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Influence of Temperature and Rainfall on *Coelaenomenodera elaeidis* (Coleoptera: Chrysomelidae) Abundance in Okomu Oil Palm Plantation, Nigeria

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Abstract: The leaf miner, *Coelaenomenodera* elaeidis (Coleoptera: Chrysomelidae) is a high priority insect pest of the oil palm. The study examined the influence of temperature and rainfall on *C. elaeidis* abundance in the Okomu oil palm plantation between 2007 and 2009. Climatological data were obtained from the Okomu meteorological station. Pest and weather data were analyzed using multiple linear regressions. Highest mean temperature (33.13 ^{0}C ± 1.29) and rainfall (233.73mm ± 176.01) were recorded in 2007. There were significant relationships between adult (0.045) and pupa (0.02). *C. elaeidis* stages with rainfall and minimum temperature in 2007. Leaf miner predictions were evaluated for the different leaf miner stages using their corresponding model equations. The mathematical relationship between the insect stages (larva, pupa and adult) and weather factors (rainfall and temperature) implies that pest prediction can be made for the different leaf miner stages using their corresponding model equations giving specific values for rainfall and temperature. The variations in the seasonal patterns of temperature and rainfall are of major significance as a cue to timing leaf miner abundance and ensuring effective control. This study recommends control of the *C. elaeidis* before the onset of the dry season and temperature build up. This improves management of the leaf miner by controlling it more effectively.

Keywords: Oil palm; *Coelaenomenodera elaeidis*; Temperature; Rainfall; Prediction.

1. Introduction

Agroecosystems have evolved over time to highly specialized, carefully regulated production systems. They often comprise vast areas and are composed of homogenous, and often near homozygous, high density populations that are highly selected for yield or energy conversion. Theory and considerable experimental data [1, 2] suggest that highly simplified ecosystems are more vulnerable to devastation by pests than by the more genetically and species diverse natural systems. Studies of the dynamics of insect populations have historically emphasized pest species [3]. Effective pest management systems are essential to agriculture. However, basic information must be obtained on population composition, population regulation (Predators, parasites, and pathogens), and climatic effects on populations [4]. Weather refers, generally, to day-to-day temperature and precipitation activity, whereas climate is the term for the average atmospheric conditions over longer periods of time [5]. The mean temperature for Nigeria is 27^{o}C, in the absence of altitudinal modifications. Over the last few decades, there has been a general increase in temperature throughout Nigeria [6]. In Nigeria, climate change causes higher temperatures and relative humidity, which increases the likelihood of such stressors as pest infestations and diseases [7]. Oerke, *et al.* [8] estimate pre-harvest losses to pests in major food and cash crops to be 42% of global potential production. Seasonality is a common phenomenon among insects [9].

Agricultural pests severely constrain the productivity potential of global agriculture. Scientific evidence gathered over the last 50 years suggests that climate conditions are changing rapidly and that this trend is likely to continue and even accelerate [10, 11]. These anticipated changes in climate baseline, variability, and extremes will have far-reaching consequences on agricultural production, posing additional challenges to meeting food security for a growing world population [12, 13].

Palm oil has been a safe and nutritious source of edible oil for healthy humans for thousands of years [14]. Like other common edible fats and oils, palm oil is easily digested, absorbed and utilized in normal metabolic processes. It plays a useful role in meeting energy and essential fatty acid needs in many regions of the world [15]. Oil palm is the most productive oil producing plant in the world, providing approximately 40% of the world's vegetable oil [16].

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The palm has a life of over 200 years, but the economic life is 20-25 years: nursery 11-15 months; first harvest is 32-38 months from planting, and peak yield is 5-10 years from planting. Normally, oil palm grows in the lowlands of the humid tropics, 15^0N-15^0S with evenly distributed rainfall of 1800-5000 mm/year. The palm has a wide adaptability range of soils, to low pH, but sensitive to high pH (above 7.5), and to stagnant water. Palms are cultivated on large blocks of land with planting density of 128-148 palms per hectare and largely dependent on the planting materials, soil and climate [17].

C. *elaeidis* Mlk (Coleoptera: Chrysomelidae) feeds on the chlorophyll, water and nutrients from the leaf cells and the occurring foliar damage result in loss of oil palm yield. The adult beetle feeds on the lower surface of the leaflets leading to the partial drying up of the fronds [18]. In severely affected plantations, the lower canopies of most palms appear scorched, grey-brown with desiccated rolled – in leaflets. Later, the withered laminae shatter, leaving the leaflets midribs only. Both the adult and larval forms of the leaf miner cause damage to the palm [19, 20]. Morin and Mariau [19] and Hartley [21] gave accounts of the incidence, life cycle and damage of this pest. The developmental periods are: eggs, 20; larvae, 44; pupae, 12; adult to egg laying 18; total 94 days (about 3 months). The adult lives on the under-surface of the leaf for 3-4 months after egg laying. There are thus 3 to 4 generations of this pest in a year. The adults are tiny pale-yellow beetles which scoop and feed in longitudinal grooves on the lower-surface of leaflets, the females laying their eggs in pits at the ends of the grooves and covering these with mounds of debris. The larvae hatch out, mine or tunnel within the leaflet tissue between the upper and lower epidermal layers. The larvae attain about 6.8mm in length, with brownish thorax fused to the head. They mine longitudinally under the upper epidermis of leaflets of mature palms, except those below 3 years old. Their mined galleries attain 15 cm length and 1 cm breadth. Severely attacked palms look scorched from a distance, the young leaves remain green, while the others are grey-brown, and desiccated. The pupae are mobile and are visible in the center of the galleries, when the dried furrows are teased out. The adults are pale yellow with reddish wing cases. These adults in cases of severe attack can be observed flying within the crown, and show preference for migrating to the higher leaves. Heavily attacked trees may have up to 90% of the fronds defoliated which can result in about 50% loss in yields of fresh fruit bunch (ffb) over a two year period [22].

Insect abundance can change over time for a variety of reasons, including macroclimatic and microclimatic changes, and variation in the availability of food resources [23]. There is a clear need to advance knowledge on pest response to weather and climate variability. A key justification of this work is that the linkage between weather variability and pest response is poorly understood. This study contributes to the understanding of the insect pest-weather relationship in broad agricultural and food security terms.

This study analyses temperature and rainfall patterns and their influence on the abundance of *Coelaenomenodera elaeidis*, a major pest of the oil palm in Nigeria.

2. Materials and Methods

2.1. Study Site

The study was conducted in field I - 24 consisting of 52 lines (10.2 Ha) of oil palm made up of a total of 1407 palms at the Okomu Oil palm estate, Udo, Edo State, Nigeria. The field was planted in 1989 at a planting density of 138 palms at 9m triangular spacing per hectare.

2.2. Insect Pests

Coelaenomenodera elaeidis data collections were obtained from Okomu oil palm plantation which was categorized into larvae, pupae and adult between 2007 and 2009.

2.3. Climatological Data

Climatological data (temperature and rainfall) between January 2007 – and December 2009 were obtained from Okomu oil palm meteorological data base. The data were monthly averaged records.

2.4. Statistical Analysis

Both pest and weather data (temperature and rainfall) were analyzed using multiple linear regression. In order for better understanding, the influence of temperature and rainfall on the abundance of leaf miner was investigated at various stages of growth (larva, pupa and adult).

3. Results

Summary statistics and results of regression analysis between weather factors (temperature and rainfall) and insect stages (larva, pupa and adult) are presented in tables 1 – 3. Table 1 shows summary statistics for temperature and rainfall during the duration of the study period (2007-2009). Highest mean temperature (33.13 $^{\mathbf{0}}$C ± 1.29) and rainfall (233.73mm ± 176.01mm) were recorded in 2007. Lowest mean temperature (26.90 ^{0}C ± 12.68) and rainfall (114.09mm ± 143.43m) was recorded in 2008 (table 1).

Table-1. Summary Statistics for Temperature and Rainfall (2007-2009)

	2007		2008		2009	
Parameter	**Rainfall (mm)**	**Temperature** (^{0}C)	**Rainfall (mm)**	**Temperature** (^{0}C)	**Rainfall (mm)**	**Temperature** (^{0}C)
Mean	233.73	33.13	114.09	26.90	202.02	26.94
Std. Dev.	176.01	1.29	143.43	12.68	143.96	9.68
Range	496.50 – 0.0	34.70 – 21.75	409.70 – 0.0	34.20 – 21.96	404.40 – 0.0	34.0 – 22.13

Table 2 shows the relationship between the various insect stages (Larva, pupa and adult) and weather factors (rainfall and temperature) between 2007 and 2009. Larva had a significant relationship (0.032) with rainfall and maximum temperature in 2008. However rainfall made a more significant contribution. This was also the case for larva, rainfall and minimum temperature (21.96^{0}C) relationship (0.032) in 2008. Pupa had a significant relationship (0.02) with rainfall and minimum temperature in 2007 with both rainfall and minimum temperature making contributions. Adult had a significant relationship (0.045) with rainfall and minimum temperature in 2007 with both rainfall and minimum temperature making contributions (Table 2).

Table-2. Relationship between the various insect stages and weather Factors (Rainfall and Temperature) from 2007-2009

	2007		2008		2009	
Insect stage/rainfall and temperature	**Gen. Sig. (rainfall and temperature)**	**Individual significance**	**Gen. Sig. (rainfall and temperature)**	**Individual significance**	**Gen. Sig. (rainfall and temperature)**	**Individual significance**
Larva vs RF. & Max. temp.	NS (0.836)	None	Sig. (0.032)	RF (0.013)	NS(0.716)	None
Larva vs RF. & Min. temp.	NS (0.899)	None	Sig. (0.032)	RF (0.017)	NS (0.881)	None
Pupa vs RF. & Max. temp.	NS (0.557)	None	NS (0.755)	None	NS (0.189)	None
Pupa vs RF. & Min. temp.	Sig. (0.02)	Both	NS (0.761)	None	NS (0.322)	None
Adult vs RF. & Max. temp.	NS (0.784)	None	NS (0.729)	None	NS (0.765)	None
Adult vs RF. & Min. temp.	Sig. (0.045)	Both	NS (0.663)	None	NS (0.584)	None

$P \leq 0.05$
X^1 – Rainfall
X^2 – Temperature (Minimum/Maximum)

Table 3 shows a mathematical relationship between the insect stages (larva, pupa and adult) and weather factors (rainfall and temperature) between 2007 and 2009. Larva relationship with rainfall and temperature (maximum) in 2007 is represented by the equation ($L = 35.44 – 0.597X_1 + 0.007X_2$). From the equation, a unit change in X_1 (rainfall) will reduce the number of larvae. In addition, a unit change in X_2 (maximum temperature) will increase the number of larvae, while 35.44 is the number of larvae when rainfall and temperature are held constant through out the year. Pupa relationship with rainfall and temperature (maximum) in 2007 is represented by the equation ($P = 3.25 – 0.006X_1 – 0.012X_2$). From the equation, a unit change in X_1 (rainfall) will reduce the number of pupa. In addition, a unit change in X_2 (maximum temperature) will decrease the number of pupa, while 3.25 is the number of pupa when rainfall and temperature are held constant. Adult relationship with rainfall and temperature (maximum) in 2007 is represented by the equation ($A = 12.06 – 0.007X_1 + 0.030X_2$). From the equation, a unit change in X_1 (rainfall) will reduce the number of adult. In addition, a unit change in X_2 (maximum temperature) will increase the number of adult, while 12.06 is the number of pupa when rainfall and temperature are held constant.

Table-3. Regression equations for relationship between Insect Stages and Weather factors (Rainfall and Temperature)

Insect stage/rainfall and temperature	2007	2008	2009
Larva vs RF. & Max. temp.	$L = 35.44 - 0.597X_1 + 0.007X_2$	$L = 16.37 + 0.032X_1 - 0.027X_2$	$L = -3.798 + 0.006X_1 + 0.543X_2$
Larva vs RF. & Min. temp.	$L = 13.82 + 0.006X_1 + 0.083X_2$	$L = 16.22 - 0.027X_1 + 0.056X_2$	$L = 1.996 + 0.002X_1 + 0.558X_2$
Pupa vs RF. & Max. temp.	$P = 3.25 - 0.006X_1 - 0.012X_2$	$P = -1.03 - 0.01X_1 + 0.123X_2$	$P = -20.393 - 0.007X_1 + 0.847X_2$
Pupa vs RF. & Min. temp.	$P = -35.54 - 0.011X_1 + 1.82X_2$	$P = -1.18 - 0.01X_1 + 0.196X_2$	$P = -17.859 - 0.014X_1 + 1.181X_2$
Adult vs RF. & Max. temp.	$A = 12.06 - 0.007X_1 + 0.030X_2$	$A = 11.04 - 0.005X_1 + 0.058X_2$	$A = 0.194 - 0.01X_1 + 0.492X_2$
Adult vs RF. & Min. temp.	$A = -67.34 - 0.018X_1 + 3.803X_2$	$A = 9.46 - 0.007X_1 + 0.17X_2$	$A = -13.467 - 0.016X_1 + 1.407X_2$

X^1 – Rainfall
X^2 – Temperature (Minimum/Maximum)

3.1. Climatic Condition

A summary of climatic conditions in Okomu oil palm plantation between January 2007 and December 2009 is presented in appendix 1. Variation in monthly mean temperature and rainfall between 2007 and 2009 is presented in figures 1 and 2.

3.2. Air Temperature

The minimum air temperature during the study period was 20.4^{0}C while maximum temperature was 30^{0}C. Variation in the monthly mean temperature in Okomu plantation is provided in figure 1. Generally, as expected, temperatures were higher in the dry season than in the rainy season.

3.3. Rainfall

The maximum rainfall was recorded in October 2007 (496.50mm) while minimum rainfall occurred in January 2007, 2008and 2009. The variation in mean monthly rainfall distribution during the study period is provided in figure 2. Generally, rainfall was higher in the rainy season with July and October having highest values.

Figure-1. Variation in monthly mean temperature in Okomu Plantation (2007-2009)

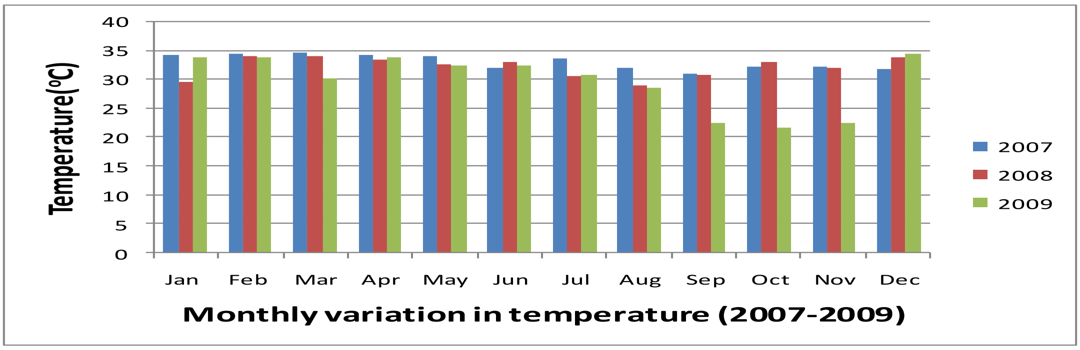
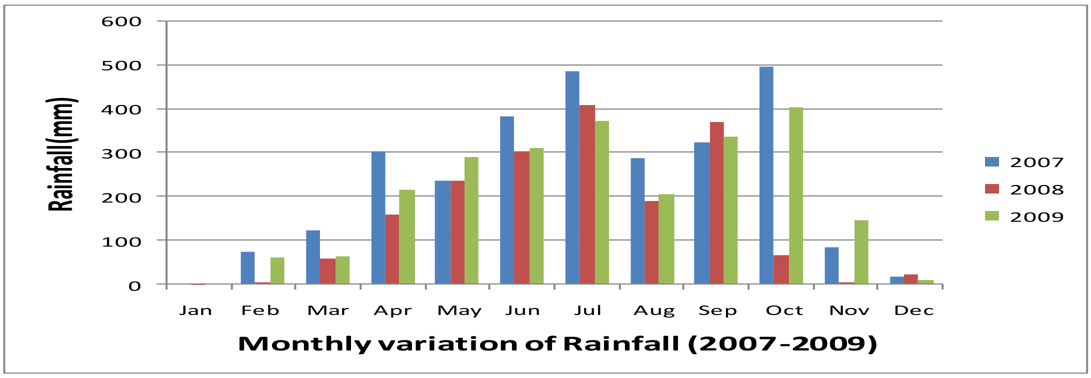


Figure-2. Variation in monthly mean rainfall in Okomu Plantation (2007-2009)



3.4. Variation in Leaf Miner Population between 2007 and 2009

Summary of leaf miner observations in Okomu between January 2007 and December 2009 is presented in appendix 2. Variation in monthly population of adult leaf miner, pupae, and larvae are provided in figures 3-5. Seasonal variation in total leaf miner population between 2007 and 2009 is presented in figure 6.

Adult leaf miner population was highest in April (2007 and 2008) and February 2009 (Figure 3). During the period under review, adult leaf miner was most prevalent between February and April. This coincides with higher average temperatures and lower rainfall. Adult control is recommended before onset of the dry season.

Leaf miner pupae population was highest in April (2007), January and May 2008; and January 2009 (Figure 4). Leaf miner pupae were most abundant between January and May during the review period. This coincides with adult abundance and control is recommended before the beginning of the dry season.

Leaf miner larvae population was highest in November (2007), January (2008); and April 2009 (Figure 5). The rainy season had a higher population of leaf miner (2007 and 2009), attributed to more rainy season months, although the dry season had a higher population in 2008 (Figure 6). Leaf miner larvae were most abundant in November, January and April.

Figure-3. Variation in monthly adult leaf miner (2007 – 2009)

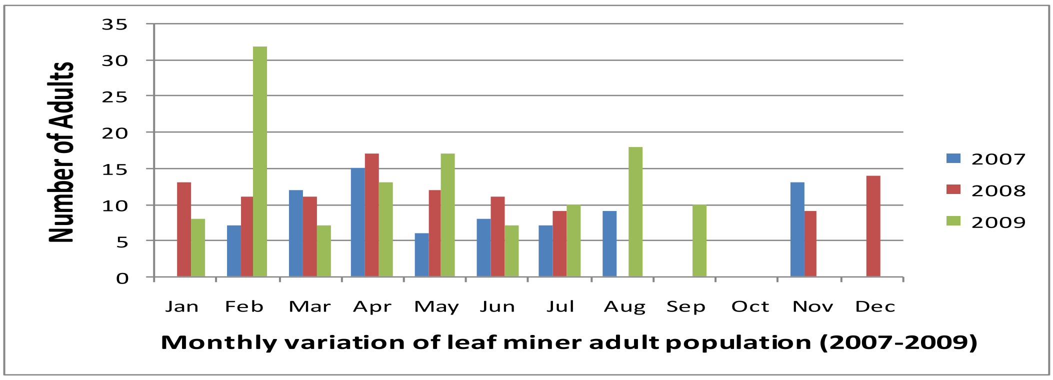


Figure-4. Variation in monthly leaf miner pupae (2007 – 2009)

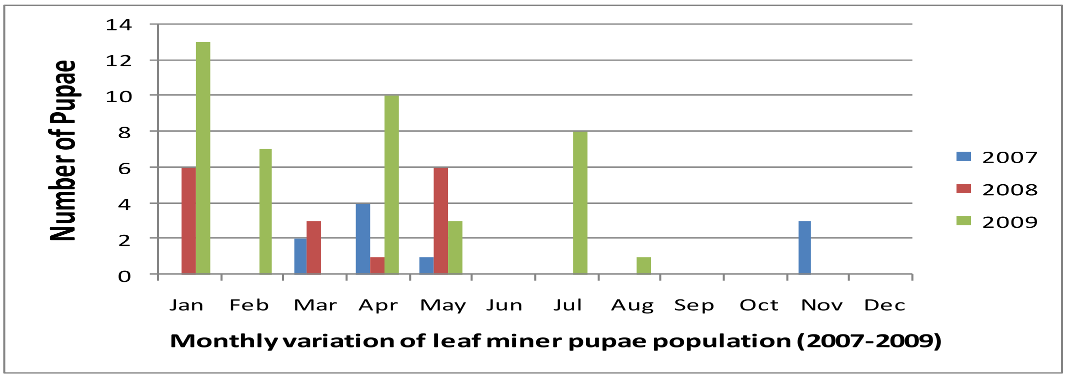


Figure-5. Variation in monthly leaf miner larvae (2007 – 2009)

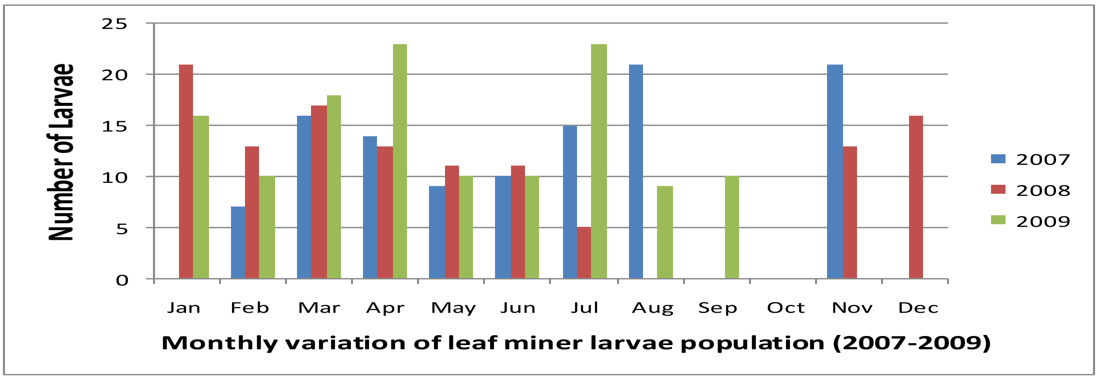
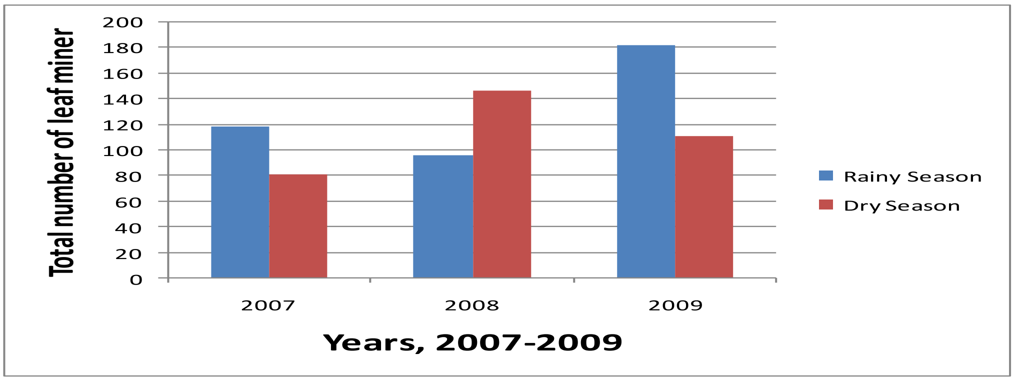


Figure-6. Seasonal variation in leaf miner population, 2007- 2009



3.5. Variation in leaf miner population and weather factors between 2007 and 2009

Variation in the monthly population of adult leaf miner, pupae, and larvae, and mean temperature (2007-2009) is presented in figures 7-9. Variation in the monthly population of adult leaf miner, pupae, and larvae, and mean rainfall is presented in figures 10-12. Larvae variation with temperature peaked in November (2007). It recorded an observed increase in January and December 2008. It peaked in April 2009 (Figure 7). Pupae variation with temperature peaked in April and November (2007). It peaked (Figure 8) in January and May (2008), while highest peak was recorded in January 2009 (Figure 9). Adult variation with temperature peaked in April and November (2007). It recorded highest peaks in April and December (2008), while it peaked in January 2009 (Figure 9). Larvae variation with rainfall peaked in August and November (2007). It peaked in January and December (2008), while it recorded highest peaks in April and July 2009. Adult variation with rainfall peaked (Figure 10) in April and November (2007). It recorded peaks (Figure 11) in January and December (2008) and February 2009 had a marked increase (Figure 12). Pupae variation with rainfall recorded no distinct trend in 2007 and 2008. However, it recorded peaks in January and April 2009 (Figure 12). Generally, leaf miner abundance was observed during the dry season with increase in temperature and decrease in rainfall.

Figure-7. Monthly Adult, pupae and larval leaf miner and mean temperature variation in Okomu, 2007

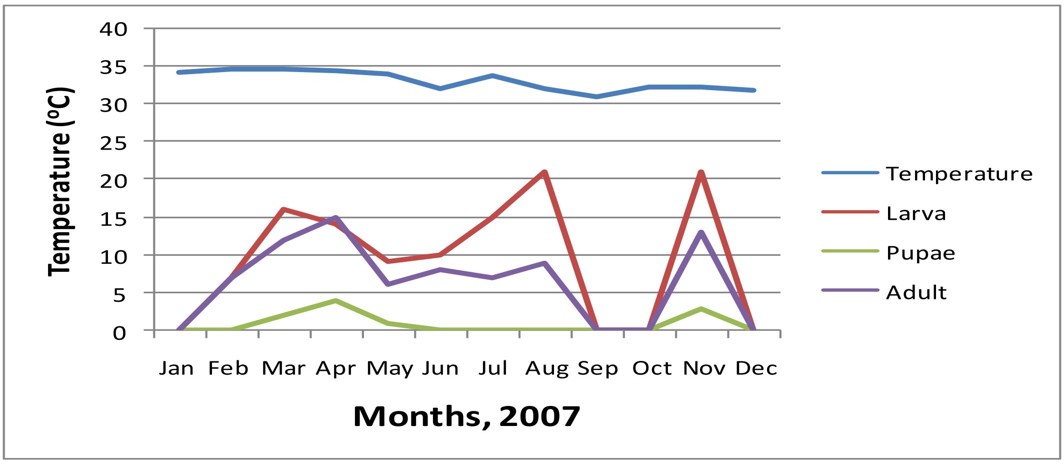


Figure-8. Monthly Adult, pupae and larval leaf miner and mean temperature variation in Okomu, 2008

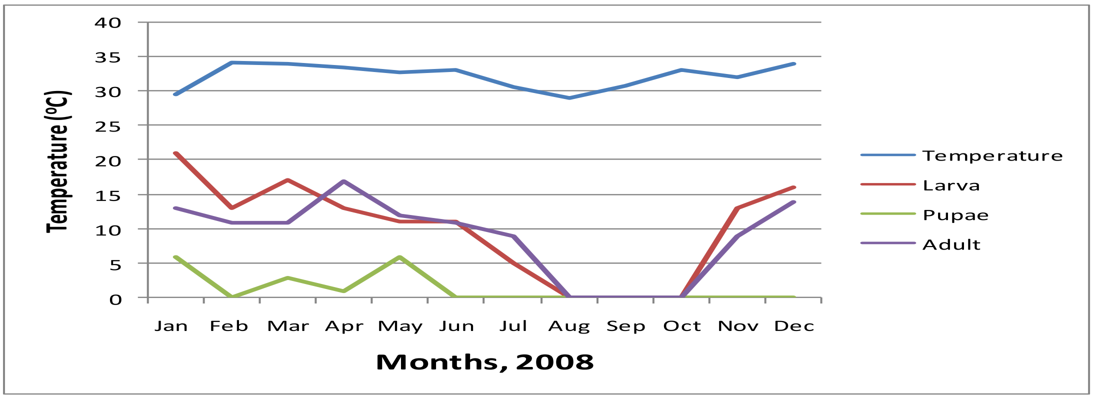


Figure-9. Monthly Adult, pupae and larval leaf miner and mean temperature variation in Okomu, 2009

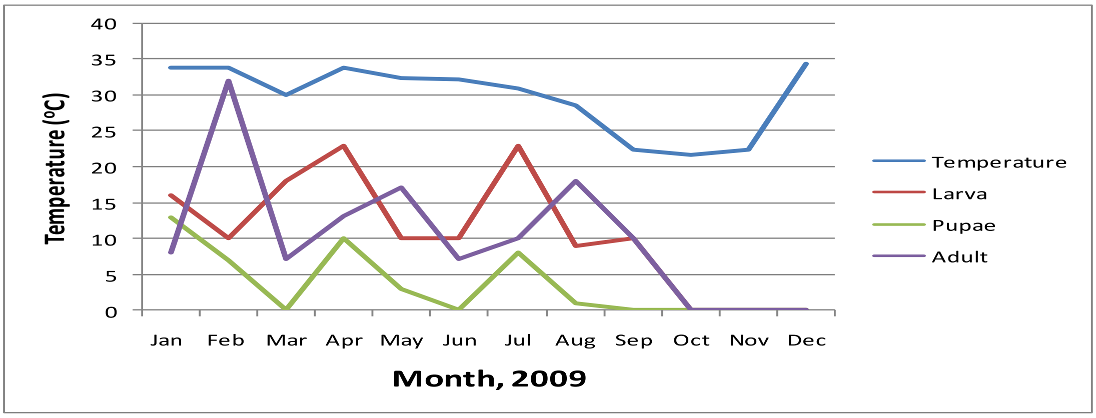


Figure-10. Monthly Adult, pupae and larva leaf miner and mean rainfall variation in Okomu, 2007

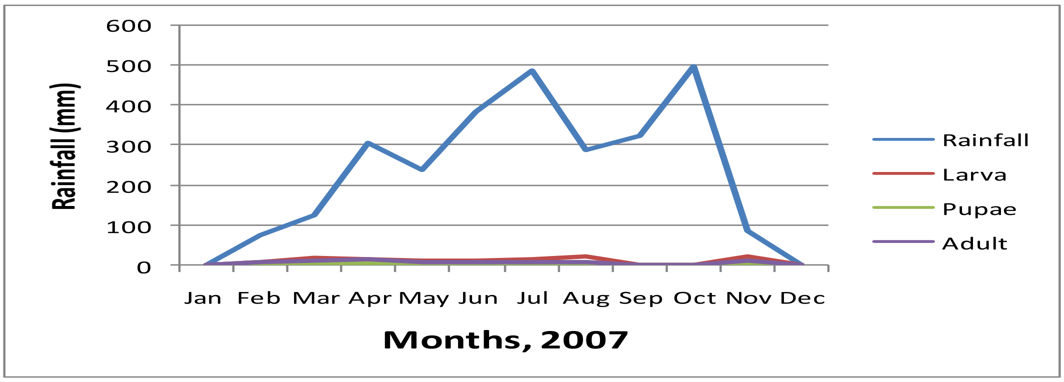


Figure-11. Monthly Adult, pupae and larval leaf miner and mean rainfall variation in Okomu, 2008

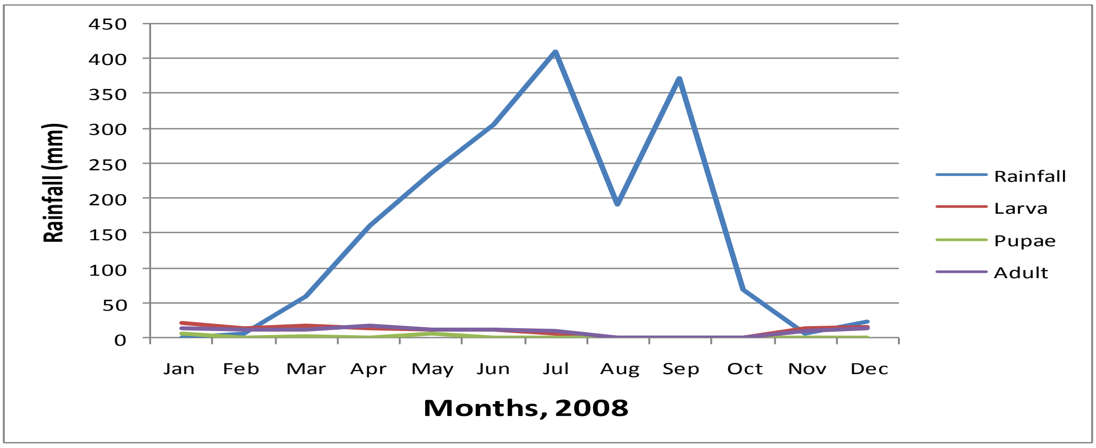
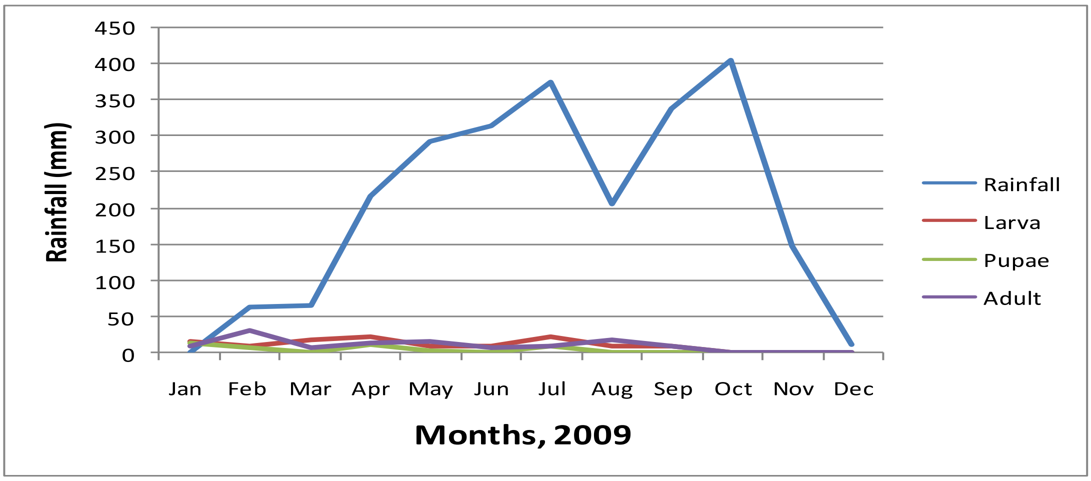


Figure-12. Monthly Adult, pupae and larval leaf miner and mean rainfall variation in Okomu, 2009



4. Discussion

Links between climate variability and insect pests will increase the severity of threats associated with climate warming. Generally, leaf miner abundance was observed during the dry season with increase in temperature and decrease in rainfall. Leaf miner distribution could be used to track seasonal population trends. Although most studies have emphasized the adaptability of insects, and concluded that their population dynamics will – unlike vegetational responses – probably be able to track environmental change as it occurs [24].

The mathematical relationship between the insect stages (larva, pupa and adult) and weather factors (rainfall and temperature) between 2007 and 2009 implies that pest prediction can be made for the different leaf miner stages using their corresponding model equations giving specific values for rainfall and temperature. The results indicate that leaf miner larvae, which are the most destructive stage, are most abundant in November, January and April. Control is recommended at the end of the rainy season.

Environmental change issues are rapidly increasing in relevance to pests of agriculture. Oil palm – pest interactions will change significantly with climate variability and change leading to impacts on pest abundance and crop loss. The study has showed significant relationships between adult and pupa leaf miner stages with rainfall and temperature. The variations in the seasonal patterns of temperature and rainfall are of major significance as a cue to timing leaf miner abundance. This study recommends control of the *C.* elaeidis before the onset of the dry season and temperature build up. This improves management of the leaf miner by controlling it more effectively.

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Reference

[1] Tahvanainen, J. O. and Root, R. B., 1972. "The influence of vegetational diversity on the Population ecology of a specialized herbivore, Phyllotreta cruciferae (Coleoptera: Chrysomelidae)." *Oecologia*, vol. 10, pp. 321-346.

[2] Southwood, T. R. and Way, M. J., 1970. *Ecological background to pest management, In R.L. Rabb and F.E. Guthrie (eds.) Concepts of pest management*. Proc. Conf. North Carolina State Univ., Raeigh, N.C, pp. 6 – 29.

[3] Boer, P. J. and Gradwell, G. R., 1971. *The dynamics of populations. Proc. Adv. Study Inst. On Dynamics of Numbers in populations*. Oosterbeek, Netherland,: Wageninger, Pudoc. p. 611.

[4] Farnworth, E. G. and Golley, F. B., 1973. *Fragile ecosystems*. New York: Springer-Verlag. p. 258.

[5] American Meteorological Society, 2008. "Climate. Glossary of Meteorology." Available: http://amsglossary.allenpress.com/glossary/search?id=climate1

[6] Federal Ministry of Environment, 2003. *Nigeria's First National Communication*. Abuja, p. 132.

[7] Nigerian Environmental Study/Action Team (NEST), 2004. "Executive summary of five sector surveys on nigeria's vulnerability and adaptation to climate change." pp. 1-17.

[8] Oerke, E. C., Detine, H. W., Schohnbeck, F., and and Weber, A., 1995. *In crop production and crop protection: Estimated losses in major food and cash crops*. The Netherlands: Elsevier, Amsterdam. p. 808.

[9] Wolda, H. and Wong, M., 1988. "Tropical insect diversity and seasonality, sweep- Samples vs. light-trap." *Proc. Konin Nederl. Akad. Wetens.*, vol. C 91, pp. 203-16.

[10] IPCC, 2007. *IPCC fourth assessment report: climate change 2007 (AR4)*. Geneva, Switzerland: IPCC.

[11] Moss, R. H., Edmonds, J. A., Hibbard, K. A., Manning, M. R., Rose, S. K., van Vuuren, D. P., Carter, T. R., Emori, S., Kainuma, M., *et al.*, 2010. "The next generation of scenarios for climate change research and assessment." *Nature*, vol. 463, pp. 747–756.

[12] Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P., and Naylor, R. L., 2008. "Prioritizing climate change adaptation needs for food security in 2030." *Science*, vol. 319, pp. 607–610.

[13] Roudier, P., Sultan, B., Quirion, P., and Berg, A., 2011. "The impact of future climate change on West African crop yields: what does the recent literature say?" *Global Environmental Change*, vol. 21, pp. 1073-1083.

[14] Cottrell, R. C., 1991. "Nutritional aspects of palm oil." *Am. J. Clin. Nutr.*, vol. 53, pp. 989S – 1009S.

[15] Calloway, D. H. and Kurtz, G. W., 1956. "The absorbability of natural and modified fats." *Food Research*, vol. 21, pp. 621-629.

[16] Nigerian Institute for Oil Palm Research, 2008. "NIFOR In-house review report." p. 8.

[17] Keu, S. T., 2006. "Review of previous similar studies on the environmental impacts of oil palm plantation cultivation on people, soil, water and forests ecosystems." pp. 1-10.

[18] Natural Resources Institute, 1996. *Insect pests of Nigerian Crops: identification, biology And control. Natural Resources Institute Chatham, U. K.* Science, University of Ghana: Legon. p. 253.

[19] Morin, J. P. and Mariau, D., 1970. "The study of the biology of coelaenomenodera elaiedis MlK. I. Morphology and study of Development." *Oleagineux*, vol. 25, pp. 11-16.

[20] Afreh-Nuamah, K., 1999. *Insect pests of tree crops in Ghana. Identification, damage and Control measures*. Buck press. Inc., p. 65.
[21] Hartley, C. W. S., 1988. *The Oil Palm*. 3rd ed. London: Longman. p. 761.
[22] Obeng-Ofori, D., 1998. " Pests of field, plantation and vegetable crops." Their biology, Damege and control.
[23] Wolda, H., 1988. "Insect seasonality: Why?" *Ann. Rev. Ecol. Syst.*, vol. 19, pp. 1-18.
[24] Lawton, J. H., 1995. *The response of insects to environmental change. In: Insects in a Changing Environment (eds Harrington, R. and Stork, N.E.)*. Oxford: Blackwell Science. pp. 41-58.

Appendix-1. Climatology Data for Okomu Oil Palm Plantation (Jan. 2007-Dec. 2009)

Weather Data for 2007

Months	Rainfall	Max Temp	Min Temp
Jan	0	34.29	18
Feb	74.3	34.6	23.1
Mar	123.9	34.7	23.41
Apr	304.6	34.4	22.53
May	236.4	34.09	22.32
Jun	384	32.16	22.5
July	487	33.8	21.5
Aug	288.2	32	22
Sept	324.4	31	22
Oct	496.5	32.21	21.98
Nov	85.4	32.2	22.13
Dec	17.1	31.87	20.38

Weather Data for 2008

Months	Rainfall	Max Temp	Min Temp
Jan	0.7	29.6	19.2
Feb	6.7	34.2	21.56
Mar	59.8	34.1	22.76
Apr	159.7	33.5	23.49
May	237	32	22.12
Jun	305.1	33	22.17
July	409.7	30.63	22.4
Aug	190.4	29	22.81
Sept	371.7	30.8	23.1
Oct	68.6	33.1	23.4
Nov	6.9	31.98	20.68
Dec	23.6	34	22.4

Weather Data for 2009

Months	Rainfall	Max Temp	Min Temp
Jan	0	34	21.51
Feb	61.9	34	22.25
Mar	65.4	30.2	19.9
Apr	217.2	33.9	23.3
May	291	32.5	22.48
Jun	312.7	32.4	22.32
July	373.5	30.96	21.93
Aug	205.1	28.6	22.4
Sept	336.6	22.48	29.35
Oct	404.4	21.76	31.56
Nov	146.4	22.45	32.19
Dec	10	34.5	24.5

Appendix-2. Leaf miner survey observation in Okomu between January 2007 and December 2009

Observation of leaf miner in 2007

Date	Number of insects		
	L	**P+IA**	**EA**
05-02-07	7	0	7
22-02-07	16	2	12
10-04-07	14	4	15
15-05-07	9	1	6
26-05-07	10	0	8
12-07-07	15	0	7
12-10-07	21	0	9
09-11-07	21	3	13
Total	**113**	**10**	**77**

Observation of leaf miner in 2008

Date	Number of insects		
	L	**P+IA**	**EA**
11-01-08	21	6	13
20-02-08	13	0	12
19-03-08	17	3	15
10-04-08	13	1	6
07-05-08	11	6	8
09-06-08	11	0	7
09-07-20	5	0	7
07-11-08	13	0	9
29-11-08	16	0	13
Total	**120**	**16**	**107**

Observation of leaf miner in 2009

Date	Number of insects		
	L	**P+IA**	**EA**
31-01-09	16	13	8
09-02-09	10	7	32
11-03-09	18	0	7
14-04-09	23	10	13
13-05-09	10	3	17
15-06-09	10	0	7
17-07-09	23	8	10
18-08-09	9	1	18
11-09-09	10	0	10
Total	**129**	**42**	**122**

Key: L-Larva
P + IA-Pupa + Internal adult
EA-External adult