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Monitoring of Aphid Fauna in Passionfruit Orchards in Kenya

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Abstract

Passionfruit woodiness disease viral pathogens limit passionfruit production and are non-persistently transmitted by aphid vectors. The study was conducted to identify aphid species and assess the population dynamics of potential vectors in the orchards for purposes of developing viral disease management tactics. Field trials laid out in a randomized complete block design with four replicates, were conducted in Kabete and Embu and aphid populations monitored weekly in passionfruit orchards for a year using yellow water pan traps under natural conditions. Aphid transmission tests using commonly found aphids *Aphis gosypii, A. fabae, Brevicoryne brassicae, Ropalosiphum maidis,* and *Sitobion avenae* and a CABMV isolate from the field were also carried out in the greenhouse. These tests would establish the ability of the aphid species to transmit CABMV. Twelve species of aphids were captured but the most abundant were *Aphis gosypii, Ropalosiphum maidis, Acyrthosiphon pisum* and *Brevicoryne brassicae* accounting for 97% and 95 % of the total aphids collected in Embu and Kabete, respectively. The species diversity was rich and abundant at 0.79 and 0.7 for Kabete and Embu, respectively. The aphid population in Kabete (8000) was significantly ($p < 0.05$) higher than that collected in Embu (2900) whereas the population collected during the long rains season was significantly ($p<0.05$) higher than that which was collected in the short rains. Individual species populations were higher in Kabete than in Embu but only *A. gosypii, Macrosiphum euphorbiae, Myzus persicae*

and *R. maidis* had significantly ($p<0.05$) higher populations in Kabete. About 70% of the total aphids were collected during the peak period in both sites indicating greatest aphid dispersal and flight activity. The aphids were present in the orchards throughout the year with one major seasonal peak in June, a time period when food crops and other vegetation such as weeds grow vigorously. The occurrence of aphids in the orchards throughout the year with the peak population density coinciding with the cropping season has serious implications in the management of the pest and spread of viral diseases of passionfruit.

Keywords: Cowpea aphid borne mosaic virus, *Aphis gosypii, Ropalosiphum maidis, Myzus persicae*, passionfruit woodiness disease, seasonal changes, IPM

Introduction

Viral diseases are a major limiting factor to passionfruit production worldwide (Moreira, 2008). In Kenya, passionfruit woodiness disease (PWD) is associated with Cowpea aphid borne mosaic virus (CABMV) and a yet to be identified potyvirus affecting passionfruit orchards. These viruses are a potential threat to the passionfruit industry in Kenya. In areas where PWD is prevalent, the disease can reduce the orchard life span to only a year resulting to 100% yield loss (Trevisan *et al.,* 2006). In Kenya, Wangungu et al. (2010) have reported 50-100% loss due to biotic stresses. Crop susceptibility, virus strain and environmental conditions are some of the factors that influence the extent of loss incurred (Bashir *et al.,* 2002). Typical symptoms of PWD include strong mosaic, stunted growth, leaf rugose, size reduction and distortion, inhibition of fruiting, hard fruits of reduced size with thick pericap with little or no pulp (Novaes and Rezende, 2003). Despite reports of the presence of the disease in Kenya, no quarantine measures have been undertaken to contain the spread. To date the disease is widely spread in all regions where passionfruit is grown reducing fruit yield and quality. Viral diseases have no remedy and can be spread long distances by germplasm, rootstocks or grafted seedlings.

Passionfruit production is an important source of income to the small scale farmers some of whom are out growers for large companies that export passionfruits. It is a source of employment and nutritional food for the rural population. In order to protect the quality and quantity of the crop, farmers rely on pesticides to control biotic stresses that include viruses. The pesticides are applied disregarding the environmental/ecological conditions.

Once the viruses are established natural spread within and between orchards occurs by aphids in a non-persistent manner (Shukla *et al.*, 1994). Immigrating aphids that do not feed on or colonize the host plant can effectively transmit the viruses (Zeger *et al.,* 1990). Omatsu *et al.* (2004) reported three main vectors of PWV in passionfruit orchards which are the sow thistle aphid (*Hyperomyzus lactucae*), green peach aphid (*Myzus persicae*) and Cotton aphid

(*A. gosypii)*. The aphids cause more harm by transmitting viruses other than by feeding on the plants hence the need to control them. Currently, limited information exists on aphid species composition, population dynamics and potential aphid vectors in passionfruit orchards in Kenya. Knowledge of aphid population and their flight activity within and around the orchards is necessary to assess the potential aphid species in the spread of viruses infecting passionfruit in Kenya. The study was undertaken to determine the species prevalent and to contribute to the understanding of aphid population dynamics in the orchards. The knowledge would be useful in recommending appropriate strategies for biotic stress management and reduce pesticide use in the environment.

Materials and methods

Site description and experimental layout

Two experiments were conducted in Kabete field station at an altitude of 1940m, latitude 1^{o}15'S and longitude 36^{o} 45'E and in Embu, Manyatta area, altitude 1545m, latitude 0^{o} 53S and 37^{o} 45'E. In Kabete, a one acre plot was divided into three equal parts while in Embu, four farms belonging to small scale farmers were selected for monitoring of aphids. Each plot/farm had four water pan traps placed in a zig zag transect along the length to trap the flying aphids. The traps standing on a representative area ($5m^2$) within the plot or farm served as replicates. The study was carried out over two seasons in each site from April 2009 to February, 2010. Prior to this monitoring work, preliminary monitoring was conducted in Kabete from May 2008 to November, 2008. Data collected was mainly aphid populations in water pan traps and on vines and aphid species identified.

Assessment of aphid populations in the field

Aphids were assessed using yellow water pan traps and direct counting on five growing points of the vine from different directions of the wind. In each plot/farm four traps were placed equidistantly. Water pan traps used were yellow round basins 30 cm diameter and 20 cm deep, covered with a sunshine yellow plastic paper. The traps were placed on wooden frames 1.5m high above the ground. They were half filled with clean water and a few drops of liquid detergent (monoethylene glycol) added to break the surface tension to allow the insects to sink to the bottom and to preserve the specimens. Samples were collected weekly for 35 continuous weeks. The specimens were preserved in 70% ethyl alcohol for identification and counting. These were later combined /merged to one cumulative sample to give the total sample collected per month per field. Surrounding vegetation and crops were recorded for the two growing seasons. The aphids collected were separated, identified and counted in the laboratory using a stereomicroscope. Apart from the traps, direct sampling was done on the vines. Four vines randomly selected per field were examined for aphid presence and quantification on five different growing points

per plant. These observations were made on a weekly basis to count nymphs or alates on leaves, while collecting aphids in the traps.

Aphid species identification

Aphids were collected once a week from the field, preserved in 70% ethyl alcohol and taken to the College of Agriculture and Veterinary Science Entomology laboratory for identification. Voucher specimens were selected on the basis of shared morphological characteristics used to identify similar aphids to species level. The species were identified with the help of existing laboratory collection and entomological keys based on morphological features as described by Martin (1983) and Blackman and Eastop (2000) (Table 1). These features include body colour, length of antennae relative to the body, antennal tubercles development and placement, cornicles length and colour, siphunculi shape, number of caudal hairs and length relative to the cauda and dorsal abdominal pigmentation.

Table 1 Features used to identify different aphid species collected in traps

Species	Body colour	Antennal tubercles	Siphunculi	Dorsal abdominal pigmentation
Myzus persicae	Green or olive	Well developed and inner sides converging	clavate	Has a dorsal black patch
Macrosiphum euphorbiae	Green or olive or yellow/ orange	Well developed and inner sides diverging	Cylindrical or tapering	No pigment completely green
Aphis gosypii	Black or green	Less developed or absent		Black transverse bars on abdominal side
Aphis fabae	black	Less developed	Short and same length with cauda	No abdominal marks all dark
Ropalosiphum maidis	Blue-green or grey	Less developed		Dark strip in the middle

Source Martin (1983); Blackman and Eastop (2000)

Specific diversity of aphids was determined by Simpson diversity index (Margurran, 1988) using the following equation: $D = 1- (P_i)^2$; $Pi = n_i /N$ where:

D = species diversity; N = total number of individuals; P_i = proportion of sample that contributes to the total population; n_i = Number of individuals of the ith species. The value of Simpson diversity index (1-D) ranges between 0 and 1. The greater the value of the diversity index the greater is the richness

and abundance of the species (Margurran, 1988).

Aphid transmission tests

Aphid species which included Maize aphid (*Rhopalosiphum maidis*), Wheat grain aphid (*Sitobion avenae*), Cabbage aphid (*Brevicoryne brassicae*), Bean aphid (*Aphis fabae*) and cotton aphid (*Aphis gosypii*) were reared on their respective hosts in a greenhouse. These were chosen because of their abundance in the main passionfruit growing areas, since their preferred hosts are grown as food crops in the same areas. The aphid species are present in different agro ecosystems and will fly into orchards which are within close range because of the farming systems prevailing in the passionfruit growing areas. The aphids were captured in the field and reared in green houses on preferred hosts. They were then removed gently from the hosts using camel hair/paint brush and placed on petri-dishes with moist filter papers. The aphids were starved for 1 hour. After the hour, leaf discs from infected passionfruit plants, maintained in a separate green house, were given to the aphids in the same petri-dishes to allow acquisition of the virus for 10mins. Thereafter, the aphids were collected in groups of 10 and transferred onto healthy/clean passionfruit plants in three replicates (Walkey, 1991) The aphids were allowed an inoculation period of 24 hours on the plants and were then killed with an insecticide (cypermethrin). This experiment was repeated three times using 10 plants /aphid and replicated 3 times each time. Once the virus symptoms developed plants were tested serologically with DAS ELISA protocol.

Data analysis

Experimental data collected was analyzed by one way analysis of variance (ANOVA) using Genstat Discovery Edition software (Rothamsted, UK) to determine aphid population density and species differences between seasons. The means were compared using Fischer's protected least significant difference (LSD) procedure at $p<0.05$ (Steele and Torrie, 1980)

Results

The year 2009 and part of 2010 was relatively warm, the lowest temperatures were experienced in July (11^oC) and the highest in March (27^oC). The rains were poorly distributed and insufficient in Kabete averaging up to five rainy days per month (Fig 1). In Embu, the rains were enough but poorly distributed in the year 2009 (Fig 1). During the rainy period, May to July the passionfruit plants exhibited spectacular virus symptoms especially mosaics following the rainfall received.

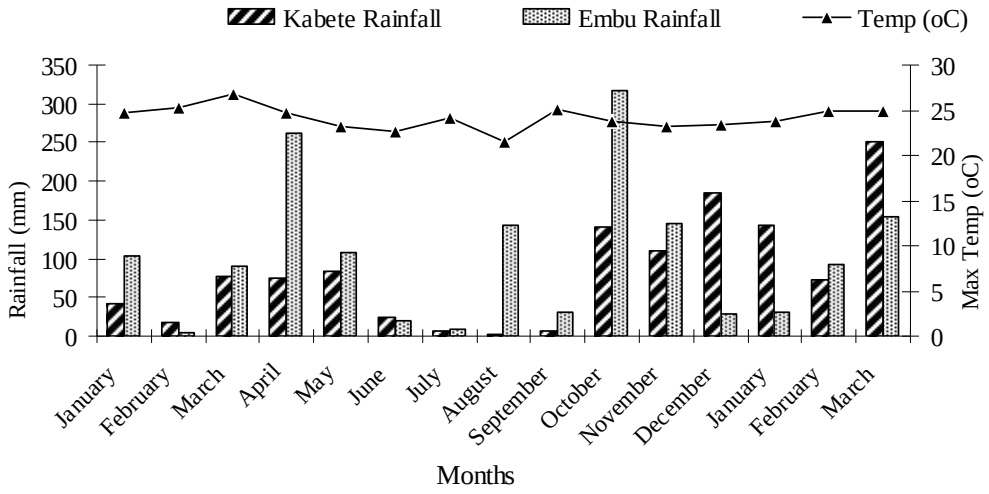

Fig 1 Mean rainfall (mm) received and Temperature (oC) in Embu and Kabete 2009 to March 2010

Aphid abundance and fluctuation trends

A total of 10, 900 aphids were collected, 8000 and 2900 from Kabete and Embu, respectively. The aphid population in Kabete was significantly ($p<0.001$) higher compared to that collected in Embu (Table 2). Similar aphid species were observed in both sites. These species were *Aphis gosypii* Glover, *Ropalosiphum maidis* Fitch, *Acyrthosiphon pisum* (Harris), *Aphis fabae* Scopoli, *Brevicoryne brassicae* Linnaeus, *Cavariella aegopodii* Linnaeus *Macrosiphum euphorbiae* Thomas, *Myzus persicae* Sulzer and *Lipaphis erysimi* Linnaeus, *Uleurocon spp*, *Hyperomyzus lactucae* L *and Therioaphis trifolii* L. Some individual species such as *A. gosypii*, *M. euphorbiae*, *Myzus persicae* and *R. maidis* had significantly ($p<0.05$) higher populations in Kabete compared to the same species populations in Embu (Table 2). *Aphis fabae, Acyrthosiphon pisum*, *B. brassicae and M. pesicae* had higher populations in Kabete compared to Embu but the differences were not significant. *Aphis gosypii*, *R. maidis*, *B. brassicae* and *A. pisum* were the most abundant in both sites. No aphids were observed developing or feeding directly on the vines throughout the sampling period.

Table 2 Mean number of aphids captured in passionfruit orchards in Embu and Kabete from May, 2009 to February 2010

Sites	*A. fabae*	*A. gosypii*	*A. pisum*	*B. brassicae*	*M. euphorbiae*	*M. persicae*	*R. maidis*	Total* aphids
Kabete	61	310	56	37	49	56	208	792
Embu	16	142	35	23	1	32	62	290
Mean	39	226	46	30	25	30	135	541

F-test	ns	**	ns	ns	**	ns	**	**
$LSD_{(p=0.05)}$	45.8	79.8	85	36.2	42.9	32.6	62.5	197.5

* Total aphids = overall mean of all aphid species; ** significance level at $p<0.05$; ns: No significant difference

Aphid population trends were different in the two sites. In Kabete the population peaked in June continued on into July followed by a sharp drop in August. Two smaller peaks were observed in September and October followed by another drop before peaking again in December and February, 2010. In Embu, the population peaked only in June followed by a sharp drop and it remained low for the rest of the sampling period (Fig 2). The aphid population peaks followed the rainfall which was received 4-6 weeks before (Fig 1). The least aphid population was observed in November (Fig 2). The aphid population in the short rains season (November, 2009 to February, 2010) was significantly ($p<0.001$) lower than that which was collected in the long rains season.

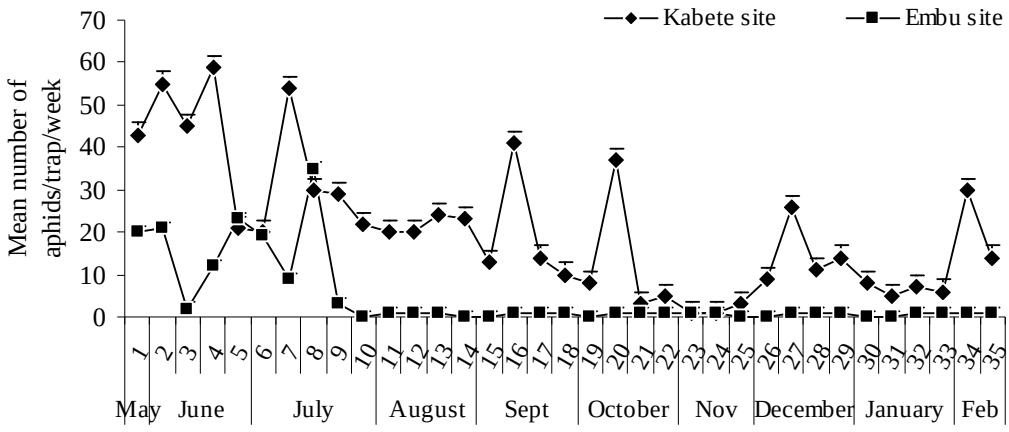

Fig 2 Mean number of aphids collected in Embu and Kabete sites May 2009 to February 2010

In 2008, preliminary work done in Kabete revealed only one peak activity of aphids in June, 2008. The peak was followed by a sudden drop in population density which remained low for the rest of the sampling period (year) (Fig 3). The total aphid population was significantly affected by the prevailing conditions over time ($p< 0.001$). Figure 4 shows the monthly rainfall amount received during the period (2008). In 2009, six aphid species were considered abundant in Kabete. They exceeded 5% of the relative abundance during the year (Fig 5). The species diversity index in Kabete was 0.79, indicating a species richness and abundance of aphids. The abundant species

were *A. gosypii* Gloverii *(31%) R. maidis* Fitch *(18%), B. brassicae* Linnaeus *(15%), M. persicae (*Sulzer*) (9%), A. fabae* Scopoli *(8%)* and *M. euphorbiae* Thomas *(5%)* and *A. pisum (3%)* making 97% of the total aphid population trapped in Kabete. Sixty eight percent of all the aphids in Kabete were collected during May to August, 2009.

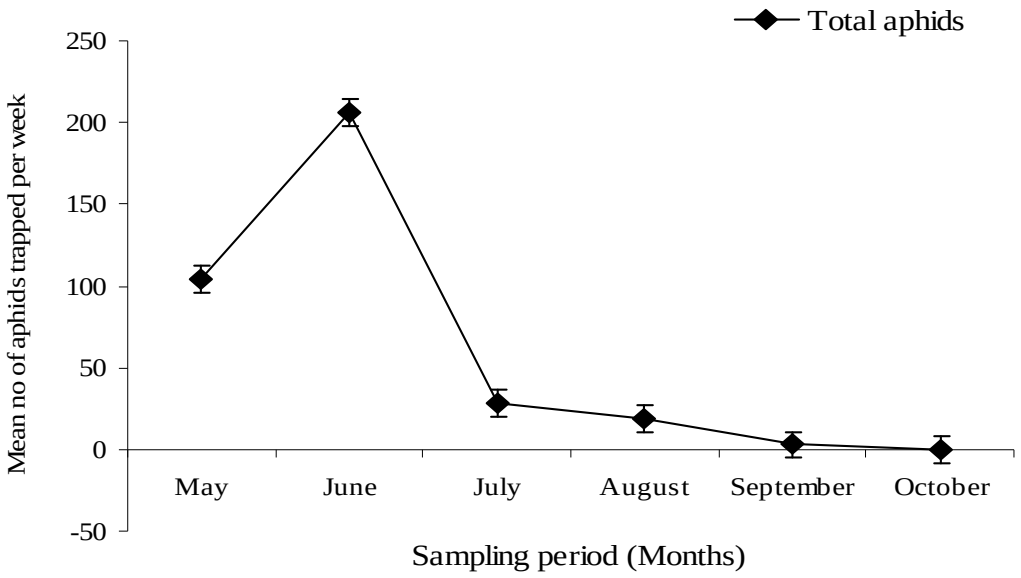

Fig 3 Aphid population variation in the orchards in Kabete between May to November, 2008

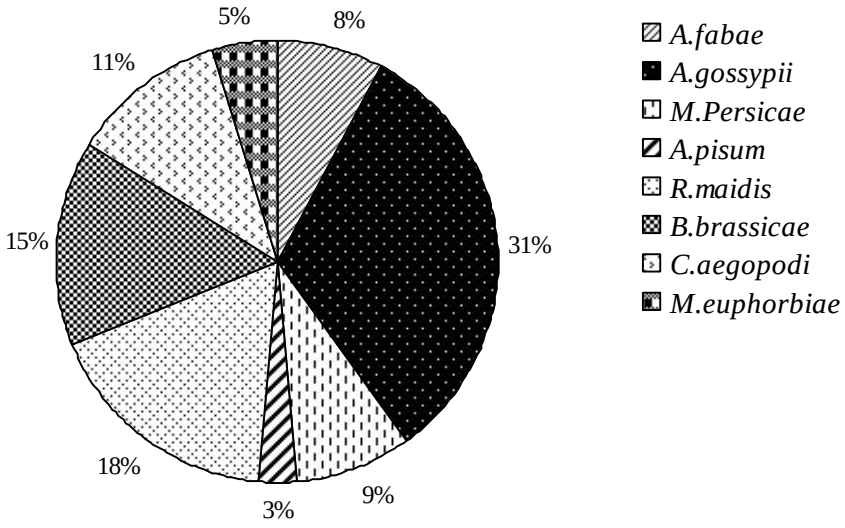

Fig 5 Proportion (%) of total aphids sampled in Kabete and categorized into individual species from May 2009 to February 2010. A total of 8000 aphids collected

Aphids in Kabete were significantly ($p<0.001$) affected by the prevailing weather conditions. All aphids were active with peaks observed in June, July, September, October, December, 2009 and February, 2010. An unusual high peak of aphids was observed in September and October 2009, a period that is relatively dry that comes before the short rain season. *Aphis gosypii* and *R. maidis* followed the same trend but the peaks were lower than those of the total aphids (Table 3). *Aphis gosypii* had the highest population density above the population of the other species ($p<0.001$) while *Lypaphis erysimi* had the least population density.

Table 3 Mean number of alate aphids captured per trap per week in Kabete from May, 2009 to February, 2010

Month	Sampling week	*A. gosypii*	*R. maidis*	Total aphids*
May	1	16.7	5.1	43.4
June	2	20.3	16.1	55.4
	3	20.5	19.2	44.8
	4	36.7	19.5	58.5
	5	9.9	4.9	21.4
July	6	12.5	5.1	20
	7	24.9	17.7	53.8
	8	12.7	10.3	29.8
	9	6.8	6.3	28.5
August	10	7.9	4.6	22.2
	11	5.2	3.8	19.8
	12	4.6	40	20.2
	13	4.1	3.1	24.4
September	14	3.8	6.2	22.9
	15	2.6	1.9	12.8
	16	8.7	5.1	40.5
	17	2.7	13	14.0
October	18	2.8	1.1	10.3
	19	2.8	1.0	8.3
	20	14.2	7.3	37.3
	21	1.6	1	2.8
November	22	0	0	5.1
	23	0	0	1.3
	24	0	0	1.4
	25	2.4	0	3.3
December	26	5.6	2	9.0
	27	13.5	5.3	2.2
	28	4.3	5.5	11.8
	29	6.8	4.8	13.6
January	30	7.2	0	7.8
	31	2.6	1	47

	32	3.8	1	7.1
	33	4.3	0	5.8
February	34	14.5	8.4	30.4
	35	6.8	5.7	13.9
mean		8.4	5.12	21
Significance		**	**	**
Lsd $_{p<0.05}$		4.71	4.07	10.51

Mean no. of aphids captured per trap weekly, * Total aphids = overall mean for all aphid species; ** Significance at $p<0.05$

Four aphid species were considered dominant in Embu, because they exceeded 5% of the relative abundance during the year (Fig 6). The species diversity index was 0.70 in Embu indicating a richness and abundance of aphid species. The most abundant species were *Aphis gosypii (48%), R. maidis (23%), Acyrthosiphon pisum* (12%), *Brevicoryne brassicae (8%) and Aphis fabae (5%)* making 96% of the total aphids collected (Fig 6). Seventy two percent of all the aphids in Embu were collected during the wet season that coincided with the peak activity of the aphids May to July 2009. Peak activity of the aphids was observed in June 2009 (Table 4). Thereafter, there was a sharp drop in aphid population density which remained low for the rest of the sampling period. The least density was collected in November 2009 (Table 4). The increase of aphid populations followed a rainfall received 4 weeks before (Fig. 1). The total aphid population and all aphid species were significantly ($p< 0.001$) affected by the prevailing weather conditions over time. Like in Kabete, the aphids were always present in the orchards.

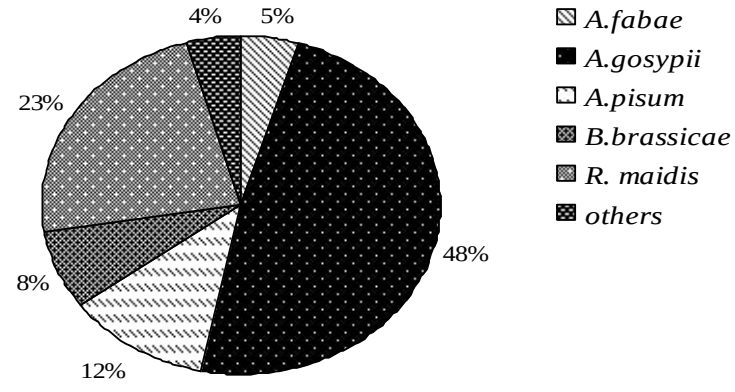

Fig 6 Proprtion (%) of total aphids sampled in Embu and categorized by individual species from May 2009 to February 2010. A total of 2900 aphids collected

Table 4 Mean number of alate aphids captured per trap/week in Embu from May, 2009 to February 2010

Month	Sampling week	*A. gosypii*	*R. maidis*	Total aphids*
May 2009	1	8.6	0	20
June	2	5.4	0	21.3
	3	1.2	0	1.7
	4	68	2.4	12.2
	5	13.9	6.5	22.6
July	6	7.9	9.0	19.3
	7	4.1	3.6	8.8
	8	18	12.4	34.6
	9	2.3	0	3.1
August	10	0	0	0
	11	0	0	1.6
	12	1	0	1.5
	13	0	0	1
September	14	0	0	1
	15	0	0	0
	16	0	0	0
	17	0	1	1
October	18	0	1	1
	19	0	0	0
	20	0	0	0
	21	1	0	0
November	22	1	1	1
	23	1	0	0
	24	0	0	0
	25	1	0	1
December	26	1	0	1
	27	1	0	0
	28	1	0	1
	29	0	0	0
January 2010	30	0	0	0
	31	1	0	1
	32	0	1	1
	33	0	0	0
February	34	0	0	0
	35	1	0	0
mean		3.23	1.6	6.7
Significance		**	**	**
Lsd		6.62	4.43	13.23

Mean no. of aphids captured per trap weekly; * Total aphids = overall mean for all aphid species; ** Significance at $p<0.05$

Transmission of the Cowpea aphid borne mosaic virus (CABMV)
The CABMV isolate used was transmitted by aphid species after 10 min of acquisition period. ELISA tests indicated presence of the virus protein in the leaf extracts. *Aphis gosypii, Ropalosiphum maidis, Aphis fabae, Brevicoryne brassicae* transmitted the virus with variable ability. The aphids ability to transmit CABMV isolate was significantly ($p<0.001$) different from control. *Aphis gosypii* had the highest transmission ability of CABMV isolate at 71% but was not different with that of *R. maidis* at 62.8%. *Aphis fabae* and *B. brassicae* were not different from each other but differed with *A. gosypii* and *R. maidis* in the ability to transmit CABMV isolate. *Sitobion avenae* did not transmit the CABMV isolate. It was not significantly different from control (Table 5).

Table 5 Transmission ability of CABMV from passionfruit by five different aphid species

Aphid species	% plants with virus symptoms	Mean ELISA values (10 ELISA positives)
Aphis gosypii Gloverii	71.0	3.5
Ropalosiphum maidis (Fitch)	62.8	3.4
Aphis fabae Scopoli	30.3	3.3
Brevicoryne brassicae L.	25.5	3.3
Sitobion avenae Fabricius	11.4	3.2
Control**	0.00	0.2
F-test $_{(5, 66)}$	*	
LSD ($_{p<0.05}$)	11.4	
cv %	37.9	

* Significance at $p<0.05$, ** Control *Aphis gosypii* allowed to feed on a plant with no CABMV and used for transmission

Discussion

Aphids are prevalent in small scale farmers' fields. Twelve aphid species were trapped in passionfruit orchards and the most abundant in both sites were *A. gosypii, R. maidis, B. brassicae* and *A. pisum*. These were consistently identified and were prevalent throughout the year. The composition is similar to that which was observed by Atsebeha *et al.* (2009) and Nault *et al*. (2004) in pepper fields and by Iwai *et al.* (2006) and Garcez *et al*. (2011) in passionfruit orchards in Japan and Brazil, respectively. The aphid composition reflected the diverse cropping system in the adjacent landscapes. The main crops surrounding or intercropped within the orchards consisted of Napier grass, maize, dry beans, potatoes, kales, tomatoes, pigeon pea, bananas, tea and coffee. Hence, the aphid species had the preferred hosts represented within the mix of crops listed.

The aphid species were non-colonizers and were able to alight on passionfruit vines throughout the year. Several of these species are well known vectors of CMV and CABMV (Bashir *et al.,* 2002). It is hypothesized that the aphids were immigrating from their preferred hosts into the passionfruit orchards. The peak aphid population activity especially for the most abundant aphids, namely *A. gosypii and R. maidis*, was in June as observed in 2008 and 2009 in Kabete and Embu and maybe linked to the cultivation of food crops (Maize, wheat, beans, potatoes) on a large scale during the wet season. The cropping season favoured aphid population increase as preferred hosts for food, shelter and breeding were present. Similar findings were observed by Khalleshwarraswamy *et al.* (2007) and Khalleshwarraswamy and Krishankumar (2008) while studying the efficiency of transmission of Papaya ring spot virus by three aphid species and when monitoring aphid vectors responsible for the spread of *Papaya ring spot virus*, respectively. The absence of aphids on vines confirms non-colonization of passionfruit by aphids but the non-colonizing aphid species have a role as virus vectors in passionfruit orchards.

The aphid populations were high during the long rains season and were more abundant in Kabete than in Embu; unlike in Irish potatoe fields where it is reported that the aphids are abundant in the short rains and in warmer conditions (Olubayo *et al.,* 2004; Nyaga, 2008). According to Radcliffe (1982) temperatures below 17.8^{o}C restrict aphid population growth. The prevailing temperatures during the experiments, were above 22^{o}C hence favoured the survival of aphids in Kabete and Embu. Aphids prefer warm conditions as opposed to cold conditions as long as food is available (Hanafi, 2000). The temperatures may not have been a limiting factor for the increase in aphid population density but the rainfall. Heavy rainfall received in Embu above 150 mm/day in April and May and in October, November and December, compared to approximately 80mm/day in Kabete could have confounded the increase of aphid populations. The aphids were probably washed away from the hosts and the populations did not peak as expected. This explains why the aphid populations were much lower in Embu than in Kabete.

Aphid population peaked in June when there was plenty of food resource for the aphids after the rainfall hence the increase in numbers. The crops and vegetation vigorously growing around the orchards could have acted as reservoirs of aphids that were immigrating into the orchards. This observation is consistent with the findings by Handizi and Legorbou (2002) who reported that the first vegetation around a target crop such as seed potato plays a critical and important role in aphid population dynamics. Rainfall promotes growth of weeds and pasture plants which aphids utilize to increase populations and acquire virus pathogens that are later transmitted to target crops (Thackray *et al.,* 2002). The populations peaked after rainfall events such as in March, April, May, October and November 2009 thus explaining the unusual peaks of aphids in September and October in Kabete.

The aphid species found immigrating passionfruit orchards are confirmed vectors of viruses. *Aphis gosypii* and *M. persicae* are efficient vectors of

woodiness disease pathogens according to Baker (1974) and Omatsu *et al.* (2004). *Ropalosiphum maidis, A. gosypii, M. euphorbiae, M. persicae* and *A. pisum* are vectors of CABMV in cowpeas (Bashir *et al.,* 2002). These aphid species are also vectors of CMV and other virus pathogens in a wide host range of crops (Diaz-Perez *et al*., 2003). The most abundant aphid species *A. gosypii and R. maidis,* in Embu and Kabete are efficient vectors of CABMV. These aphid species and others are the cause of viral infections observed in the passionfruit orchards.

The abundance of *A. gosypii, R. maidis* and *A. pisum* which are polyphagous insects, coincided with the wet season depicting peak activity of aphids in the orchards. The occurrence of aphids in the orchards throughout the year with the peak population density coinciding with the cropping season and the time passionfruit vines are lush, favour probing and feeding by insect pests. The kind of mixed cropping systems present and the species richness and abundance observed within the passionfruit growing areas, have serious implications on the epidemiology and management of the viral diseases. Careful monitoring of the aphid species activity is necessary to initiate preventive measures. Farmers would be advised to take management actions to reduce aphid activity and spread of viral diseases during this period.

This study showed that the yellow water traps used for sampling vectors in passionfruit orchards could be used to indicate the aphid species entering the agro-ecosystem and the greatest dispersal period. The results compare with those of Omatsu *et al.* (2004) and Garcez *et al.* (2011) who used yellow water traps to monitor aphid species immigrating passionfruit orchards in Japan and Brazil, respectively. Khaleshwaraswamy *et al.* (2007) used similar traps to study the role of transient aphid vectors in the spread of *Papaya ring spot virus* in India. In their studies, Demirel and Yildrim (2008) and Garzo *et al.* (2004) reported that yellow water traps were better indicators of peaks of aphid flight activity representing periods of greatest dispersal of an aphid infestation in addition to attracting some aphid species more often.

In this study aphid species alighting in the yellow water traps located at different sites varied with the cropping systems within the vicinity of the orchards. This implies that the crop plants adjacent to the passionfruit orchards had a role in the composition and abundance of aphid species. In their studies, Ban *et al*. (2009) and Summers *et al.* (2004) reported that aphid species alighting in a field crop were influenced by the type and colour of the trap used and major crops and weeds growing around the sampled areas. The traps used in this study are simple and low cost and could be adopted by farmers for monitoring vector presence and activity. An understanding of aphid-transmitted viral disease epidemics requires an appropriate method of monitoring vector activity.

Aphid transmission results indicate ability of several aphid species; *A. gosypii, A. fabae, R. maidis and B. brassicae* to transmit CABMV in varying degrees and that transmission can take place from a passionfruit plant to another. The CABMV isolate is aphid transmissible in a non-persistent manner.

According to Omatsu *et al.* (2004) and Iwai *et al.* (2006) aphid vectors in passionfruit orchards in Japan transmitted viruses in a non-persistent manner. *Aphis gosypii* is an efficient vector of PWV in passionfruit according to Taylor and Kimble (1964). *Aphis gosypii, Toxoptera citricidus, R. maidis, M. euphorbiae, A. pisum and A. fabae* are CABMV vectors in peanuts and cowpeas (Bashir *et al.,* 2002). In this study, results obtained indicated differences in the ability to transmit CABMV among aphid species (*A. gosypii, A. fabae, R. maidis, B. brassicae* and *S. avenae)*. *Aphis gosypii* had the highest ability (71%) while *Sitobion avenae* was unable to transmit the virus isolate. It shows that vector species differ in virus pathogen transmission. This implies that the aphid species were influenced by insect biotype, host plant, virus strain and weather conditions which are reported to influence pathogen transmission by aphids (Mathews, 2002).

Aphis gosypii; *R. maidis* and other aphid species such as *B. brassicae, A. fabae* and *S. avenae* are present in most agro ecosystems in Kenya. They are vectors of several viruses and are able to transmit CABMV from passionfruit to passionfruit (Brault *et al.,* 2010). Considering the characteristic mixed cropping systems, particularly during the maize, bean and wheat growing seasons these results have implications on the distribution pattern and management of the virus disease in the passionfruit orchards. *S. avenae*, a wheat grain aphid, did not transmit CABMV, a characteristic of most grain aphids. Nevertheless, inefficient vectors cannot be underestimated in their ability to transmit viruses when the population densities are high in a field. There is need to consider all other aphids in the field when deciding virus management actions.

The study has confirmed that non-colonizer aphid species are prevalent in passionfruit orchards which were not captured on plants but in traps. The main aphid species were *A. gosypii, R. maidis, A. pisum and B. brassica.* In the month of June, most flight activity characterized by large aphid populations' coincided with the dominance of other food crops in the vicinity of the orchards. During the same period, vigorously growing lush passionfruit attracted aphids encouraging feeding and possible spread of virus pathogens. Transmission studies confirmed the ability of the most predominant species, *A. gosypii, R. maidis, B. brassicae and A. fabae* in transmitting CABMV that infects passionfruit orchards. Based on these observations then the most likely vectors of passionfruit viruses are *A. gosypii, R. maidis, A. fabae, A. pisum* in addition to *M. persicae* which appears in low abundance. These play a role in disease spread. The influence of cropping patterns and rainfall on seasonal aphid population abundance cannot be ignored. Many vectors present in the orchards throughout the year and the influence of cropping patterns and rainfall on the vectors presents a complex agroecosystem in relation to woodiness disease spread and management. Farmers need to adopt monitoring as part of the pest management strategies which currently is conspicuously lacking. An aphid monitoring system that is low cost, not time consuming and possibly acceptable to farmers has been used. This aphid monitoring procedure can be

used to alert the farmers to initiate measures to reduce aphid activity and hence viral disease spread. These results best reflect the conditions in the studied area and can be used to develop an IPM package for the farmers.

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