Report

Aphid monitoring in seed potato production regions (July 2014-June 2017)

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EXECUTIVE SUMMARY

1. **The South African aphid monitoring network** is one of the most extensive suction trap networks in the southern hemisphere. The network was initiated in 2005 by Potatoes South Africa to alert growers to the risk of potato virus spread by aphids. The University of Pretoria is coordinating the network, which presently consists of 13 Rothamsted-type suction traps, 10 of which are situated in seed potato production regions. Aphid samples are collected on a daily or weekly basis. Growers and regional laboratories receive weekly SMS notifications on aphid vector numbers in KwaZulu-Natal and weekly emails on vector pressure in the Western Cape. In addition, the data are used to alert growers to the risk of virus spread through news bulletins. These provide information on aphid flight activity and cumulative vector pressure based on aphid species numbers (abundance) and their species-specific relative efficiency values (mean values derived from published literature and own unpublished results on the efficiency of virus transmission of a given species relative to *Myzus persicae,* the most efficient vector of *Potato virus Y* (PVY) and *Potato leafroll virus* (PLRV). The news bulletins are also available on the South African aphid monitoring internet site (www.aphidmonitoring.co.za).

2. **Expansion of the aphid monitoring network.** The importance of the Potatoes South Africa (PSA) aphid monitoring network has been recognised by the wheat industry, for which the aphid-transmitted *Barley yellow dwarf virus* (BYDV) is of great concern. Four further suction traps were added to expand the network for monitoring aphids in wheat-growing regions. The aim is to assess the risk of BYDV transmission, which is causing considerable yield losses to the wheat industry. Dr Goddy Prinsloo of the ARC-Small Grain has initiated aphid monitoring in wheat. The Winter Cereals Trust and the Agricultural Research Council (ARC) cover the running costs of the network and aphid identification.

3. **Position of suction traps used for aphid monitoring in seed potatoes.** Four suction traps are currently operational in KwaZulu-Natal (Cedara, Underberg, Fort Nottingham and Winterton). There is one suction trap in the Free State (Christiana), one trap in the Northern Cape (Douglas) and four traps in the Western Cape (Lambert's Bay [Joos], Sandveld [Redelingshuys], Koue Bokkeveld [Ceres] and Malmesbury [Skaapkraal]). All traps provide weekly aphid species composition and aphid flight activity data throughout the year.

4. **Aphid flight activity patterns.** A common trend based on aphid suction trap catches is that throughout the regions monitored, aphid numbers tend to be low during the mid-summer period (December, January). Other trends show distinct peaks for aphid vectors of PVY and PLRV. Common to all regions is a peak in late summer/autumn. In some regions (Christiana) there is an additional peak in spring for aphid vectors of PVY. The exact timing of the peaks may shift from year to year. In Cedara aphid vector activity peaks during different times of the year. Aphid monitoring data provide growers with information on aphid flight activity during potato planting and growth and assists with determining the timing of haulm destruction.

5. **Vector pressure.** Suction trap data provide information on migrating aphids from a radius of 30 km to ca. 80 km. However, vector pressure on the ground at field level may be variable and can depend on numerous additional factors. The relationship between vector pressure based on suction trap catches and vector pressure at field level should be established on a regional basis. Aphid species composition within a region depends on climate, geographical characteristics and vegetation, including, for example, crops planted other than potato.

6. **Long-term objective of the ongoing programme.** The objective is to determine the possible impact of environmental changes, e.g. changes in climate, on aphid species composition and abundance and disease transmission, and ultimately to develop a virus-risk forecasting system for growers. Due to the high variation in aphid abundance, there is a need for longer term data series, which requires the continuation of the network as well as traps staying in their region to accumulate long-term data.

1. BACKGROUND

The South African aphid monitoring network has been established as a service to members of Potatoes South Africa (PSA) to alert growers to the risk of potato virus spread to seed potatoes. The two most economically important viruses of concern to potato growers worldwide are *Potato virus Y* (PVY, genus *Potyvirus*) and *Potato leafroll virus* (PLRV, genus *Luteovirus*). Both viruses lead to a loss in quality and yield and result in the downgrading of seed lots because of the low tolerances required by seed certification programmes (e.g. South African Seed Potato Certification Scheme, 2010). The primary vectors of the two viruses are aphids. The viruses are usually transmitted to potato fields by immigrating winged aphids (Ragsdale, Radcliffe & DiFonzo (2001).

To predict the risk of virus transmission to seed potato fields, aphid monitoring networks have been established as part of an integrated virus management system in different parts of the world, for example in several European countries, the USA, China, and New Zealand, as well as South Africa. The South African long-term aphid monitoring network has been in effect since 2005. The network initially comprised nine 12.2 m high Rothamsted-type suction traps situated in major seed potato production regions. Suction traps at this height collect random standardised aerial samples of winged aphids (Harrington, Hullé & Plantegenest, 2007).

Since 2013 the suction trap network has been expanded by four additional traps for the monitoring of aphids in wheat. In regions where seed potato and wheat production overlap, the aphid trap catches provide additional information for seed potato growers.

The objective of the project is to provide producers with up-to-date information on the flight activity of aphid vectors of PVY and PLRV in major seed potato production areas in South Africa through continued aphid monitoring. The information on vector species composition together with their abundance (numbers) is used to calculate vector pressure indices for the different regions and serves to assess the risk of virus spread to seed potatoes and provides an early warning system. Knowledge of aphid flight activity assists growers in making management decisions regarding the location and timing of aphid control measures and the timing of haulm destruction.

Project team

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- Potatoes South Africa
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- KwaZulu-Natal Department of Agriculture & Rural Development
- Agricultural Research Council (ARC)
- Western Cape Department of Agriculture

Project Duration

July 2013 to June 2017

2. INTRODUCTION

Based on human consumption, potato is the third most important food crop after rice and wheat in the world (International Potato Center). The production of disease-free seed potatoes is essential for commercial seed potato production. Aphid-transmitted potato viruses, especially PVY and PLRV, which can cause considerable economic losses to seed potato industries worldwide, pose a significant challenge for seed potato producers. Both viruses can lead to the downgrading of seed potatoes even if present at low levels.

The success of insect vector monitoring programmes depends on the ability to accurately predict virus risk. The spread of PVY and PLRV is related to aphid species and their virus transmission efficiency, flight patterns and numbers (abundance), location/region, potato cultivars, and climate. In South Africa, aphid species composition, abundance and flight patterns differ between the summer rainfall region (e.g. western Free State, Northern Cape, KwaZulu-Natal,) and the winter rainfall region in the Western Cape. The season in the summer rainfall regions commences in July and ends in June and in the winter rainfall region it commences in January and ends in December. Furthermore, the composition of aphid species differs within the summer and the winter rainfall regions. Region-specific reliable estimates of aphid numbers are, therefore, an essential aspect of predicting the risk of virus transmission.

Suction trap networks in several parts of the world, e.g. Europe and the USA, are used to monitor winged aphids. The onset of aphid flight and an increase in aphid numbers determine the increase in virus risk during growing seasons. Long-term aphid monitoring data are essential to, firstly, provide a reliable forecasting system on virus risk and secondly, to evaluate the possible impact of changes in climate on aphid numbers and virus transmission. Monitoring winged aphids serves to assess the risk of virus transmission to seed potato fields and provides support in making decisions concerning the nature and timing of control measures in a specific location/region.

Successful aphid monitoring for PVY and PLRV management is linked to rapid processing and distribution of monitoring data in order to provide seed potato growers with an early warning system of the risk of virus transmission.

The monitoring network aims to provide growers with an early warning system to assist in making management decisions regarding the location and timing of aphid control measures.

Significance of the South African monitoring network:

- Improved disease control through virus risk forecasting by determining the onset of aphid flight and increases in aphid numbers, and consequently increase in virus risk, during growing seasons.

- Long-term aphid monitoring data are essential to, firstly, provide a reliable forecasting system on virus risk and secondly, to evaluate the possible impact of environmental changes, e.g. impact of climate changes on aphid abundance and virus transmission.

The specific objectives of the study were to:

1. Collate information on aphid abundance and vector pressure based on suction trap samples to provide seed potato and wheat producers with a centralised early warning system on the risk of virus transmission.

2. Incorporate results from both the potato suction trap network and, where relevant, the wheat suction trap network, to inform seed potato growers of virus risk.

3. Provide weekly feedback to growers through SMSes with vector numbers (KZN) and vector pressure (Western Cape).

4. Construct Microsoft Access databases to deal with the large volumes of data more efficiently.

5. Identify trends in aphid flight activity patterns based on suction trap samples.

All objectives are expected to lead to improved disease management.

3. MATERIALS AND METHODS

Of the 13 Rothamsted-type suction traps, 10 are distributed in major potato seed production regions.

The 12.2-metre-high suction traps continuously collect airborne insects on a regional scale at a standardised volume of 45 m^3 air/min from a radius ranging from 30 to 80 km^2 or more, depending on the topography of the region (Harrington *et al.*, 2007).

Samples are collected at daily or weekly intervals throughout the year. Aphids from samples from traps in KwaZulu-Natal are pre-sorted regionally (Cedara, Underberg) or sent to the laboratory at the University of Pretoria (UP). Samples from Christiana and Douglas are sent pre-sorted to UP. All samples from KwaZulu-Natal (KwaZulu-Natal Department of Agriculture & Rural Development) including those from Winterton, a wheat suction trap), the western Free State and the Northern Cape are sent to UP for aphid species identification. Samples from the Western Cape are sorted and identified at the Department of Agriculture: Western Cape. Aphids are identified to species level or, in a few instances, to genus or species group level, e.g. *Aphis* species.

4. RESULTS

4.1 The suction trap network

KwaZulu-Natal. Four suction traps are currently operational in KwaZulu-Natal. Continuous longer-term data are available from the traps at Cedara (since 2006) and Underberg (since 2013). The suction trap stationed at Kamberg ceased operation in 2013 and was transferred to Fort Nottingham. Since the transfer, the trap has provided continuous weekly aphid data from November 2016. Data from a trap set up at Winterton in 2013 for monitoring aphid vectors of *Barley yellow dwarf virus* (BYDV) in wheat are also being made available to seed potato producers.

Free State. The suction trap at Christiana has been continuously providing weekly aphid flight data since 2008. The trap also provides aphid data for wheat producers.

Northern Cape. The suction trap in Douglas had to be relocated due to power supply problems. It is now fully operational again after relocation and has provided continuous weekly information on aphid vectors since November 2016.

Western Cape. The four traps in the Western Cape, Lambert's Bay (Joos), Sandveld (Redelinghuys), Koue Bokkeveld (Ceres) and Malmesbury (Skaapkraal), have been continuously providing weekly aphid flight data during each main seed potato-growing season since 2007, with the exception of the Koue Bokkeveld where year-round monitoring commenced in 2013.

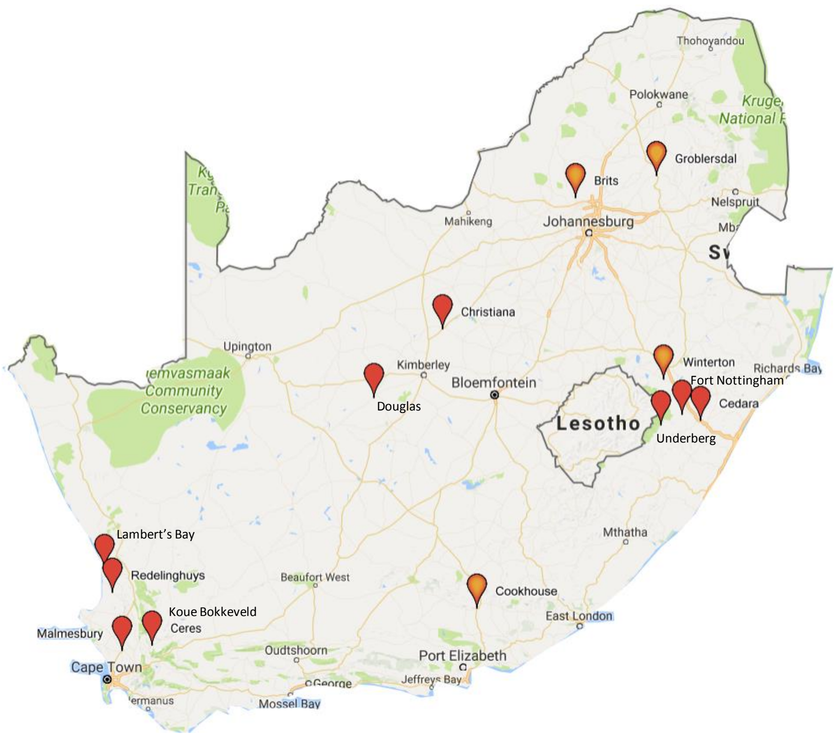

Fig. 1. Position of Rothamsted-type suction traps in South Africa. Red markers: traps originally established for monitoring aphids in seed potatoes; orange markers: traps originally established for monitoring aphids in wheat.

4.2. Processing of samples and dissemination of results

All aphids collected are identified to species or species group (e.g. *Aphis* spp., *Sitobion* spp.) level. Species-level identifications of all aphids trapped are available for samples from all four traps in the Western Cape (Lambert's Bay, Redlingshuys, and Malmesbury since 2007, Ceres since 2013), from Christiana since 2008, Cedara since November 2013, Underberg since September 2013, Winterton since June 2013, Fort Nottingham since October 2016 and Douglas since November 2016. Emphasis on species identifications in Cedara before September 2013 was on important PVY and PLRV aphid vector species. All aphid species and abundance data are captured in Microsoft Access databases, which were established because the previous system could no longer cope with the high volume of data. The databases currently contain 20 060 data entries.

More than 63 000 aphids from suction trap samples were identified between 2013 and 2017.

Growers receive information on aphid vector numbers and vector pressure via weekly SMS messages on PVY and PLRV vector numbers (KwaZulu-Natal), usually on the same day of receipt of samples, or via weekly emails on vector pressure (Western Cape). Regular news bulletins are sent out via email, which are also uploaded to the aphid monitoring internet site (aphidmonitoring.co.za). The news bulletins provide information on aphid species, their abundance, and a cumulative vector pressure index.

The vector pressure for each virus (PVY, PLRV) is based on the number of each vector species multiplied by the mean relative efficiency factor of that particular species, and by then calculating the sum for all species. The value is added to the value of the previous week to provide the cumulative vector pressure. This value informs growers of the risk of virus spread in their region at a particular time of the year.

4.3. Aphid monitoring results

The contribution of different virus vector aphid species to the vector pressure varies within regions (Table 1). Aphid species composition varies with geographical location, climate and vegetation types, including crops planted in a region in a particular year. In the summer rainfall region in the western Free State, *Rhopalosiphum padi* (bird cherry-oat aphid) is the most abundant vector of PVY, followed by *Aphis* spp. In KwaZulu-Natal, the bird cherry-oat aphid, *Aphis gossypii* (cotton aphid), and *Aphis* spp. are the most abundant vectors. Although the bird cherry-oat aphid is the most abundant vector species in these regions, it is considered a poor vector of PVY. In the Sandveld, a winter rainfall region in the Western Cape, PLRV is considered a greater threat than PVY. The most important virus vectors in seed potatoes in this region are *Macrosiphum euphorbiae* (potato aphid), *Myzus persicae* (peach-potato aphid), *Acyrthosiphum pisum* (pea aphid), and several cereal aphids (*Metopolophium dirhodum, Sipha flava, Sitobion avenae*).

Table 1. The most abundant virus vector aphid species, their vector status and relative abundance in three seed potato production regions.

Aphid species				Importance		
Scientific name	**Common name**	**PVY vector**	**PLRV vector**	**KwaZulu-Natal**	**Western Free State**	**Western Cape**
Acyrthosiphon pisum	pea aphid	yes				**
Aphis gossypii and other *Aphis* spp.	cotton aphid	yes	yes	**	**	
Aulacorthum solani	glasshouse potato aphid	yes	yes	**[2]		
Macrosiphum euphorbiae	potato aphid	yes	yes			**
Metopolophium dirhodum	rose-grain aphid	yes		**		
Myzus persicae	peach-potato aphid	yes	yes			**
Rhopalosiphum padi[1]	bird cherry-oat aphid	yes		**	**	
Sipha flava	yellow sugarcane aphid	yes		**		
Sitobion avenae	grain aphid	yes				**

[1] Although the bird cherry-oat aphid is the most abundant vector species in KwaZulu-Natal and the Western Free State regions, it is a poor vector of PVY.

[2] Not Winterton

** Important PVY and PLRV vectors

4.3.1 KwaZulu-Natal (Cedara, Underberg, Fort Nottingham, Winterton)

Cedara

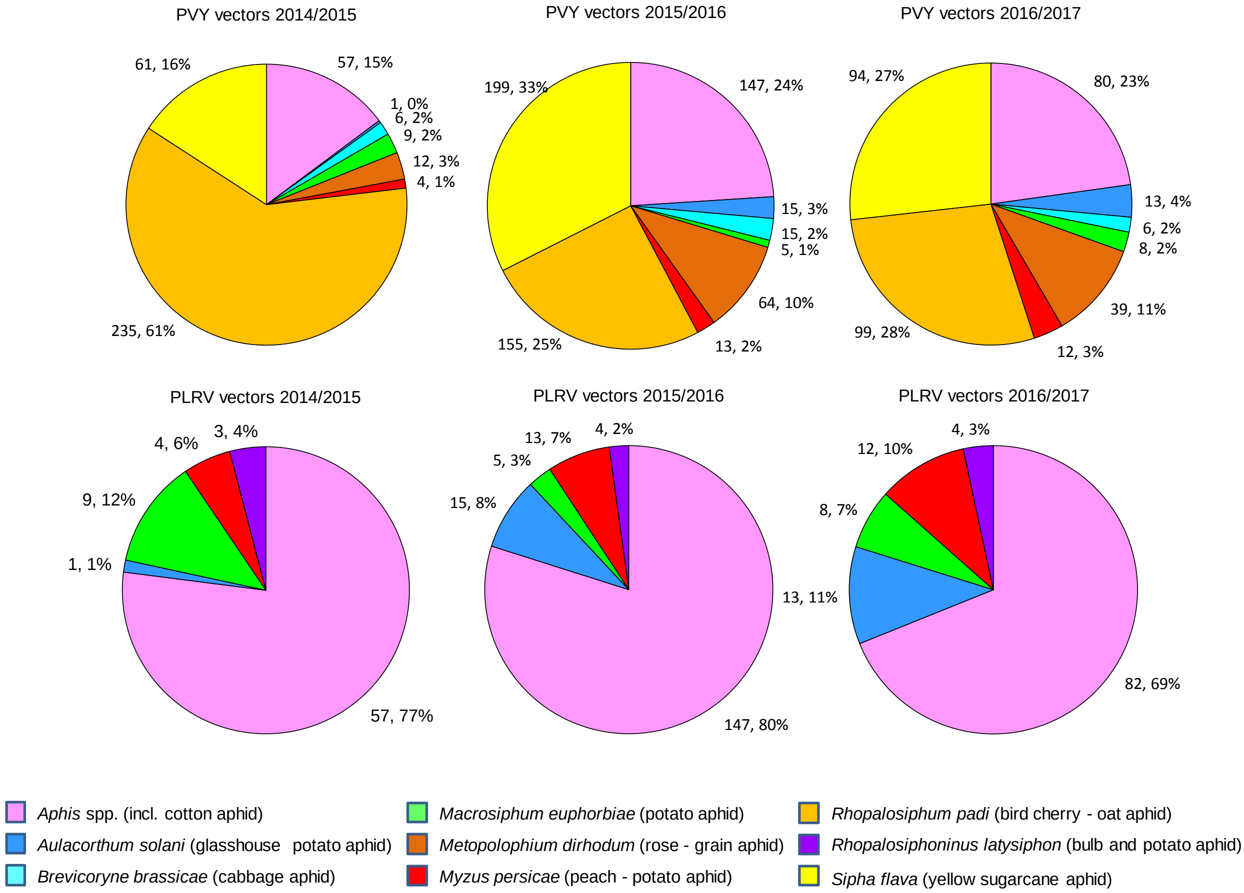

Fig. 2. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in KwaZulu-Natal (Cedara trap).

The most important PVY vector species in the Cedara region were the bird cherry-oat aphid, *Aphis* species and *Sipha flava* (yellow sugarcane aphid). The most abundant vectors of PLRV belong to the *Aphis* species group (*Aphis* species which are morphologically very similar and difficult to distinguish) (Fig. 2). The number of individuals of the bird cherry-oat aphid collected decreased from 235 in the 2014/2015 season to 99 in the 2016/2017 season. Whereas the number of bird cherry-oat aphids declined from 2014/2015, the number of yellow sugarcane aphids and *Aphis* species was more variable during the same period. In general, the number of aphids vectoring PVY was highest during 2015/2016 compared to the 2014/2015 and 2016/2017 seasons. Vectors of PLRV other than *Aphis* species were caught in relatively low numbers.

Vectors of PVY and PLRV tended to peak in autumn (March) and then again, with a smaller peak, in May, followed by another peak in winter in August (Fig. 3). The winter peak was mainly due to high numbers of *Aphis* species and in the 2009/2010 season also due to relatively high numbers of the peach-potato aphid (Fig. 4). Aphid vector numbers were lowest in mid-summer in January throughout the entire sampling period.

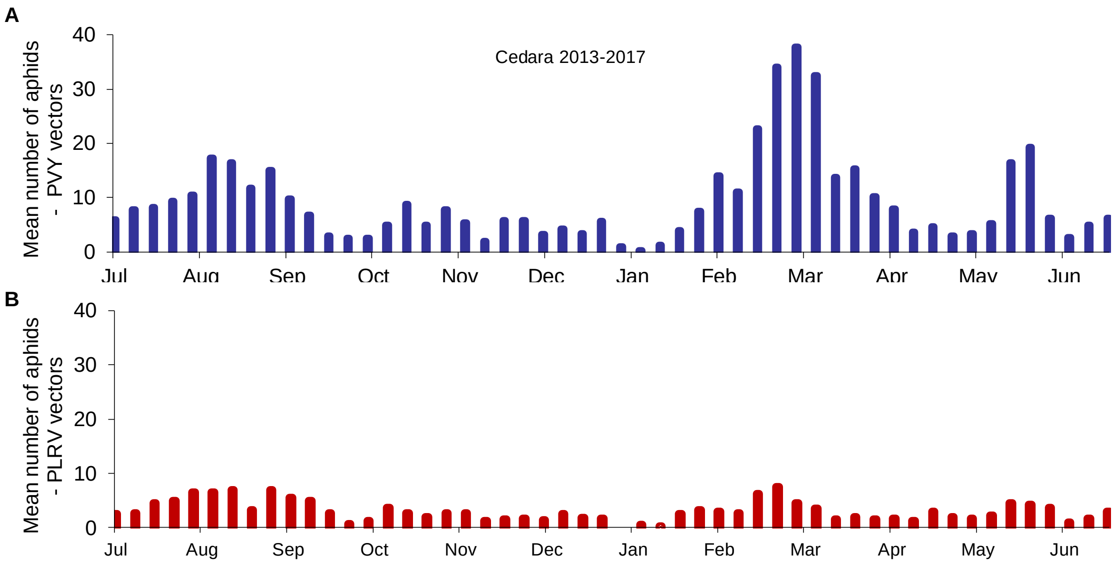

Fig. 3. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Cedara region based on the mean abundance of aphid vectors caught in the suction trap between November 2013 and December 2017.

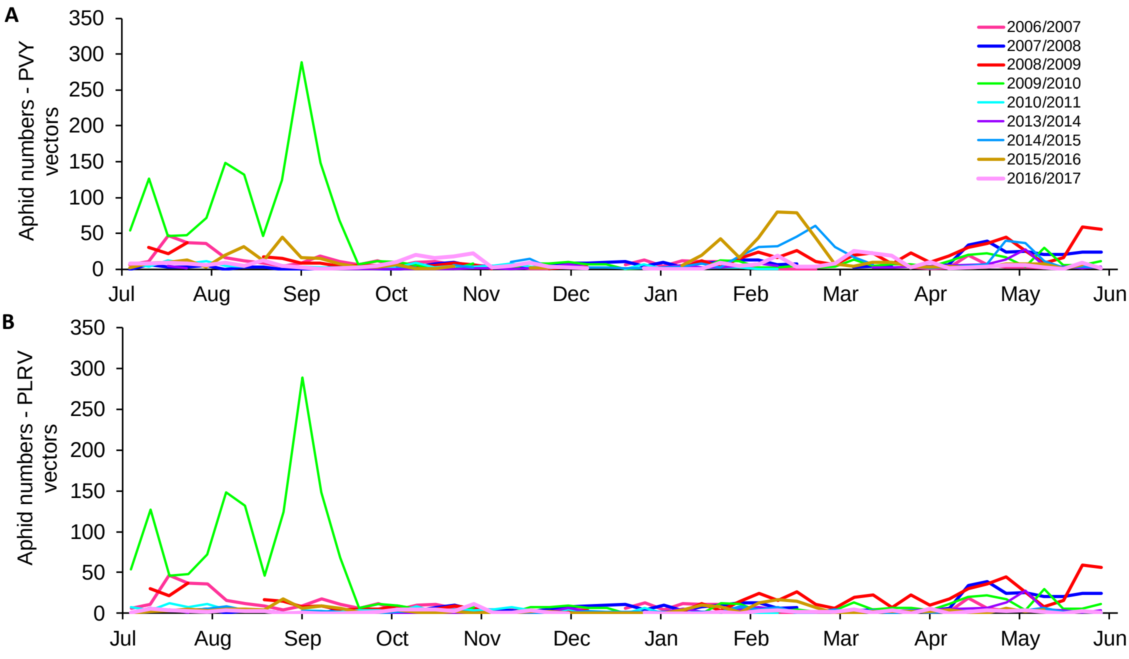

Fig. 4 Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Cedara suction trap. The trap was not operational during the 2011/2012 and 2012/2013 seasons.

Underberg

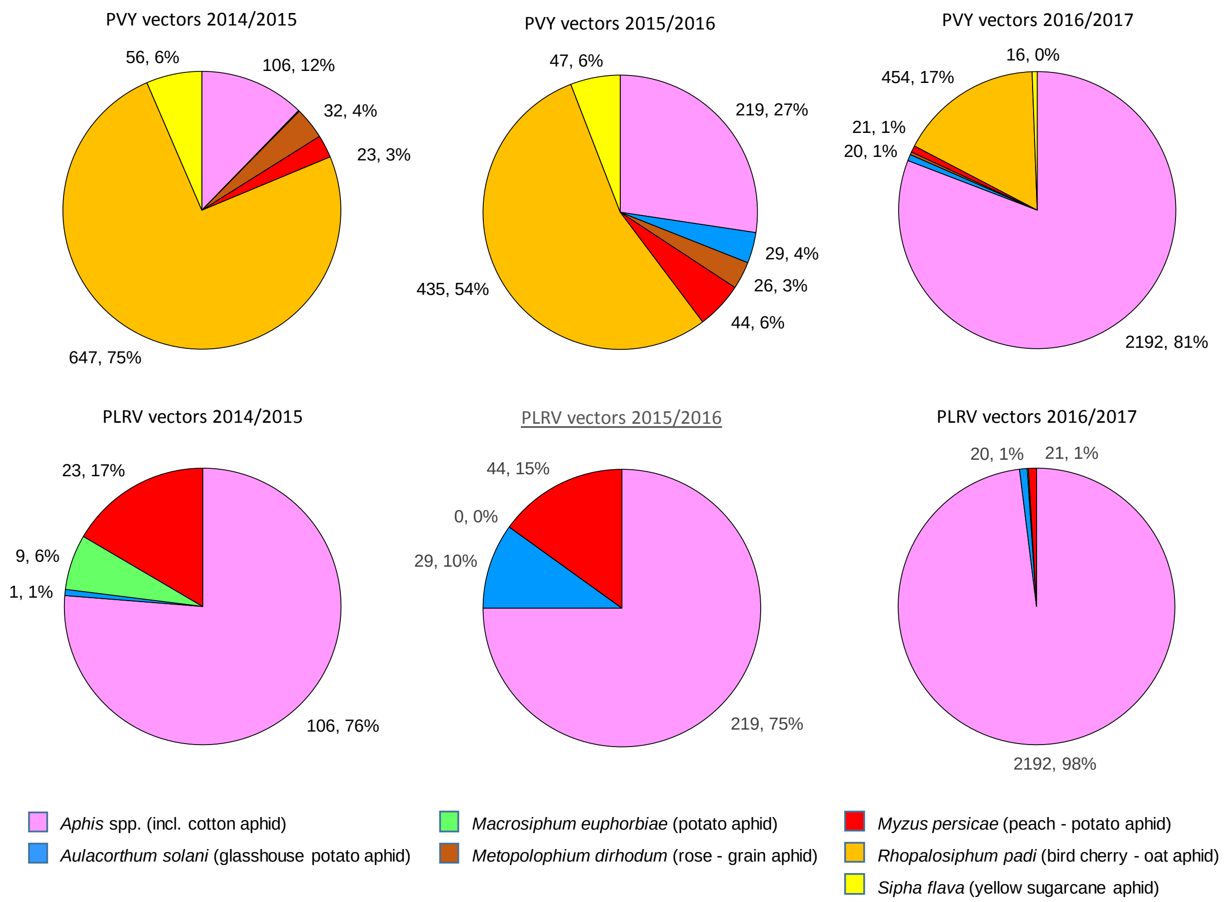

Fig. 5. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in KwaZulu-Natal (Underberg trap).

The most important vector species in the Underberg region were the bird cherry-oat aphid and *Aphis* species for PVY, and *Aphis* species for PLRV (Fig. 5). The number of bird cherry-oat aphids decreased from 647 in the 2014/2015 season to 435 in the 2016/2017 season. However, the number of *Aphis* species increased considerably from 106 individuals in 2014/2015 to 219 individuals in 2015/2016 and 2192 individuals in 2016/2017. The yellow sugarcane aphid, a vector of PVY, was caught in lower numbers in the Underberg than in the Cedara trap. The peach-potato aphid was trapped in relatively high numbers during the 2014/2015 and 2015/2016 seasons.

The numbers of vectors of PVY and PLRV tended to increase early in the season, with a small peak in September (PLRV) and October/November (PVY). Aphid numbers increased considerably from the end of January and reached peaks for both viruses in autumn (April and May; Fig. 6). The autumn peaks for PVY and PLRV were mainly due to high numbers of *Aphis* species and relatively high numbers of the peach-potato aphid (Fig. 5). Aphid vector numbers were lowest in mid-summer in January.

Aphid numbers tended to be lowest during the hot summer months in December and January and in winter during June and July (Figs. 6, 7). The aphid flight pattern differed in the 2016/2017 season from the previous seasons. Peak vector activity shifted from September/October to October/November and from February/March to March/April/May. In addition, aphid numbers were unusually high during these peaks due to the increase in *Aphis* spp.

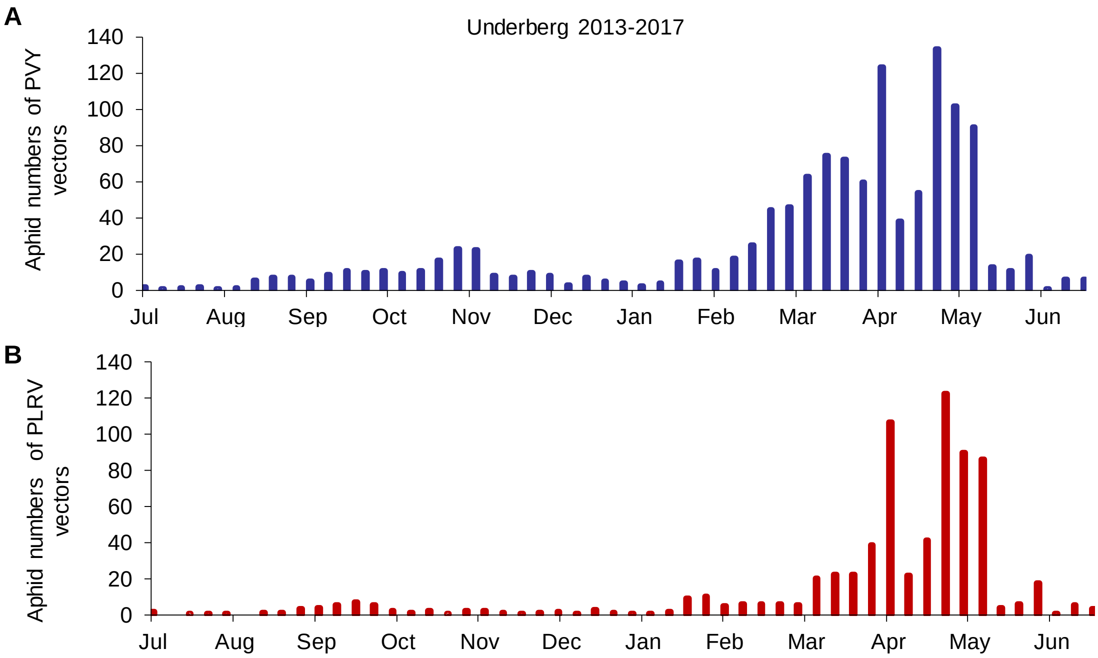

Fig. 6. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Underberg region based on the mean abundance of aphid vectors caught in the suction trap between September 2013 and December 2017.

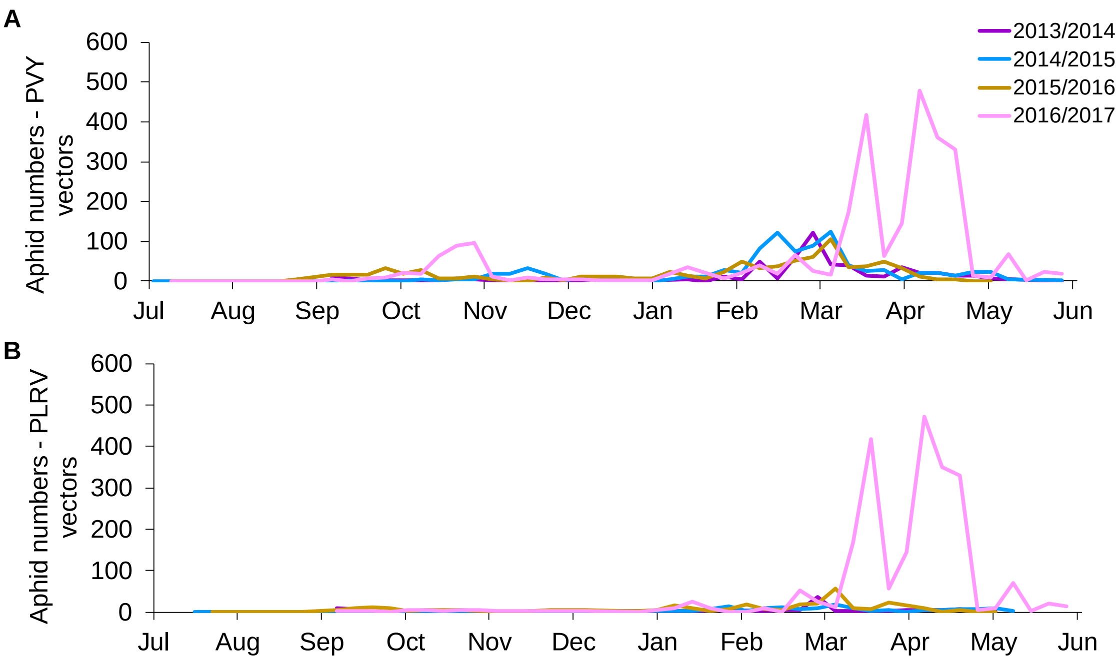

Fig. 7. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Underberg suction trap.

Fort Nottingham

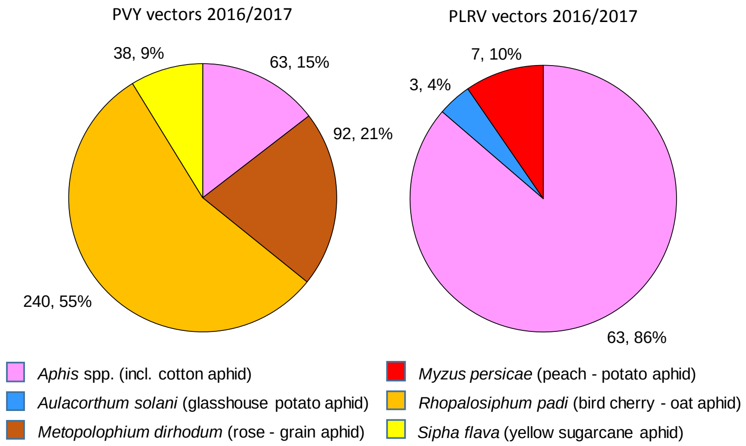

Fig. 8. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in KwaZulu-Natal (Fort Nottingham) caught between October 2016 and June 2017.

The most abundant vectors of PVY were the bird cherry-oat aphid followed by the rose-grain aphid, *Aphis* species and the yellow surgarcane aphid (Fig. 8). The most abundant PLRV vectors were *Aphis* spp. and the peach-potato aphid. In all four trap regions in KwaZulu-Natal, aphid numbers were lowest in summer (December) and during the winter months (June to August) (Fig. 9).

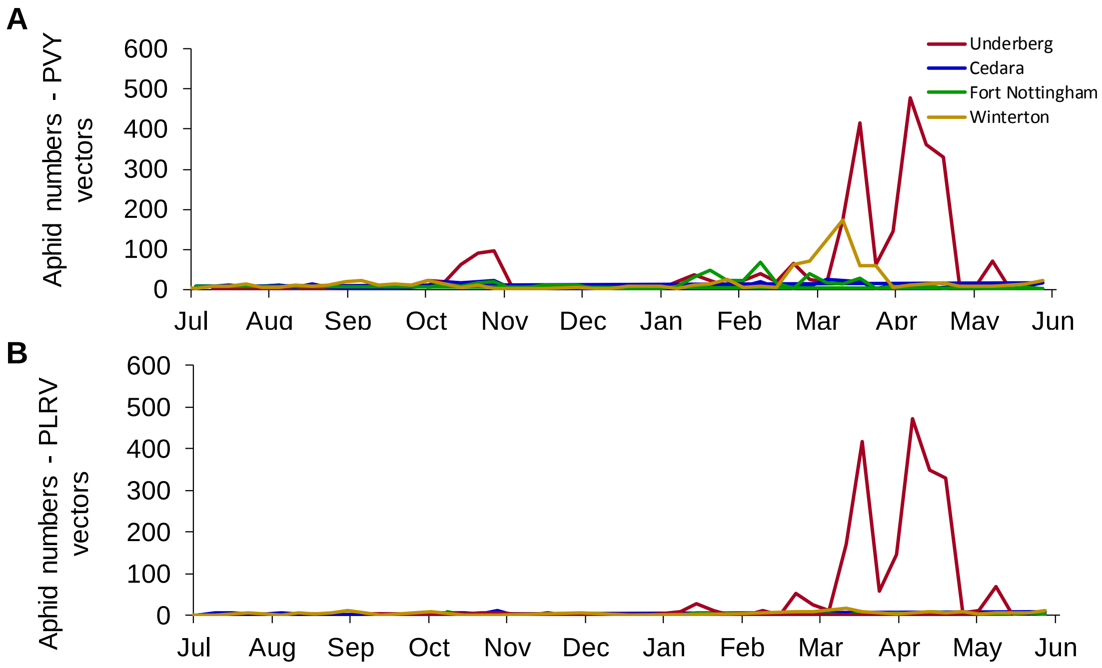

Fig. 9 Comparison of aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in four KwaZulu-Natal suction trap

Winterton

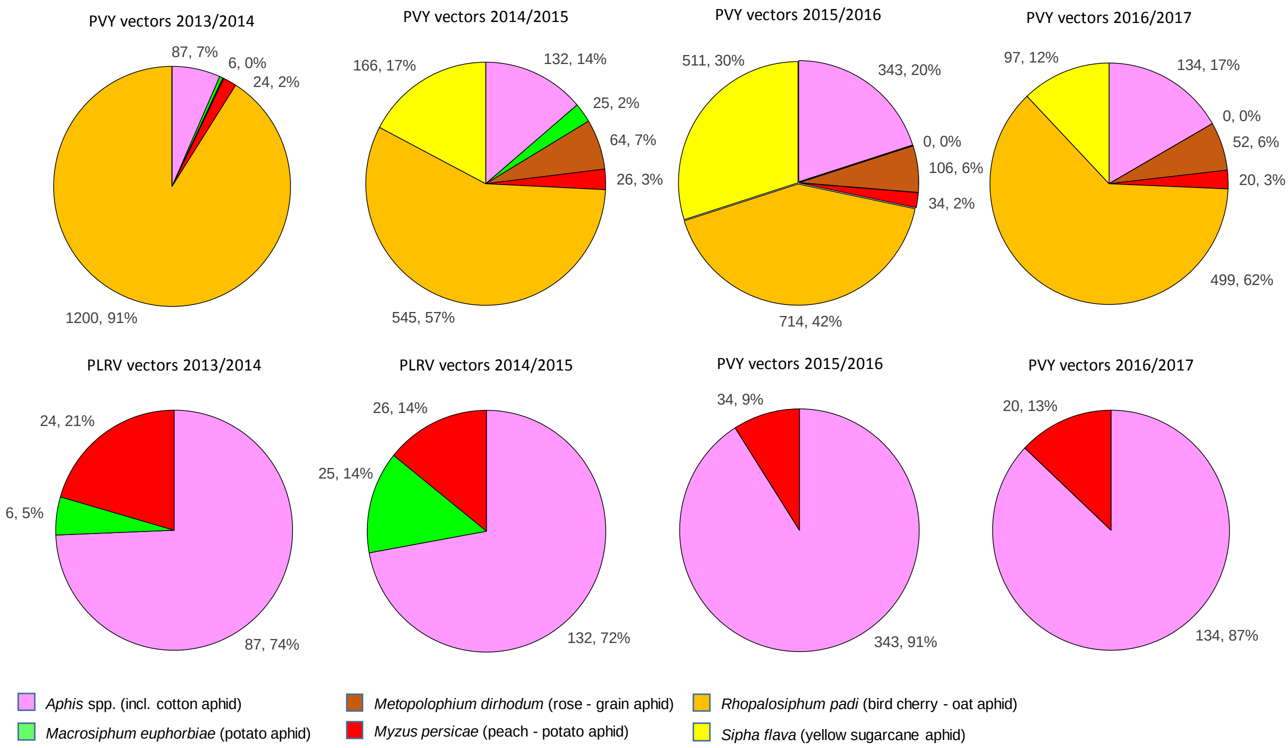

Fig. 10. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in KwaZulu-Natal (Winterton).

The most important PVY vector species in the Winterton region were the bird cherry-oat aphid, *Aphis* species and the yellow sugarcane aphid (Fig. 10). The most important vectors of PLRV were the *Aphis* species and the peach-potato aphid, and during the 2014/2015 season also the potato aphid (Fig. 10). The number of aphid vectors differed considerably among seasons. The peach-potato aphid was trapped in relatively high numbers throughout the reporting period.

Unlike in the Cedara and Underberg regions which had more than one peak in aphid vector activity in a season, there was only a double peak in late summer (February) and early autumn (March) in Winterton (Fig. 11).

Aphid vector numbers tended to be lowest in December (Figs 11, 12).

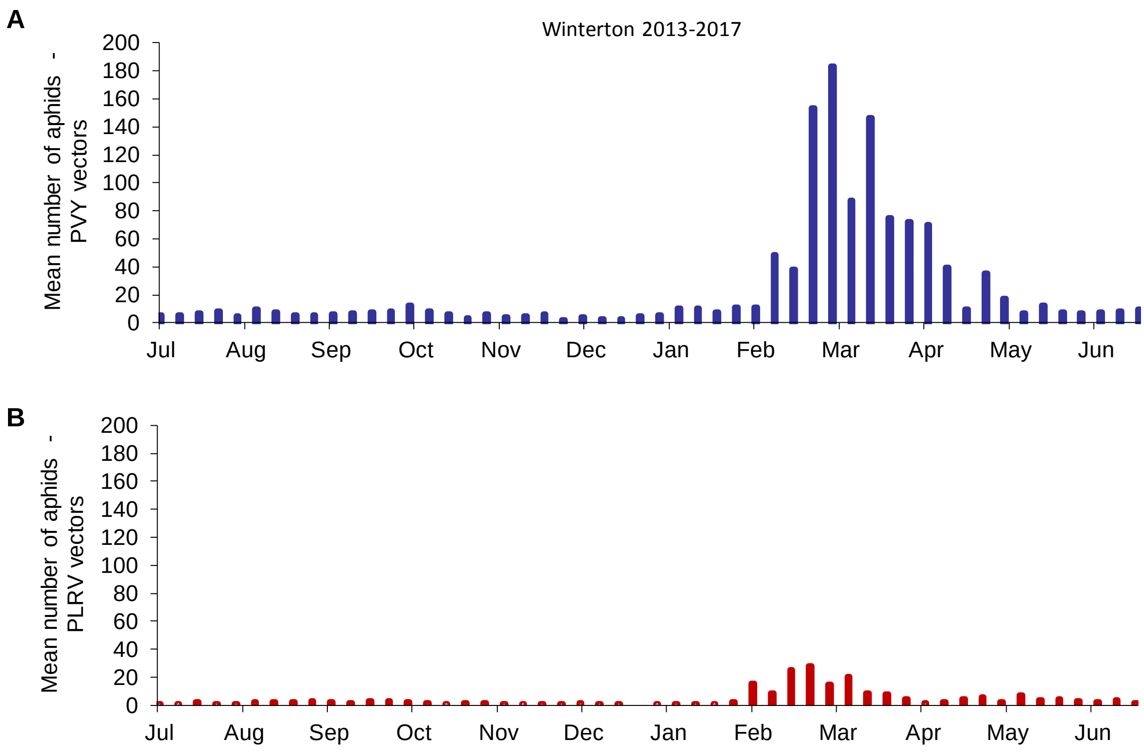

Fig. 11. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Winterton region based on the mean abundance of aphid vectors caught in the suction trap between September 2013 and December 2017.

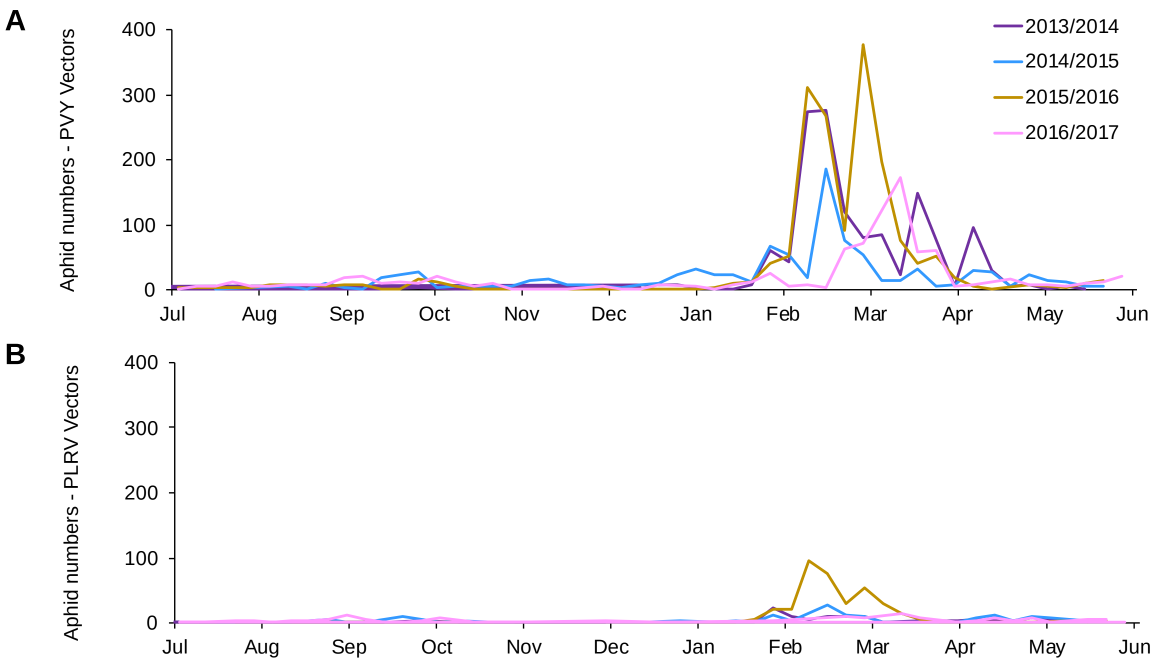

Fig. 12. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Winterton suction trap.

4.3.2 Western Free State (Christiana)

Fig. 13. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in the western Free State (Christiana).

In the Christiana region, 49 species and species groups were caught in the suction trap throughout the trapping period. Of these, 11 are vectors of PVY and three (listing *Aphis* spp. as one) vectors of PLRV. The most important vector species in the region were the bird cherry-oat aphid for PVY and *Aphis* species for PVY and PLRV. Numbers of individuals of the bird cherry-oat aphid collected decreased from 4860 in the 2013/2014 season to 460 in the 2016/2017 season. Likewise, the abundance of *Aphis* spp. decreased from 2213 aphids to 90 individuals from 2013/2104 to 2016/2017, whereas the importance of the rose-grain aphid as a vector of PVY increased during the 2016/2017 season. PLRV vectors such as the peach-potato aphid and the potato aphid only occurred in low numbers, with the exception of the 2013/2014 season (Fig. 13).

Aphids that transmit PVY in the western Free State peak during spring in October and November, and then again in late summer/autumn in February and March (Fig. 14A). The peak in spring coincides with the movement of wheat aphids from the ripening crop to grasses, and the February/March peak could coincide with aphids moving from maize to sorghum. The peak in spring was largely due to the bird cherry-oat aphid, whereas the peak in later summer/autumn was due to both the bird cherry-oat aphid, the most abundant vector (Fig. 15A), and, to a lesser extent, *Aphis* spp. (Fig. 15B). *Aphis* spp. were the most abundant vectors of PLRV and were responsible for the single peak in February and March (Figs 14B, 15B).

Aphid numbers tended to be lowest during the cool winter months (June to August) and early spring (September) and then again during the hot summer months of December and January.

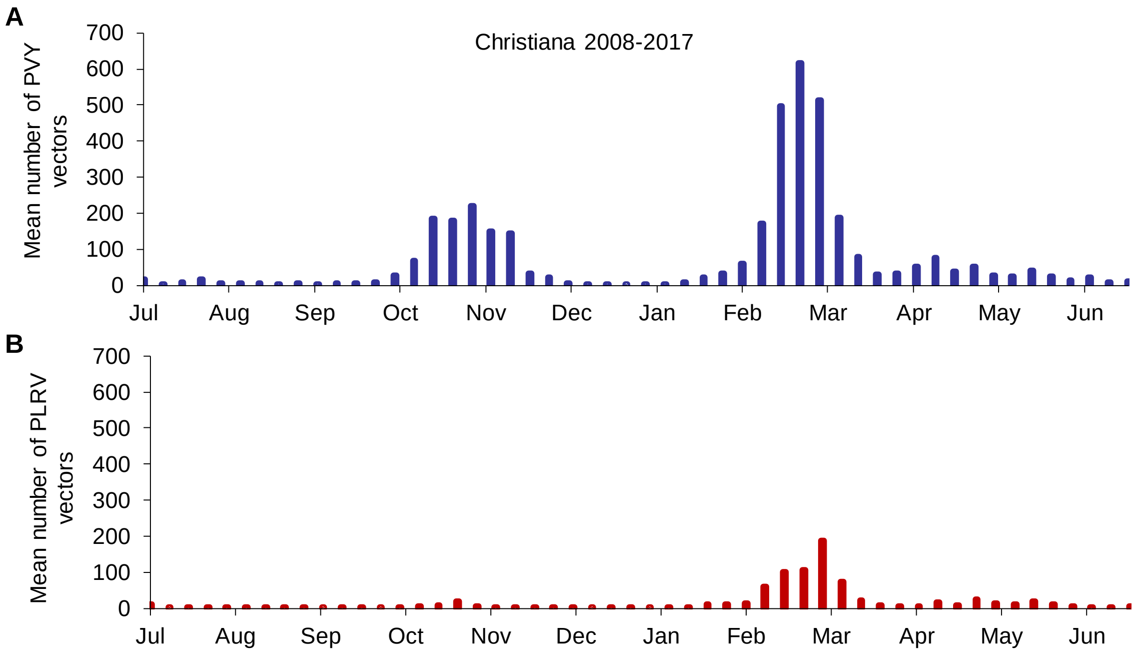

Fig. 14. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Christiana region based on the mean abundance of aphid vectors caught in the suction trap between January 2008 and December 2017.

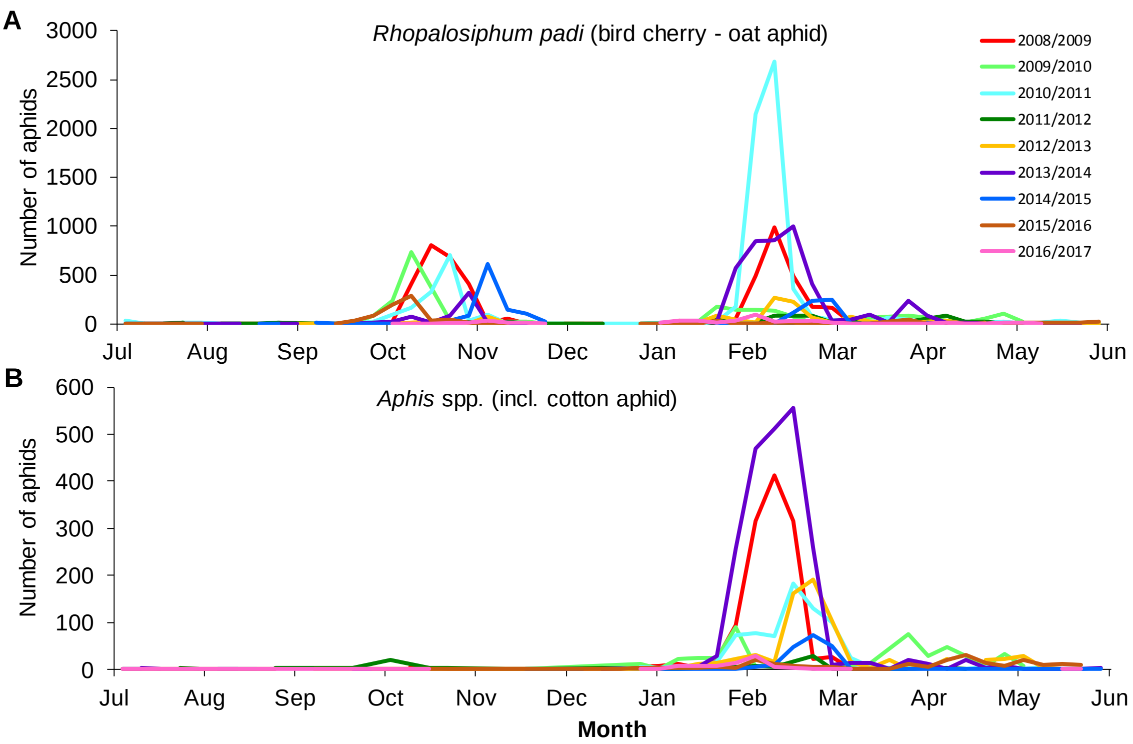

Fig. 15. Aphid flight activity of the most abundant vector of PVY (*Rhopalosiphum padi*; A) and PVY and PLRV (*Aphis* spp.; B) in the western Free State.

4.3.3 Northern Cape (Douglas)

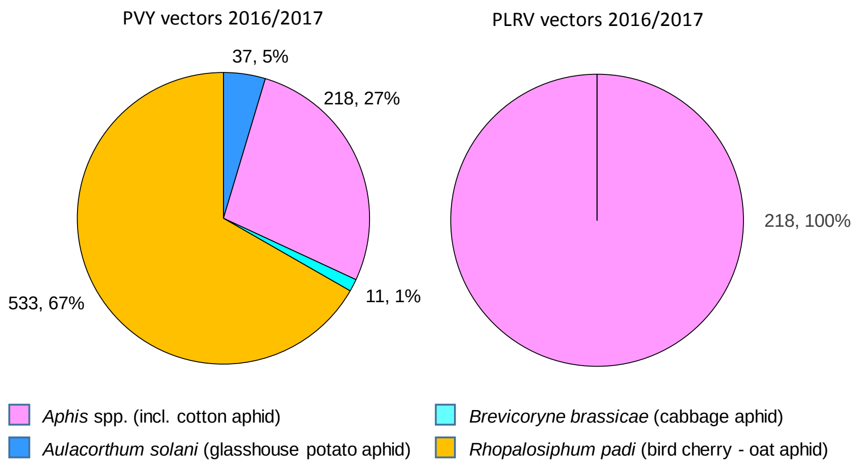

Fig. 16. Abundance of aphid vectors (total number caught, per cent) of PVY and PLRV in Douglas caught between November 2016 and June 2017.

The most abundant vectors of PVY during the 2016/2017 season trapped between November 2016 and June 2017 were the bird cherry-oat aphid and *Aphis* species. *Aphis* species were the only PLRV vectors that occurred in larger numbers in the region (Fig. 16). Aphid vector numbers for both PVY and PLRV peaked in February 2017 (Fig. 17).

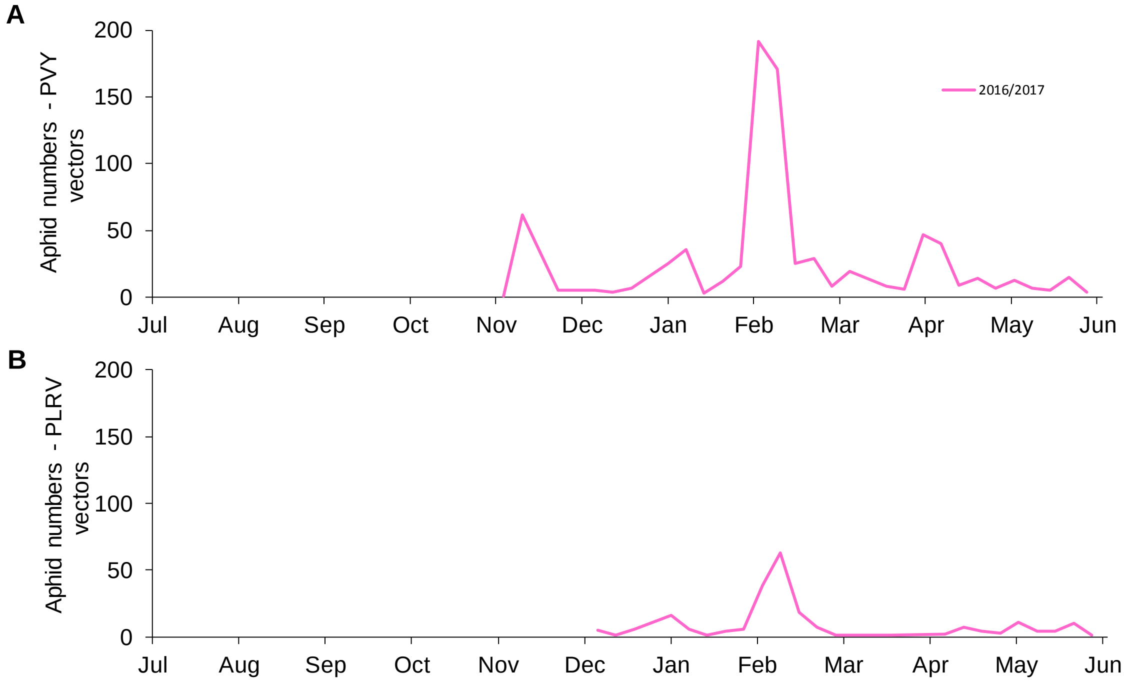

Fig. 17. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Douglas suction trap.

4.4 Vector pressure in different regions

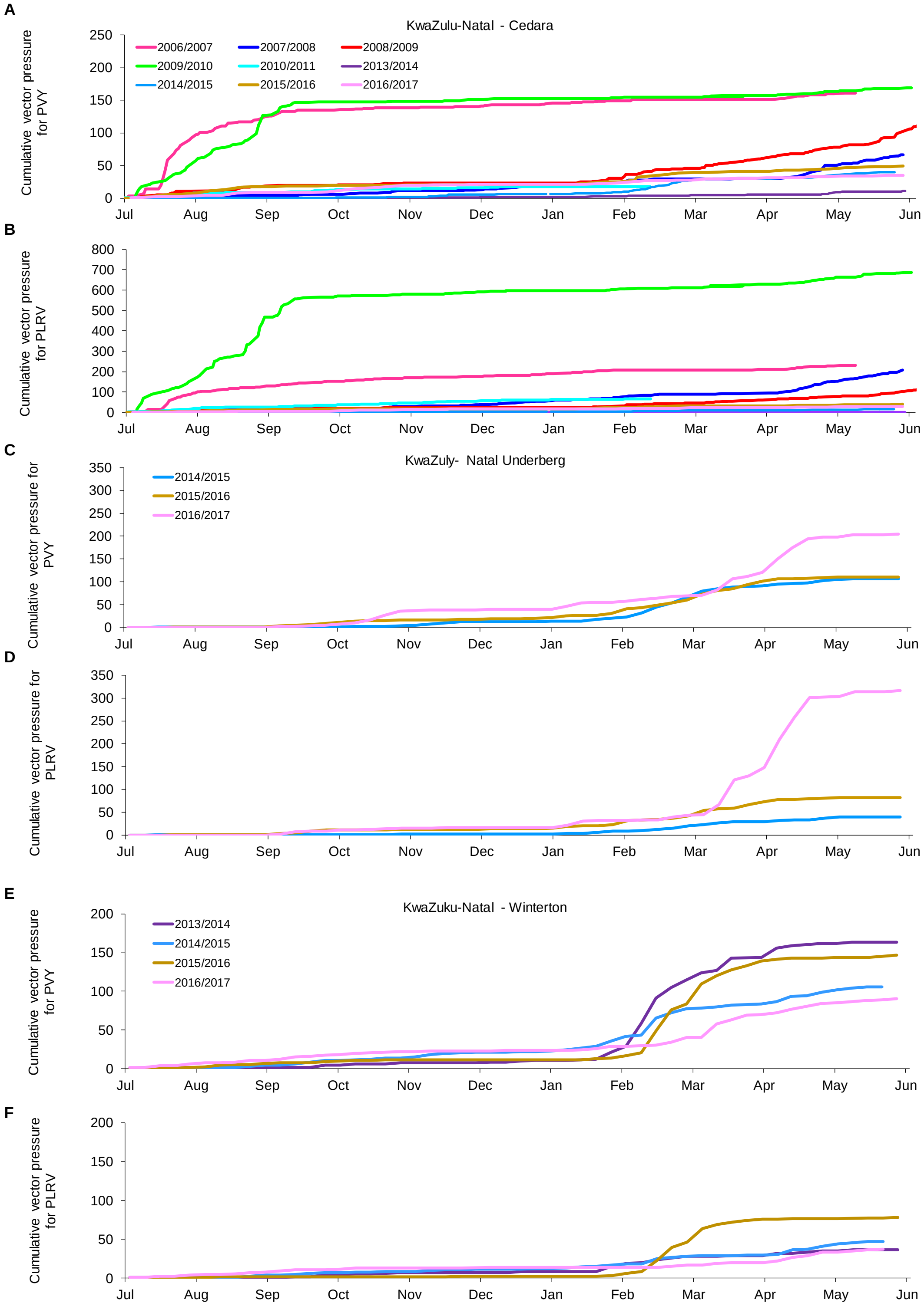

Fig. 18. Vector pressure for PVY (A, C, E) and PLRV (B, D, F) in different areas of KwaZulu-Natal showing the differences between years.

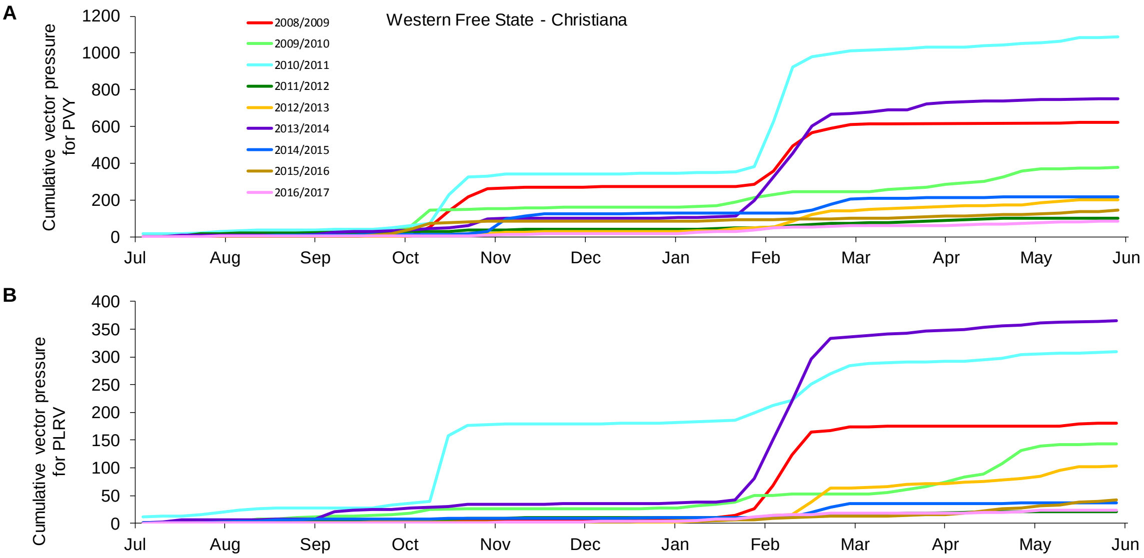

Fig. 19. Vector pressure for PVY (A) and PLRV (B) in the Christiana region showing the differences between years.

The vector pressure in KwaZulu-Natal tended to increase from September with a greater increase from February/March due to an increase in aphid vector activity (Fig. 18).

The vector pressure during the reporting period in the Christiana region was low (Fig. 19), except for the 2013/2014 season, due to a relatively high number of two efficient vectors, the peach-potato aphid and the potato aphid (Fig. 13).

Vector pressure for Douglas (Northern Cape) and Fort Nottingham (KwaZulu-Natal) could not be calculated because the traps only commenced operation during the growing season towards the end of 2016.

4.5 Western Cape (Lambert's Bay, Redlingshuys, Ceres, Malmesbury)

The most abundant vectors collected in suction traps in the winter rainfall region were the peach-potato aphid and the potato aphid, both vectors of PVY and PLRV, and the rose-grain aphid and the grain aphid, both vectors of PVY (Fig. 20).

Ceres (Koue Bokkeveld)

Aphids that transmit PVY and PLRV in the Koue Bokkeveld peaked during spring in October and during summer in January/February (Fig. 21). The most abundant vectors in spring were the rose-grain aphid and the grain aphid, both vectors of PVY, and the peach-potato aphid and the potato aphid, both vectors of PVY and PLRV. The peak in summer was largely due to the peach-potato aphid. Aphid flight activity of vectors of PVY varied between September and November during spring and between January and March (Fig. 22A). Aphid flight activity of vectors of PLRV also varied during spring between September and October and between January and March (Fig. 22B).

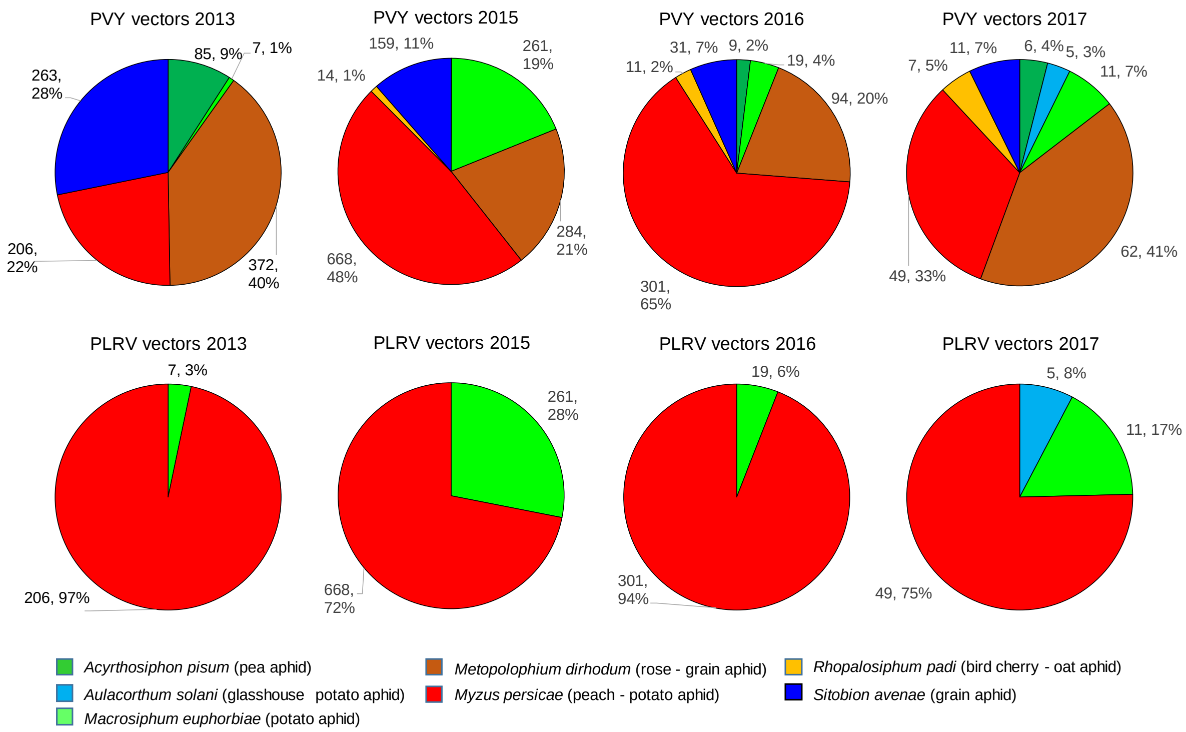

Fig. 20. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in the Koue Bokkeveld caught in 2013 and between January 2015 and December 2017. The trap was not operational for most of 2014.

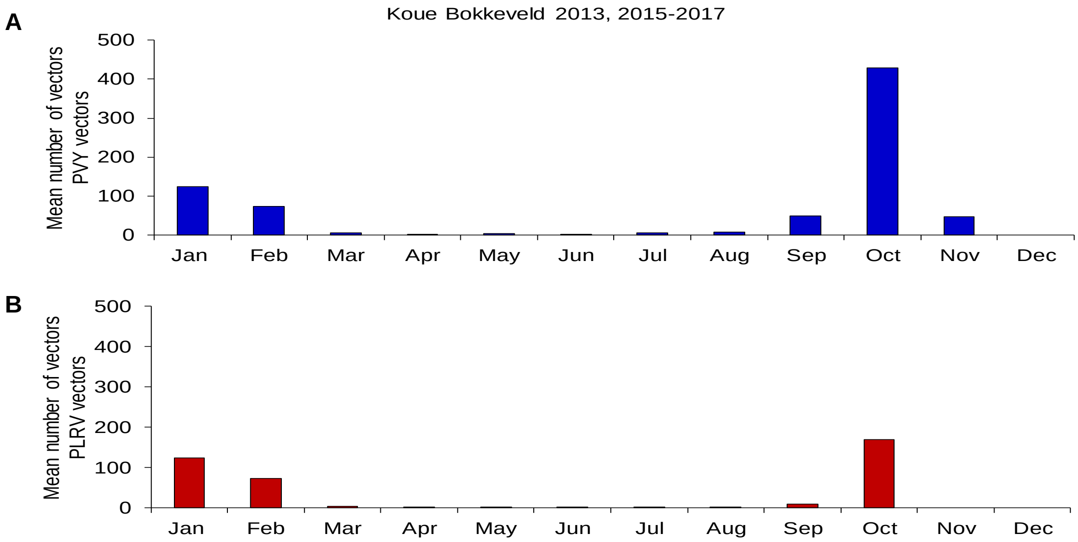

Fig. 21. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Koue Bokkeveld based on the mean abundance of aphid vectors caught in the suction trap in 2013 and between January 2015 and December 2017

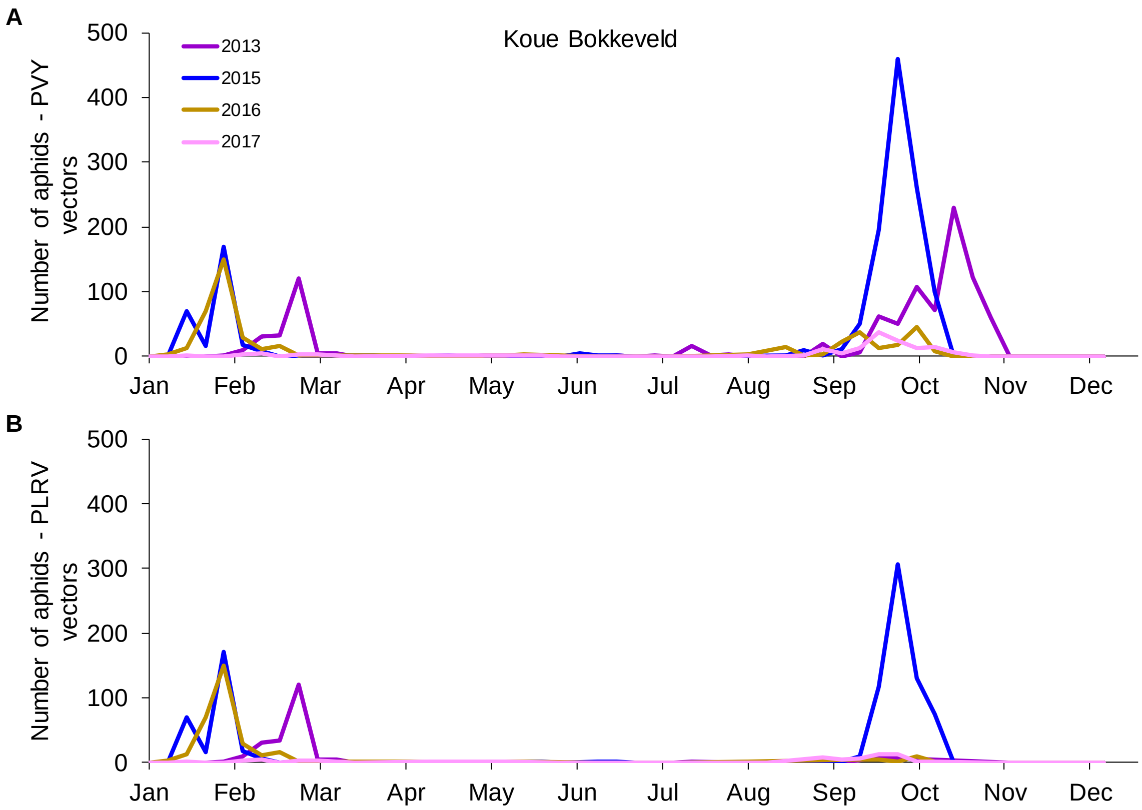

Fig. 22. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Koue Bokkeveld suction trap.

Malmesbury (Skaapkraal)

The most abundant vectors collected in the suction trap at Malmesbury (Skaapkraal) were the peach-potato aphid, a vector of PVY and PLRV, and the rose-grain aphid and the grain aphid, both vectors of PVY (Fig. 23).

Aphids that transmit PVY and PLRV at Malmesbury (Skaapkraal) peaked from July to October (Figs 24, 25). There was no peak in aphid activity during summer or autumn. The peak in autumn was primarily due to a complex of species consisting of the peach-potato aphid, rose-grain aphid and the grain aphid. Aphid flight activity of vectors of PVY varied between August and October (Fig. 25A). Aphid flight activity of vectors of PLRV varied between July and October (Fig. 25B).

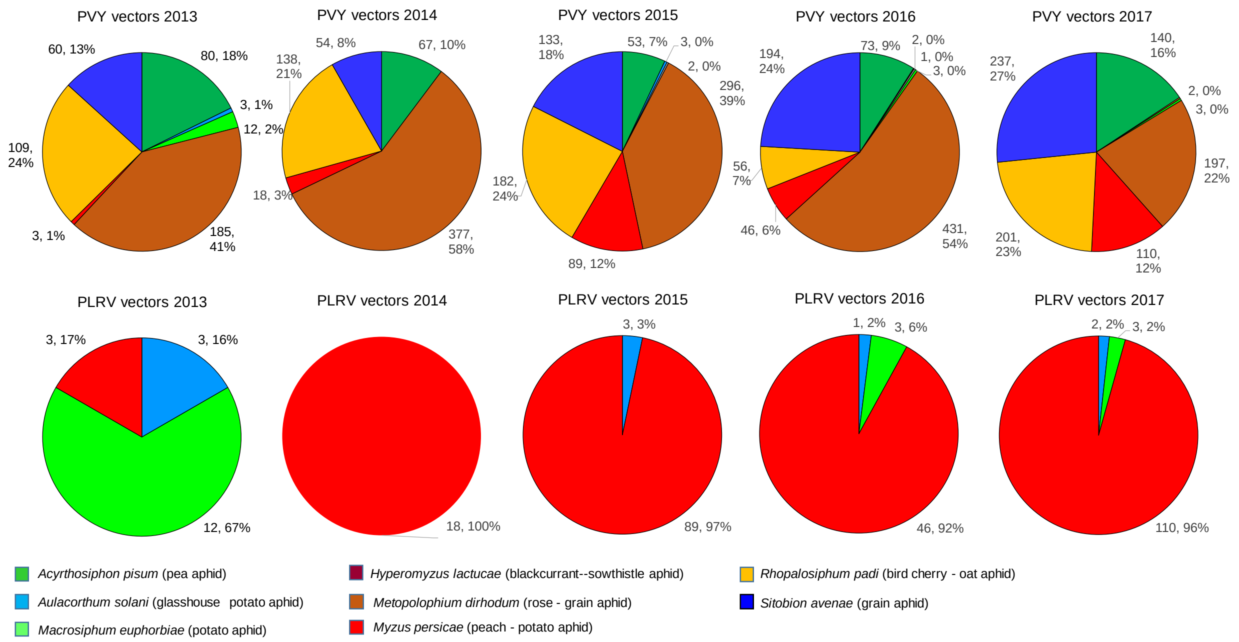

Fig. 23. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in Malmesbury.

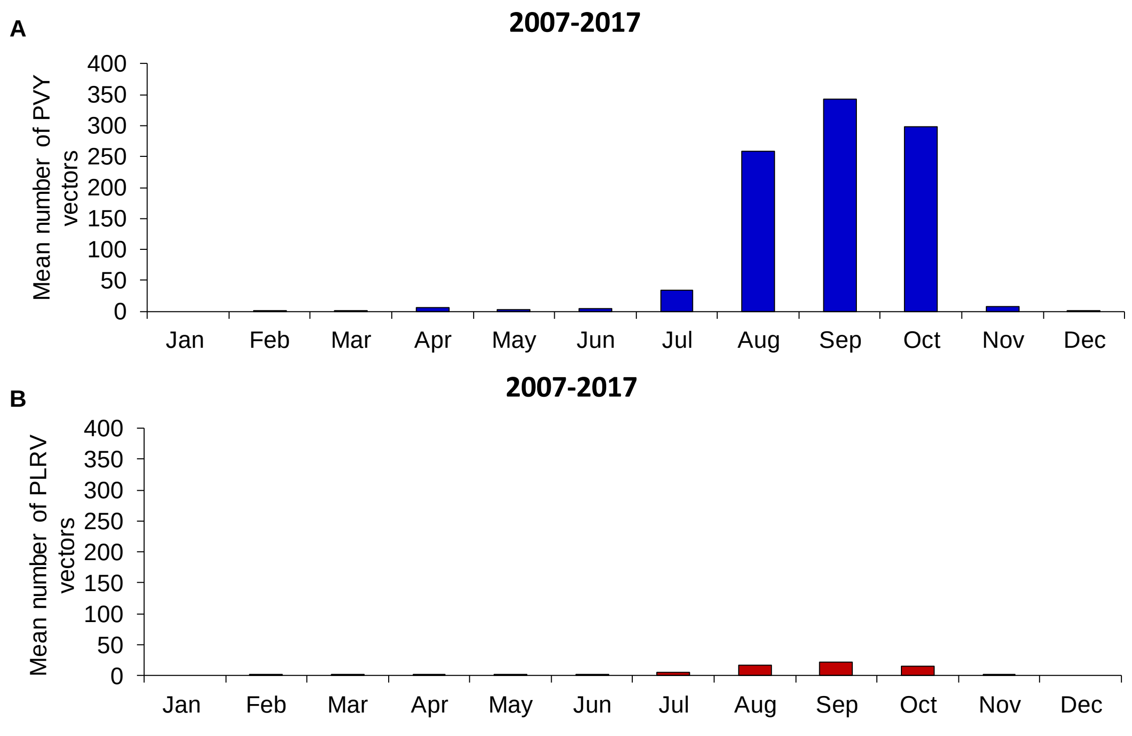

Fig. 24. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in Malmesbury based on the mean abundance of aphid vectors caught in the suction trap between January 2007 and December 2017.

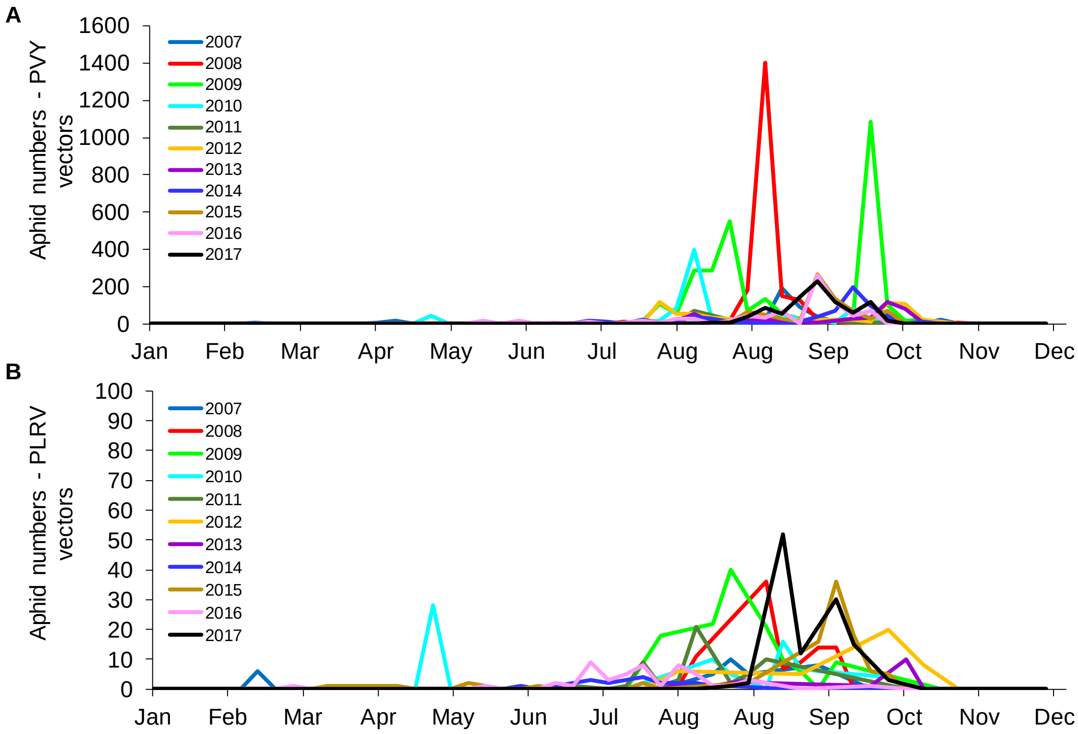

Fig. 25. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Malmesbury suction trap.

Lambert's Bay (Joos)

The most abundant vectors collected in the suction trap at Lambert's Bay (Joos) were the peach-potato aphid, a vector of PVY and PLRV, and the rose-grain aphid, a vector of PVY (Fig. 26).

Aphids that transmit PVY and PLRV at Lambert's Bay (Joos) peak from January to April during summer and autumn and from August to November during winter and spring (Figs. 27, 28). The most abundant vectors in spring were the rose-grain aphid, a vector of PVY, and the peach-potato aphid, a vector of PVY and PLRV. The peak in summer is largely due to the peach-potato aphid. Aphid flight activity of vectors of PVY can vary between January and April and between August and November (Fig. 28A). Aphid flight activity of vectors of PLRV also varies between January and April and between August and November (Fig. 28B).

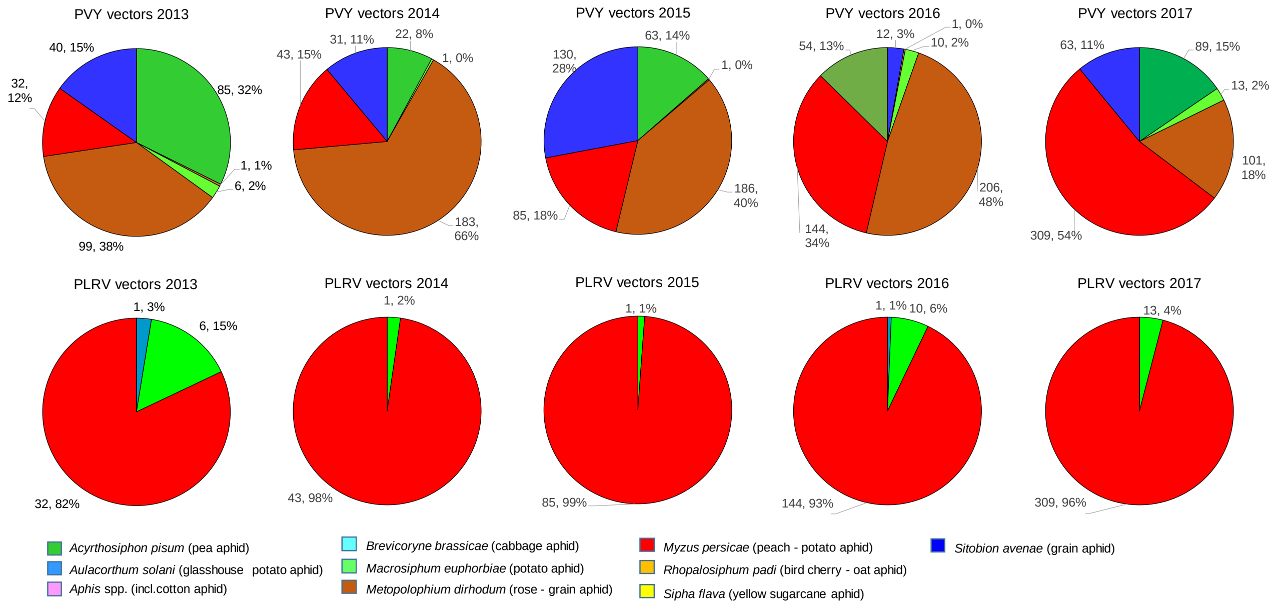

Fig. 26. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in Lambert's Bay.

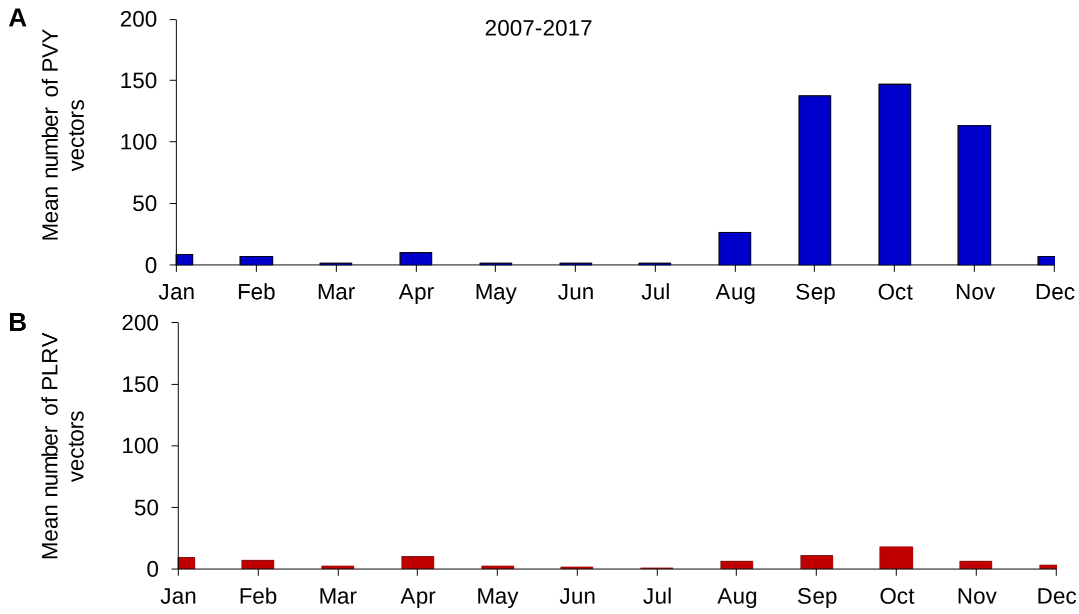

Fig. 27. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in Lambert's Bay based on the mean abundance of aphid vectors caught in the suction trap between January 2007 and December 2017.

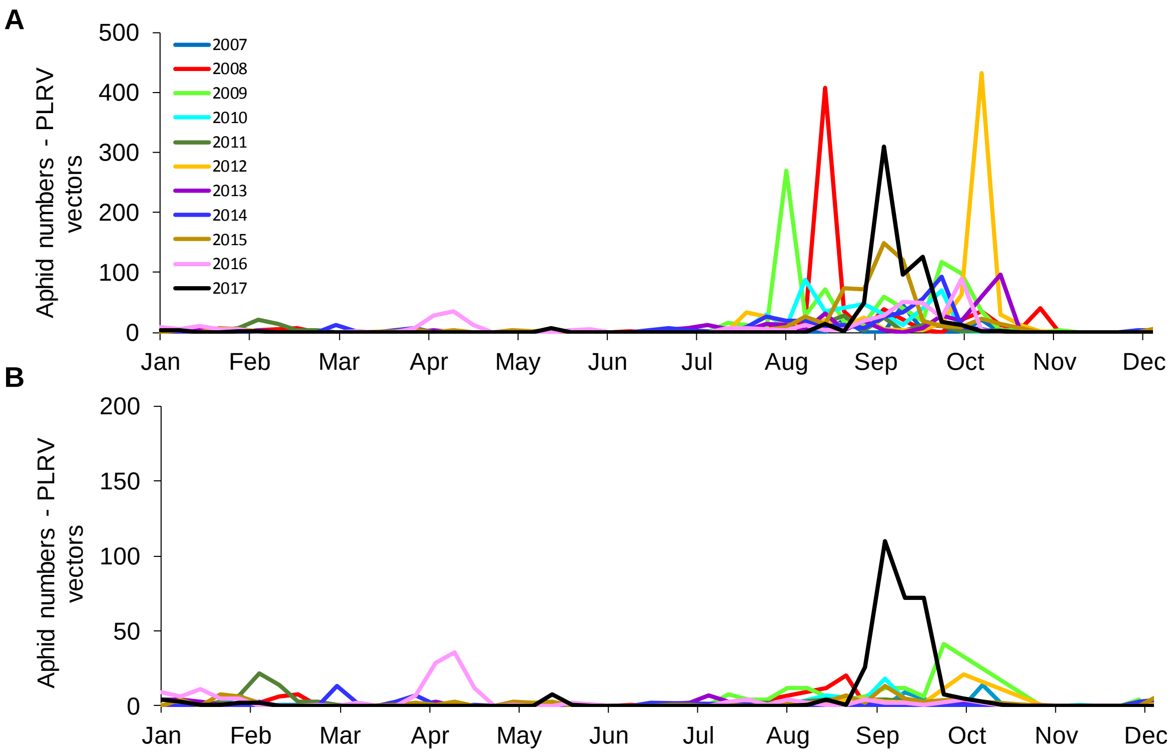

Fig. 28. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Lambert's Bay suction trap.

Sandveld (Redelinghuys)

The most abundant vectors collected in the suction trap at Sandveld (Redelinghuys) were the peach-potato aphid, a vector of PVY and PLRV, and the bird cherry-oat aphid and the rose-grain aphid, vectors of PVY (Fig. 29).

Aphids that transmit PVY and PLRV at Sandveld (Redelinghuys) peak during summer in January, in autumn in May and from July to October in winter and spring (Fig. 30). The most abundant vectors in winter and spring were the bird cherry-oat aphid and the peach-potato aphid. The peak in summer was largely due to the peach-potato aphid. Aphid flight activity of vectors of PVY varied between January and February and between July and October (Fig. 31). Aphid flight activity of vectors of PLRV varied between January and February and August and October (Fig. 31).

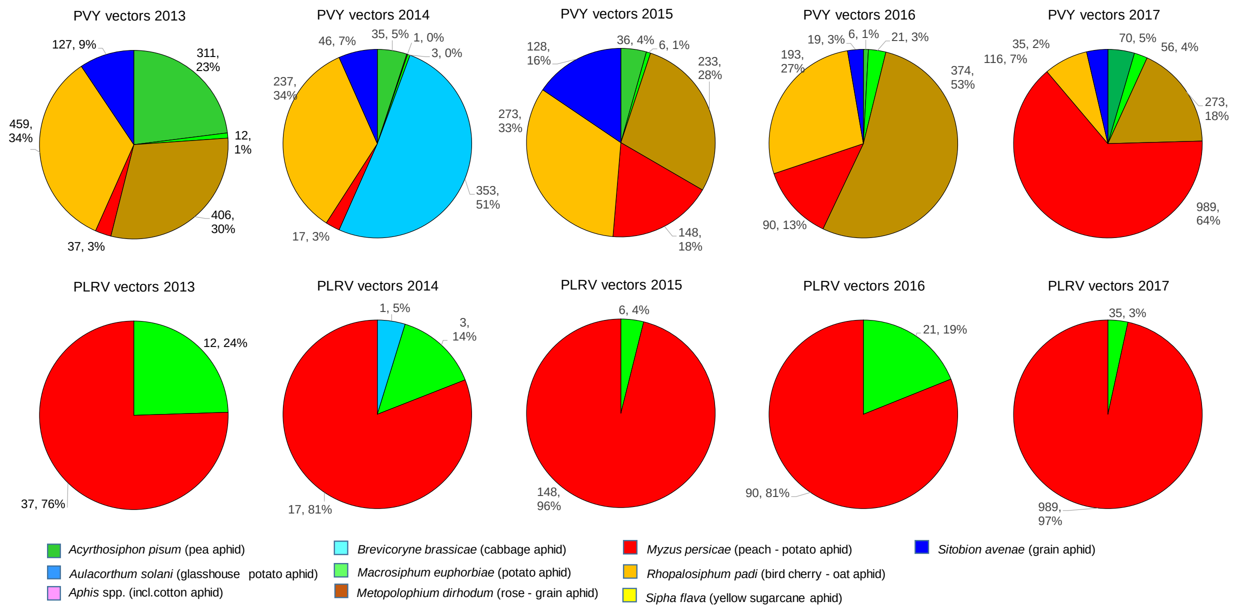

Fig. 29. Abundance of aphid vectors (total number caught, percent) of PVY and PLRV in the Sandveld (Redelinghuys).

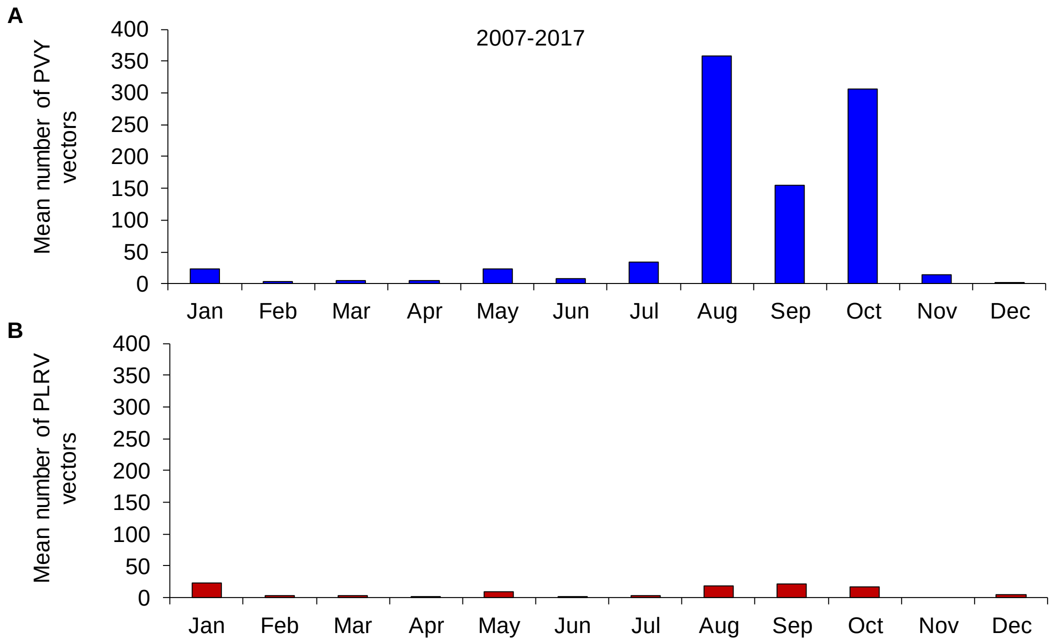

Fig. 30. Trends in aphid flight patterns of PVY vectors (A) and PLRV vectors (B) in the Sandveld based on the mean abundance of aphid vectors caught in the suction trap between January 2007 and December 2017.

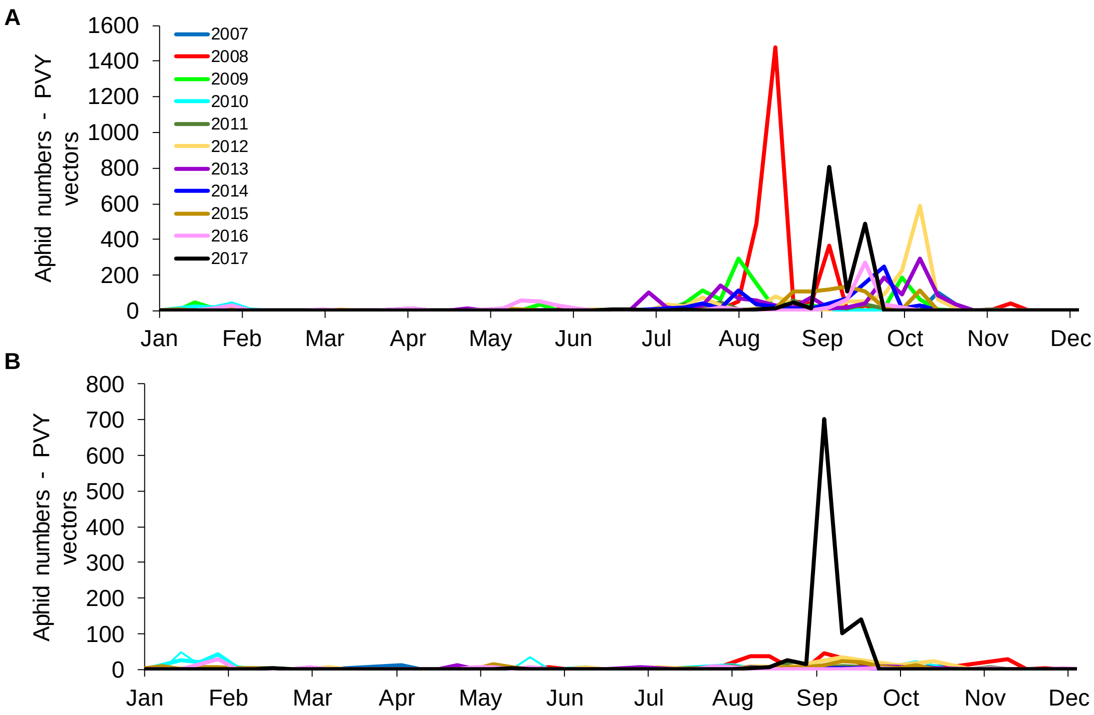

Fig. 31. Aphid flight activity of vectors of PVY (A) and PLRV (B) based on numbers of aphid vectors caught in the Sandveld suction trap

5. DISCUSSION

Some trends are discernible in regions with several years of aphid monitoring data. A common trend that applies to all monitored areas is the low aphid numbers during the hottest month (January) when the high temperatures limit aphid reproduction, development and survival. Another trend common to all regions is distinct peaks for aphid vectors of PVY and PLRV in late summer/autumn. In some regions, there are clear trends. In the Christiana region in the western Free State, for example, there are regularly two peaks of PVY vectors – one in spring and another in late summer/early autumn, whereas PLRV vectors peak once in late summer/early autumn. It is more difficult to identify trends in regions with only a few years of monitoring data. For example, aphid abundance data appears to be more variable in the Underberg region based on four seasons of aphid monitoring. The exact timing of the peaks may shift from year to year. In Cedara, aphid vector activity peaks during different times of the year, highlighting the need for long-term data sets to be able to determine trends and develop virus risk forecasting models. Vector pressure differs between regions, being low in some, e.g. Christiana, and relatively high in others, depending on aphid species composition and abundance in a particular year, which in turn may depend on crops other than potatoes planted.

Although vector pressure based on aphid flight activity may be relatively high in some regions in some years, a molecular analysis of vectors carrying these two viruses, together with virus transmission experiments, suggest that the number of infected migrating aphids is relatively low (Kruger, pers. obs.). In the winter rainfall region of the Western Cape, the most important vector of PLRV and PVY was the peach-potato aphid, *Myzus persicae*, followed by the PVY vectors *R. padi* and the rose-grain aphid, *Metopolophium dirhodum.* Of the *M. persicae* individuals tested for PLRV, 25 % tested positive. The number of *M. persicae* recorded in suction traps in the winter rainfall region was higher compared to those in the summer rainfall region.

In conclusion, the aphid monitoring data provides information on aphid flight activity during potato planting and growth and assists with determining the timing of haulm destruction.

6. CONCLUDING REMARKS AND RECOMMENDATIONS

Information on aphid flight patterns and vector pressure enables growers to strategically target the location and timing of control measures, as well as to optimise the timing of haulm destruction. The value of the network lies in providing information on aphid data as soon as it becomes available, i.e. in real time. Aphid identifications by the University are usually provided within the same day of receipt of samples to enable growers to react swiftly if required.

Future work

- Vector pressure based on suction trap data provides information on migrating aphids from a radius of 30 km to ca. 80 km. However, vector pressure on the ground at field level may be variable and can depend on numerous additional factors. The relationship between vector pressure based on suction trap catches and vector pressure at field level should be established on a regional basis.

- A long-term objective of the ongoing programme is to determine the possible impact of environmental changes, e.g. changes in climate, on aphid species composition and abundance and disease transmission, and ultimately to develop a virus-risk forecasting system for growers. Due to the high variation in aphid abundance, there is a need for longer term data series, which requires the continuation of the network as well as traps staying in their region to accumulate long-term data.

- Improved liaison with various industries, e.g. pest management companies, to make better use of the aphid data with a view to improved plant virus management.

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Ragsdale D.W.; Radcliffe E.B. & DiFonzo, C.D. (2001). Epidemiology and field control of PVY and PLRV. In: *Virus and virus-like diseases of potatoes and production of seed-potatoes.* G. Loebenstein, P.H. Berger, A.A. Brunt & H. Lawso (Eds.). Dordrecht, the Netherlands: Kluwer Academic Publishers, pp. 237-273.

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8. OUTPUTS

Popular publications

1. Venter, F. & Krüger, K. (2014). Aphid transmission of Potato virus Y in South Africa. *Chips*, January/February 2014: 32- 34

2. Krüger, K. (2015). The value of aphid monitoring in South Africa. *Chips*, July/August 2015: 52-54

3. Laubscher, K. (2017). Aphid activities in the Koue Bokkeveld – 2015/16. *Chips*, January/February 2017: 24-26

Presentations

National meetings

Oral

1. Krüger, K. & Beetge, L. (2017). *Response of aphids to heat waves and drought: The role of olfaction in host plant location of the leafhopper*. 2017 Combined Congress of the Entomological and Zoological Societies of Southern Africa. Pretoria, South Africa, July 2017, p. 141.

2. Waals, J.E.; Kruger, K.; Franke, A.; Haverkort, A. & Steyn, J.M. (2017) *Climate change: Implications for potato diseases in South Africa*. Soilborne Plant Diseases Symposium. Stellenbosch, South Africa, September 2017.

International meetings

Oral

1. Krüger, K.; Beetge, L. & Kfir, R. (2015). *High temperature, plant water stress and performance of an aphid parasitoid*. XVIII. International Plant Protection Congress (IPPC), Berlin, Germany, August 2015.

2. Krüger, K. (2015). *Current innovations in insect pest control: Plant volatiles as targets for plant breeding.* 2nd Annual DuPont Plant Breeding Symposium Africa, Pretoria, South Africa, September 2015, p. 11.

3. Krüger, K.; Beetge, L. & Kfir, R. (2016). *Climate change: Effect of heat and water-deprived plants on the potato aphid, Macrosiphum euphorbiae, and its parasitoid Aphidius ervi.* 13th Symposium "Ecology of Aphidophaga". Freising, Germany, August/September 2016, pp. 52-53.

4. Krüger, K. & Beetge, L. *Influence of climate change on aphid vectors of potato viruses in South Africa.* 20th Triennial Conference of the EAPR (European Association for Potato Research). Versailles, France, July 2017, p. 129.

Poster

1. Krüger, K.; Prinsloo, G.; Laubscher, K.; Snyman, J. & Millar, I. (2017). *Insect monitoring: The South African suction trap network.* 2017 Combined Congress of the Entomological and Zoological Societies of Southern Africa. Pretoria, South Africa, July 2017, p. 353.

Peer-reviewed publications

1. Schröder, M.L.; Glinwood, R.; Ignell, R. & Krüger, K. (2015) Landing preference and reproduction *of Rhopalosiphum padi* (Hemiptera: Aphididae) in the laboratory on three maize, potato and wheat cultivars. *Journal of Insect Science,* 15: 63. DOI: 10.1093/jisesa/iev1048.

2. Schröder, M.L.; Glinwood, R.; Ignell, R. & Krüger, K. (2015) Olfactory responses of *Rhopalosiphum padi* to three maize, potato and wheat cultivars and the selection of prospective crop border plants. *Entomologia Experimentalis et Applicata,* 157: 241-253. DOI: 10.1111/eea.12359

3. Schröder, M.L.; Glinwood, R.; Ignell, R. & Krüger, K. (2017). The role of visual and olfactory plant cues in aphid behaviour and the development of non-persistent virus management strategies. *Arthropod-Plant Interactions,* 11: 1-13.

4. Lacomme, C.; Pickup, J.; Fox, A.; Glais, L.; Dupuis, B.; Steinger, T.; Rolot, J-L.; Valkonen, J.; Krüger, K.; Nie, X.; Modic, S.; Mehle, N. & Ravnikar, M. (2017). Transmission and epidemiology of *Potato virus Y*. In: C. Lacomme, L. Glais, D. Bellstedt, B. Dupuis, A. Karasev & E. Jacquot. *Potato virus Y: Biodiversity, pathogenicity, epidemiology and management.* Cham, Switzerland: Springer International Publishing, pp. 141-172.