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Effect of some climatic factors on insects associated with citrus agro-ecosystems in Ghana

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Abstract

The present study investigates the effects of some climatic factors on insects associated with citrus orchards in two different agro-ecological zones in Ghana. The study showed that, climatic factors affected insects differently in different agro-ecological zones. There was a negative and highly significant ($P<0.01$) correlation between insect abundance and rainfall in the Coastal Savannah zone whereas the correlation between mean temperature and insect abundance was negative and significant ($P<0.05$) in the Semi-Deciduous Rain Forest zone. Numbers of insect species peaked differently in some months during the study period due to favourable climatic conditions for their reproduction, growth and activities. The month of February was most favourable for the insects in the Semi-Deciduous Rain Forest zone whiles January was most favourable for the Coastal Savannah zone. Similarly, some months were more favourable for pests of citrus in Ghana; January and February for *Ceratitis ditissima* and *Leptoglossus* sp. in both agro-ecological zones and, January and February for *Achaea* sp. in the Semi-Deciduous Rain Forest and Coastal Savannah respectively. The months of October and September were most favourable for *Zonocerus variegatus* in the Coastal Savannah zone and Semi-deciduous rain forest zone respectively during the study period. Even though the two different agro-ecological zones had common pests, the proportions and peak periods however varied. The differences are crucial with regards to developing integrated pests management strategies to control insect pests of citrus in Ghana.

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Introduction

Environmental factors, particularly moisture and temperature control the time and duration of flowering in citrus trees and the extent and intensity of flowering varies with climatic conditions of the area (Davies and Albrigo, 1994). Citrus requires dry periods to initiate flowering and in the field, a drought period of more than 30 days is required to induce a significant number of flower buds (Ministry of Food and Agriculture, 2007). The main factors responsible for flower induction are cold and water stress, with cold being the main factor in subtropical climates and water stress in tropical climates (Davies and Albrigo, 1994). It has been noted that the degree of flower induction is proportional to the severity and duration of the stress, thus in Ghana, there is a major (December-March) and a minor citrus season (July-August) in response to the duration and severity of the dry season (Ministry of Food and Agriculture, 2007).

Citrus orchards provide the potential to maintain a habitat that can harbour a rich complex of entomofauna, including, saprophagous, phytophagous, pollinators, dispersers, decomposers among others (Afreh-Nuamah, 1985, 2007). These insects either directly or indirectly depend on several factors for their daily activities in the orchard. Insect biodiversity is controlled by several abiotic factors and their interactions. According to Kyerematen *et al.,* (2014), Insect diversity is highest in June (intermediate season) most probably because, during this time of the year, there are ample food resources for the insects and rainfall is not too heavy since heavy rainfall sweeps most insects away and destroys many of their food resources. Climate is a crucial parameter in all ecosystems and has always been a key element in both terrestrial and freshwater habitats regulating the population dynamics of insects in ecosystems. Changes in climate may lead to changes in geographical distribution of species, increased hibernation, changes in population growth rates, increases in the number of generations, extension of the development season, changes in crop-pest synchrony of phenology, changes in interspecific interactions, increases in emerging pests and rise in risk of invasion by migrant pests (Memmott *et al.,* 2007).

Currently, Ghana ranks 26th in the world and 6th in Africa in terms of citrus fruit production coming after Egypt, Nigeria, South Africa, Morocco and Algeria (FAO, 2013). The success of citrus industry in Ghana is impeded by several production constraints, however, crucial among them is insect pests attack because, if not controlled, insect pests can completely devastate crops through transmission of virulent disease pathogens and direct feeding on the stems, leaves, flowers, and marketable fruits.

Improved pest management strategies in agro-ecosystems require weather and insect data from a thorough field monitoring as well as information on climate and forecast to develop a sustainable and efficient control measures not only to conserve target species but also to prevent insect pests outbreak. This requires data collection of insects and climatic factors in an agro-ecosystem.

Climatic factors may however vary from one habitat to another and this may affect the population trends of insects differently not only during some parts of the year but also differently in different agro-ecological zones. This underscores the critical necessity of this work to evaluate the effect of climatic factors such as temperature, humidity and rainfall on the population trends of insects associated with citrus orchards in two different agro-ecological zones in Ghana.

Materials and methods

Sampling sites

The study was conducted at the Forest and Horticultural Crops Research Centre (FOHCREC), (N 06^{o} 09.473', W 000 54.550', E: 552ft), Kade, in the Semi-Deciduous Rain Forest of Ghana and Asuansi Agriculture Station, (N 05^{o} 18.654', W 001^{o} 15.667', E: 363ft), Asuansi, in the Coastal Savannah agro-ecological zone of Ghana. Even though both zones experience bimodal rainfall patterns, each zone has different ranges of climatic variables within a year. A citrus orchard measuring 1.25 acres (0.5 ha) was demarcated for sampling throughout the experiment in each of the agro-ecological zones. The citrus trees were approximately of the same age. The citrus orchard in the Semi-Deciduous Rain Forest was established 20 years ago whereas that of the Coastal Savannah was established 15 years ago.

Data collection

The citrus tree *Citrus sinensis* Osbeck was chosen as a model crop to study the population trends of insects in citrus orchards during the study period. Field studies were carried out between September, 2013 and March, 2014. Sampling methods employed in the collection of insects were flight interception and Malaise traps for flying insects, pitfall traps for ground crawling insects, coloured bowls for insects which are attracted to a particular colour, hand picking for slow moving insects and chemical 'knock down' for the collection of insects in the citrus tree canopy. Insects collected were preserved in 70% ethanol and sent to the laboratory of the African Regional Postgraduate Programme in Insect Science, West African Sub-Regional Centre for identification, sorting and counting. Identification was done with reference to the collection in the Museum of the Department of Animal Biology and Conservation Science, University of Ghana, as well as with reference to Gullan and Cranston (2005, 2010), Scholtz and Holm (1989), Crowson (1956), Ross (1965) and McGavin (2002). Fruit flies were identified with the help of Dr. Maxwell K. BIllah of the Department of Animal Biology and Conservation Science of the University of Ghana, Legon. Rainfall data was obtained from the meteorological stations in the research centres where the study was carried out whereas temperature, humidity and dew point values were obtained with the aid of a digital hygro-thermometer (Fig. 1) during each sampling period. Temperature, humidity and dew point were recorded for eight days within each month during each sampling period for the two different agro ecological zones and the averages were computed for each month.

Fig. 1. Digital Hygro-thermometer.

Data analysis

Data was analysed using SigmaPlot statistical software (version 12) in order to determine the relationship and correlation between climatic factors and insect abundance during each month. The relationship between climatic factors and some major pests of citrus in Ghana was also determined. All probabilities were appreciated at 1% and 5% confidence interval.

Results

Correlations were used to explain the relationship between climatic factors and insects captured during the sampling period. The correlation coefficient values showed a negative correlation between all the climatic factors measured and insect species in the Semi-Deciduous Rain Forest zone, however, with the exception of mean humidity, maximum humidity and rainfall, all the other climatic factors showed a positive correlation with insect abundance in the Coastal Savannah zone. The analysis of variance indicated a highly significant difference ($P<0.01$) between rainfall and insect abundance in the Coastal Savannah zone whereas a significant difference ($P<0.05$) was found between mean temperature and insect abundance in the Semi-Deciduous Rain Forest zone (Table 1).

Table 1. Correlation between climatic factors and insect abundance during the sampling period (September, 2013-March, 2014).

Climatic factors/ Zones	Semi-Deciduous Rain Forest		Coastal Savannah	
	r-value	r-value	r-value	r-value
Mean Temperature (ºC)	-83.5856	0.0454*	74.5567	0.4990^{ns}
Maximum Temperature (ºC)	-2.6336	0.8355^{ns}	10.8319	0.6663^{ns}
Minimum Temperature (ºC)	-8.3924	0.6609^{ns}	11.2065	0.7421^{ns}
Mean Humidity (%)	-3.9200	0.9009^{ns}	-7.0919	0.6353^{ns}
Maximum Humidity (%)	-1.0046	0.8880^{ns}	-0.0108	0.9981^{ns}
Minimum Humidity (%)	-0.4619	0.8491^{ns}	0.0141	0.9981^{ns}
Mean Dew Point (ºC)	-15.5521	0.5772^{ns}	11.9591	0.7723^{ns}
Maximum Dew Point (ºC)	-16.2560	0.5250^{ns}	20.9068	0.5773^{ns}
Minimum Dew Point (ºC)	-38.1781	0.4492^{ns}	39.5849	0.3017^{ns}
Rainfall (mm)	-43.0864	0.2717^{ns}	-0.7701	0.0013**

Significant*, highly significant**, non-significant^{ns}, significant at $P<0.05$, highly significant at $P<0.01$.

Insect numbers were highest during the month of February when temperature and mean rainfall recorded the lowest values of 20.3ºC and 2.5mm respectively with a relatively high mean humidity of 62.9%. In March when mean humidity was at its highest value of 81.8% and mean temperature was relatively high at 29.1ºC, insect numbers were the lowest. There was also a sharp drop in insect numbers when there was an increase in mean temperature, rainfall and mean humidity from February to March in the Semi-Deciduous Rain Forest zone (Fig. 2). In the Coastal Savannah zone (Fig. 3), insect numbers were highest in January when mean temperature was at its optimum value of 28.71ºC and rainfall lowest of value 3.11mm. December recorded the lowest insects when mean temperature was at its lowest value of 25.1ºC, and rainfall and mean humidity were moderate.

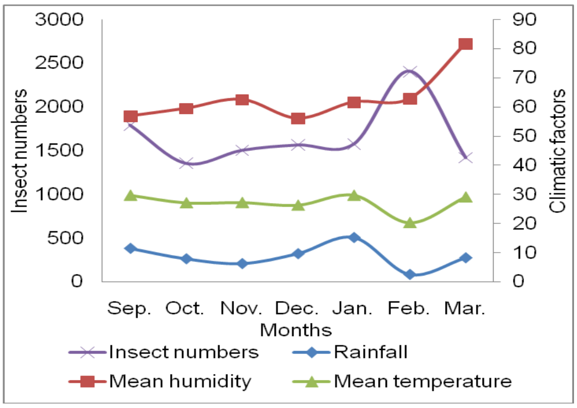

Fig. 2. Population trends of insect species and climatic factors during each month in the Semi-Deciduous Rain Forest zone.

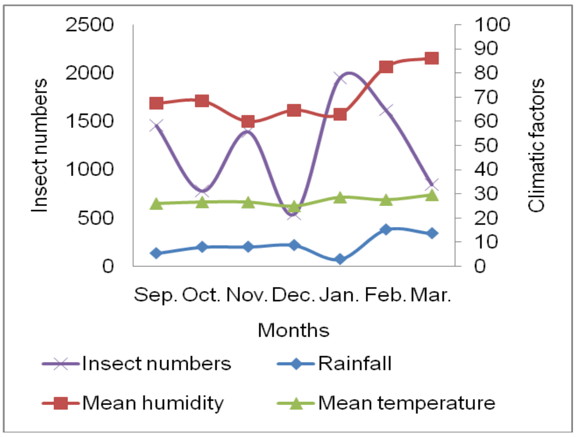

Fig. 3. Population trends of insect species and climatic factors recorded during each month in the Coastal Savannah zone.

In the Semi-Deciduous Rain Forest zone (Fig. 4), there was a sharp rise in *Achaea* sp., *Leptoglossus* sp., *Bactrocera invadens* Drew, Tsuruta and White, and *Papilio demodocus* Esper when there was a drop in mean temperature and rainfall from January to February whiles mean humidity remained moderate. From February to March, when there was a sharp increase in mean humidity to its peak and a gradual rise in mean temperature and rainfall, there was a drop in *Achaea* sp., *Leptoglossus* sp., *B. invadens* and *P. demodocus*. In February, when rainfall was at its lowest, there was a rise in *B. invadens* and *Ceratitis ditissima* Munro and a drop in *Zonocerus variegatus* Linnaeus from January to February.

In the Coastal Savannah zone, there was a sharp increase in numbers of *C. ditissima* and *Achaea sp.*

and a gradual increase in numbers of *Z. variegatus* when rainfall and mean humidity dropped whiles mean temperature increased from December to January. Furthermore, from January to February, there was a sharp drop in numbers of *C. ditissima*, *Achaea* sp. with a rise in mean humidity and rainfall whiles mean temperature remained moderate. In October, *Z. variegatus* was at its peak number when there was a rise in rainfall from September to October whereas mean humidity and mean temperature were moderate (Fig. 5).

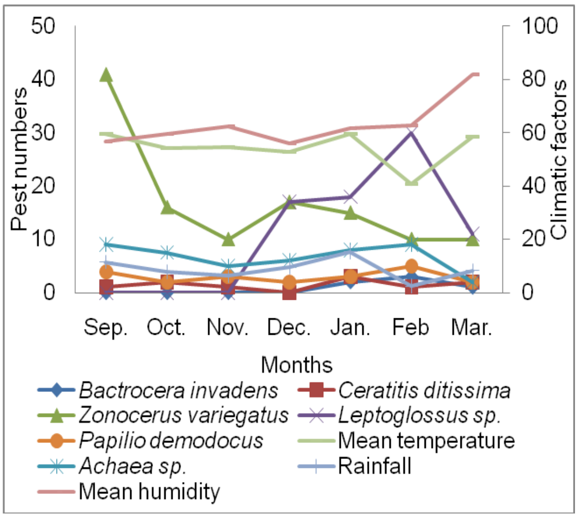

Fig. 4. Effect of some climatic factors on the population trends of major pests of citrus in the Semi-Deciduous Rain Forest zone.

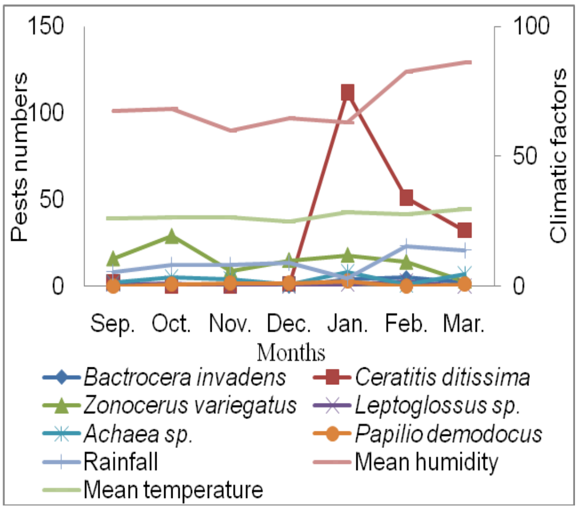

Fig. 5. Effect of some climatic factors on the population trends of major pests of citrus in the Coastal Savannah zone.

a b

Fig. 6. Larvae of beetles congregated during cooler weather conditions in the orchard.


Zonocerus variegatus *Ceratitis ditissima*

Papilio demodocus


Bactrocera invadens *Leptoglossus* sp.

Fig. 7. Images of some of the major insect pests of citrus in Ghana.

Discussion

The analyses showed that in the Semi-Deciduous Rain Forest, all the climatic factors during the sampling period showed a negative correlation with insect abundance, however, with the exception of mean temperature all the other climatic factors showed a non significant correlation with insect abundance in the Semi-Deciduous Rain Forest zone.

It was clearly evident that there was a fluctuation in the population trend of insect abundance during the study period triggered by mean temperature in this zone.

The abundance of insects was highest in February when mean temperature reached its peak value whereas a drop in insect abundance from February to March occurred when there was a rise in mean temperature from February to March. A study of butterfly diversity in two sacred groves in the Eastern region of Ghana by Nganso *et al.,* (2012) indicated that butterflies were more abundant in the dry season than the wet season due mainly to generally higher temperatures, during this period. It should be noted however that other factors such as resource availability for adults and host-plants, behavioural traits and interaction with other species may explain this increase in species richness and diversity during the dry season (Pinheiro and Ortiz, 1992). Coleopteran larvae were observed on several occasions congregated on citrus trees in the mornings (Fig. 6) probably, to produce heat. Mating was observed on several occasions when the weather was cooler in the morning and most insects were also found hiding under the leaves of the citrus trees and the vegetation of the understory in the afternoon when the weather was warmer in the afternoon. This is an indication that temperature has a profound effect on the abundance of insects as earlier reported by several studies that temperature greatly affects the distribution and abundance (Hill, 1987; Elphinstone and Toth, 2008; Ladányi and Horváth, 2010), timing and diurnal activity of insects (Young, 1982).

In the Coastal Savannah zone, the analysis showed a positive correlation between insect abundance and mean temperature, minimum temperature, maximum temperature, minimum humidity, mean dew point, minimum dew point and maximum dew point whereas rainfall, mean humidity and maximum humidity had a negative effect on insect abundance. There was however, a highly significant correlation between rainfall and insect abundance. This study has shown that climatic variability within a year, more importantly rainfall seasonality, is the crucial factor determining the differences in abundance of insects associated with citrus orchards in this zone.

The findings suggest that, in Ghana, agro-ecological zones with more pronounced temporal rainfall variability will experience a higher probability of variations in the availability of food resource (specifically flowers, fresh leaves and matured fruits), a factor which regulates the population density of insects in an ecosystem, hence greater variation in insect abundance during some parts of the year. Several studies have reported that many species of insects peak in abundance depending on the time that the resources that they exploit are most abundant (Akotsen-Mensah, 1999; Pinheiro *et al.,* 2002; Afreh-Nuamah, 1985, 2007; Appiah *et al.,* 2009). Ross (1965) also reported that food is the most important determinant which affects the distribution and abundance of insects.

It was clearly evident that the fluctuation in the population trend of insect abundance during the study period was regulated by rainfall in this zone. Insect abundance was highest in January when rainfall was at its lowest. Similarly, a drop in insect abundance occurred when there was a rise in rainfall from February to March. This was manifested when some insect pests belonging to the orders diptera (e.g. *C. ditissima* and *B. invadens*) and lepidoptera (*Achaea* sp.) were observed on several occasions foraging after rains in the citrus orchards. The population of *Z. variegatus* was more pronounced during the wet season (September-March) when there were more fresh citrus leaves compared to the dry season (January–February). This may be due to the presence of new, soft and fresh leaves during the wet season which were low in toxicity but high in nutrient contents as earlier observed by Feeny (1970). Rainfall has been reported by several authors to affect the population dynamics and activities of insects (Cheke and Tratalos, 2007; Hernández, 2007; Chaniotis *et al.,* 1971).

The present study has shown that, mean temperature and rainfall are the most crucial climatic factors manipulating the population trend of insects in citrus orchards in the Semi-Deciduous Rain Forest zone and the Coastal Savannah zone respectively. Mean humidity, however, seems to regulate the population of insects in the orchards but we do not have enough evidence to support our findings that humidity was a factor responsible (statistically significant) for the changes in the population trend of insect abundance during the study period in any of the agro-ecological zones. It has however, been earlier reported that changes in temperature, humidity and rainfall, and differences in the availability of food resources are vital factors initiating seasonal activities of insects (Vineesh, 2007) with the onset of rain being the main factor (Sabu *et al.,* 2008).

Conclusion

Rainfall and temperature affect the biological activities of insects through their effect on reproduction and growth. During some parts of the study period, abundance of insects reached peak values due to optimal conditions. Each of the citrus pests observed reached its peak abundance during the month favourable for its breeding and activities. Climatic factors affect insects differently in the two agro-ecological zones. The two different agro-ecological zones had common pests, however, the proportions and periods varied. The differences are crucial with regards to developing integrated pests management strategies to control insect pests in citrus orchards in Ghana. It is evident from the results that the activity of *C. ditissima* peaks in January in each zone whereas that of *Leptoglossus* sp. peaks in February in each zone. It is recommended that pest management strategies should be adopted before these months to prevent them from building up to their peak values in order to reduce their negative effects on citrus. Activities of *Achaea* sp. peak in February and January in the Semi-Deciduous Rain Forest zone and Coastal Savannah zone respectively; it is therefore recommended that control measures should be adopted before these months to prevent them from reaching their peak periods in each agro-ecological zone in order to minimize damage to citrus crops.

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