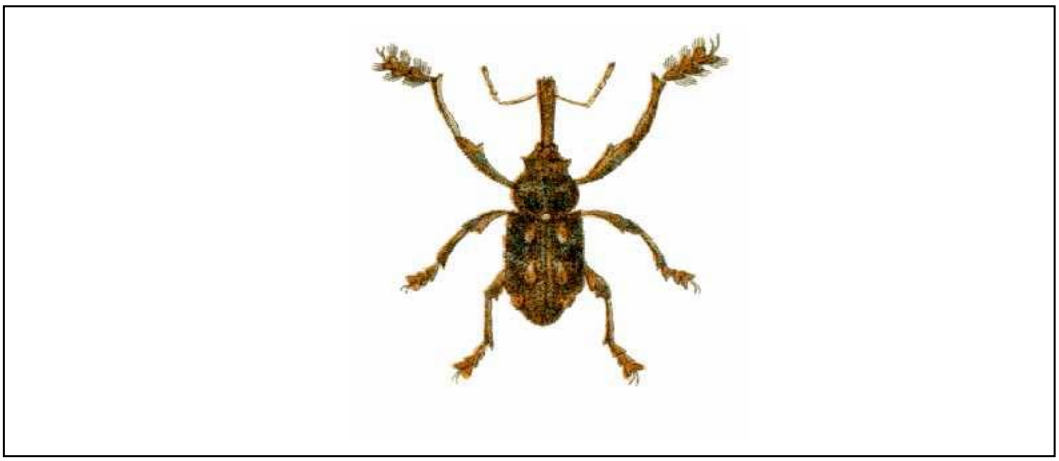
Elephant Weevil impact and control in vineyards – Stage 3: Regional Survey & Evaluation Trials of Elephant Weevil (*Orthorhinus cylindrirostris*) in the Langhorne Creek Grape Growing Area.



FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **RT 03/08-2**

Principal Investigator: **Mr. Steven Coventry.**

Research Organisation: **Langhorne Creek Vine Improvement**

Date: **30th June 2004.**

Executive Summary:

This project represented the third and final stage of an initial investigation into the incidence and impact of the Elephant Weevil pest in Langhorne Creek vineyards.
The project helped raise awareness of this pest to growers and gained the cooperation of the community in endeavours to better understand and monitor for the Elephant Weevil.
A grower survey proved it difficult to isolate any particular impacting factors but did provide a very good map compilation of the incidence of the Elephant Weevil. It also served to highlight areas for the student, Steven Coventry, to focus his field efforts (given the relatively short period of the project).
This project has resulted in a better understanding of the lifecycle, developmental stages, behaviour and activity of the Elephant Weevil in the Langhorne Creek wine region.

The primary findings are summarised below:

- Weaker vines tend to be favoured by the Elephant Weevils.
- Not grape vine variety specific.
- Early indications are that the main incidence is nearer the river systems (Angas & Bremer).
- The basic control measures of cutting out affected wood or vines and burning the material seems to be quite effective (though costly in time and income).
- Adults have been found from about late September through into vintage.
- By all indications with weevils kept at the office the adults can be quite long-lived.
- Growers can use simple insect pan traps to monitor many of the insect populations in their vineyards.
- Vigilance with monitoring and scouting is still the best way to assess weevil activity in vineyards.
- There is early evidence that there may be a natural predatory wasp that preys on the weevil larva and this could present a means of biocontrol.
- An outstanding insect collection (both pest and beneficial) has been started as a result of this project and these collections will remain available at the LCWIC office as a grower reference.

There is potential to further this research with continued study of the potential wasp predator (via a "predator / prey interaction" study), longer-term assessment of the effects of the crude "cutting & burning" control measures used by growers to control populations, addition to the reference insect collection, and further study of the Elephant Weevil biology (under a more significant time-frame) including development of better trapping/monitoring methods.

Background:

There has been an Elephant Weevil problem in Langhorne Creek for several years. In the spring of 2001 it was noted that the problem seemed to be escalating, though in a regionally inconsistent manner. It was estimated that yield was reduced by 15% in some vineyards (vintage 2002) due to damage caused by this pest. This loss in yield may continue for 2-3 years in affected vine blocks due to the requirement to retrain or at worst re-establish vines. The incidence of Elephant Weevil damage is not unique to Langhorne Creek and any project outcomes will be of benefit to the whole industry. The unpredictable nature of pest levels, potential yield losses and lack of grower knowledge about this pest warranted further investigation.
A staged project was devised to learn more about this pest and possible control or management techniques. Stage 1 (complete) comprised a literature review of this topic. Stage 2 (complete) aimed at grower education. This stage (3) aimed to gain an understanding of the distribution of Elephant Weevil in the Langhorne Creek wine region and also gain a better understanding of the activity and life stages of this insect pest. The ultimate hope is that a greater knowledge of the biology of Elephant Weevil will allow

future biological control &/or vineyard management control methods to be available to growers.

Objectives:
To conduct a mail-out survey to all growers in the Langhorne Creek region to identify the incidence, location and potential impact of Elephant Weevils in vineyards.
To acquire the services of a student (over a period of 20 weeks) to evaluate the biology and seasonal activity of Elephant Weevil in target vineyards.
To understand the lifecycle, oviposition behaviour, sites of attack on grapevines, spatial distribution (key information for developing a monitoring program), and seasonal activity. This could assist in better timing of management, and more efficient monitoring, which is important both for detecting problems as well as evaluating the effectiveness of control measures.
To compile a useful resource of data, observations and insect samples for local growers.
To assist the student to complete a required study project, thereby delivering mutual benefit.
To build a fruitful liaison with the Adelaide University.
To determine the nature of any future extension of the current Elephant Weevil studies in Langhorne Creek.

Results of these preliminary trial/survey results shall be made available to local members and to other interested regional groups and their affiliated associations upon request to the Langhorne Creek Wine Industry Council. Groups shall be notified via newsletter features or email/fax. A full file of results shall be on display at the Langhorne Creek Wine Industry Council office to provide a public and industry resource.

Outcome/Conclusion: (see provided project report)
Steven Coventry presented a seminar of his findings at the AGM of the Langhorne Creek Vine Improvement Committee held on the 27th May 2004. This presentation was very well received and generated a lot of discussion. Also available for viewing at this meeting was the literature review (stage 1), the poster and grower guide (stage 2) and the boxed insect collections which resulted from this stage of the project (stage 3).
A poster presentation will also be displayed at the 12th Australian Wine Industry Technical Conference in Melbourne in July 2004. This poster will represent a compilation of all the findings from this 3-stage project and will remain on display at the LCWIC office after the conference.

Thanks are extended to GWRDC (RITA funding assistance), Steven Coventry (student and author of the attached report), Dr. Michael Keller (Plant & Pest Science, Adelaide University, Waite and student supervisor), and the Adelaide University campus for assistance and support with this project.

Elephant Weevil (*Orthorhinus cylindrirostris*) impact and control in vineyards Stage 3: Field assessment and grower survey

SUMMARY:

Langhorne Creek is one of the oldest and fastest growing producers of wine in South Australia. In the past 3 years much grower concern has been expressed about escalating incidence of a little known insect pest the Elephant Weevil (*Orthorhinus cylindrirostris*). To understand more about this vineyard pest an integrated approach was set up with such methods as trapping, scouting, local grower surveys, communication with growers and other field studies. The Elephant Weevil has 3 main life stages the larva, pupa and adult. The two main stages which cause damage are the larva, which tunnels through vines causing structural weakness, and the adults, which chew buds and have been known to ring bark young canes. The adults have a large membranous wing structure, which indicates the potential to transport them over reasonable distances around the district with the aid of winds generated from nearby Lake Alexandrina. Often tell tale signs of Elephant Weevils in vineyards are stunted growth of the vine, snapping of cordons upon twisting, round emergence holes, and greater water shoot growth. Through the studies it has been found that a lot of Elephant Weevils were seen in properties in close proximity to the Bremer and Angus Rivers where there is a high concentration of trees, notably River Red Gums. Often they have been attracted to stressed or weak vines, but are not selective to varieties or the trellising system used, often causing more severe damage to younger vines. In the Langhorne Creek vineyards studied, evidence of Elephant Weevil activity was generally not observed in vine wood below 20 cm from ground level, contradictory to other findings. More than one grub can inhabit a cordon at the same time, which can cause severe structural damage to the vine. Through a chance finding a possible parasitic wasp was found which may have the potential to control the Elephant Weevils in conjunction with other practices such as cutting out and burning of affected wood. Populations of Elephant Weevils have decreased this year perhaps due to cultural practices, environmental conditions or the potential wasp parasitoid. Even though this brief study indicated that Elephant Weevil activity and numbers are somewhat reduced in comparison to grower observation from the previous year, they are present in numbers sufficient to cause significant damage and an integrated approach to reducing the pest should be employed.

INTRODUCTION:

Langhorne Creek is situated in South Eastern South Australia (Figure 1) in close proximity to Lake Alexandrina. There are around 5800 ha of productive vines with the main varieties being Shiraz, Cabernet Sauvignon and Chardonnay. The original vineyard plantings were established on the rich soils of the natural flood plain surrounding the Angus and Bremer Rivers; on land studded with large River Red Gums. Langhorne Creek still experiences winter flooding of the Bremer River, which helps to irrigate the vineyards in these areas. The irrigation by flooding and modern drip irrigation methods are vital to keep vines watered in Langhorne Creek because of the low annual rainfall of approximately 380mm. Cooling breezes from Lake Alexandrina help to reduce temperatures and give a cool even growing season.

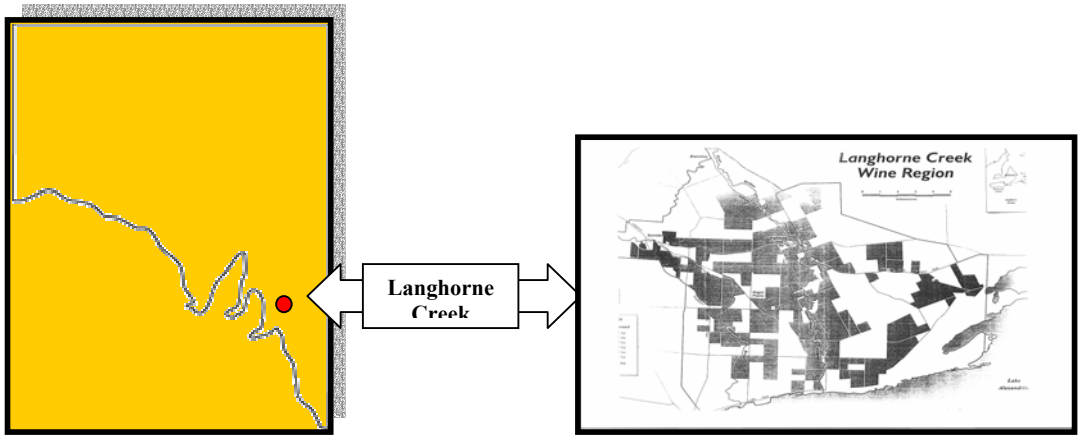


Figure 1: Map of South Australia indicating the Langhorne Creek area in which Elephant Weevils were studied

The Elephant Weevil (*Orthorhinus cylindrirostris*) is a native insect to Australia (Seeman 2002) and has been found as far as Queensland and to the edge of South Australia (Figure: 2) (CSIRO 2004)

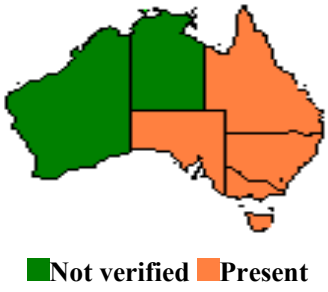


Figure 2: Identification of areas in Australia where Elephant Weevils have been found

Adult Elephant Weevils grow from about 8-20mm in length. They are brown grey in colour and have a long slender snout called a rostrum and very long forelegs, which make them excellent climbers. On their body they have thick protruding scales of a black to brown colour. Their antennae are clubbed and form a distinct elbow shape. They have a very strong membranous hind wing structure, which expands to about 2 cm and would vibrate rapidly allowing flight. Their fore wings (elytra) are used for protection and have no mechanism in flying. These wings would suggest that they could be very good flyers and in presence of wind could travel substantial distances (Figure 3).

The larvae of the Elephant Weevil grow about 16mm in length and are similar in appearance to a witchetty grub. The larvae are creamy in colour with no legs and have a brown head. At this stage chewing mouth parts are distinct and when curled they form a distinct "c" shape (Figure 3).

The pupa stage of the Elephant Weevil grows to about 20mm in length. At the pupa stage the snout (rostrum), legs and wing covers are seen developing. The early stage of the pupa is a light almost transparent colour and as they develop they become a darker brown (Figure 3).

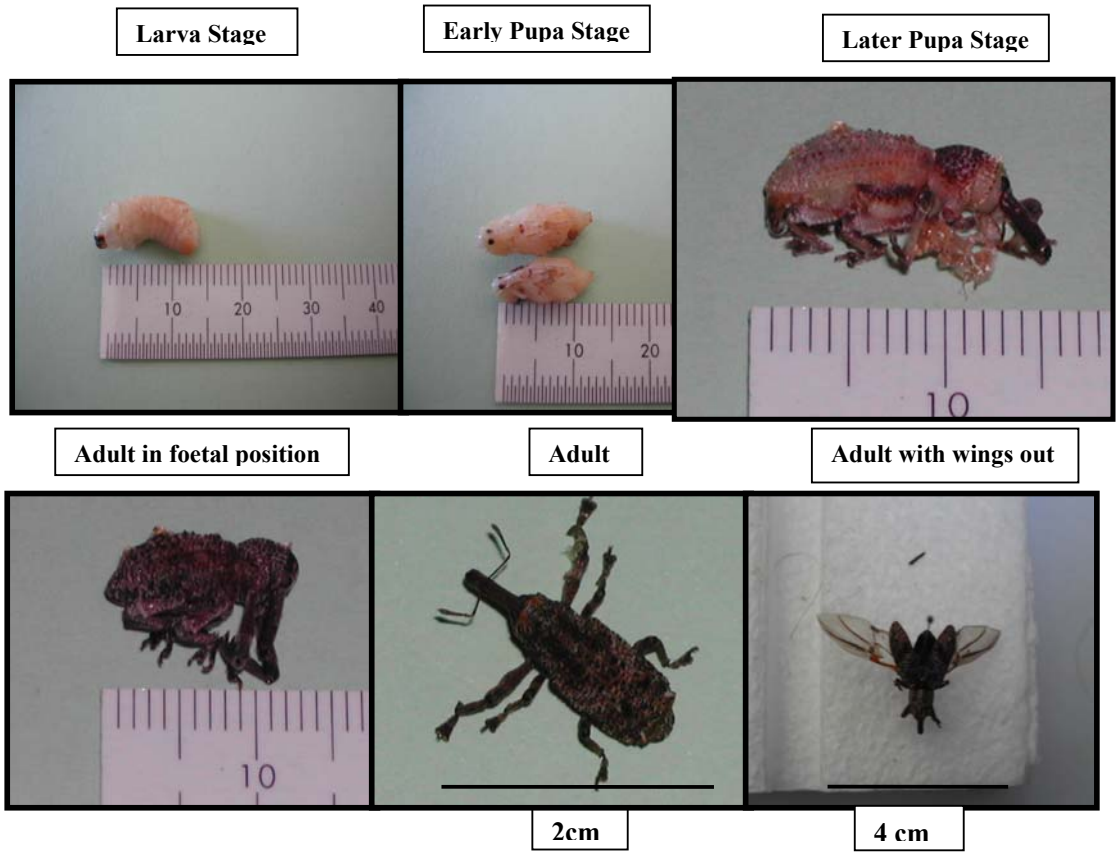


Figure 3: Stages of Elephant Weevil development

In the district of Langhorne Creek it had been noticed by growers that an increase of Elephant Weevils had been seen over the last few years, with the worst case seen in 2001. It was estimated that about 15% yield was lost in some vineyards in the area due to this single pest.

The formulation of a good control strategy could not be undertaken by growers as they did not know the biology and ecology of the Elephant Weevil. The project I have been undertaking aimed to find out more about the Elephant Weevil in Langhorne Creek, to try and evaluate its life cycle and habits, try to devise ways of catching or monitoring the weevil and increase growers awareness of it and other insects that may be present in their vineyards.

OBJECTIVES & AIMS:

- To develop relations with growers in the region
- Gain better understanding of the biology, ecology and behaviour of the Elephant Weevil
- Be an active and reliable part of a real world I.P.M project
- Be the start of an ongoing liaison with Adelaide University and the Langhorne Creek Vine Improvement group
- Design methods for catching the elephant weevil in the field.
- To try and identify key information for developing a monitoring program
- Compile a useful resource of data, observations and insect samples for local growers
- Raise grower awareness and interest in this vineyard pest
- Further add to reference materials across the wine industry
- Identify future progression of this project

It was hoped to find a link between the Elephant Weevil and certain features in the Langhorne Creek area. Of interest were any association of incidence of the Elephant Weevil and variates of grape vine, adjacent native vegetation, or land marks such as the rivers Bremer and Angus and the Lake. Appropriate methods to aid in catching the Elephant Weevil were looked at and trialled and the possibilities of natural predator or parasites which may provide biological control were also investigated. Other control practices; burning of infected cordon wood from vines, chemical applications and the affect on Elephant Weevil populations were assessed. Also of interest was clarifying the identification of the Elephant Weevil to avoid confusion with other common vineyard weevil pests such as the Vine Weevil.

MATERIALS & METHODS:

This project had a scope of 2 days per week over a period of 20 weeks beginning the 20th of November and concluding on 2nd of April

Grower survey

112 survey forms were sent out in the Langhorne Creek region with a 60% return rate. The data from the survey was looked and collated to help with the project. Growers were asked to locate their properties on a regional map to gain an indication of the distribution of Elephant Weevil in the Langhorne Creek region. Growers who had no Elephant Weevil or only Vine Weevil were requested also to indicate location on the map, giving an overall distribution of Weevils and to see if correlation between species existed. Growers were also asked general questions in the survey to again gain more understanding of this insect pest. It also gave us an idea who would be willing to undertake this project on their property and would allow traps to be set on their sites. (Appendix I Figure A: Survey form)

Traps (see Appendix II: Trapping systems)

A. Yellow pan traps are plastic bowls about 3.5cm deep filled with water and a drop of detergent to break the waters surface tension. A pinch of salt to preserve the insects is also added. These are placed under vine canopies at the base of the trunks. Yellow is a colour attractive to many insects including some beetles, but other colours can be used This trap was set at sites 1,2,3,4,5,6 and 7.

B. The window trap is a large frame which is hammered into the ground with a clear sheet in between the frame to resemble a window. At the base of it a flower punnet is situated which has water, detergent and salt as per the yellow pan trap. These traps are placed at the end of each row of the vines to catch insects which have a habit of flying down rows. The clear sheeting is not visible to the insect so as it flies along a row it runs into the window trap at full flight knocking it into the punnet. The punnet containing water, detergent and salt drowns and preserves the insect. This tap was set at sites 1,2,3,5 and 7.

C. Corrugated cardboard traps are corrugated cardboard wrapped around infected cordons. The cardboard acts as a refuge for the weevils when they emerge. This has been used on Vine Weevils (Anon 1999) at the base of vines where they like to hide under bark and trialled for Elephant Weevils. This trap was set at sites 2 and 3.

D. Fly mesh traps are pieces of fly mesh wrapped around infected cordons and sealed at each end with sticky tape. These were used to see if Elephant Weevils would emerge from an infected cordon and be trapped in the fly mesh. This trap was set at sites 1,2 and 3.

E. Fruit fly traps were adapted to catch wasps in the vineyards which may be potential predators or parasites of the Elephant Weevil. The design was taken from Gardening Australia 2002 and Elephant Weevil frass used as the bait to attracted potential wasps by chemical stimuli. The traps consisted of a

large 2Lt bottle with two smaller 600ml bottles cut off in a funnel shape and put in either side of the larger bottle. Water was put with the frass at the bottom of the two litre bottle to disperse any chemical attractants. This trap was set at sites 1, 2, 5, 6 and 7.

F. Yellow sticky traps were traps placed randomly in vineyards with vials secured to them with bread ties. In some vials moist Elephant Weevil frass was added and others were left empty to test wasp attractiveness to Elephant Weevil frass. These traps are purchased from gardening stores and were placed at sites 1 and 2.

Sites were selected for trapping giving consideration to site accessibility, grower approval, and Elephant Weevil damage. Not every site could have traps set up due to the time frame of the project and the maintenance time required.

Scouting

Selected properties from the surveys were scouted with samples taken of infected vines, notes of damage caused and observational notes on life cycle as well as habit of the Elephant Weevil recorded. A part of scouting was also to communicate with the growers to find out about their properties and information and experience they had of Elephant Weevils. This also involved collecting insects for the boxed insect collections and investigating any other interesting factors of note. Not every site with Elephant Weevils could be investigated due to the time frame and the scope of the project.

Harvest occurrence

Grape bins were checked at harvest due to reports of growers in previous years finding tops of their grape bins riddled with Elephant Weevils.

Vine dissection

Elephant Weevil infected vines were donated by growers and removed. Vines were looked at as a whole plant and dissected every 5cm and the observations noted to get a good scientific representation of the behaviour, general life cycle and preferences of the Elephant Weevil.

RESULTS:

Grower survey

The survey conducted helped to find out more about the prevalence of Elephant Weevil in the Langhorne Creek area. There was a correlation indicated between the distribution of the Elephant Weevil and the proximity of the local Bremer and Angus Rivers. There appeared to be no selectivity for types of vines or vine training systems in use.

Traps

Various trapping methods as per the materials and methods were trialled with varied success on selected sites. This showed that no one trapping system was effective for trapping the Elephant Weevil but more time and different traps should still be trialled. The traps did have a great success in collecting an array of other insects for the collection boxes.

Scouting

From scouting, a better understanding was gained of the life cycle and habits of the Elephant Weevil, including the manner in which they damage vines and the degree of damage throughout the Langhorne Creek area. There seemed to be links between the prevalence of Elephant Weevils in the vines and stress levels that the vines appeared to be suffering. Vines which had been in direct competition with trees and others which had been watered or cared for less were often affected first. Sites of infection of each life stage of the Elephant Weevil were observed and discussions with growers revealed more about the

various effects this pest can have on the vines like increasing water shoot growth, giving patches of cordons with no growth and stunting vines.

Harvest occurrence

Contrary to grower reports of previous years, Elephant Weevils proved difficult to find in grape bins during the 2004 harvest. However, some growers did collect a small number from grape bins this year.

Vine dissection

Dissection of vines revealed the following information about the tunnelling habits and location of Elephant Weevils within the vine wood. Damage was never seen any lower than around 2.5 feet from the base of the vine. Tunnelling was seen in stages travelling for 30cm then stoping for 5cm and a new tunnel travelling for another 30cm. Within one space there could be more than one tunnel up to 5, often depending on the size of the cordon. Grubs of the Elephant Weevil were often found in harder thick wood and often found in knuckles on the vine, where the adults and pupae were found near the end of the cordon near new growth and off shoots.

DISCUSSION

Grower Survey

After collating the results of the survey a map of the Langhorne Creek district was generated to indicate the distribution of Elephant Weevil (Appendix I: Figure B). This map indicates the incidence of Elephant Weevil and of Vine Weevil (another common weevil pest), as well as confirmed areas where weevils have not yet been observed. Obviously, without a 100% return rate of the surveys, much of the area is still to be accurately mapped for these factors. After colour coding the map it shows a lot of the Elephant Weevils are seen in close proximity to the Bremer River and Angus River. It is postulated that the rivers could be an area from which Elephant Weevils migrated. It is known that the Elephant Weevil is native to South Australia (Seeman 2002) and various native vegetation can host this pest. Around the rivers a lot of native vegetation is present, including River Red Gums, other Eucalypts, Casuarinas and other native shrubs which could all harbour this insect. Two local growers suggested they have found Elephant Weevils in native vegetation, one indicating that they had some in a Tuart Gum and another in Red Gums.

Incidence of Vine Weevil is also indicated on the map (Appendix I: Figure B). From field research and discussions with local growers it appeared that vineyards affected by Elephant Weevil did not seem to have a great incidence of Vine Weevil and vice versa. From observations of damage caused by Elephant and Vine Weevils, it appears that in large numbers the Vine Weevil causes great damage to a vine. Vine Weevils would be able to fit in a cordon in large numbers due to their smaller size and cause substantial tunnelling damage (Figure 4). The Elephant Weevil on the other hand fits fewer weevil larvae per

cordon due to its substantial size, but only needs 1 to 2 weevils per cordon to cause substantial tunnelling damage. The greatest number of Elephant Weevil tunnels observed during this study was 5 in one cordon. This made the cordon very brittle and hardly needed to be twisted to be broken off. From other pieces of vine cordon tunnelling was found from both the Elephant and Vine Weevil but often the Elephant Weevil tunnelling was more severe than the Vine Weevil tunnelling. It is assumed that the tunnelling damage has an effect on xylem and phloem tissue in a cordon. This would cause severe damage to this tissue structure giving rise to the vine putting energy into other areas and this may be why a greater number of water shoot growth can be seen in vines affected by Elephant Weevils.



Figure 4: Tunnelling damage caused by Vine Weevils

A. Yellow pan trap

Many insects are attracted to the colour yellow, especially bright "sunflower" yellow. Thus, yellow containers filled with water can be used to trap them. This kind of trap was used in this study to see if Elephant Weevils could be caught and also to catch other insects which could be collected and displayed for local grower awareness of what is in their vineyard. No Elephant Weevils were caught using this method but a lot of Vine Weevils were caught and this could be a good monitoring tool for this vineyard pest. There were also many other insect samples caught for the growers collection with this method. A summary of the insects collected can be found in Appendix IV.

B. Window trap

The window trap was tried as it is very specific to large flying beetles. This trapping method did successfully catch a few beetles and larger insects like crickets and wasps but did not catch any Elephant Weevil. The large trap size made them difficult to handle and easily blown around by the wind. They were also in the way of tractors and harvesters often needing to be taken down.

The efficiency of window traps is limited because flying adults could avoid the traps and may bounce off the trap without being collected. Also we don't know exactly when the Elephant Weevil flies, or how high above the canopy they fly. These traps were set just below the top of the trunk so another trap that may be useful is an interception net above the vine canopy, which could catch an insect which flies above the canopy. This project was limited in resources to allow only 2 days per week for field observation and a greater dedication of time would have to be employed to successfully test the usefulness of these types of traps.

C. Corrugated cardboard trap

The design for this trap was intended to catch Weevils after they emerge from the vine wood. At night adult weevils and other insect species are often active, causing damage to the vines, but at day rest and hide under bark or in vines (Seeman 2002). It was hoped that the grooves of the cardboard would mimic an attractive resting place for vineyard insects.

Unfortunately Elephant Weevil were not found in these traps, but they did prove very attractive to earwigs. It is not known whether the traps were not attractive as a refuge to the Elephant Weevils, whether this is not a common behaviour of adult Elephant Weevils, or if the traps were just not set at an opportune time and the weevils were just not around or active.

D. Fly mesh traps

The fly mesh traps were put on vines that were known to have had Elephant Weevils due to the emergence holes present. The fly wire mesh was wrapped around a cordon and sticky taped at each end. This provided a funnel around the cordon in which an Elephant Weevil would be stuck. These were checked to see if an adult Elephant Weevil had emerged from the vine and been trapped. No Elephant Weevils were found using this trapping method. It was subsequently realized that adult Elephant Weevils were capable of chewing through fly wire mesh. There was also uncertainty about exactly when adult weevils emerged and which part of the vine they emerged from. It was not known if the emergence holes seen were from years before and these vines may not be infected any more. Again the limited time frame of the project placed restrictions on the trialling of the various trapping methods. A better

understanding of the breeding cycle of the Elephant Weevil will greatly benefit future field studies of this pest.

Other traps

Other traps which have been used in the area are sticky resin put at the bottom of vine trunks to try and catch weevils as they land or crawl up trunks, but with no success. It was hoped to put out an interception net which could intercept weevils flying at canopy height but time constraints did not allow this.

General scouting

At present, it would appear that scouting vineyard rows and physically testing cordons by twisting them to identify places of weakness is the best way to find Elephant Weevils. When scouting adult Elephant Weevils were often found in the end of young cordon growth and the larvae were found in the larger harder cordon wood and also in the top of the vine trunk. Pupae were also often found in younger cordon growth. Up to 5 Elephant Weevils have been found in a single cordon, which is potentially devastating to the vine.

From scouting it was found that the Elephant Weevils were easy to find for 10 months of the year, but from the end of March to April it became difficult to find the weevils in vines. From October to early January it is best to go in the field and find larvae and pupae as well as adult stages of the weevil. From observations of a captured pupa it only takes a few weeks for a young pupa to develop into an adult Elephant Weevil (Figure 3). The weevils were probably at their highest incidence at larval stage from November to December and easily found by twisting a cordon of an affected vine. Adults are seen more at the end of December or in January. This suggests the Elephant Weevil has an annual life cycle. No eggs of the Elephant Weevil were ever found or have been found by growers in Langhorne Creek. It is presumed these are very small and would be extremely difficult to find.

Some night time scouting should be done when the Elephant Weevils reach the adult stage. This could provide more information on breeding habits and also may help to find where they lay their eggs. From observation it is presumed that the female would chew a small hole, which is very hard to see, somewhere on the cordon arm and rear up to it laying her eggs. It is presumed that the female does not favour laying eggs in the trunk due to the hardness of the wood and the fact that most of the tunnelling was found in cordon wood.

Discussions with growers revealed a correlation between stress and colonization of vines by Elephant Weevil. Growers indicated that the vines which had been infected first were near large native trees, or under other stresses such as lack of watering. Large native trees could compete by shading the vines and

take much needed water away from the vines making them weaker. Being under water stress, nutrient stress or suffering other pest pressures resulting in general reduced health of vines would presumably increase the susceptibility of vines to the damage caused by Elephant Weevils. One grower mentioned only starting to see a problem this year with Elephant Weevils in relatively young vines which were planted next to large Athel Pines. This grower mentioned that the first observation of Elephant Weevils was in the vines closest to these trees and that they have since been observed further into the vineyard rows. Still, the greatest damage was in the first rows near the Athel Pine trees. Native vegetation, as well as causing competition, may be a site for harbouring the Elephant Weevil but none were found by scouting the native vegetation. However, this may not be conclusive without undertaking some dissection of the trees and a more thorough investigation.

It is possible that the adult Elephant Weevil could be attracted to chemicals given off by a recently dead or stressed plant. When adults cause ringbarking of vines it could enable premature senescence (Fisher 2003), which could attract other weevils to inhabit the vines from bushland or from the native trees planted on the property. Once one row of vines is infected Elephant Weevils could easily move to the next vine or row selecting the weaker vines becoming a bigger problem in the vineyard.

A practice which has been done for the last 3 years which may be having an impact on Elephant Weevil populations is the cutting and burning of infected wood. This may be reducing numbers but is also very costly to the grower with having to retrain infected vines or completely replant severely damaged vines. This also cannot be done all year round due to burning restrictions but there have been reports of growers putting affected cut wood in a bin and applying pesticides outside of burning season to control Elephant Weevils. Another practice, mulching of pruned canes, which is used to help reduce auger beetles (Fisher 2003), could be used to help reduce Elephant Weevil numbers as well, in conjunction with the other practices and may help to reduce numbers even more.

The use of a pesticides to control these insects has also been limiting because Elephant Weevils are so entrenched in the vines, even a systemic pesticide would not be able to be used safely or regularly enough to penetrate hardy vine wood. Many pesticides can only be applied during vine dormancy, which is not appropriate, and not when adults are active. Not many chemical insect control options are available to the viticulture industry and growers also wish to restrict the use of harmful chemicals in the industry. Chemicals can also devastate populations of beneficial insects in vineyards.

Observations of stages of development

There are 3 stages of development of the Elephant Weevil. The larva is the most common stage seen in vines and is the stage that causes most damage. The chewing mouth parts of the larva chew through the

vines with ease and cause the most devastating damage. They are at this stage for probably 9-10 months of the year.

As for many insects, the pupae stage is a very vulnerable stage where the grub remains in a static state as it develops into an adult. This stage takes a couple of weeks as the wings; rostrum and legs start to become visible. At the start of this stage the pupa is a light cream colour during early development and becomes dark brown as it matures until it eventually develops into an adult.

The adult stage is seen around late November to April. The adults have the ability to fly with a strong wing structure and are probably carried by strong winds. They are often found in the end of a smaller cordon piece before emerging where there is most new shoot growth. The males and females probably disperse from their vines to mate, after females have been fertilized they may nibble small holes with their rostrum into a cordon, where they lay their eggs. It is not known exactly how long adult stages live for and after mating and laying the eggs it is presumed they die. Live adults were kept for several months in sample jars and could be easily maintained with some vine wood and moistened tissue to drink from. Size differences were seen between some of the adults caught. It often seemed that when mating the smaller of the insects was on top indicating that maybe males are a bit smaller than females.

Possible parasitoid findings

When scouting at site 2, vine wood was found which had evidence of Elephant Weevil damage. Pieces of wood were cut which had tunnelling and new frass associated. Closer observation showed two very small neat bore holes evident in the wood, these were about 2mm in diameter (Figure 5).Cutting into the vines and following the bore holes revealed remains of what looked like Elephant Weevils encased in a cocoon (Figure 6). Each small tunnel led to the site of a cocooned weevil. One of the cocooned weevils was found in the cordon near a spur shoot and the other slightly lower down. A third cocooned weevil was found in the cordon, just below the first two but there was no evidence of any small hole leading to it.

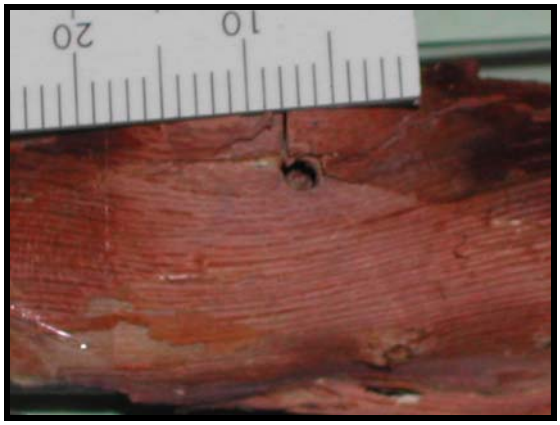
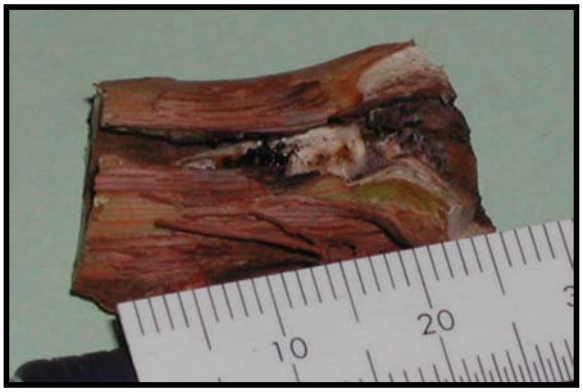


Figure 5: 2mm wasp hole





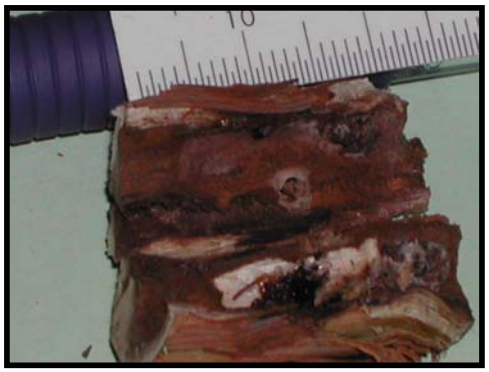


Figure 6: 3 pictures showing a cocooned Elephant Weevil after cutting into the 0.2mm wasp hole

The sites where the cocooned insects were found were clearly that resulting from Elephant Weevil activity. The remains were too big to be that of Vine Weevils, so Vine Weevils were ruled out. The cocooned insects had a hard light brown shell like the Elephant Weevil and appeared to be the perfect size for an Elephant Weevil, and were also found in frass tunnels. The only other insect in a frass tunnel

I had seen were earwigs, which colonize old tunnelling systems, but these remains had no similarity to earwigs at all and the frass around the cocoon appeared fresh (not aged).

The vineyards were scouted in search of more holes 2mm holes. Wasps were noted "wandering" on the cordons of infected vines at sites 1 and 2 doing what appeared to be a "dance", as if they were moving to stimuli (Figure 7). One of the wasps was caught and taken to the Adelaide University for identification. The wasp was of the superfamily Braconidae. These wasps are known to be ectoparasites of coleopteran and could potentially be a natural predator of the Elephant Weevil (Wildlife of Sydney 2004). The size of this wasp was large for a Braconidae, being 2 to 2.5cm long, and seemingly being the ideal size for a potential parasitoid of such a big insect as the Elephant Weevil.



Figure 7: Wasps "dancing" on a vine cordon

Wasp traps

E. Adapted fruit fly traps

The trap made to catch the wasp was a plastic drink bottle design (Gardening Australia 2002). Elephant Weevil frass was used as an attractant, which was soaked in water for dispersal of any possible chemical attractant. The reason the frass was used was because in an article on Vine Weevil studies they found that other Vine Weevils were attracted to each other by chemicals in frass (Van Tol (2004). It was thought that if it can work within a species why not between species in a predator to host relationship.

When talking to a couple of peers at the Adelaide University who studied Braconid wasps similar to that caught in the field, it was noted that "Braconids were more attracted to chemical stimulants like the regurgitated remains of a grub or frass, than to actual hosts themselves". This was another reason to trial frass over live larva. Also live larva specimens of Elephant Weevils were scarce at the time, probably due to their development into adults at this time.

At the end of about 6 weeks a wasp had been caught in one of the traps in site 2 (Figure 8). It was exactly the same as the other wasps caught prior to distributing the traps in the field. When comparing the wasp, the one caught in the trap was smaller and had almost a non-visible ovipositor. This was taken to the Adelaide University and keyed out and found to be the same as the previous wasps caught in the field (Braconid). Peers at the University checked these findings and also confirmed it as a Brachonid. The size difference seen could be sexual dimorphism in the species. The fact that only one was caught could have been a factor of chance. It was decided that a better trap design was needed.



Figure 8: Wasp caught in a modified fruit fly trap with frass as an attractant

F. Yellow Sticky traps

Yellow Sticky traps were used in an attempt to find a more comprehensive means of catching the wasp. They were hung in the field by string to try and identify if the wasps were really attracted to frass (some contained frass, some did not). Eight sticky traps were put at site 2, where most of the wasps had

previously been observed. Another control and trap were placed at site 1, where this wasp had also been observed. A week later the traps were checked but nothing was found. The traps needed to be monitored for longer and maintained more regularly, but due to the project nearing completion this was not possible. This is something that could be followed up in a future project.

It may have been that the peak time of the season for using these traps had been missed, because it seemed that there were many more wasps seen in February then by the end of March when the first fruit fly traps were put out. It was interesting that the time of the wasps being found coincided to the time when it was hard to find Elephant Weevil larvae or pupae. This would be a period where the Elephant Weevil are laying eggs or at a very young developmental stage and therefore a prime time for a parasitoid to parasitize its enemy (Wermelinger 2004).

Vine Weevil/Elephant Weevil/ Wasp holes

There are obvious differences when looking at the emergence holes produced by Vine Weevil, Elephant Weevil and the proposed wasp. All are perfectly symmetrical and it almost looks like they have been drilled. The Elephant Weevil emergence hole is about 5-6 mm in diameter, whereas the Vine Weevil is 2-3 mm in diameter and the supposed wasp hole is 1-2mm (Figure 9).

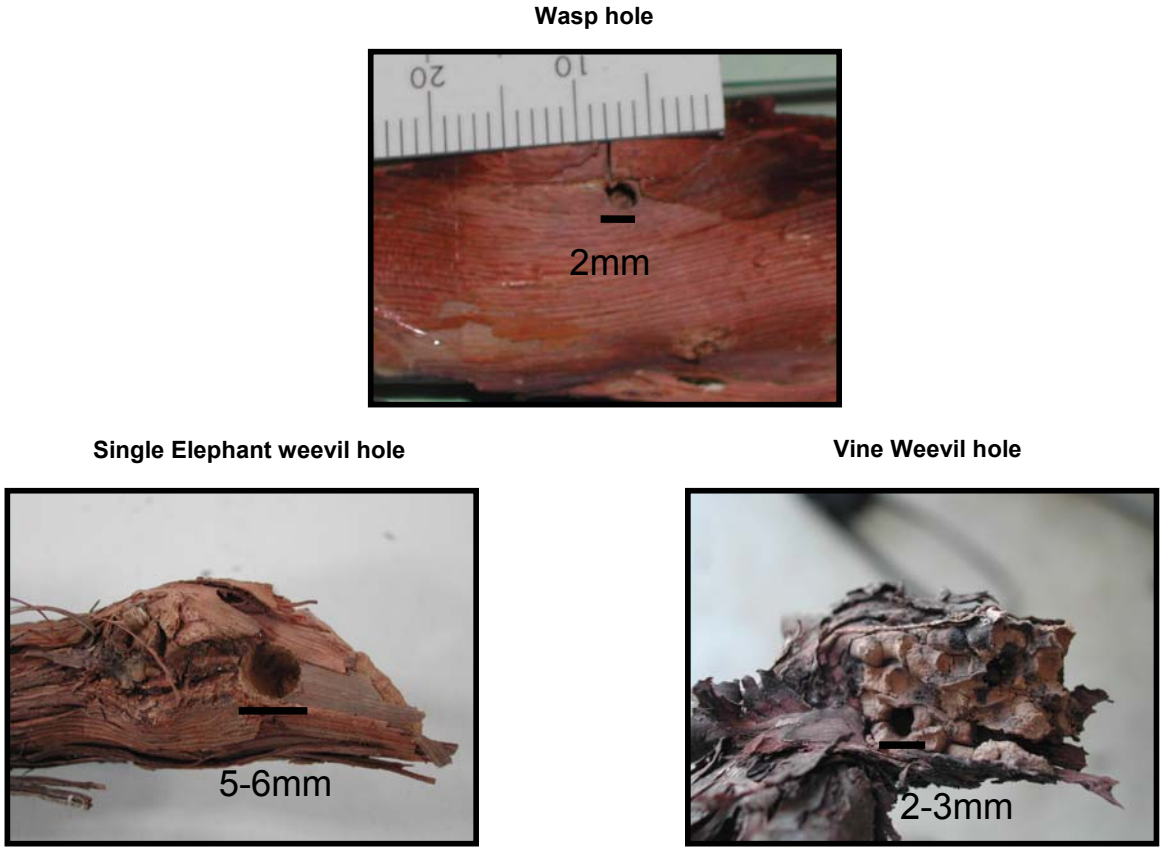


Figure 9: Comparison of the wasp hole compared to Elephant and Vine Weevil emergence holes

Harvest occurrence

During harvest grape bins at site 5 were scouted and the growers asked if any Elephant Weevils were being seen in the grape bins. When looking in the bins it was hard to get an accurate estimate because only the top layer could be observed. . The bins measured 1.2m deep by 2.2m wide. No Elephant Weevils were found in the small number of bins that were viewed. The fruit was very juicy and hard to inspect. If a few Elephant Weevils were found on top of the bin it was postulated that an estimate of how many may be in a bin could be made by multiplying the number found by the depth of the bin. In other sites 1, 2 and 5 growers indicated that they had found Elephant Weevils in grape bins. Weevils were found on top of a bin in the Chardonnay block at site 1 and 2 and at site 5 Elephant Weevils were seen on two bins in the Cabernet Sauvignon block. Another grower at site 6 had found 2 Weevils on top of a Shiraz bin. Local contract harvest operators were contacted to find out if they had found Elephant Weevil numbers high this year. It was indicated that they had found at most 5 or so in a bin but generally there were none seen and this year is one of the years where they have seen less weevil damage and less weevils in grape bins.

The bins were looked at because growers reported that in previous years Elephant Weevils were crawling all over the grape bins. Growers indicated that the 2004 year showed the lowest incidence of Elephant Weevil in grape bins in several years."..

Vine dissection

A few vines were taken from two sites to look at damage caused by Elephant Weevils. The first vines dissected were a 9 yr old Chardonnay and a 30 year old Cabernet Sauvignon. From this process it was found that older frass tended to be a lighter sand colour whereas new frass appeared browner and richer in colour. Elephant Weevils were found to have up to 5 tunnels in one badly affected cordon. Adult weevils were usually found near the end of the cordon where there was newer growth. There has been little or no infection seen directly at the base of the trunk until about 1 meter up in the younger vines but in one of the older vines chewing damage was found near the base in one case. Larvae and pupae are often seen at the top of the trunk near the cordon arm or at the middle of the arm. Vines with damage have less leaf coverage. Older vines seemed to be able to cope with the tunnelling damage and continue growing where younger vines can be susceptible and die. This is probably due to so much of the younger vines structure and xylem system being destroyed compared to an older larger vines. Tunnels seemed to go along a cordon for about 30 centimetres then stop for a few centimetres then another tunnel seemed to start. Larvae were also found, often with more than one being found in a "knuckle" where vine offshoots occurred. The tunnelling almost looked as if the Weevils tunnelled back on themselves, maybe back to the initial site they where the egg was deposited (Seeman 2002).

Vine wood was also collected from pruning off-cuts. A lot of damage was found caused by Elephant Weevil and Vine Weevil in Merlot and Chardonnay wood from site 1. It was estimated that 40% of the pruning off-cuts had some type of Elephant Weevil damage.

Other observations

I have found that there are a great range of beneficial insects and pests in the vineyards at Langhorne Creek (as evidenced by the contents of the collection boxes, APPENDIX IV). The most diverse ranges and abundance of beneficial insects were found at sites 1 and 2. The collection box is a tool that local growers and people at Langhorne Creek can look at to get an idea of the insects in vineyards and what an Elephant Weevil looks like compared to other weevils or insects in the field.

At the start of this project a jar with approximately a total of 1.8m of wood infected with Vine Weevil sourced from site 6 was left at the Langhorne Creek Wine Industry Council office. After several months it was noticed that a tiny wasp had emerged inside the sealed jar along with about 40 adult vine weevils. The wasp looked similar to those caught in the field where Elephant Weevil infection had been seen, but was much smaller and similar in length to the Vine Weevils. This smaller wasp may have been a natural parasitoid of the Vine Weevil. It was interesting to note the large number of adult Vine Weevils that emerged from this 1.8m length of wood, indicating a density of about 4.5 Vine Weevils per cm of wood!

It would be of interest to further investigate the following:

a.) Clarify if Elephant Weevils are attracted to each other by chemical signals from frass as has been indicated by Van Tol (2004) for Vine Weevils.
b.) Investigate how susceptible 'stressed' vine plants are to attack from Elephant Weevils. This might be via irrigation or nutrient manipulation.
c.) Investigate the biology and behaviour of the Braconidae wasps and try and confirm if they could be a parasitoid of weevil larvae.

CONCLUSIONS:

It seems that this year Elephant Weevil populations have been at their lowest in recent years. This could be due to the increasing practice of cutting out and burning infected vines and wood, environmental conditions or control by a natural predator. The possible wasp parasitoid should be further investigated in an attempt to confirm this relationship. If confirmed, it would then be of interest to devise a method to encourage populations of this beneficial insect as a possible means of assisting control of the Elephant Weevil population. General practices like keeping the vineyard tidy and healthy helps to reduce stress and other vineyard pests as well as encourage beneficial insects. Looking into other trapping methods and detection by scouting for symptoms like stunted growth 3-7 weeks into the growing season, growth

of extra water shoots, emergence holes and patches on the cordon where no shoot growth is present should be continually done. A single appropriate management for this pest is still unknown but an integrated approach of the above things should be the first step in reducing the Elephant Weevil.

Future directions:

It would be of benefit to further this project with more extensive field work over a longer and more frequent time frame. Two days a week over 20 weeks is not sufficient to adequately monitor traps and visit all the sites. Nonetheless valuable information has been collected and a somewhat better understanding of the life stages of the Elephant Weevil has been gained. It is suggested that in the Langhorne Creek region a follow up project should begin in October when it is expected that a lot of Elephant Weevil adults should be found and continue at least until several months post-harvest.

Another alternative project focussed at investigation of other insects and their populations at Langhorne Creek could also be beneficial. This may even help with uncovering more about a natural predator for the Elephant Weevil as more study could be focused on wasp populations. This could be set up as a predator prey interaction project.

Acknowledgments:

This project was supported by the Grape & Wine Research & Development Corporation (GWRDC) through RITA funding support.

The support of the following persons is gratefully acknowledged: Dr. Michael Keller (Senior Lecturer Entomology, Plant & Pest Science, The University of Adelaide), Mr Richard Glatz (Research scientist at The University of Adelaide), Ms Cate Paul (PhD student at The University of Adelaide), all the local growers who participated in the project, Lian Jaensch for collaborating and organizing the project, and the Langhorne Creek Vine Improvement Committee.

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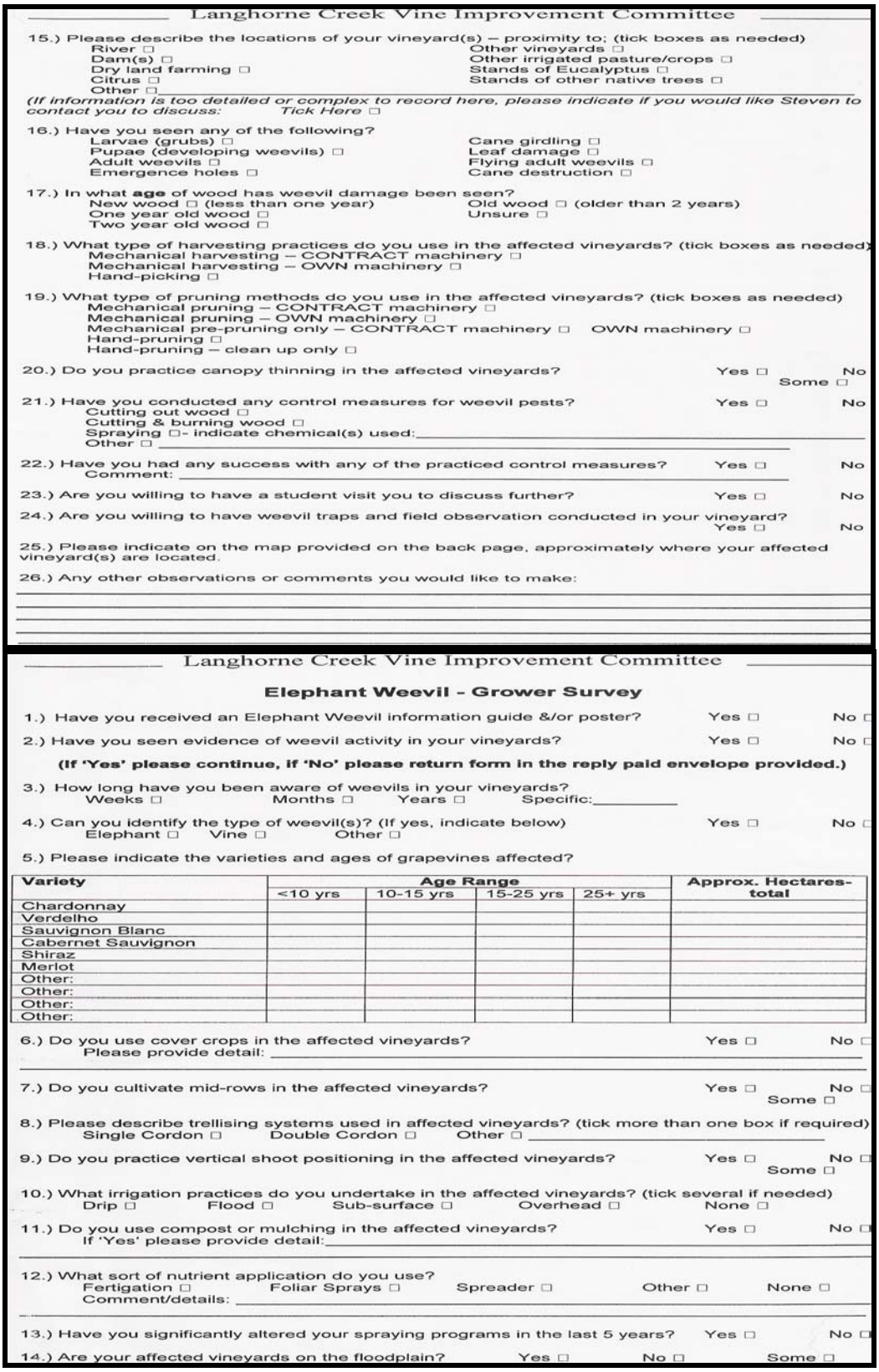
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APPENDIX 1



Langhorne Creek Vine Improvement Committee

15.) Please describe the locations of your vineyard(s) – proximity to; (tick boxes as needed)
River ☐ Other vineyards ☐
Dam(s) ☐ Other irrigated pasture/crops ☐
Dry land farming ☐ Stands of Eucalyptus ☐
Citrus ☐ Stands of other native trees ☐
Other ☐_____
(If information is too detailed or complex to record here, please indicate if you would like Steven to contact you to discuss: Tick Here ☐

16.) Have you seen any of the following?
Larvae (grubs) ☐ Cane girdling ☐
Pupae (developing weevils) ☐ Leaf damage ☐
Adult weevils ☐ Flying adult weevils ☐
Emergence holes ☐ Cane destruction ☐

17.) In what **age** of wood has weevil damage been seen?
New wood ☐ (less than one year) Old wood ☐ (older than 2 years)
One year old wood ☐ Unsure ☐
Two year old wood ☐

18.) What type of harvesting practices do you use in the affected vineyards? (tick boxes as needed)
Mechanical harvesting – CONTRACT machinery ☐
Mechanical harvesting – OWN machinery ☐
Hand-picking ☐

19.) What type of pruning methods do you use in the affected vineyards? (tick boxes as needed)
Mechanical pruning – CONTRACT machinery ☐
Mechanical pruning – OWN machinery ☐
Mechanical pre-pruning only – CONTRACT machinery ☐ OWN machinery ☐
Hand-pruning ☐
Hand-pruning – clean up only ☐

20.) Do you practice canopy thinning in the affected vineyards? Yes ☐ No ☐ Some ☐

21.) Have you conducted any control measures for weevil pests? Yes ☐ No ☐
Cutting out wood ☐
Cutting & burning wood ☐
Spraying ☐- indicate chemical(s) used:_____
Other ☐ _____

22.) Have you had any success with any of the practiced control measures? Yes ☐ No ☐
Comment: _____

23.) Are you willing to have a student visit you to discuss further? Yes ☐ No ☐

24.) Are you willing to have weevil traps and field observation conducted in your vineyard? Yes ☐ No ☐

25.) Please indicate on the map provided on the back page, approximately where your affected vineyard(s) are located.

26.) Any other observations or comments you would like to make:
_____
_____
_____
_____

Langhorne Creek Vine Improvement Committee

Elephant Weevil - Grower Survey

1.) Have you received an Elephant Weevil information guide &/or poster? Yes ☐ No ☐

2.) Have you seen evidence of weevil activity in your vineyards? Yes ☐ No ☐

(If 'Yes' please continue, if 'No' please return form in the reply paid envelope provided.)

3.) How long have you been aware of weevils in your vineyards?
Weeks ☐ Months ☐ Years ☐ Specific:_____

4.) Can you identify the type of weevil(s)? (If yes, indicate below) Yes ☐ No ☐
Elephant ☐ Vine ☐ Other ☐

5.) Please indicate the varieties and ages of grapevines affected?

Variety	Age Range				Approx. Hectares-total
	<10 yrs	10-15 yrs	15-25 yrs	25+ yrs	
Chardonnay					
Verdelho					
Sauvignon Blanc					
Cabernet Sauvignon					
Shiraz					
Merlot					
Other:					
Other:					
Other:					
Other:					

6.) Do you use cover crops in the affected vineyards? Yes ☐ No ☐
Please provide detail: _____

7.) Do you cultivate mid-rows in the affected vineyards? Yes ☐ No ☐ Some ☐

8.) Please describe trellising systems used in affected vineyards? (tick more than one box if required)
Single Cordon ☐ Double Cordon ☐ Other ☐ _____

9.) Do you practice vertical shoot positioning in the affected vineyards? Yes ☐ No ☐ Some ☐

10.) What irrigation practices do you undertake in the affected vineyards? (tick several if needed)
Drip ☐ Flood ☐ Sub-surface ☐ Overhead ☐ None ☐

11.) Do you use compost or mulching in the affected vineyards? Yes ☐ No ☐
If 'Yes' please provide detail:_____

12.) What sort of nutrient application do you use?
Fertigation ☐ Foliar Sprays ☐ Spreader ☐ Other ☐ None ☐
Comment/details: _____

13.) Have you significantly altered your spraying programs in the last 5 years? Yes ☐ No ☐

14.) Are your affected vineyards on the floodplain? Yes ☐ No ☐ Some ☐

Figure A: Growers survey form

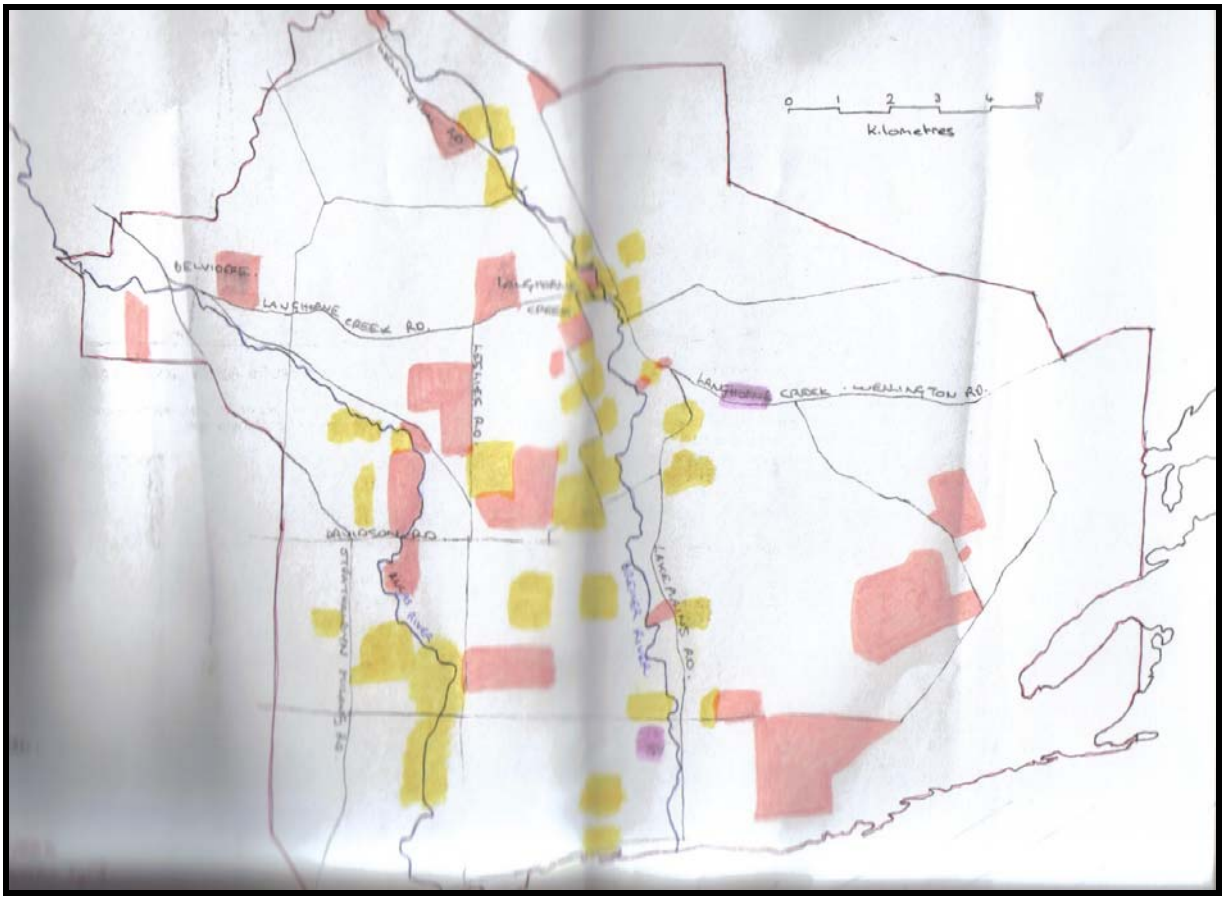


Figure B: Map of Weevil distribution in Langhorne creek

The Yellow = Elephant Weevil

The Pink = No Weevils

The Purple = Vine Weevil

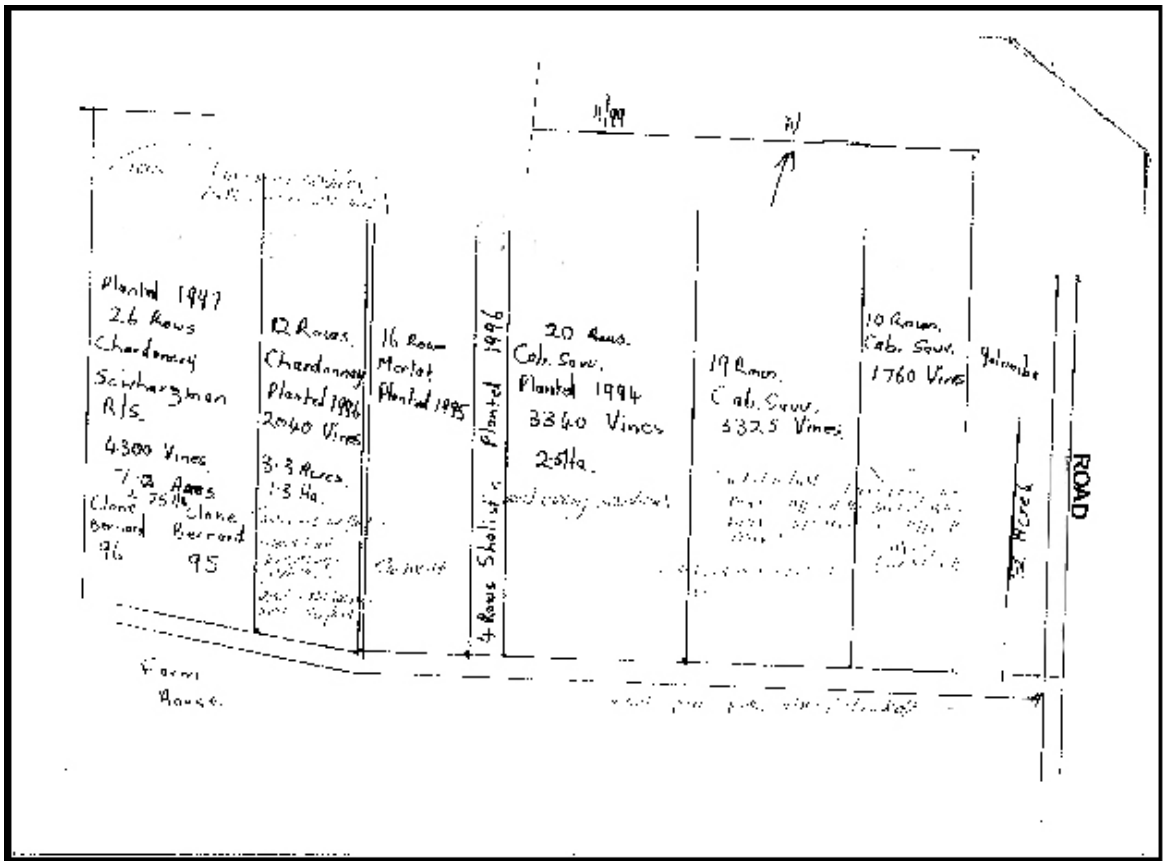
The Map shows that the largest congregation of Elephant Weevil effected properties are near the Bremer and Angus River.

Figure C: Selected Sites

Site 1

On this site there were two varieties of vine that were looked at with bad damage by Elephant Weevil, single cordon 30 yr old Cabernet sauvignon and younger 13 year old Chardonnay. The younger vines were effected by a frost making some weaker than others. On this property the vines are flood and drip irrigated

3 years ago the worst damage was seen in the Chardonnay when some vines had to be completely removed and burnt. The Cabernet Sauvignon vines also showed damage from Elephant Weevils, but due to the greater size of the cordons, a factor of age, they were perhaps not as susceptible to erratic damage and could continue to grow without the damage resulting in vine death. Inside the cordon arms it looked like internal ringbarking was present in some of the larger vines, due to Elephant Weevil damage. In another block Merlot was also infected but this was not investigated as these other sites showed the worst damage.



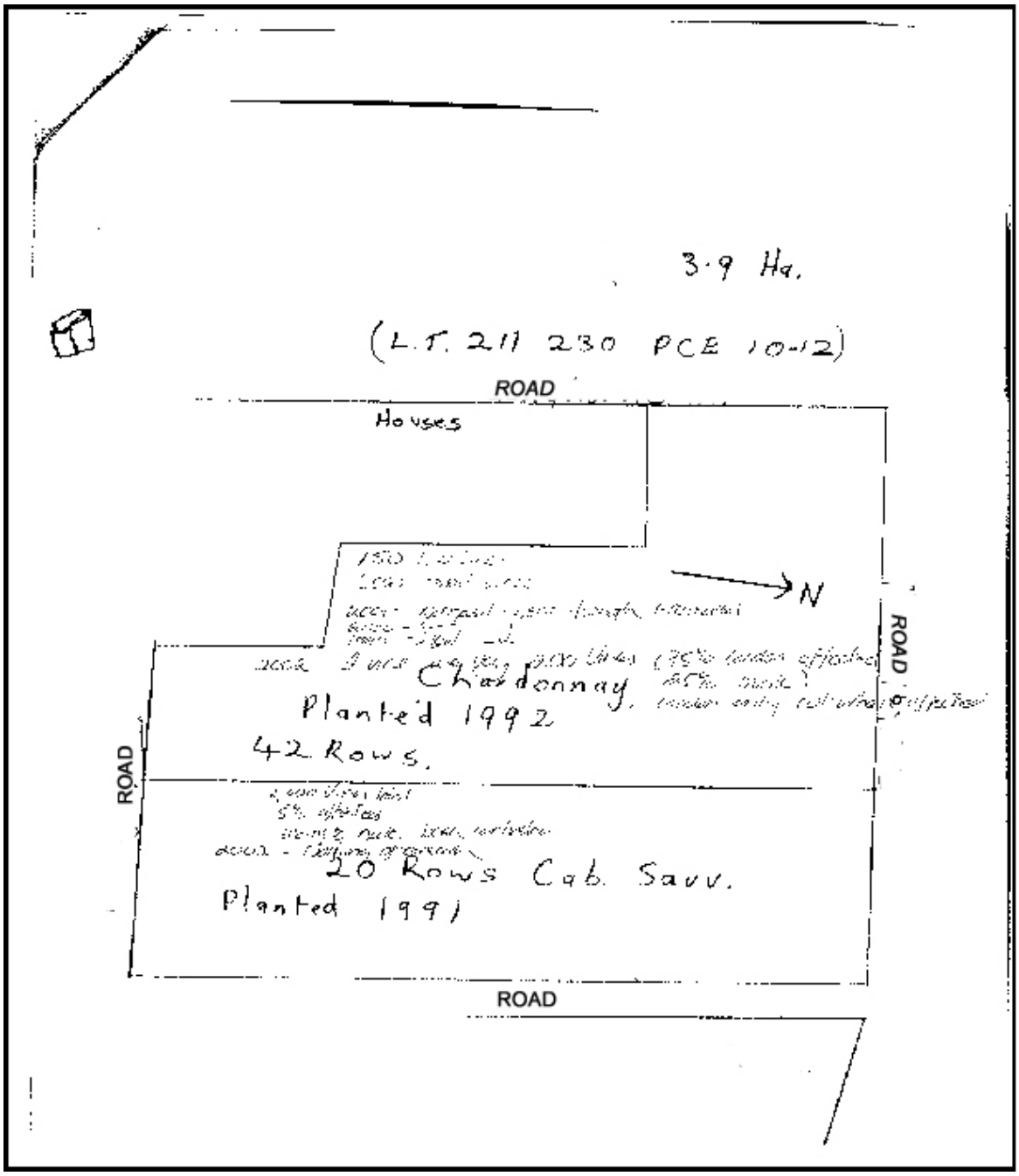
Site 1 map

Site 2

The varieties on this site are single cordon 12 yr old Chardonnay and 13 year old Cabernet Sauvignon. The variety mainly of interest here was the Chardonnay as it showed most Elephant Weevil damage. This site is drip irrigated and subject to natural flood irrigation

Adjacent to the worst infected Chardonnay vines are Casuarinas (River Oak). The trees could be a source of competition by shading the vines and they have large root systems which could take water and nutrients from vines. The vines with the most Elephant Weevil damage were cut out and burned. The vines worst damaged were the ones directly adjacent to the Casuarinas. When cutting back infected plants a lot had to be cut back to the water shoot level where no infection by weevils was present, some plants were cut off twice because of re-infection, at a later stage.

It has been noticed by the owner that when weevils have attacked the top of vines a lot more water shoots emerged at ground level and the top shoots have been weakened. He had noticed that 10 months of the year he has seen Elephant Weevils developing (long pupa stage), but for about 2 months there are none present. The weeds here are slashed

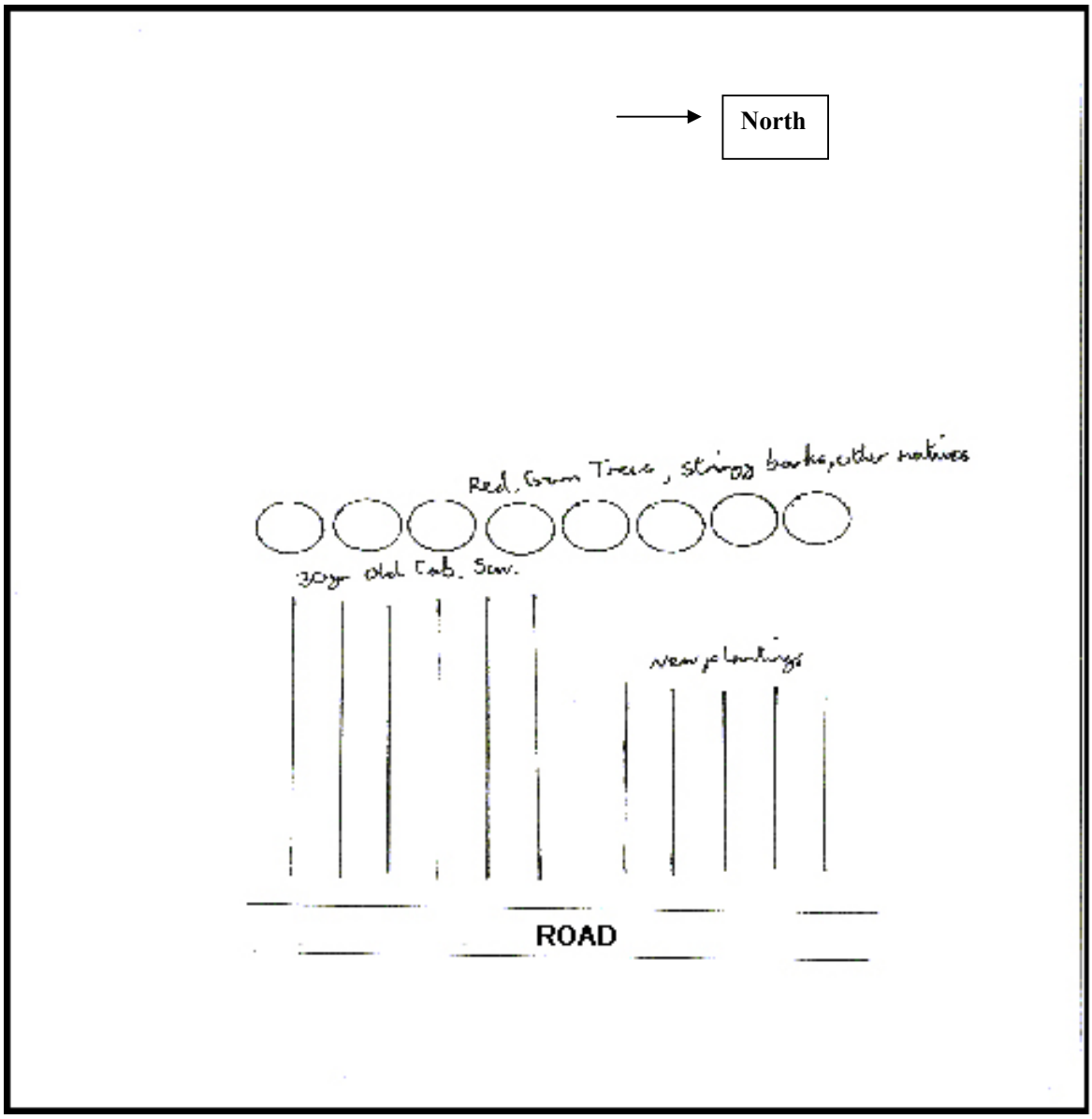

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Chardonnay.
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ROAD
20 Rows Cab. Sauv.
Planted 1991
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Site 2 map

Site 3

The varieties of vines found on this site with infection by Elephant Weevil are single cordon, 30 year old Cabernet Sauvignon. The vineyard here is drip irrigated and flood irrigated. The vines when first planted were subject to lack of water and some stress.

At the back of the planting many stringy barks and other natives were present. As a control dormant dead wood was cut and then burnt by the owner. The older branching wood on the variety seemed to be weakest. It was noticed that infection was present with larvae, just upon flowering of 6-8year old vines. Emergence holes found were > 60-70mm. . Emergence holes were seen approx. 1m off the ground. Weevil infection caused limbs to be brittle and easily broken off. Some damage by weevil reduced a whole branching arm which is substantial damage, when you think of the grapes lost. Some weevil holes found back in older thicker main stem. Infection by Elephant Weevil was found to be on nearly every plant. Many weeds were present.



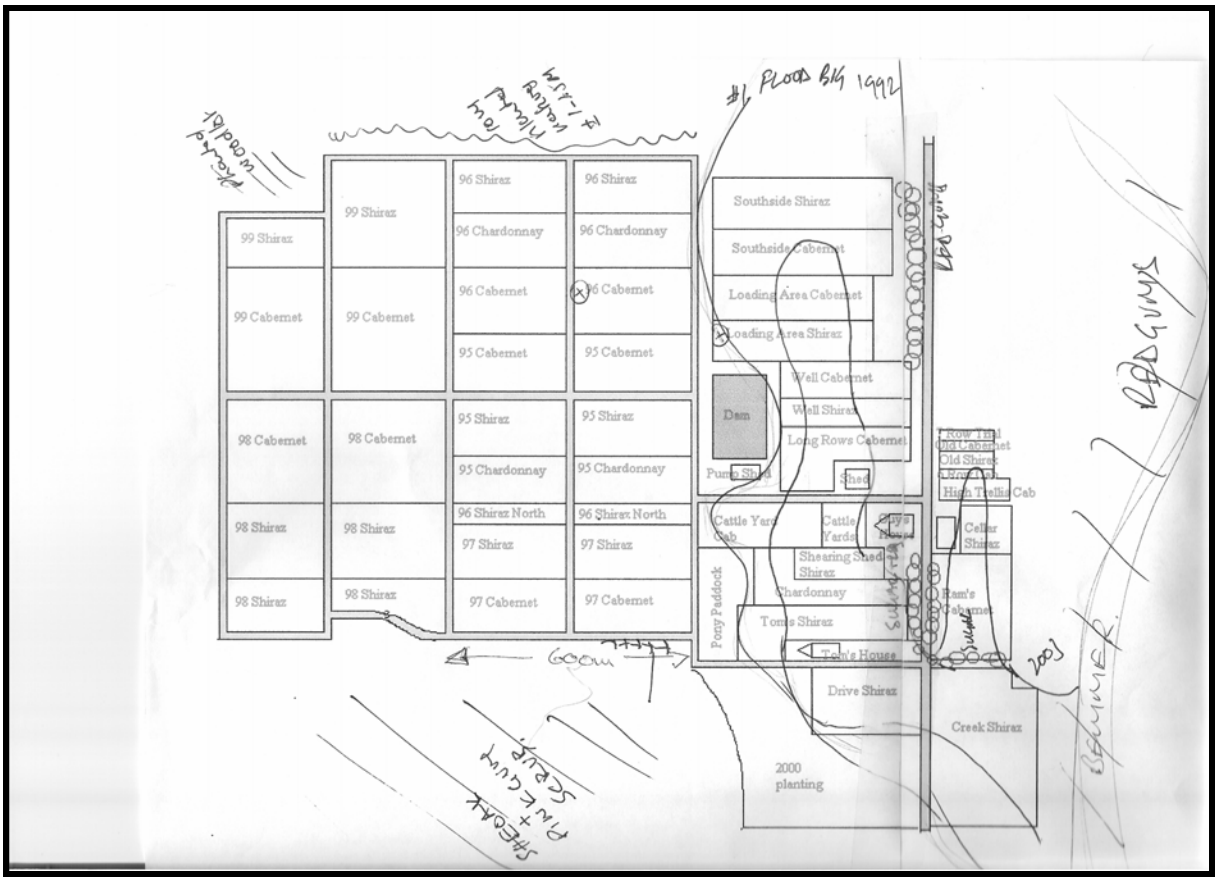
Site 3 map

Site 4

At this site there were no Elephant Weevils present but they had had incidence of Vine Weevil. Vines here ranged from 120 years old to 2 years and most are single cordon. I looked at 9 year old Chardonnay which had shown high incidence of Vine Weevil. Other varieties grown here were Shiraz and Cabernet Sauvignon. Older vines are situated on the flood plain and this is how they were watered for many years, but now drip irrigation is incorporated.

Not many weevils have been noticed this year. The Vine Weevil has been seen here on the second node of the shoot with its proboscis inserted to feed. Annually grown barley cover crops are used in between

rows and round up is put on the barley to kill it instead of mulching. Herbicides under the vines are also used to kill weeds. This site has a very high weed control in the vines.

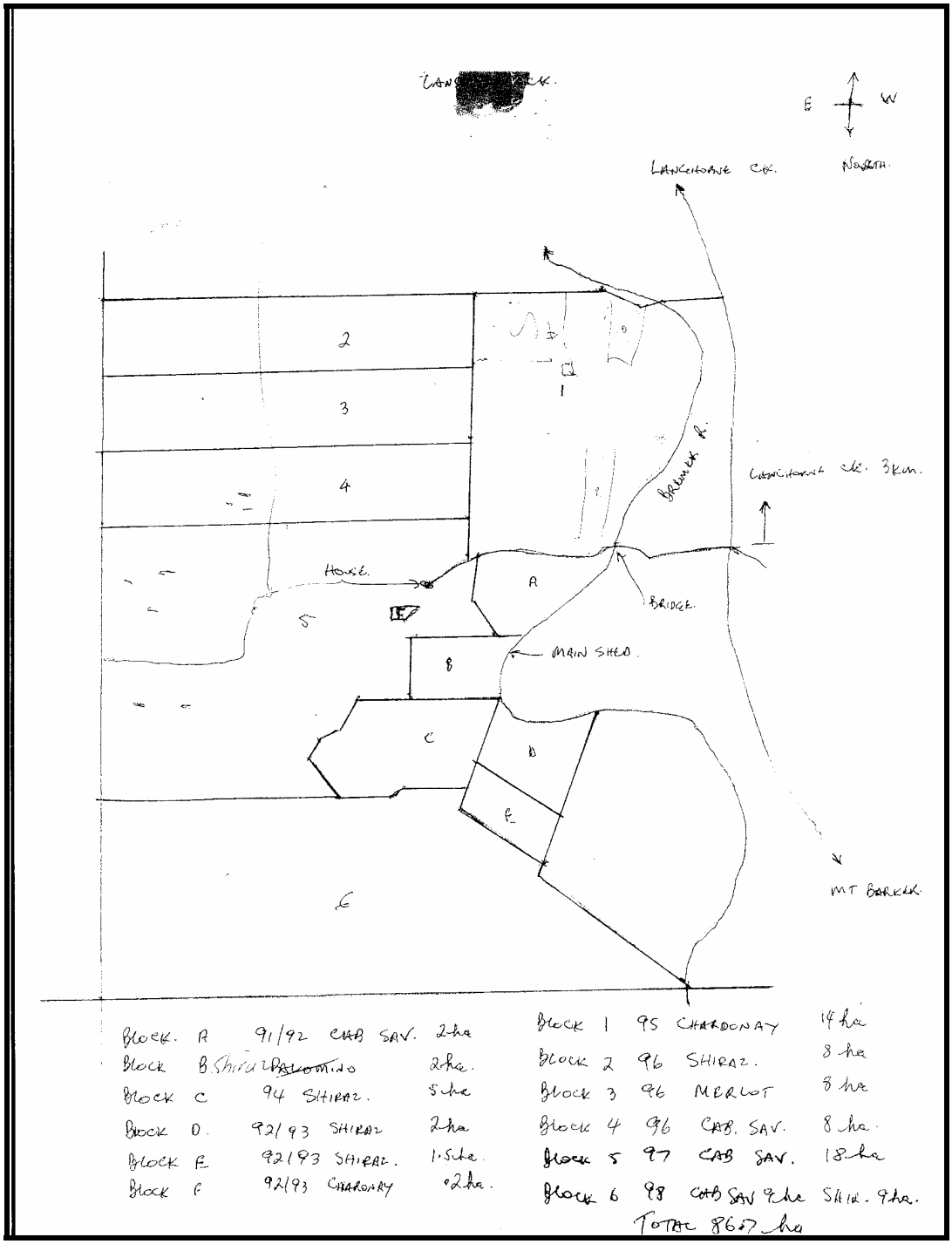


Site 4 map

Site 5

At this site Elephant Weevils were found in Cabernet Sauvignon, Merlot and Chardonnay. Due to some reason, maybe burning practices, there are only Elephant Weevils now present in the 9 year old Chardonnay, which I investigated. There is 17 ha of Chardonnay but it is hard to say how much is infected. Double trellising is used for most of the varieties on this site and the Chardonnay I studied was double trellised. They use drip and flood irrigation on this site. Part of the Chardonnay I studied didn't get sufficient flooding at the beginning of its growth making the vines weak. Now these vines have shown infection by the Elephant Weevil, which has spread to the other vines.

Elephant Weevils have been found in the Chardonnay at different stages of development. Only two stages the larva and pupa were ever found in the same cordon arm. Elephant Weevils were found in the 3rd year of growth of the Chardonnay, and they were found in the second cordon, being the younger cordon. None have been found in the thick cordon or in the trunk, but there has been no real effort to search for them by the growers. This year less damaged wood has been cut and burned out compared to the previous 4-5 years they have had Elephant Weevils. There is limited vegetation compared to other sites at the edge of the infected vines, but the site is next to the Bremer River. Stunted growth and no leaves have been the main symptoms of the Elephant Weevil here. Observations show they may be chewing in the arm and following back down original path.

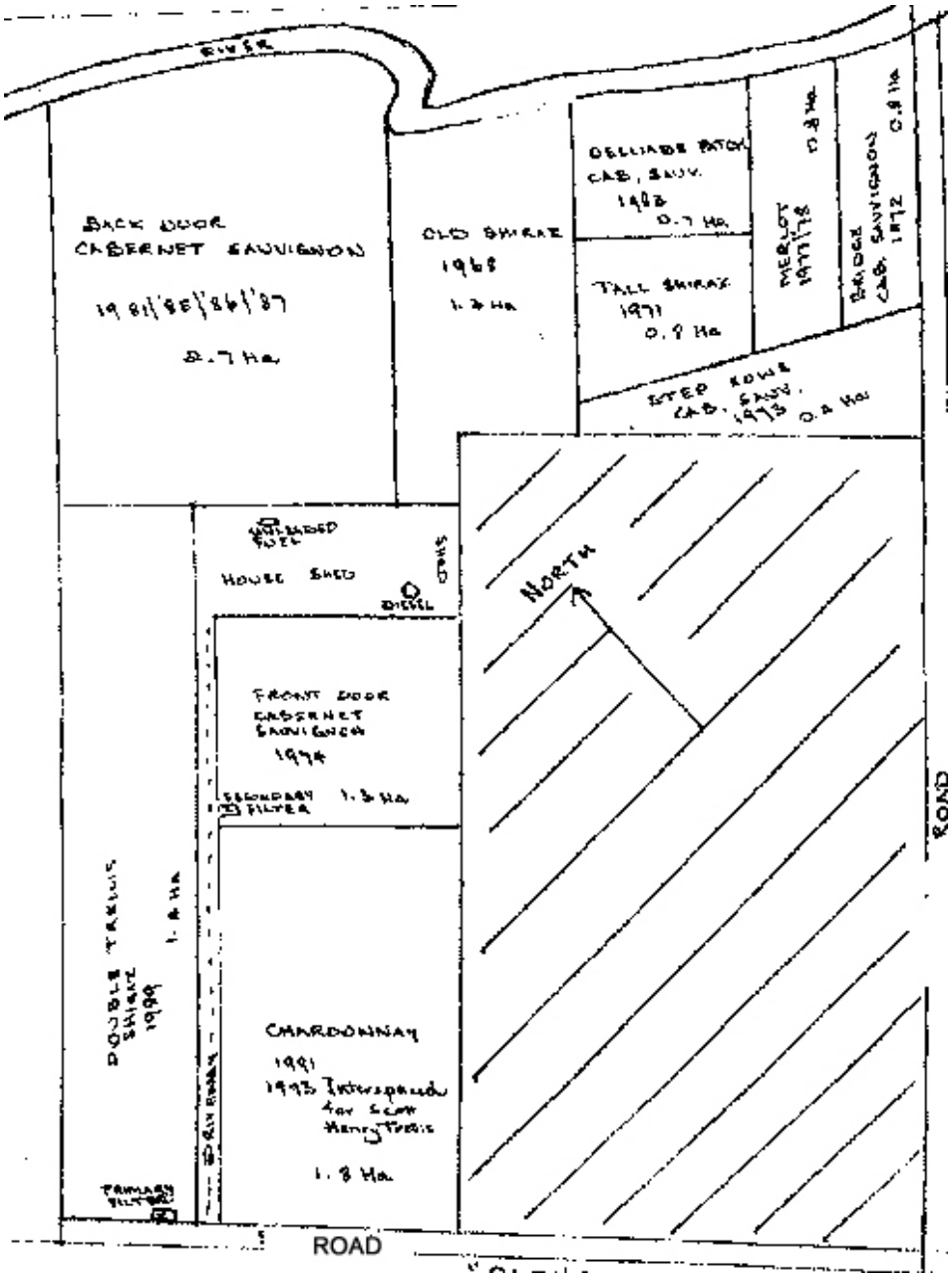

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LANCELEAFE CK. 3Km.
HOUSE.
A
BRIDGE.
MAIN SHED.
B
C
D
E
F
MT BARKER.
Block. A 91/92 CAB SAV. 2ha
Block B Shiraz/Malbec 2ha.
Block C 94 SHIRAZ. 5ha
Block D. 92/93 SHIRAZ 2ha
Block E 92/93 SHIRAZ. 1.5ha.
Block F 92/93 CHARDONAY .2ha.
Block 1 95 CHARDONAY 14 ha
Block 2 96 SHIRAZ. 8 ha
Block 3 96 MERLOT 8 ha
Block 4 96 CAB. SAV. 8 ha.
Block 5 97 CAB SAV. 18 ha
Block 6 98 CAB SAV 9 ha SHIR. 9 ha.
TOTAL 86.7 ha

Site 5 map

Site 6

The varieties on this site are Shiraz and Chardonnay on a 12ha block and predominantly the vines are double cordon. The area is drip and flood irrigated.

Garden Weevils have been a massive problem seen 2nd-3rd week of August until February in the Chardonnay, and there has been a few Elephant Weevils located in the Shiraz. Vine Weevil started to be seen in the front Chardonnay and some in the Shiraz in December.

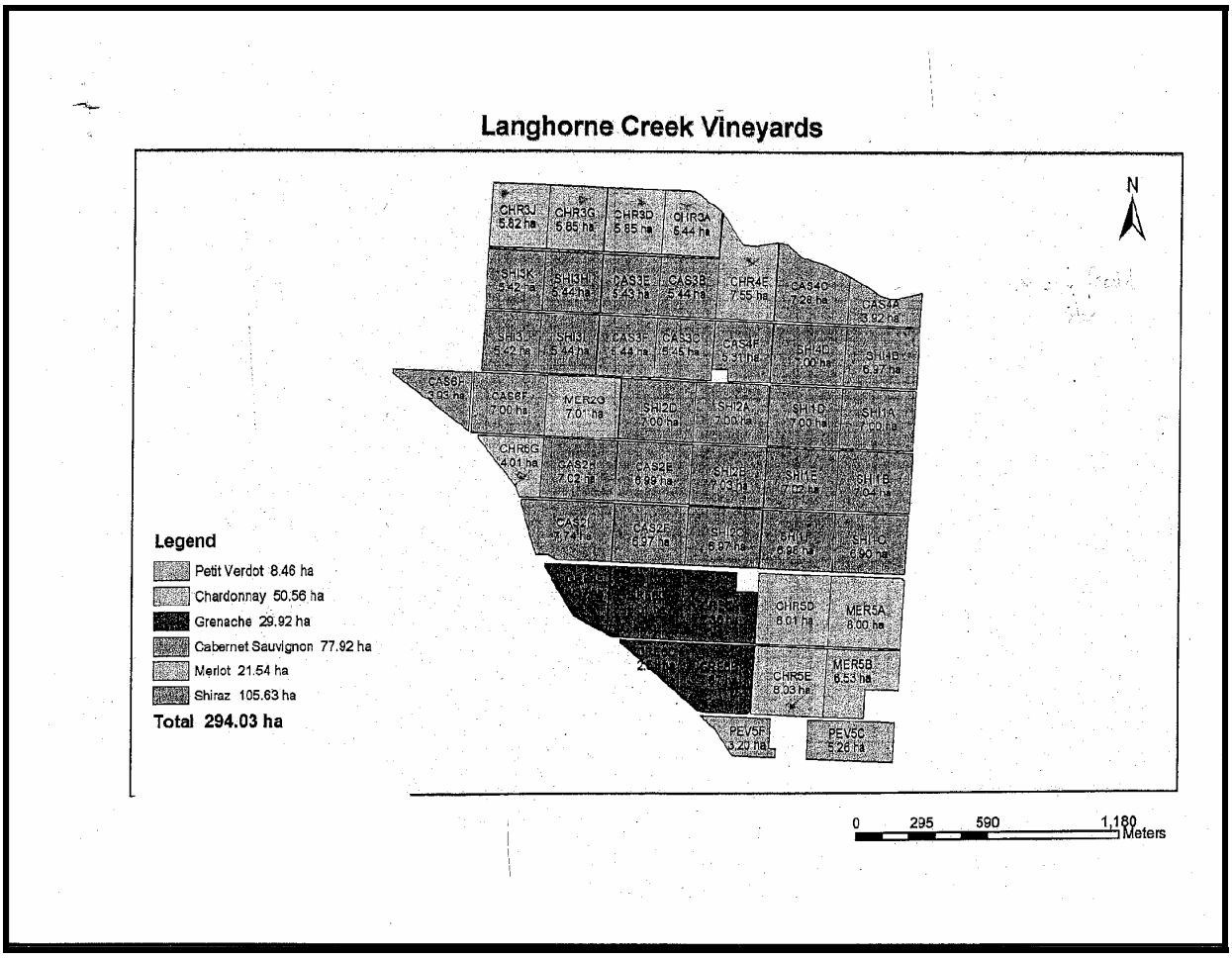


Site 6 map

Site 7

In this site the main block looked at was a Chardonnay block with 8 year old vines all single cordon. Drip irrigation but no flood irrigation is done on this site.

Acacia trees are in close proximity to the vines as a border crop. This area was affected by frost and there is a higher incidence of Elephant Weevil compared to other blocks. Soil is banked up and treated with grape mark/ mulch or straw. Another area, with a double cordon system had Elephant Weevils in the top and bottom cordon. The double cordon didn't seem to have as much infection as the single cordon site and had less stress but Eucalypts were seen just across from it. Elephant Weevil was noticed 4 years ago at this site. As many as 5 weevils were seen in one cordon in the single cordon.

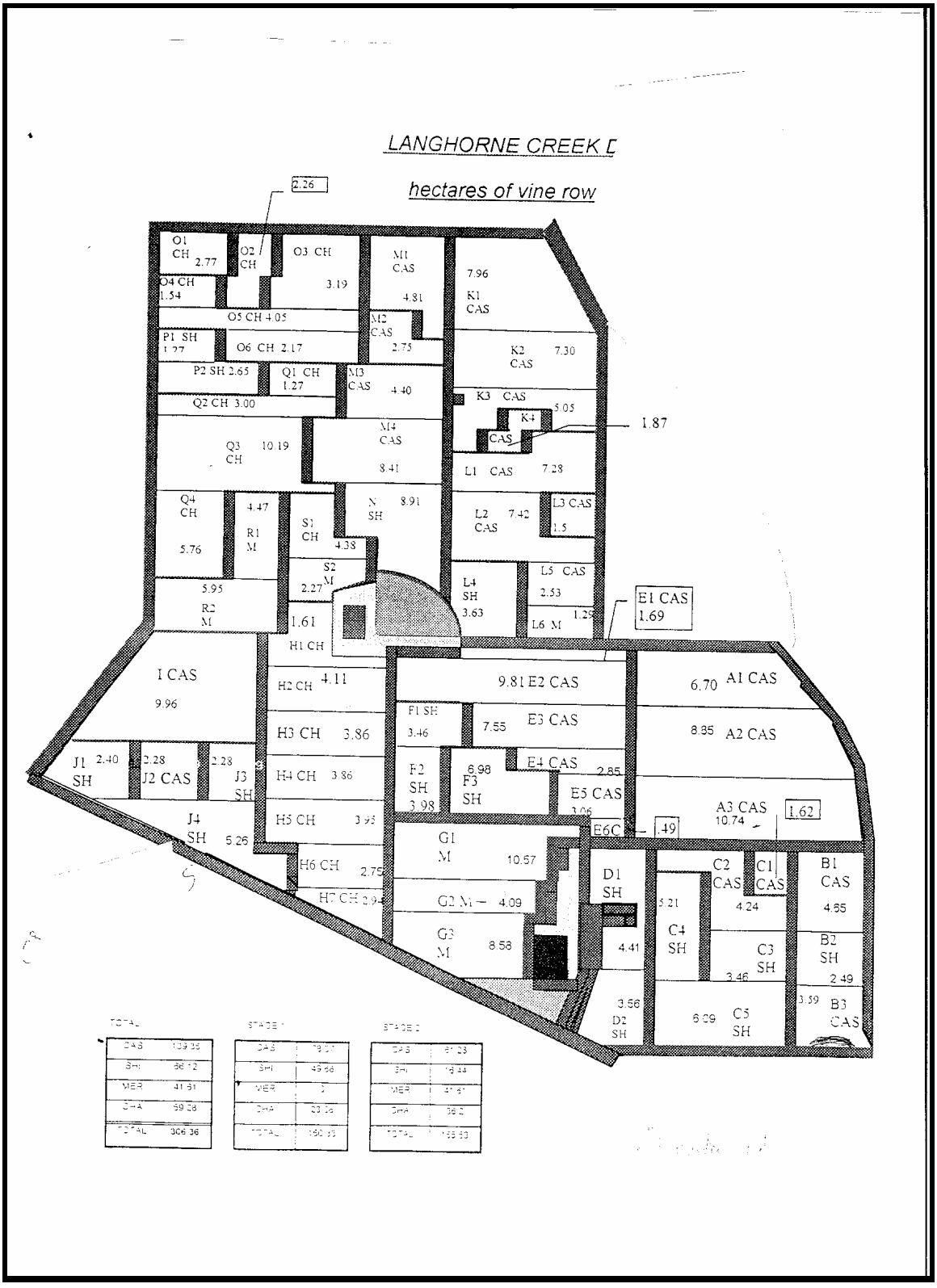


Site 7 map

Site 8

At this site 10 or 11 Cabernet Sauvignon vines were found infected 12 months ago with Elephant Weevils. The vines seen infected were 7 years old and grown as double cordon. This site is flood and drip irrigated.

This site is near the Bremer River close to a wind break of Athel Pines. It was noticed that worst damage was in the vines right next to the Athel Pines, reducing further into the rows. The Elephant Weevils here have been seen in the canopy and inches off the ground in the vines. The infected vines here have been cut and burned cut. After bud burst next season they will monitor to see if they have any more incidences. The Athel Pines could be taking water from vines stressing them making them weaker and easier for the weevil to establish. This could also show why the first row of vines is affected to a greater degree than those further from the bordering trees.


LANGHORNE CREEK D
hectares of vine row
2.26
O1 CH 2.77
O2 CH
O3 CH 3.19
M1 CAS 4.81
O4 CH 1.54
O5 CH 4.05
M2 CAS 2.75
P1 SH
O6 CH 2.17
P2 SH 2.65
Q1 CH 1.27
M3 CAS 4.40
Q2 CH 3.00
Q3 CH 10.19
M4 CAS 8.41
7.96
K1 CAS
K2 CAS 7.30
K3 CAS
K4 CAS 5.05
1.87
L1 CAS 7.28
L2 CAS 7.42
L3 CAS 1.5
L4 SH 3.63
L5 CAS 2.53
L6 M 1.25
E1 CAS 1.69
Q4 CH 5.76
4.47
R1 M
S1 CH 4.38
N SH 8.91
S2 M 2.27
5.95
R2 M
1.61
H1 CH
I CAS 9.96
H2 CH 4.11
H3 CH 3.86
H4 CH 3.86
H5 CH 3.93
H6 CH 2.75
H7 CH 2.94
9.81 E2 CAS
F1 SH 3.46
E3 CAS 7.55
F2 SH 3.98
F3 SH 6.98
E4 CAS 2.85
E5 CAS 3.06
E6C
49
6.70 A1 CAS
8.85 A2 CAS
A3 CAS 10.74
1.62
J1 SH 2.40
J2 CAS 2.28
J3 SH 2.28
J4 SH 5.26
G1 M 10.57
G2 M 4.09
G3 M 8.58
D1 SH
4.41
3.56
D2 SH
C2 CAS
C1 CAS
5.21
4.24
C4 SH
C3 SH 3.46
6.09
C5 SH
B1 CAS 4.65
B2 SH 2.49
3.59
B3 CAS

Site 8 map

APPENDIX II

Trapping systems

A. Yellow pan trap

The yellow pan trap is 3.5cm deep by 8cm wide. These traps caught an array of insects in the vineyards, but were very selective towards wasps and flies. They needed constant attention because they kept on drying out so deeper ones would be better to use in a hot area. They also were moved by the wind sometimes so a rock was needed to hold them down.



B. Window Trap

The Window trap was made with Acetate sheeting, 100cm tall x 75 cm wide, a wooden frame which was 1000mm by 700mm and had a thickness of 40 x 19mm, held into the ground by two metal droppers about 5 foot tall. A window box flower pot about 75cm wide was place at the bottom with a pinch of salt, couple drops of detergent and filled with water. This was then held in by some metal pegs.

These traps were good at catching large insects like crickets and beetles. Due to their large size they were often knocked or blown down so didn't have a chance to effectively monitor for Elephant Weevils.



C. Corrugated cardboard trap

Strip of corrugated cardboard (15cm x 15cm) were wrapped around vines with sticky tape. These yielded no results.

D. Fly mesh traps

Strip of fly mesh (15cm x 10cm) were wrapped around vines with sticky tape. These yielded no results.

E. Fruit fly traps

These were made from one large clear plastic drink bottle with a lid, and 2 smaller 600ml or 1 litre bottles. To make this I had to soak off any paper labels. About 20mm below the neck taper of the large bottle cut a cross 27mmx2mm. On the opposite side of the large bottle and about 50 mm down from the taper cut another cross the same size as before. Then cut off the bottoms of the small bottles 15mm below the neck taper so you have 2 funnel looking bottles without lids. Push the smaller bottles into the cross sections to have the entrances protruding from the larger bottle. Put string around the top of the bottle and tie it to an affected vine. Elephant Weevil frass was then added to the bottle and moitened with water to expel potential chemical attractants.

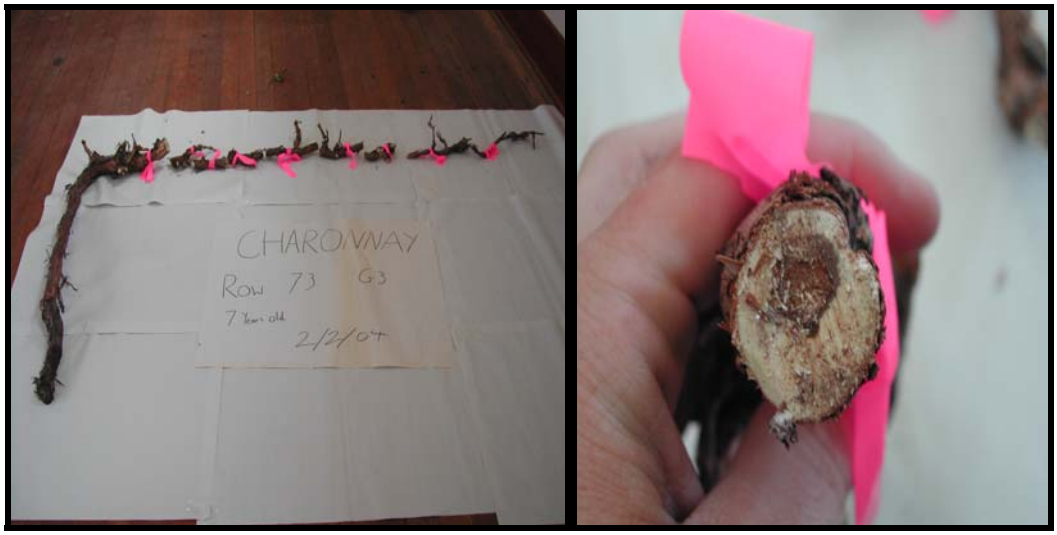


F. Sticky trap

Yellow sticky trap were purchased from gardening outlets. Vials were tied to the bottom of these with bread ties. There were 10 traps. In total 5 vials contained Elephant Weevil frass and five had water only as a control. This trap was only put out for a week before my project was finished so did not get monitored for long.

APPENDIX III

Vine dissection and cuttings photos





Pictures taken from vine dissection





Pictures from cuttings

APPENDIX IV

Insects collected

Coleoptera – Beetles: Auger beetles (scouting)
Christmas beetles (window trap)
Elephant Weevil (scouting)
Garden Weevil (yellow pan trap)
Lady beetles (yellow pan trap)
Pasture beetles (window trap)
Vine Weevil (yellow pan trap, scouting)

Dermaptera – Earwigs: European earwig (yellow pan trap, scouting)
Native earwig (yellow pan trap, scouting)

Diptera – Flies: Blow fly (yellow pan trap)
Robber fly (yellow pan trap)

Hemiptera – True insects: Assassin bug (window trap)
Stink bug (window trap, yellow pan trap)

Hymonoptera: Ants, bees and wasps: Ants (yellow pan trap)
European Bees (scouting, yellow pan trap)
Wasp "*Braconidae*"(scouting, fly trap)

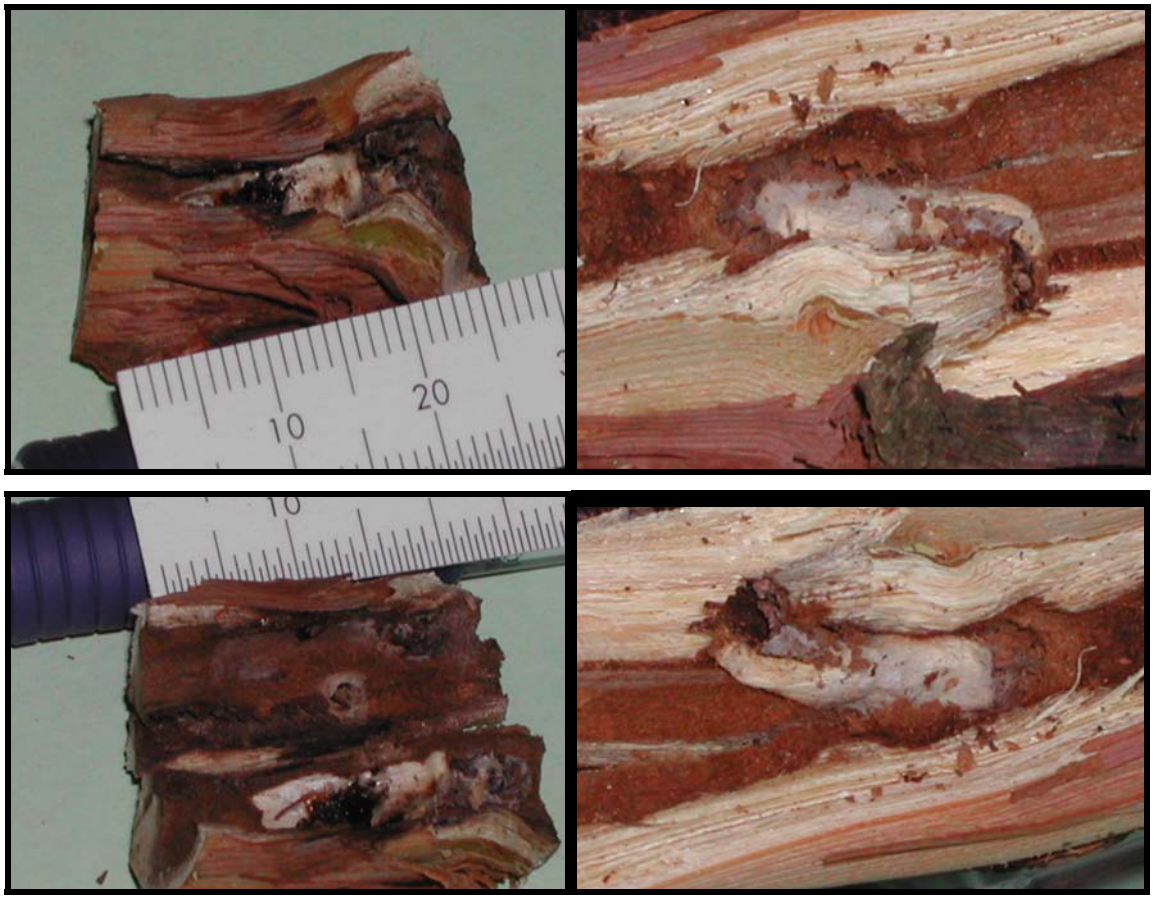
Spider wasp (window trap)

Wasp "*Vespidae*" (window trap, yellow pan)

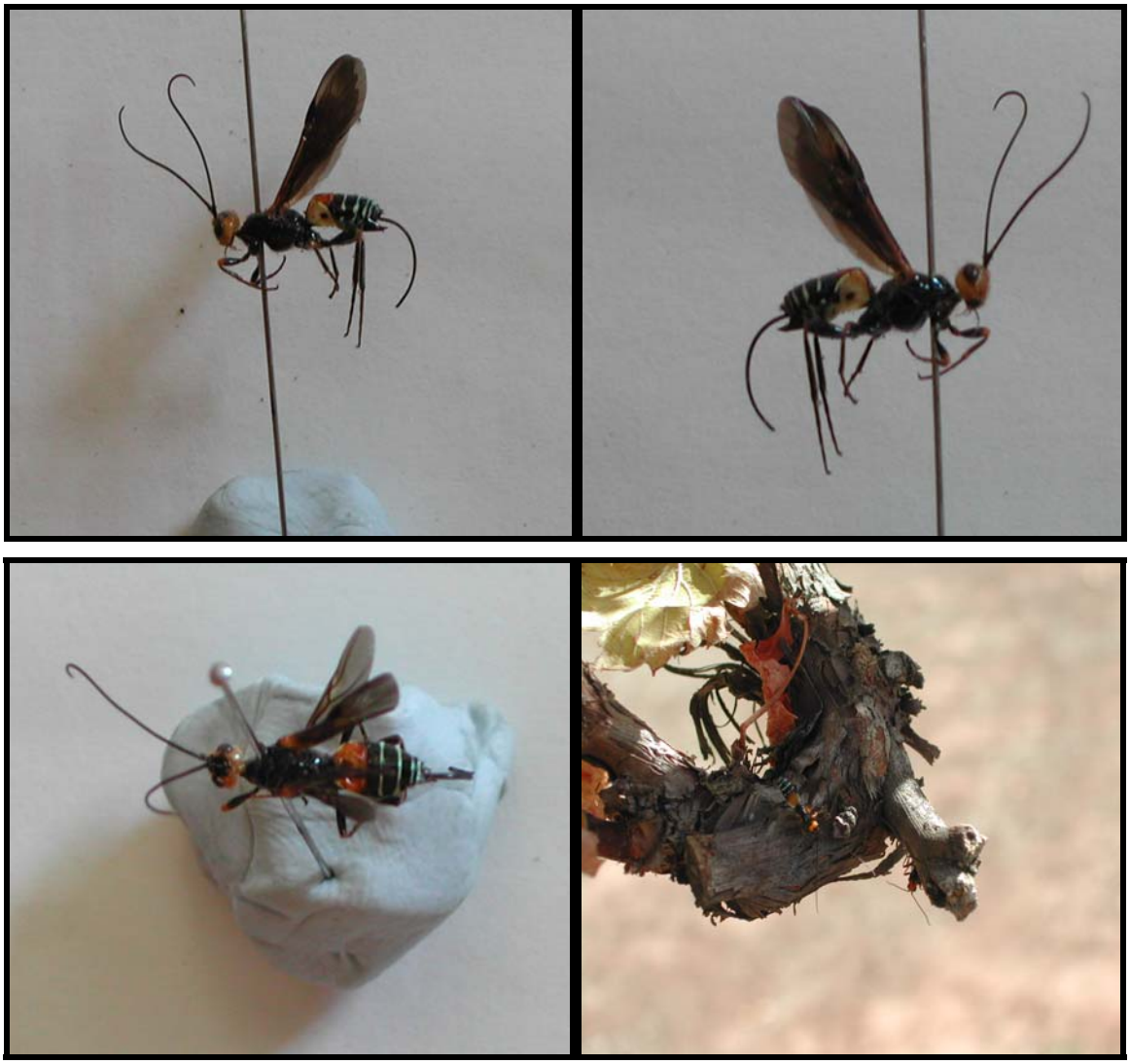
Neuroptera: (Window trap)

Orthoptera: Cricket and grasshoppers (window trap)

Other pictures



Cocooned Weevil inside a frass tunnel



Possible wasp: "*Braconidae*" parasitoid



Pictures of stages of Elephant Weevil (Larva, Pupa and Adult)



Adult Elephant Weevil with wings extended placed in relation to wood containing evidence of a "cocooned" Elephant Weevil which did not reach emergence.