Avocado fruit sucking bugs – Development of a forecasting model for an areawide monitoring system

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ABSTRACT
It was previously reported that the avocado bug (*Taylorilygus* spp.) causes lesions under the skin of avocado fruit making it unsuitable for export (Bruwer, 2004; Du Toit, 1993). These lesions are called Vosknoppe and has a bumpy appearance. Reports of pimple-like lesions in the Soutpansberg district and from parts of the Tzaneen area are also attributed to the same bug complex (Alberts, 2002).

Investigations are showing that many minute sucking bugs belonging to the suborders Sternorrhyncha and Auchenorrhyncha, as well as from the group Heteroptera, are captured on avocado trees during the flowering and fruit set periods. A new symptom with a bumpy (Vosknop) appearance was also reported this season from the Morebeng area. Pimple-like protuberances are reported from the Levubu area on most avocado cultivars. The bump-like lesions which are reported from other areas are found mainly on the 'Hass' cultivar.

Avocado miniature sucking bugs (Miridae complex) was monitored during the 2010/11 season on three farms in the Soutpansberg district, representing three different climate zones. A forecast model was developed with the aim of pre-warning farmers on possible future pest outbreaks.

This is the second report of a three year project to further collect data with the aim to find correlations between the number of avocado bugs per tree and damage resulting in pack house cull of fruit.

It is difficult for farmers to know in advance when to expect an outbreak of a specific pest. Many attempts have been made in the past to explain the occurrence of the possible outbreak of a pest. The usual method is to use climatic data and degree-day models to do the predictions.

Avocado flowering in the South African avocado growing districts occur in the May to September period. Most of the larger insect sucking bugs (Pentatomidae and Coreidae) hibernate during the colder winter period. The minute avocado sucking bug complex (Miridae) is very active during this colder period. A new method of calculating physiological time for them is proposed.

INTRODUCTION
The minute avocado bug complex consists of about five different Mirid species. A dark brown to black Taylorilygus species has been identified in the White River area which causes bump-like lesions on 'Hass' fruit, called Vosknoppe (Van den Berg *et. al*., 2001). Similar bump-like lesions and other pimple-like protuberances are also found on avocados in the other different growing regions (Alberts, 2004; 2009). The dominant mirid species found in the Soutpansberg area is light brown and might be a *Lygus* spp.

Pack losses of up to 60% have been reported by various pack houses and farmers in the past. In most years, however, the losses are less than 5%. Forecast models to pre-warn farmers in advance are therefore very important.

It is difficult for farmers to know in advance when a certain pest (or disease) might pose a possible threat. Many attempts have been made in agriculture to assist farmers with various models that can predict when pests or diseases have to be controlled (Brett, 2008; Roberts, 2006; US Dept. Agric, 2004). The most common method is using climate data and degree-day models to do the predictions.

Many methods of pest surveillance are used to monitor the build up of pests and diseases (FAO, Department of Agriculture and Cooperation, 2007). Early-warning systems are therefore very important and must be able to pre-warn farmers to enable them to prevent possible losses with effective control measures.

The pimple-like lesions does not have any scarred tissue below the skin, but does make fruit unsightly and bruising of the pimples might lead to early fruit decay during transit or ripening. The bump-like lesions do have scarred tissue below the epidermis, suggesting that the *Taylorilygus* spp. injects a more powerful enzyme into the fruit than the insects causing the pimple-like lesions.

MATERIALS AND METHODS

Scouting for avocado bugs on a weekly basis in three different areas representing three local climate zones was done. Visual scouting all inflorescences between hip and shoulder height around each data tree was recorded during the avocado flowering period. This scouted area represented about one seventh of the tree surface. The vertical distribution of fruit sucking bugs was taken to be evenly dispersed on the tree. (DuPont & Dennil, 1996).

Climate data from an automatic climate recording station was used to calculate physiological time.

Forecast model

The larger members of the fruit sucking insect complex (Pentatomidae and Coreidae) usually enter into hibernation in the winters of very cold seasons and into facultative aestivation in the winters of warmer seasons. This does not explain why the minute members of the sucking bug complex (Miridae) do not do the same but stay active during every colder season.

In order to develop the forecast model for minute fruit sucking bugs in avocado orchards, the following aspects where taken into consideration:

Body surface area to body volume ratio

Endothermic organisms generate their own heat whilst ecothermic organisms (*e.g.* insects) obtain most of their heat from an outside source (radiation or conduction). Larger insects have a small body surface to body volume ratio. Body heat is slowly gained and lost and this explains why they enter into hibernation or facultative aestivation if the season becomes cooler. The smaller insects (Miridae) with a much larger body surface to body volume ratio will quickly loose their body temperature during the night and enter into quiescence until they again quickly regain heat from their surroundings the next day.

To calculate the body mass and surface area of the avocado sucking bug complex, an ellipsoid shape was used as it best describes the body shape of these insects. The following formulas where used to calculate body size and body surface area (Wikipedia, 2011):

Body surface: $4\pi[(a^p b^p + a^p c^p + b^p c^p)/3]^{\frac{1}{p}}$

(where p = 1.6075)

Body volume: $\frac{4}{3}\pi abc$

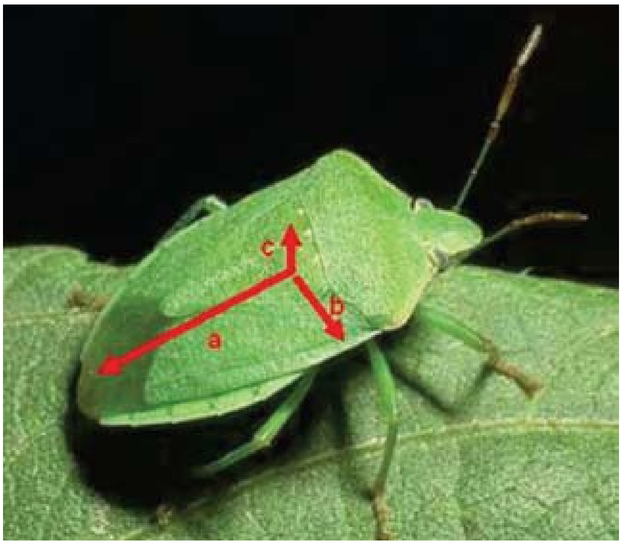

Figure 1. The axis used to calculate sucking bug surface area and body volume.

The approximate average size of some members of the avocado fruit sucking complex where used to calculate their body surface to body volume ratio (**Table 1**).

The smaller avocado bugs (Miridae) had a body surface area to body volume ratio that is five times larger than the *Bathycoelia* spp. This explains why they are able to regain enough body heat early on winter mornings to allow them to be active during the relatively warmer part of the day.

Physiological time

The traditional method of expressing physiological time in insect development is by calculating degree-days from standard meteorological measurements of daily minimum and maximum temperatures.

The average base temperature used to calculate Growing Degree-days (GDD) for Miridae is 12.2ºC. The following formula is usually used:

$GDD = ((T_{max} + T_{min})/2) - T_{base}$

Table 1. The calculated body surface to body volume index of different members of the avocado fruit sucking bug complex.

	Avocado bugs	Nezara spp.	Nezara viridula	*Bathycoelia*
Axis a (mm)	2	3	5	7.5
Axis b (mm)	1	2	3	5
Axis c (mm)	0.5	1	1.5	3
Surface area (mm^2)	15.90	48.99	121.12	327.36
Volume (mm^3)	4.19	25.14	94.29	471.43
Ratio S/V	3.79	1.95	1.28	0.69

A base temperature of 12ºC is used for the larger members of the Pentatomidae. To later refine the forecast model, it will, however, be necessary to re-calculate these values for the specific insects that are pests on avocados in South Africa.

This traditional method of calculating physiological time did not really explain the daily activity of small insects that have larger body surface to body volume indexes. A new method is proposed using hourly temperature values to calculate the physiological time for those hours that exceed the base temperature. The following formula was used to calculate the physiological time of Miridae during the colder part of the season when temperatures frequently dropped below the base temperature:

$$\mathbf{GDD_{new} = \Sigma ((H_1 - T_{base})/24, (H_2 - T_{base})/24, \ldots (H_{24} - T_{base})/24)}$$

(where all negative values were taken as 0).

The physiological time of one day for Miridae using the alternative proposed method is shown in **Figure 2**. The green area represents the optimum period during the day when the temperature was high enough to give positive degree-day units. On this day there accumulated 3.4 degree-day units in 10 hours from 09:00 to 19:00. This corresponds with the daily activity of the insects in the orchards.

In a comparison between the two methods (**Figure 3**) there is little difference between the total accumulated degree-days over a period of 54 days during July and August 2010. In Table 1 the average difference per day between the two methods of calculation for this specific winter period is only 0.1 degree-day units per day.

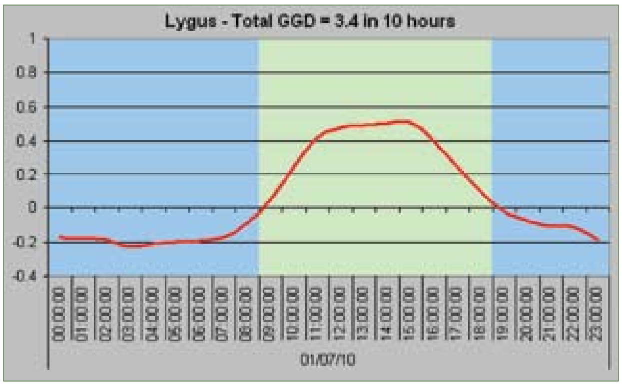

Figure 2. The physiological time for a Mirid using an alternative proposed method.

The new proposed method explains why minute insects with a large body surface area in relation to body volume can be active during colder periods. The standard method of calculation gave zero heat units on many days, whilst with the alternative method, positive heat units are calculated.

Modeling the life cycles of Miridae

A total of 443.9 degree-days were calculated by Pickel *et.al.*, 1990 for *Lygus* bugs on strawberries in Santa Cruz, California. Physiological time for an insect stays constant and these values can be used to model the life cycles of that specific insect in many locations and during different seasons in different localities. (**Table 3**).

The degree-day accumulations for the total sucking bug complex on avocados in South Africa must also be calculated to refine the forecast model for our local conditions. The total amount of heat units accumulated per week is shown in **Figure 4**. An average of about 20 heat units per week is recorded in the winter, compared against an average of about 70 to 80 heat units per week during the summer months. Applying the *Lygus* model of Pickel *et.al.* to the total amount of heat in one season, estimates that it is possible for the Mirids to go through six to seven generations during a typical season.

The winter population of avocado bugs in the Soutpansberg district always consists of pre-egg-laying adults. Eggs are laid later on other crops and weeds as soon as the temperature rises after the avocado flowering season has finished. *Taylorilygus* spp. in the White River area appear on the flowers as pre-egg-laying adults and lays eggs on the avocado flowers and small fruit. A second generation of these insects feeds on the small fruits causing bump-like lesions called Vosknoppe. It is also possible that a similar pattern for damage is found in the Morebeng

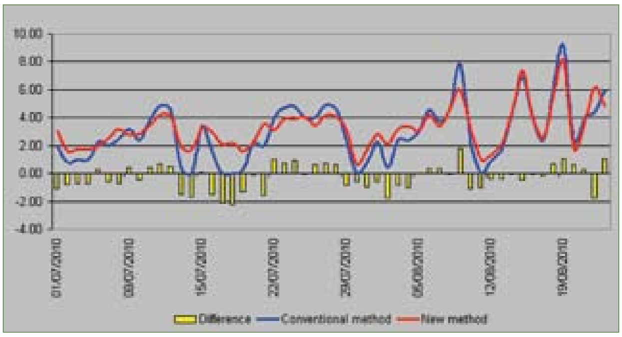

Figure 3. A comparison between the two methods of calculating physiological time.

Table 2. A comparison between the standard method of calculation of physiological time and the proposed alternative method.

	Conventional method	New method	Difference
Total for period	110.75	113.93	-3.17
Average per day	3.57	3.68	-0.10

Table 3. Degree-day accumulations required for each stage of development.

Host: Strawberries	DD (°C)
Eggs	140
Nymphs	206.1
Total generation time (egg to adult)	346.1
Pre-egg laying adults	97.8
Total generation time (egg to egg)	443.9

and Tzaneen areas.

Weekly counts of avocado bugs during the flowering period showed that an increase in bug numbers were recorded from week 34, when average temperatures began to rise after the winter (**Figure 5**).

A hail storm on the slopes of the Soutpansberg, as well as the colder temperatures on the top of the Soutpansberg, influenced the total population of avocado bugs during the 2010/11 season.

Both the total heat units per week, as well as the average number of avocado bugs per tree recorded during scouting, must be used when a forecast model of avocado bugs is developed.

Recording of data in a Geographical Information System (GIS)

The value of a forecasting system of possible pest outbreaks lies in the timely distribution of weekly scouting data to all the avocado growers in a specific area. Using Google Earth™ as a very convenient GIS and applying the data with freeware software makes it possible to distribute the necessary information regularly to growers via e-mail. The freeware EarthPlot™ and GE-Graph™ software generates KML files which open in Google Earth™ and can show the distribution of insect numbers in an area or in an orchard (**Figure 6**).

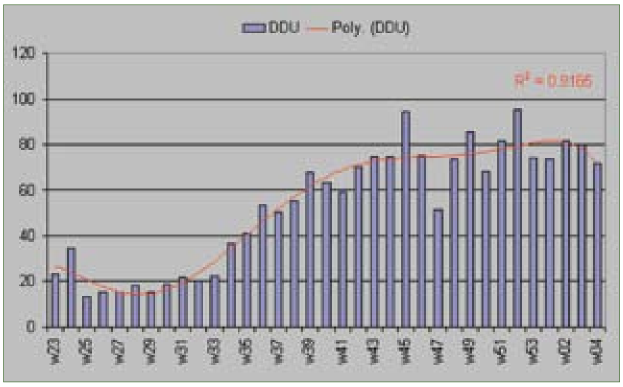

Figure 4. Weekly total heat units for avocado minute sucking bugs.

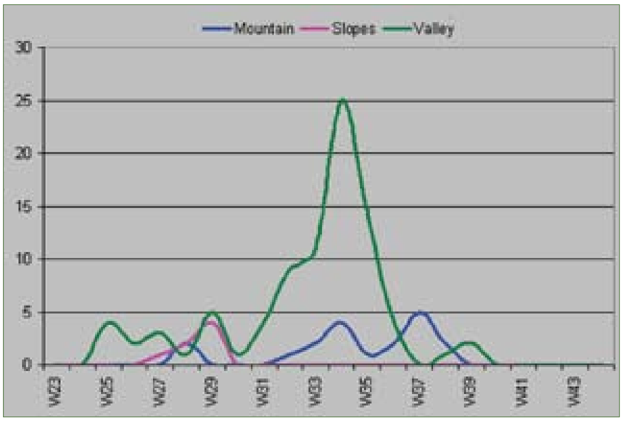

Figure 5. Average weekly count of avocado minute sucking bugs per tree in three localities.

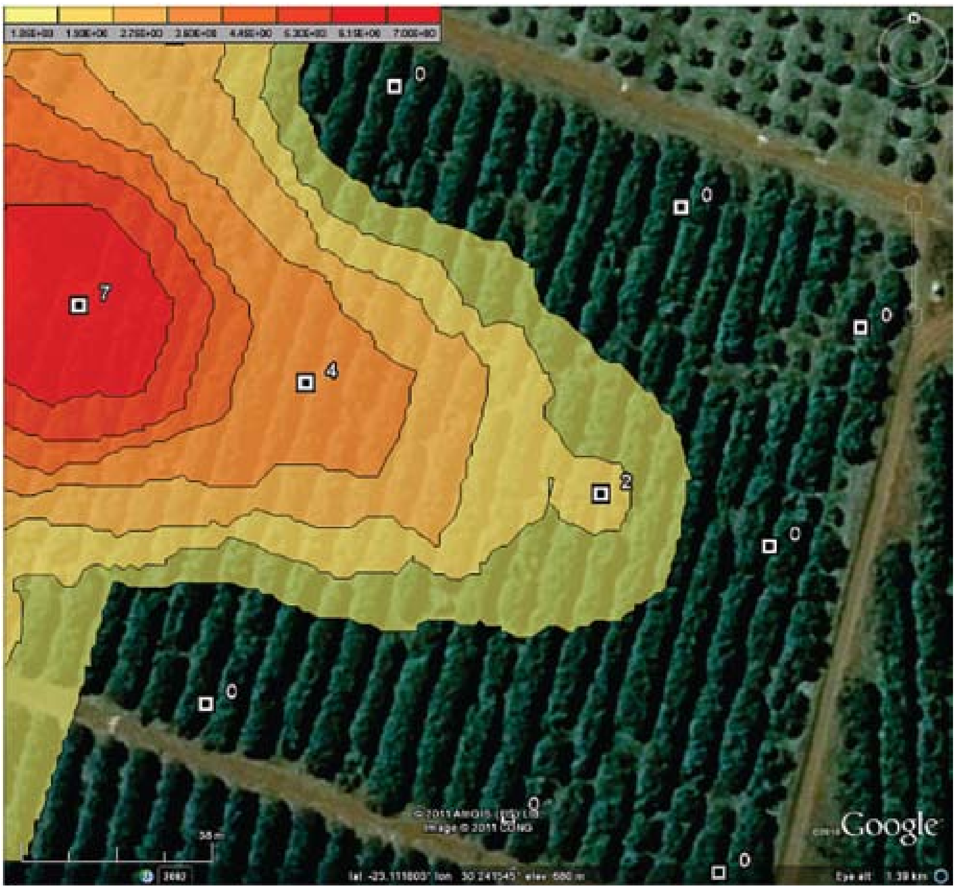

Figure 6. Using EarthPlot™ to map the distribution of avocado bugs in an avocado orchard on Google earth™.

CONCLUSION

The better understanding of the minute sucking bug complex in avocado orchards during the winter period allows for the developing of forecast models to pre-warn growers of possible outbreaks. The use of the internet to make contact with farmers and the use of easily available freeware software allows all farmers to be able to participate.

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