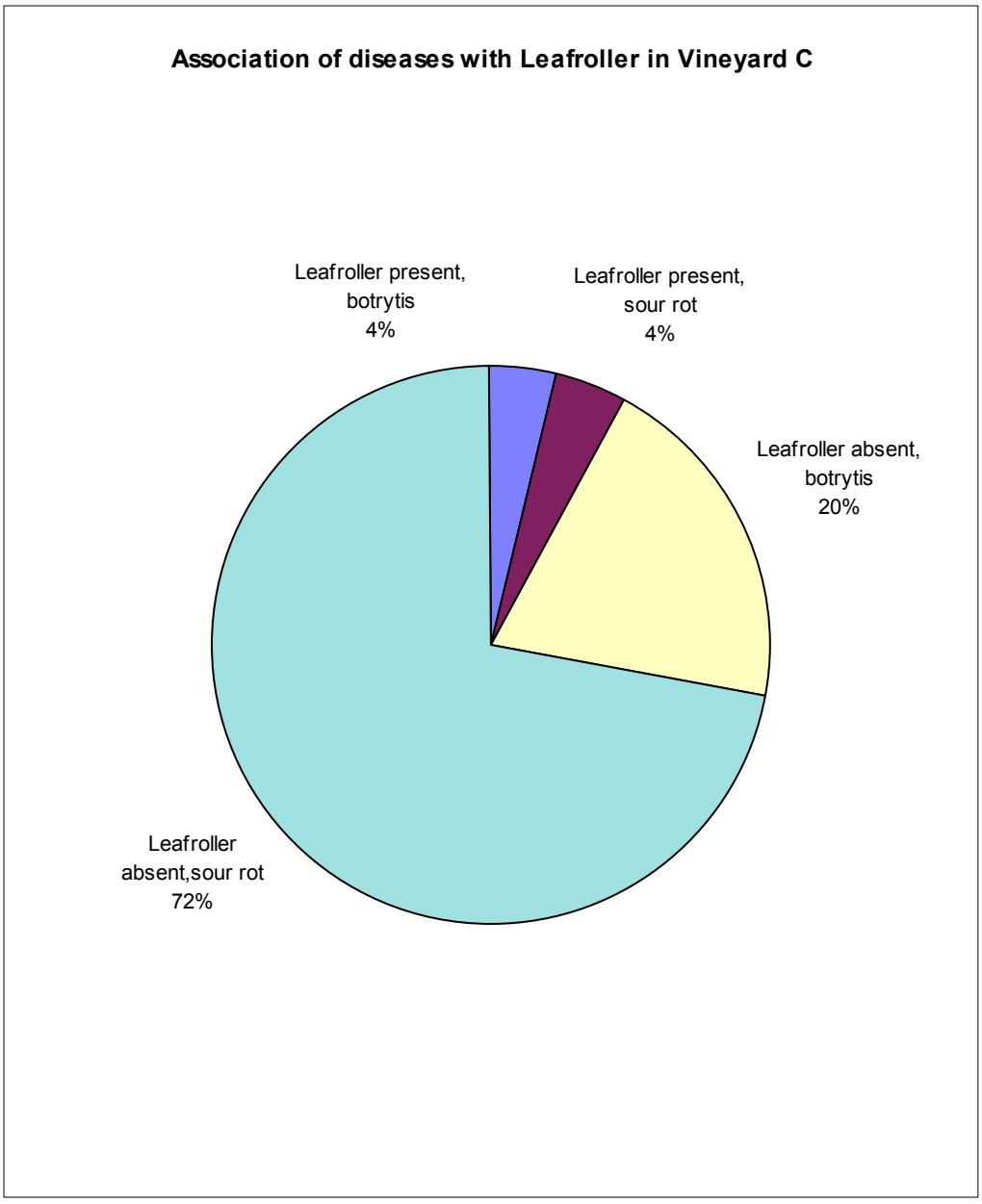

Fig. 21 Disease present in Clone 15 grapes in Vineyard C in March.

Most of the disease found (92%)in this vineyard was free of leafroller (fig.21). Sour rot was the more common disease. The clone 15 grapes had been bunch thinned and the bunches were distributed very evenly along the vines. The Merlot vines from this vineyard suffered little from either leafroller or disease(fig.25).

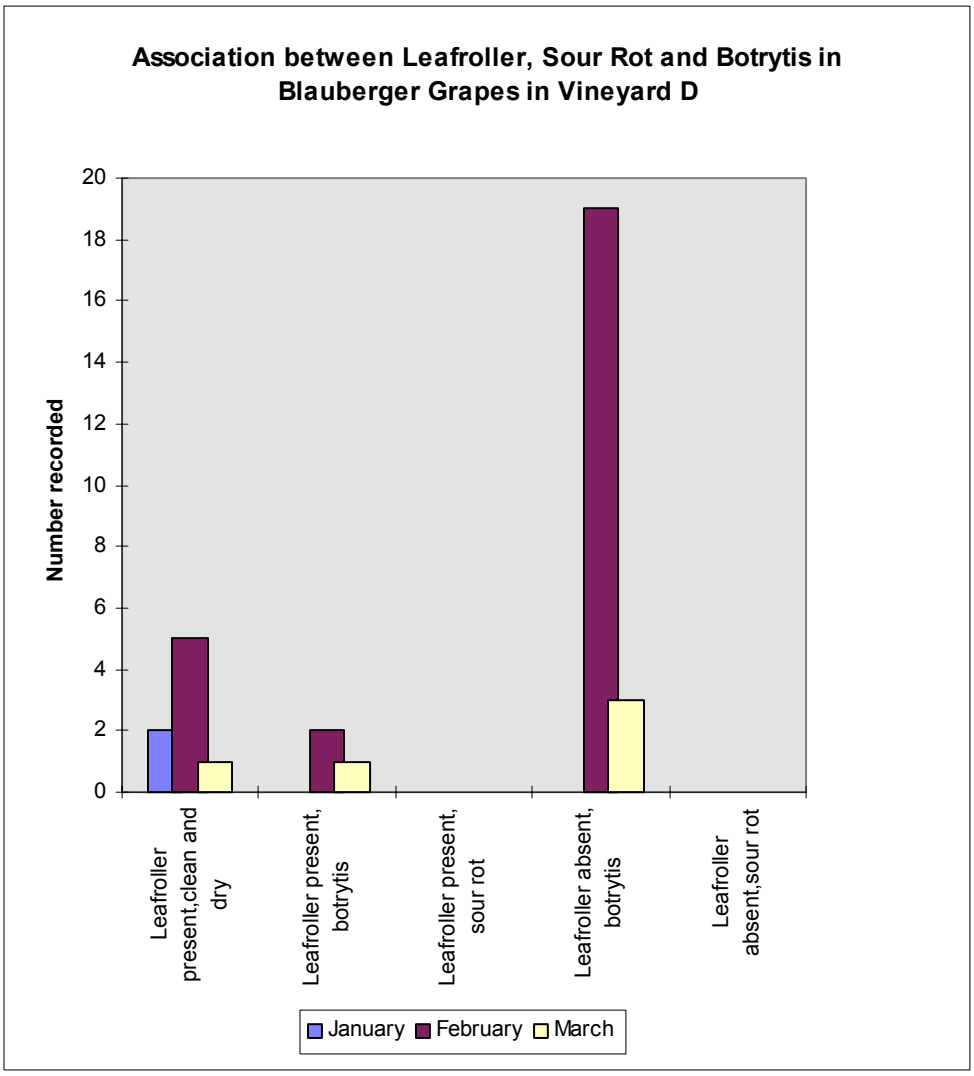

Fig.22 All the bunches from 21 Blauberger vines were sampled from Vineyard D in December, January, February and March. Most of the bunches had been harvested when the March sample was made. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

The observed pattern of leafroller activity and disease in vineyard D was much the same for the two varieties sampled (fig.s 22 and 23). A small amount of leafroller activity was seen in each of the months. The most frequent disease was Botrytis recorded in February (Blauberger) and March (Cabernet Sauvignon).

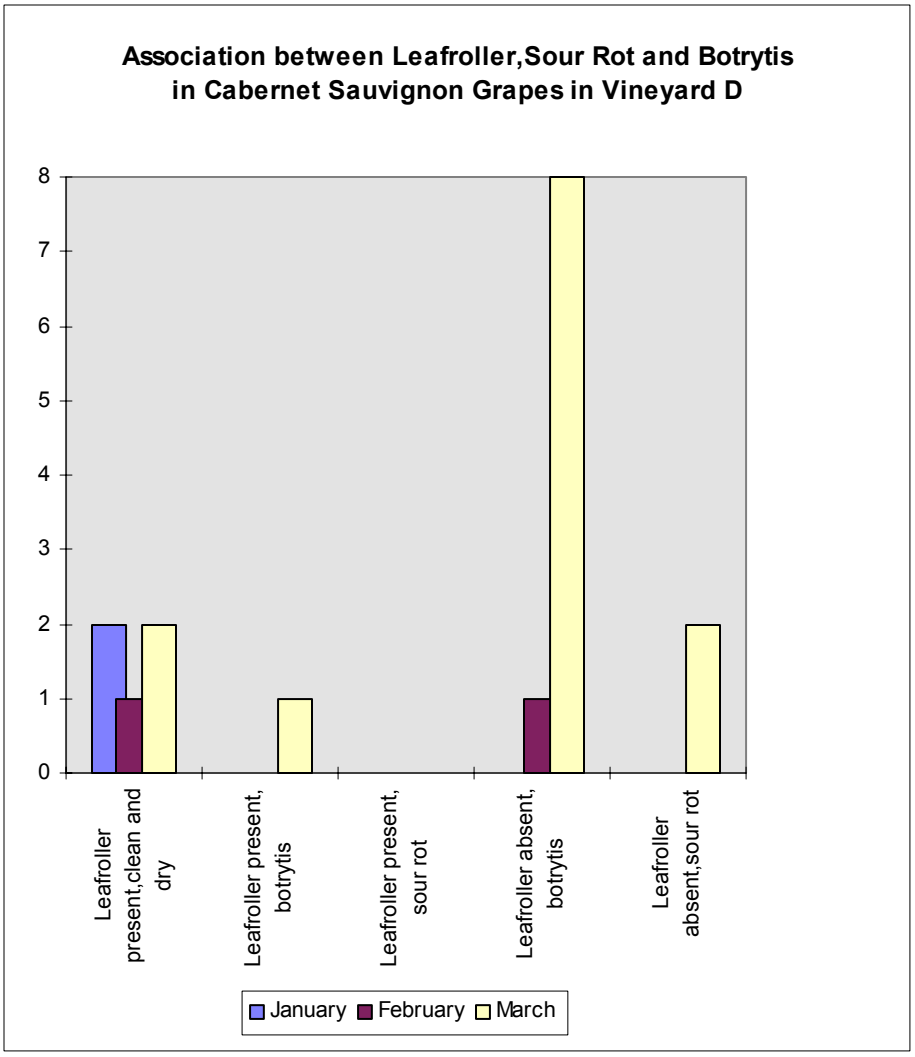

Fig.23 All the bunches from 9 Cabernet Sauvignon vines were sampled from Vineyard D in December, January, February and March. Leafroller excavations were scored as clean and dry if no signs of disease were present and the areas fed on had healed or were clean cut. If one or more berries within the area of leafroller silk-ways were infected with Botrytis or Sour rot, the bunch was scored as diseased. If both diseases were present the bunch was scored in both categories.

Most (84%) of the diseased bunches were free of leafroller (fig. 24).

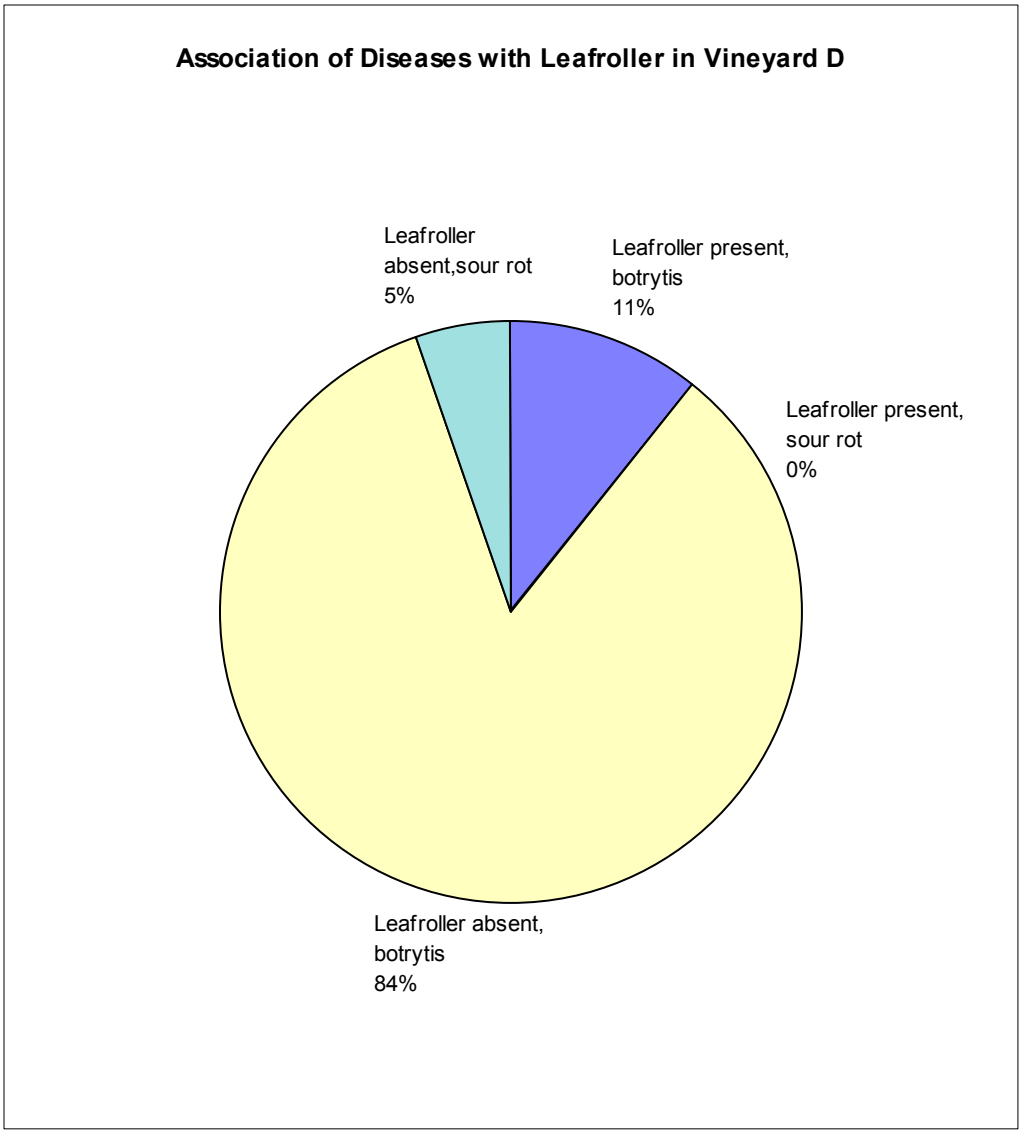

Fig.24 Disease present in Blauberger and Cabernet Sauvignon grapes from Vineyard D in February and March.

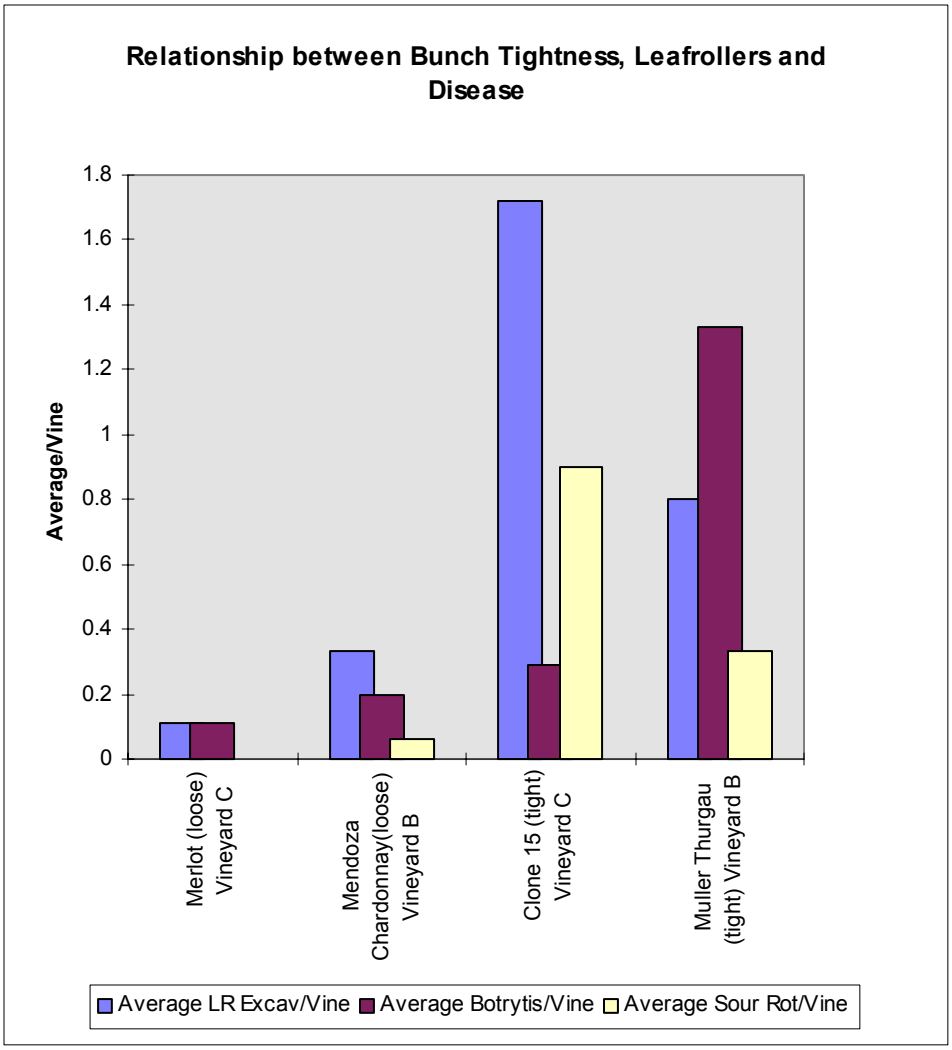

Fig.25 Paired comparison of tight-packed and loose grape varieties from Vineyards B and C.

Discussion and Conclusions

Three of the vineyards studied (A,B,D) have a similar pattern of leafroller activity and structure of the insect population. Most of the life-stages collected are young (egg batches or caterpillars). The numbers of the parasitiods are comparable. None or very few of the caterpillars collected from these three vineyards successfully complete development as adult moths because they have been attacked by the parasitiods. Vineyard A did not spray insecticide. Vineyards B and D were sprayed with Tokuthion/oil in spring. Results from this project show that early season use of this spray does not prevent good biological control of leafrollers. This is very valuable information for the mainstream grower of grapes in Gisborne. Growers should monitor their vineyard in autumn for the presence of mealybug and make the decision whether or not to spray in spring on the basis of this information.

The remaining vineyard C used a spray of Lorsban in late January. This was the only vineyard that contained dead leafroller caterpillars and dead parasitiod wasps. Most (80%) of collected caterpillars completed development to adults. Later life-stages (pupae, exuviae, adults) made up almost half of the leafroller collected. Numbers of parasitiods were low. These separate measures reinforce the conclusion that biological control of leafrollers had been disrupted by the spray. The insecticide spray had created a "window of safety" for the caterpillars from the attentions of the wasps. This disruption had little economic impact, as the leafroller population did not increase to unacceptable levels before harvest of the grapes.

The excellent agreement between data sets make these conclusions well founded. Compare the field structure of the leafroller populations (fig.s 5 -8) and the probability of survival of collected caterpillars (fig.9). The field structure of leafrollers in vineyards A and D shows almost all caterpillars and eggs with 6% (fig.5, A) and 8% (fig.8, D) sum of pupae and exuviae completing development. This agrees very well with the modest recovery in March seen in fig.9 for these two vineyards. Vineyard B is the only one in which the field collection (fig. 6) shows no leafroller more developed than caterpillars and it is the only one to show no resurgence in fig.9. The field collection from vineyard C has almost half passing the caterpillar stage (fig. 7) and a marked resurgence of the caterpillars in March (fig. 9).

Accurate measurement of the full impact of a parasitoid requires that the caterpillars collected must be reared, so that any parasitoid grubs feeding inside the leafroller caterpillars have an opportunity to reveal themselves. Adding the rearing results to the field collections increased the numbers of beneficials dramatically (fig.s 13-16). Mayse *et. al.*(1998) working on wine-grapes in Madera county, California found that when larvae and pupae of the Omnivorous Leafroller were returned to the lab for rearing a figure of 50% parasitism was reached, a big improvement on the Manual figure of 10%. The Gisborne Vineyards A, B and D recorded 100% kill by parasitoids in February. This is an outstanding result and a major factor in the low populations of the pest found in this study.

The species *Goniozus jacintae* Farrugia was included in introductions to New Zealand by W. P. Thomas in 1967-9 (Berry 1998). Specimens deposited in the New Zealand Arthropod Collection (NZAC) dated 1962 showed that this species was already in the country. It may have been introduced in collections sent by R. J. Tillyard in 1922 but as no voucher specimens were deposited, this will remain uncertain (Berry 1998).

The steady reduction of the activity of the leafrollers in vineyard A (fig.1) provides a puzzle. Activity drops from January onwards despite a steady, low number of leafroller caterpillars. The activity recorded is a product of the number of caterpillars available multiplied by the time available to carry out the activity. If as fig.1 shows, the number of caterpillars varies little, the results suggest that the leafrollers are allowed less and less time to be active as the season progresses. This could be accomplished by the beneficial wasps finding the caterpillars earlier and younger as the season progresses. This is in fact appeared to happen with much the smallest caterpillars collected from vineyard A

collected in March. This hypothesis requires careful testing by measuring the size (head capsules) of the caterpillars collected in the regular samples.

The results from Vineyard D provide additional evidence that the presence of the wasp *Gl. demeter* may reduce the biological control of leafroller. This is the only one of the vineyards in this study that contains this species. The activity of the leafrollers in Vineyard D steadily increases as the season progresses (fig. 4). The distribution of the wasps between leaves and bunches is also unusual (fig. 12). *D. tasmanica* is the dominant species on the leaves as usual. The leafroller in the bunches are shared between three species (*D. tasmanica, Gl. demeter* and *G. jacintae*) all taking a similar small portion of the prey. *G. jacintae* is found on the leaves in this vineyard. The three species differ in the number of new wasps produced from each caterpillar. *D. tasmanica* always produces only one new wasp per caterpillar, *G. jacintae* produces from one to nine and *Gl. demeter* produces around 20. *Gl. demeter* may out-compete the other species but because a large caterpillar is needed to fuel the production of so many new wasps, the caterpillar has more time to feed. I now have examples of two organic apple orchards (Waihi, Hastings) and another vineyard (Hastings) where *Gl. demeter* is present and the biological control of leafroller is inferior. This hypothesis needs further testing.

Mealybugs in Vineyard A appeared to be under excellent bio-control by the predator *Cryptolaemus montrouzieri.*

Leafroller activity more than a month away from harvest has not been associated with disease. As the harvest approaches, leafroller numbers and disease incidence increases When small amounts of disease are found near harvest (e.g. Fig.19) most of the disease occurrence is associated with leafrollers. When the disease is common, little of the occurrence is associated with the leafroller. I conclude that leafroller activity and disease are at most weakly related causally.
Observations from the Wairarapa support this observation. I was invited to the Wairarapa to give a seminar and conduct a field day (March 7) by Clive Paton of Atarangi Vineyard. The population of leafrollers seen was approximately 100 fold greater than any seen in Gisborne. No damage of economic importance (disease or leafroller damage) was seen at harvest (Paton pers.com.).
It is important to distinguish between correlation (simultaneous appearance of affects) and causation (one event causes the other events). For example my last visit to Gisborne, heavy rainfall and the song “why does it always rain on me” playing on a national station on my car radio were correlated but there was no causal relationship between the three events. The results from this study provides additional evidence for the hypothesis that leafrollers and disease are correlated (fig.25) but weakly at most casually related (fig.s 21 and 24). There was a good correlation between the presence of leafroller and the presence of disease (fig.25). The loose packed bunches of Merlot grapes from Vineyard C had little disease and few leafroller. The tighter packed Clone 15 grapes from this Vineyard are more diseased and host more leafroller. Earlier analysis (see fig.21) showed that most of the diseased bunches were free of leafroller. The better conclusion is that the tighter packing of the grapes **independently** favoured

the leafrollers and the disease. Similar arguments can be made for the two varieties from vineyard B featured in fig. 25 (and see fig. 18).

Fermaud (1998) found a good relationship between bunch tightness and the ability of the leafroller *Lobesia botrana* to settle in the bunch and survive well. Merlot grapes were found to be the loosest packed and the least likely to contain leafroller in this study in Bordeaux, France in agreement with this Gisborne study.

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