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F. OLUBAYO[1], D. KILALO[1], S. OBUKOSIA[1], S. SHIBAIRO[1] AND M. KASINA[2]

[1]Department of Plant Science and Crop Protection, University of Nairobi. P.O. Box 30197-00100, Nairobi, Kenya; [2]Entomology Section, Kenya Agricultural Research Institute, P.O. Box 14733-00800 Nairobi, Kenya.

Corresponding author & address: Dr. Muo Kasina, Email: jkasina@yahoo.com
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ABSTRACT

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On farm studies in collaboration with farmers who grow citrus were conducted in upper midlands and lower midlands agro-ecological zones in Machakos district Kenya. The aim of the study was to understand the factors affecting population fluctuations of homopteran pests attacking citrus in Kenya. White flies (*Aleurothrixus flocossus* Maskell) and black flies (*Aleurocanthus woglumi* Ashby) were the most common pests of citrus observed throughout the monitoring. Aphids (*Toxoptera citricidus* Kirk.) and psyllids (*Triozae erytreae* Del Guercio) were occasional pests while scales (various) were rare attacking only a few plants within the farms. Time period of sampling had an effect on whitefly, psyllid and blackfly populations. Aphid populations were not affected by the sampling time period. However, there were ecological differences in the development of aphid, blackfly and psyllid populations. It has been observed that populations of homopteran pests on citrus trees do vary with time. There was one major flush period of the citrus trees during the monitoring period. High aphid and psyllid populations seemed to coincide with the flush period. Flushing of the trees may have contributed in the variation of the pest populations that were being monitored. These findings are discussed in relation to their possible use in the development of integrated pest management (IPM) strategies for the management of these pests.

Key words: aphid, psyllid, blackflies, whiteflies, monitoring, IPM, flush growth

INTRODUCTION

There is a diverse assemblage of Homopteran pests reported infesting citrus (*Citrus sinensis*) crops (Davies and Albrigo, 1994). They include leafhoppers (Cicadellidae and Delphacidae), psyllids (Psyllidae), whiteflies (Aleyrodidae), aphids (Aphididae), cottony cushion scales (Margarodidae), mealy bugs (Pseudococcidae), soft scales (Coccidae) and armoured scaled (Diaspididae) (Samways 1981; Hill 1997). Scales and mealy bugs have enormous reproductive potential. They can form high densities especially in absence of their natural enemies brought about by geographic separation or farm practices that do not favour them. Leafhoppers, psyllids, whiteflies, and winged aphids are highly mobile. They are often dispersed on wind currents. They also reproduce rapidly and exploit the food resources where they land. Other than direct feeding, and formation of sooty moulds, some aphids and psyllids are vectors of important citrus diseases.

Citrus (*Citrus* spp.) is ranked third most important fruit crop after bananas and mangoes in Kenya (Waithaka and Obukosia, 1988; MoA 2006). This fruit crop is an important source of income to small-scale farmers, a source of employment for the rural population and is also used as food. In an attempt to protect the quality and quantity of their crop, farmers rely almost exclusively on chemical pesticides to control pests and diseases. They often apply pesticides in total disregard of the potential advantage of beneficial insects or the effects of such chemicals on environment and the health of the users.

Most farmers rarely carryout crop monitoring or scouting, as a basis for their plant protection practices that they apply. This implies that they either depend on calendar pesticide application, or only intervene when pest population is quite high. This lowers effectiveness of the applied pesticides, which is also compounded by use of low dosages and/or wrong control measure (Burns 1987). In order to have an effective pest management programme, information on population dynamics and seasonal occurrence of pest species is important. It determines when and whether a pest management programme is necessary. This study was undertaken in order to contribute to the understanding of the population dynamics of homopteran pests of citrus in relation to the seasonal weather changes (rainfall and temperature), the phenology of the citrus plants and the abundance of natural enemies. This information would contribute to the understanding of the population changes of homopteran pests and recommend appropriate strategies for their management, especially to avoid over-reliance of pesticides.

MATERIALS AND METHODS

Machakos was selected to represent semi-arid districts of Kenya since it has all characteristics of the target ecologies. The area is located in the lower Eastern Province of Kenya. The different agro-ecological zones in the district were Lower Highlands (LH), Upper midlands (UM) and Lower midlands (LM) (Jaetzold and Schmidt, 1982). The study was carried out for 8 months from June 2002 to February 2003. A stratified sampling technique was employed to randomly selected farms from the list of citrus farmers provided by the Agricultural extension

office in the district. A pre-test exercise was performed in the district to establish presence of sufficient number of citrus trees. Four farms in each agro ecological zone; upper midlands (UM, represented by Kathiani division) and Lower midlands (LM, represented by Yatta division) were selected for the studies (Table 1). The farms had mature (12-14 years old) citrus plantation, with a tree spacing of 5 x 5 m and an average height of 2-3 m. Four trees were marked per farm for monitoring and sampling of the pests after every two weeks. During the sampling period, all homopteran pests were recorded and collected for identification. The target pests included aphids, whiteflies, blackflies, scales and psyllids. Sampling methods were modified from Sutherland *et al.* (1996), Smith *et al.* (1997) and FAO (1996). It included use of visual/direct count of the absolute number of adults and nymphs belong to aphids, whiteflies, blackflies, scales and psyllids. This was done on ten randomly selected 15 cm long growing shoots from all four quarters of a tree in all the selected trees per farm (plot). The count represented the damage outlook since the targets were the destructive stages of these pests. Natural enemies present on the selected shoots were also counted. In addition, flush growth on the citrus trees was monitored during the same period. Weather data was obtained from the meteorological stations nearest the farms. Data obtained were analysed to determine differences in population densities in the different agro-ecological zones and the sampling periods. This was done using SPSS statistical software version 12.

Table 1. Location of the farms that were monitored and where the pesticides trials were carried out in Machakos, 2002

AEZ	Farm code	Location	Latitude (E)	Longitude (S)	Altitude (m)
UM	1	Khayewa	37° 21.650'	1° 29.927'	1354
UM	2	Khayewa	37° 21.361'	1° 28.169'	1400
UM	3	Khayewa	37° 21.363'	1° 28.165'	1390
UM	4	Khayewa	37° 20.170'	1° 25.390'	1428
LM	1	Kithimani	37° 26.965'	1° 11.549'	1362
LM	2	Kithimani	37° 25.854'	1° 10.964'	1354
LM	3	Kithimani	37° 26.119'	1° 09.381'	1307
LM	4	Kithimani	37° 27.636'	1° 10.811'	1292

AEZ- Agro ecological zone, UM- Upper midland zone, LM- Lower midland zone

RESULTS

Pest situation in the farms

Homopteran pest species were observed in both agro-ecological zones and seasons. These included the citrus aphid (*Toxoptera citricidus* Kirkaldy), citrus psyllid (*Trioza erytreae* Del Guercio), citrus woolly whiteflies (*Aleurothrixus flocossus* Maskell), citrus black flies (*Aleurocanthus woglumi* Ashby) and scales (*Coccus viridis* Green). There were significant differences in population development (densities) between the two agro-ecological zones for aphids (p=0.018), black flies (p<0.001) and psyllids (p=0.006). High aphid populations per 15 cm long growing shoot were found in the LM zone [122] compared to those in UM [13]. Black flies were more in the LM zone [6] compared to UM [1] per 15cm long growing shoot. The citrus psyllids were high in the UM [5] compared to LM [1] per 15cm long growing shoot (Fig. 1).
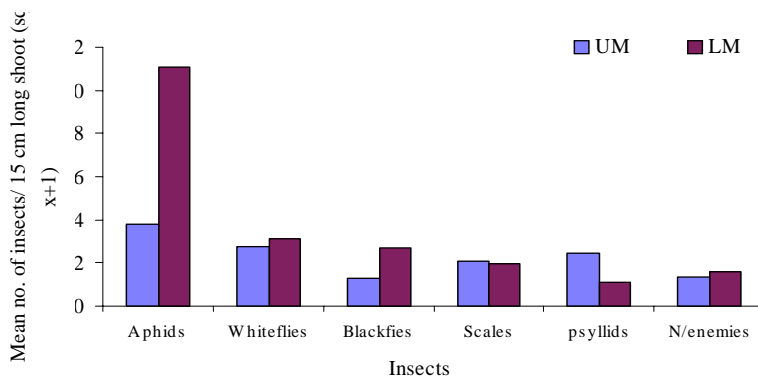

Fig. 1. Mean number of homopteran pests recorded infesting citrus in two agro ecological zones, June 2002 to February 2003, Machakos Eastern Kenva

Insect species monitoring

Fig. 2 and Fig. 3 show the population fluctuations for each pest species in each agro-ecological zone and the population trends for the natural enemies (mainly the coccinellids) encountered during the same monitoring period. There was a significant variation in the fluctuation of the populations from one sampling period to another for

aphids (p<0.001), whiteflies (p=0.04) and psyllids (p<0.001) in the UM zone. Only citrus psyllids populations fluctuated significantly between sampling periods (p<0.001) in the lower midland (LM) zone.

Upper Midland zone (UM)

The aphids exhibited two peaks in June and January. In between, the population levels reduced to zero in Sept, Oct and Nov (Fig. 2). Three peaks were observed for whiteflies, two were following one another closely, in July and Sept. The third peak occurred in Jan-Feb. The first peak was the highest whereas the third was the lowest (Fig. 2).

Between Sept and Jan the whitefly populations steadily decreased to reach the lowest densities in Dec. High population densities of the whiteflies was observed in the UM zone although black flies and scales occurred in low densities. Scale population increased slightly in Oct (Fig. 2), however no significant fluctuations of scale population densities between the sampling periods were observed. Low densities of the citrus psyllid were observed throughout the monitoring period. However, there was one low peak observed in Jan (Fig. 2). Natural enemies (mainly coccinellids) were observed in low densities and remained low throughout the monitoring period (Fig. 2). There were no significant variations of the natural enemy populations between sampling periods.
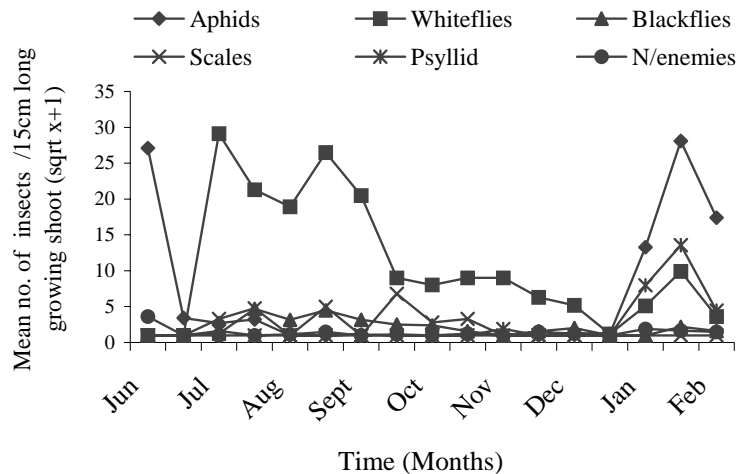

Fig. 2. Insect populations on citrus, June 2002- Feb. 2003 in the upper midlands of Machakos District

Lower Midlands zone (LM)

The aphids exhibited three peaks of populations in June, Sept-Oct and Jan-Feb. In between the peaks, there were very few aphids observed (Fig. 3). There were no significant differences in the population density during the sampling periods. Population densities in this zone were higher than those of UM. The populations of the whiteflies oscillated between high and low throughout the monitoring period (Fig. 3). Two peaks were however defined in Aug-Sept and Nov-Dec but no significant differences in population densities between the sampling periods were. The pest population densities were lower than those of the UM. The black flies were encountered throughout the monitoring. They exhibited two peak densities in July and Nov. The first peak remained high up to Sept followed by a sharp population decrease to a low in Oct. The population increased steadily to rich the second peak in Nov. Later the population decreased slowly to another low in Jan that remained constant into Feb (Fig. 3). There were no differences in populations between the sampling periods. The black flies were present throughout the monitoring period. The densities were

Fig. 3. Insect populations on citrus, June 2002- Feb. 2003 in the Lower midlands of Machakos District

higher than those of the UM. Low densities of scales were encountered during the monitoring period. Nevertheless, there were very slight increases in July (Fig. 3). The densities of the citrus psyllids were very low. These remained low except a slight increase in Jan (Fig. 3). There were higher populations in the lower zone than in the UM. Very
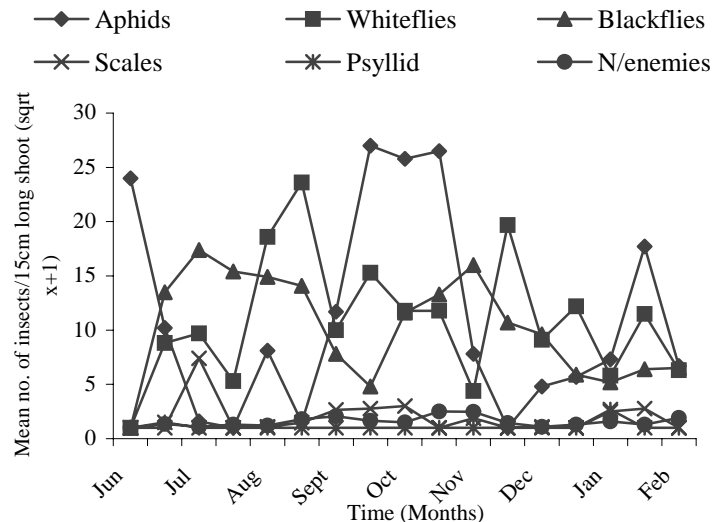
low densities of natural enemies were observed during the monitoring period and its population densities were not significantly varied between sampling periods.

In both agro ecological zones, pests appeared to give way to one another. For example as the aphid populations reduced in July, the whitefly population rose sharply to reach a peak in Aug/Sept in the LM zone (Fig. 3). Later as the whitefly population reduced, the black fly population rose to reach a peak in Oct (Fig. 3). There was no single time, when the trees were completely free from infestation. The pest load was found lowest between Oct and Dec and highest in July/Aug and Dec/Jan. (Figs. 2 and 3).

Flush growth monitoring

One major flush period was observed in each zone. In the UM zone, there was one major flush growth period in November followed by a small flush growth as the rains continued to fall. The rains received in September preceded this main flush period (Fig. 4). June and Nov. peaks of flush growth preceded the peak population densities of aphids in the UM (Fig. 4). In the LM zone, there was one major flush period in October. Rains received in August and September preceded this flush growth. There was a minor flush period in August preceded by rains in July and pruning after the harvest of fruits by the farmers A little flush growth was also observed in January as the rains continued to fall. In the LM, rains were received in all months of the year, with the least amounts in June, July and August. Flush growth in Aug., Oct. and Jan preceded peaks of aphid populations in the LM. Vigorous flush growth of Dec–Jan coincided with the citrus psyllids population peak in Jan. The main flush period in the LM zone set in a month earlier than in the UM zone. The pest high-density peaks, particularly the aphids and citrus psyllids, were preceded by rainfall and flush growth peaks.
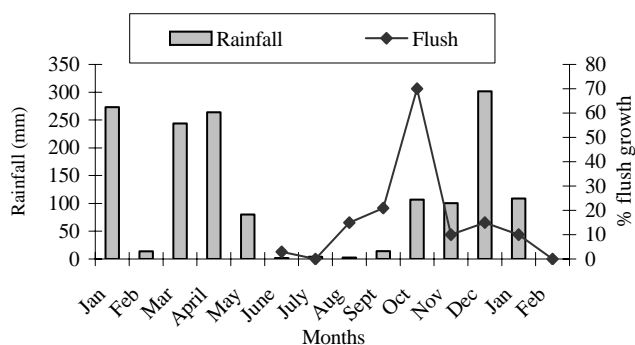

Fig. 4. Flush growth occurrence and rainfall received in the Upper midlands of Machakos District in 2002

DISCUSSION

Monitoring revealed that homopteran pests that attack citrus in these two agro-ecological zones include black flies and whiteflies as key pests, aphids, psyllids and scales as occasional pests. In the process of infesting the trees, the pest species attacked at different times appearing to hand over to one another. For example, as aphid populations reduced, the whiteflies and black flies populations increased. The trees were infested throughout with the pest load at the lowest during the months of September, October and November, which were hot and dry. Though the study did not assess yield loss, continued utilization of the trees by these pests evidently indicates that losses would occur overtime. All the pest species were active when there was vigorous feather flush. Whiteflies and black flies colonized/utilized both the "feather" flush and less than a year old expanded young citrus leaves. Their densities increased with increase in temperature as the rainfall period tailed off giving way to a favourable warm climate that preceded the hot dry spell. Different agro-ecological zones influenced the pest complex (Nyambo *et al.* 1994). Gonzalez (1980) reported that particular combinations of weather and site conditions lead to an increase in the suitability of tree foliage for insect herbivores. This, through an increase in insect survival gives rise to insect pest out breaks. Camel and Way (1987) also reiterated the fact that in perennial crops, the abundance and distribution of pests were closely related to the growth pattern of the trees. Hence, the unlimited food supply to phytophagous insects causes them to multiply rapidly without restriction and with minimum exposure to hazards of dispersal (South wood and Way, 1970). Although the study did not investigate the movements of the pests between habitats, it is reasonable to assume that there was a flow of these pests from alternative hosts and other orchards. The importance of the surrounding environment particularly for psyllids has already been highlighted in the past. Samways and Manicom (1983) suggested that there was influx of the citrus psyllid from the source of infestation and that the increase was almost a perfect exponential during the first weeks of infestation. In addition the plants in the direction of the source were more infested.

Pest species that are generally mobile such as whiteflies, winged aphids and psyllids that are easily dispersed on wind currents, as opportunists, they reproduce rapidly and exploit the food resources on which they land. Natural enemies of these pests (mainly coccinellids) were very low compared to the pest population densities. These tended to increase slightly with increase in pest densities, particularly the aphids populations. The natural enemies did not

appear to have a great role in regulating the abundance of the pest species. Intra-specific competition and weather changes appeared to be the major limiting factors regulating the pest densities. While discussing advantages and disadvantages of biological control van Emden (1989) mentioned that in many situations, natural biological control is inadequate to keep herbivores below pest status. Price (1984) reported that natural enemies tend to respond to pest population changes rather than cause the changes, and that plant herbivores interaction was more important in regulating pest populations then the role of natural enemies.

Weather patterns played a role in causing pest population fluctuations in the two zones. The least pest load occurred during the hot and dry spell (Sept, Oct, Nov). De Bach (1974) reported that, population fluctuations are influenced by important biotic and a biotic factors. These include weather and other physical factors such as competition, natural enemies and spatial as well as territorial requirements. Rarely do these factors act alone, although one may be the key regulatory factor responsible for a particular pest population in a given situation. Hot and dry weather determines the geographical distribution of pests and sustained adverse conditions dictate the seasonal abundance of the species (Samways 1987). The results here also support this contention. During the hot and dry months (Sept-Nov) when rainfall was low or absent, pest populations were low compared with the months (June-Aug and Dec-Feb) when the weather conditions were favourable (cool and moist). Altitude in moderating weather plays an important role in determining the general abundance of pest species. Drought by definition means low or no rainfall. Good rains therefore provide enough ground water while pruning helps conserve water, which encourages good root growth and vigorous flush growth. Such a flush permits immediate peaks of egg production. These high densities of eggs lead to large numbers of nymphs and later adults. This suggests that good rains promote pest species outbreaks on a seasonal basis because of providing abundant food resources. It follows then; during good rains and flush growth an upsurge of pests is inevitable. Control measures must respond to this increase in pest numbers. Such measures should target to protect the flush growth, which is the desired site of infestation by these pest species, probably by applying synthetic pesticides or augmenting natural enemies in anticipation of the impending increase of the host populations.

CONCLUSION

Monitoring of homopteran pests done revealed that the pest densities varied and affected by both weather patterns and the natural enemies present in the citrus canopy. In addition, they varied in density between the agro-ecological zones, particularly the aphids, black flies and citrus psyllids. The pest load was higher when the plants were actively growing, a period that followed adequate rainfall received. The pest load was lowest during the hot and dry weather. This suggests that the best time to protect the citrus trees is when the plants are actively growing. Pest scouting/monitoring is an important component in pest management. It indicates the presence of insects, helps identify the pests and estimate the pest populations. With this information the farmers can make logical pest management decisions. Monitoring needs to be entrenched in farmers' pest management strategies that is currently lacking in their strategies for pest control. Therefore, training the citrus farmers on identification and simple scouting methods of the pests is necessary for proper management of pests in citrus farms. Homopteran pests are part of the pest complex of citrus causing damage and reducing quality in citrus fruit production. Their populations fluctuate in time and space because of influences from various factors such as weather and the presence of natural enemies. Weather patterns and crop phenology were the major factors regulating population densities while natural enemies played a secondary role. Keen observation of the weather can provide a guideline on when farmers can take certain pest management measures to control pests in the farms. This emphasizes the need for monitoring as a component of pest management measures taken by farmers. Monitoring will help indicate the entry, presence or absence of a pest or pest species for appropriate control measures to be taken. Major limitations of crop monitoring are that they are relatively time-consuming and expensive. Flush growth appearance can be used as an indicator of impending pest increase in citrus orchards. The farmers can use it as a signal to take precautionary measures to avoid high pest infestations. This intensive case study has provided useful information on the timing of these pest species and the basis for decision-making process during the seasons. The results most accurately reflect conditions in the zones studied and hence may be used to package IPM technologies that may be adoptable and sustainable among the small-scale farmers in these areas.

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