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EMPIRICAL ASSESSMENT OF TEMPERATURE, RAINFALL AND RELATIVE HUMIDITY IMPACT ON THE POPULATION OF *COELAENOMENODERA ELAEIDIS* (COLEOPTERA – CHRYSOMELIDAE), A PEST OF THE OIL PALM IN NIGERIA

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ABSTRACT

The leaf miner (*Coelaenomenodera elaeidis*) is the most serious pest of the oil palm. It breaks out in epidemic proportions periodically, resulting in severe leaf defoliation and consequently low fresh fruit bunch (ffb) yield. This paper reports a study attempting to relate the abundance of the pest to climate variability. The leaf miner was sampled during 2009-2010 in oil palm fields and records from previous surveys from 1976-1980 were utilized. The study analyses temperature, rainfall and relative humidity between 1961 and 2010 in the main station of the Nigerian Institute for Oil Palm Research (NIFOR). Data on temperature, rainfall and relative humidity were obtained from NIFOR meteorological unit. Decadal variation in air temperature indicated increase in air temperature between 1961-1970 and 2001-2010 while variation in rainfall and relative humidity indicated a decrease. It was also observed that there was temperature increase across seasons with highest increase in the dry season, and suitable for leaf miner control. Relationship between mean weather factors (temperature, humidity and rainfall) and leaf miner insect stages (larvae, pupae and adult) between 2009 and 2010 showed significant relationship ($P \leq 0.05$). This could be attributed to relatively higher weather values and higher leaf miner population. The need for continuous monitoring has great potential for control of insect pests in oil palm growing areas.

Keywords: *Coelaenomenodera elaeidis*, Climate variability, Oil palm, Monitoring.

INTRODUCTION

Agricultural systems are vulnerable to variability in climate, whether naturally-forced, or due to human activities. Vulnerability can be viewed as a function of the sensitivity of agriculture to changes in climate, the adaptive capacity of the system, and the degree of exposure to climate hazards (IPCC 2001b). The leaf miner, a hispid, is a serious defoliating pest of the oil palm. Leaf miner outbreaks are sporadic and difficult to predict. There is need for increased knowledge of the leaf miner and its dynamics to guide environmentally sustainable integrated pest management methods. A major ability of farmers to adapt to climate variability and change with respect to insect pest infestations will depend on knowledge of pest attacks in relation to climate variability and change. In order for farmers to move away from over reliance on pesticides, dependable tools to time pest management activities are needed. There is rapidly increasing understanding of how the climate is likely to change at the global scale under various emissions scenarios, however what is less well understood is the magnitude of future temperature, rainfall and relative humidity changes at the local level, and how these are influencing agro-biological systems (Levine et al., 2011). This paper focuses on the sensitivity of the leaf miner to climate variability. The objectives include:

1. Description of temperature, rainfall and relative humidity conditions from 1961-1970 as reference point for baseline climatic conditions and description of same conditions between 2001-2010 to demonstrate patterns in climate change and variability in the study area.
2. Impacts of climate variability on *Coelaenomenodera elaeidis* abundance in the study area.

LITERATURE REVIEW

Agricultural pests severely constrain the productivity potential of global agriculture. Scientific evidence gathered over the last couple of decades suggests that climate conditions are changing rapidly and that this trend is likely to continue and even accelerate (IPCC 2007, Moss *et al*., 2010). 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 (Lobell *et al*., 2008, Roudier *et al*., 2011). A comprehensive study (Oerke *et al*., 1994) places the combined pre-harvest loss from pests at 42 percent for the world's top eight food crops, with an additional 10 percent of potential food production lost to pests during post-harvest. Agricultural production is very sensitive to climate change and it suffers from periodic outbreak of insect pests which cause considerable losses especially in the humid and sub-humid tropics. Nigeria is particularly sensitive to climate change and variability largely due to our dependence on rain fed agriculture, widespread poverty, poor infrastructure, over exploitation of natural resources, limited institutional and technological capacity. In many parts of Africa, climate is already a key driver of food security (Gregory *et al*., 2005; Verdin *et al*., 2005). Climate change and variability has been recognized as a major burden that restrains national development in the West African region from achieving desired economic and development goals. Vulnerability can be viewed as a function of the sensitivity of agriculture to changes in climate, the adaptive capacity of the system, and the degree of exposure to climate hazards (IPCC 2001b). Climate change is expected to impact both crops and livestock systems (FAO, 2003). The rate of insect growth is greatly influenced by the physical environment, particularly temperature (Pedigo, 2004).

METHODOLOGY

The study site is located at the main station of the Nigerian Institute for Oil Palm Research (NIFOR) near Benin, Edo State, Nigeria. It lies on the coordinates of latitude 6^0 30' N and longitude 5^0 40' E. It is located in the forest zone of South-West Nigeria.

CLIMATE

There are two seasons; wet and dry seasons. Average mean temperature is 26.6 ^{0}C. The station lies in the rainforest belt of Nigeria. The rainy season is from the month of April – October, while the dry season occurs between the months of November and March.

HYDROLOGY

The river Okhuo flows southwards, towards the Northern part of the station.

SAMPLING TECHNIQUE

The study involved direct field insect pest surveys and assessments at the NIFOR main station. Criterion for site selection was a plot 5-12 years of age. Data was collected monthly from 2009-2010. It involved observing and counting of *C. elaeidis* and natural enemies. No pesticides were applied during the study period to simulate a natural ambience in the sample plot. Parasitoids of *C. elaeidis* were identified and counted. The field was selected after a reconnaissance survey of experimental plots in the NIFOR main station – fields 2, 13, 16, 37, 72, 47, 25, 26, 30, 37, 54, 46 and 34. Only field 54 was planted in the year 2000. Field 37 was planted in the year 1987. All others were planted in excess of 25 years. The study field 54 was made up of 443 palms (2.95 hectares). Formerly known as field 14, it was planted in the year 2000 and harvesting of fresh fruit bunch (ffb) began in 2005. It was divided into 7 blocks (1 – 31 palms; 2 – 58 palms; 3 – 68 palms; 4 – 68 palms; 5 – 72 palms; 6 – 63 palms and 7 – 83 palms). For mature palms, various census methods have been proposed (Chung, 1997; Chung et al., 1995; Syed and Speldewinde, 1974; Wood, 1968). In this study, the census system used sample counts within specified blocks. Since the palms were planted in a triangular pattern, census lines ran in three directions. Access points are marked with reference to field boundaries and harvesting paths. The most common predatory ant (*Micromischoides* sp) were identified and counted. Census on the basis of damage by *C. elaeidis* was done monthly by walking the full length of a planted line, assessing damage on each palm and cutting 5 severely damaged leaflets from a palm frond with a harvesting knife and taken to the laboratory where the leaflets were opened up and immature stages of *C. elaiedis* counted. Parasitoids of *C. elaeidis* were also identified and directly counted. Sampling was conducted monthly between 7am-11am. Insect sampling was done by the use of insect sweep net, direct handpicking and leaflet sampling.

EXPERIMENTAL DESIGN

The experimental area was field 54 with a total size of 2.95Ha. The field was divided into 7 blocks. A census of one palm per row was utilized, and a sampling intensity of 21 palms was used, selecting 1 palm per line. The larval, pupal and adult stages of the insects were counted. A complete randomized design (CRD) was utilized following Akindele (1996), since observations were made on experimental units that are homogenous. The independent variables were temperature, rainfall and relative humidity. The dependent variable was *Coelaenomenodera elaeidis* and its natural enemies. At each point, pests were counted on fronds inclined at 45º (number 17 and 25 on the phyllotactic spiral) (Wood, 1966). In shorter palms, fronds were pulled down by hand, but in taller ones a ladder was used. A different palm is used at successive census rounds.

SECONDARY DATA COLLECTION

Leaf miner field data surveys from 1976-1980 were obtained from NIFOR Entomology division.

CLIMATOLOGICAL DATA

Climatological data (temperature, rainfall and relative humidity) were obtained from NIFOR meteorological station. The weather station is within 1km radius of the field. The data were monthly averaged records.

STATISCAL ANALYSIS

Means, standard deviation, variances, covariances, seasonal and climatic patterns for temperature, rainfall and relative humidity were computed.

RESULTS

Average variation in air temperature, rainfall and relative humidity from 1961-2010 is presented in tables 1-3. Pest – weather relationship for 1976-1980 is presented in tables 4 and 5 respectively.

Table 1: Decadal Mean Annual Air Temperature Variation from 1961 – 2010

Decades	Highest Temperature (^{0}C)	Lowest Temperature (^{0}C)
D1 (1961-1970)	1970 (31.6)	1961 (29.3)
D2 (1971-1980)	1973 (32.2)	1976 (30.7)
D3 (1981-1990)	1989 (32.2)	1982 (31.4)
D4 (1991-2000)	2000 (32.1)	1994 (30.6)
D5 (2001-2010)	2009 (33.5)	2007 (30.8)

During the study period, highest decadal temperature was recorded in 2009 (33.5^{0}C) while lowest temperature was in 1961 (29.3^{0}C). It is evaluated that between D1 (1961 – 1970) and D5 (2001 – 2010), there has been an increase in maximum temperature values by 1.9^{0}C (Table 1).

Table 2: Decadal Mean Annual Rainfall Variation from 1961 – 2010

Decades	Highest rainfall (mm)	Lowest rainfall (mm)
D1 (1961-1970)	1969 (211.69)	1961 (125.52)
D2 (1971-1980)	1979 (213.33)	1977 (96.93)
D3 (1981-1990)	1990 (176.5)	1983 (124.89)
D4 (1991-2000)	1994 (209.79)	1998 (130.45)
D5 (2001-2010)	2002 (177.93)	2005 (132.92)

During the study period, highest average yearly rainfall was recorded in 1979 (213.33mm) while lowest rainfall was in 1977 (96.93mm).

Table 3: Decadal Mean Annual Relative Humidity Variation from 1961 – 2010

Decades	Highest relative humidity (%)	Lowest relative humidity (%)
D1 (1961-1970)	1969 (70.9)	1963 (64.6)
D2 (1971-1980)	1976 (71.6)	1973 (64.9)
D3 (1981-1990)	1988 (68.7)	1989 (61.0)
D4 (1991-2000)	1996 (83.4)	2000 (63.7)
D5 (2001-2010)	2010 (68.6)	2007 (61.8)

During the study period, highest average yearly relative humidity was recorded in 1996 (83.4%) while lowest rainfall was in 1989 (61.00%). It was observed that highest yearly average rainfall values do not correspond with highest relative humidity values.

LEAF MINER - WEATHER RELATIONSHIP: 1976 – 1980

Relationship ($P \leq 0.05$) between mean weather factors (temperature, rainfall and relative humidity) and leaf miner stages (larvae, pupae and adult) for 1976 – 1980 are shown in table 4. There was no recorded dominant variable during this period, and there was no detectable impact on leaf miner development.

Table 4: Relationship between mean Weather factors and Leaf miner stages (larvae, pupae, adult), for 1976 – 1980

Insect Stage	R^2	R	P-value	Climatic variable
Grouped leaf miner				
1976	0.419	0.647	0.204	Control
	0.045	0.212	0.943	Lagged
1977	0.384	0.620	0.251	Control
	0.298	0.546	0.393	Lagged
1978	0.063	0.251	0.908	Control
	0.086	0.293	0.859	Lagged
1979	0.176	0.419	0.651	Control
	0.216	0.465	0.560	Lagged
1980	0.025	0.158	0.975	Control
	0.168	0.410	0.669	Lagged

****Significance $P \leq 0.05$**
Control – Climatic variable from month of collection
Lagged – Climatic variable with a delayed month in relation to collection
R^2 – Coefficient of determination
R – Correlation coefficient

LEAF MINER - WEATHER RELATIONSHIP: 2009 – 2010

Relationship between mean weather factors (temperature, humidity and rainfall) and leaf miner insect stages (larvae, pupae and adult) between 2009 and 2010 are shown in table 5. There was significant relationship in both the control (0.039) and lagged (0.029) in 2009.

Table 5: Relationship between mean Weather factors and Leaf miner stages (Larvae, pupae, adult) for 2009 - 2010

Insect Stage	R^2	R	P-value	Climatic variable
Grouped leaf Miner				
2009	0.714	0.845	0.014**	Control
	0.715	0.846	0.014**	Lagged
2010	0.193	0.439	0.612	Control
	0.301	0.549	0.387	Lagged

****Significance $P \leq 0.05$**

Decadal variation in temperature, rainfall and humidity between 1961 and 2010 is presented in figures 1-3. Decadal variation in air temperature (Fig. 1) showed increase in air temperature between 1961-1970 and 2001-2010. Decadal variation in rainfall (Fig. 2) shows decrease rainfall between 1961-1970 and 2001-2010. Decadal variation in relative humidity was closely related to rainfall (Fig. 3).

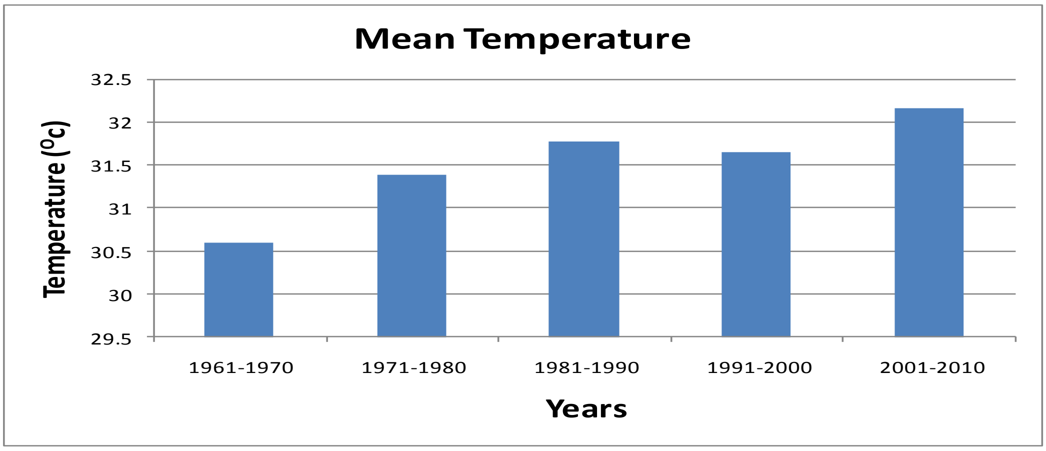

Figure 1: Decadal variation in mean temperature in NIFOR, 1961-2010

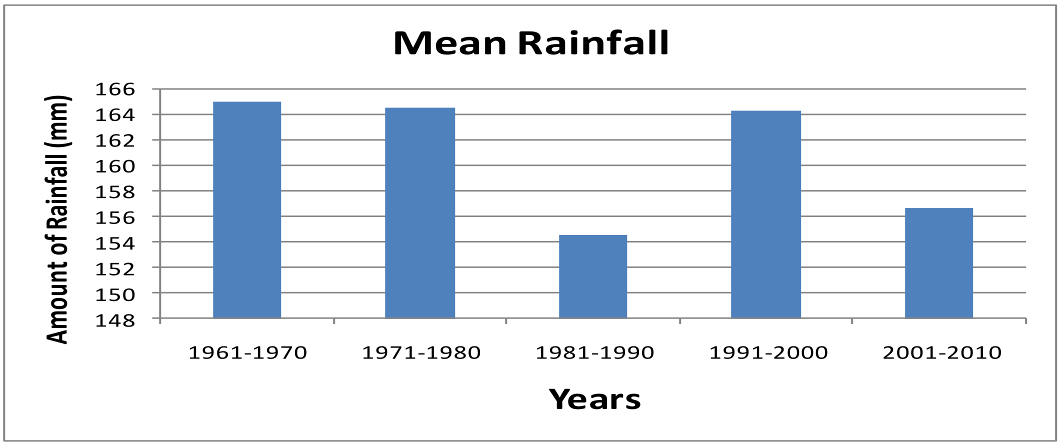

Figure 2: Decadal variation in mean rainfall in NIFOR, 1961-2010

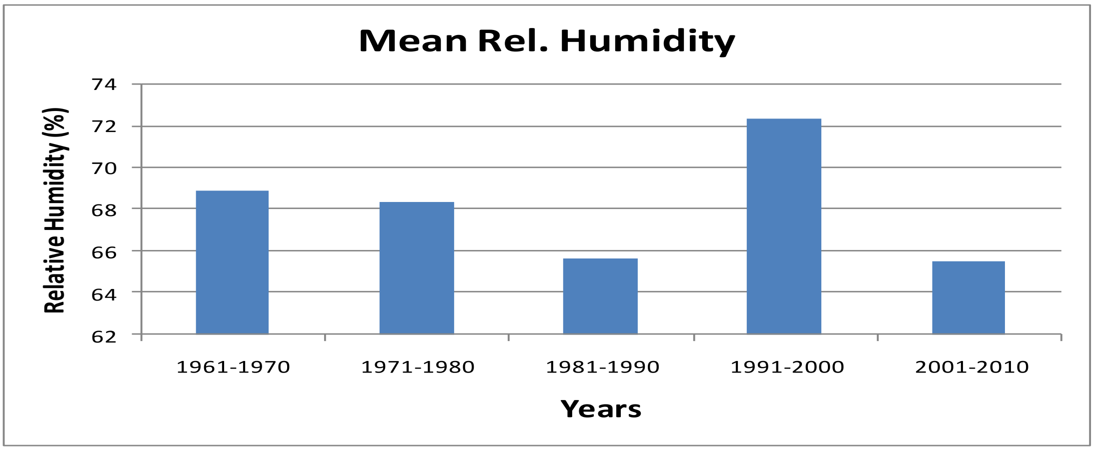

Figure 3: Decadal variation in mean relative humidity in NIFOR, 1961-2010

Summary statistics for weather factors (temperature, relative humidity and rainfall) are presented in tables 6 – 9. Summary statistics for temperature, relative humidity and rainfall between 1961 and 2010 is presented in table 6. The warmest period was D5 (2001-2010) with mean temperature of 32.16^{0}C. Variations in observed temperature was highest in D5 (CV=7.11%) and lowest in D2 (CV=6.14%). Temperature increased by 1.56^{o}C between D1 (1961-1970) and D5 2001-2010). The most humid period was D4 (1991-2000) with mean relative humidity of 72.29%. Variations in observed humidity across the years in each period was highest in D5 (CV=17.75%) and lowest in D2 (CV=14.95%). Relative humidity decreased by 3.39% between D1 and D5. The period recording highest rainfall was D1 with mean rainfall of 164.9mm. Variations in observed rainfall across the years in each period was highest in D4 (CV=88.74%) and lowest in D2 (CV=80.0). Rainfall also decreased by 8.2mm between D1 and D5

Table 6: Summary Statistics for average temperature, relative humidity and rainfall from 1961-2010

	Temperature (^oC)				Relative Humidity (%)				Rainfall (mm)			
	Mean	**Std**	**Variance**	**CV(%)**	**Mean**	**Std**	**Variance**	**CV(%)**	**Mean**	**Std**	**Variance**	**CV(%)**
D1: 1961-1970	30.603	2.167	4.69	7.08	68.91	12.13	147.03	17.6	164.9	145.9	21290.62	88.48
D2: 1971-1980	31.380	1.928	3.72	6.14	68.37	10.22	104.37	14.95	164.5	131.6	17320.28	80.0
D3: 1981-1990	31.776	2.084	4.34	6.56	65.65	10.75	115.53	16.38	154.5	133.0	17683.84	86.08
D4: 1991-2000	31.645	2.221	4.93	7.02	72.29	11.07	122.64	15.31	164.2	137.5	18900.20	88.74
D5: 2001-2010	32.161	2.288	5.24	7.11	65.52	11.63	135.25	17.75	156.7	124.2	15418.62	79.26

Key:
D - Decade
Std. – Standard deviation
CV – Covariance

Seasonal rainfall variation between 1961 and 2010 is shown in table 7. In the dry season, there was the highest variation in observed rainfall in D3 (CV=144.1%) and lowest variation in D2 (CV=116.2%). Rainfall decreased by 2.92mm between D1 (1961-1970) and D5 (2001-2010) with the highest amount of rainfall observed in D2 (1971-1980). In the rainy season, variations in observed rainfall was highest in D1 (CV=49.9%) and lowest in D5 (CV=36.33%). Rainfall also decreased by 11.85mm between D1 and D5 in the rainy season. In the dry season, amount of rainfall observed across the years varied by 49.44mm in D1 and 44.78mm in D5 while in the rainy season, it varied by 126.26mm in D1 and 87.72mm in D5 respectively.

Table 7: Summary Statistics for average Seasonal Rainfall from 1961-2010

	Dry Season (mm)				Rainy Season (mm)			
	Mean	**Std**	**Variance**	**CV (%)**	**Mean**	**Std**	**Variance**	**CV (%)**
D1	41.05	49.44	2444.30	120.4	253.29	126.26	15942.38	49.9
D2	49.29	57.26	3279.10	116.2	246.81	105.12	11050.41	42.6
D3	34.28	49.38	2438.28	144.1	240.35	104.01	10817.68	43.3
D4	39.65	50.34	2534.16	127.0	253.21	107.32	11517.64	42.4
D5	38.13	44.78	2005.49	117.4	241.44	87.72	7694.40	36.33

Seasonal temperature between 1961 and 2010 is presented in table 8. In the dry season, highest variation occurred in D1 (CV=5.6%) and lowest variation occurred in D2 (CV=2.9%). Temperature increased on the average by 1.75^{o}C between D1 (1961-1970) and

D5 (2001-2010) with highest temperature observed in D5. Also, temperature observed across the years in D1 and D5 varied between 1.80^{o}C and 1.74^{o}C respectively. In the rainy season, highest variation occurred in D5 (CV - 6.13%) and lowest variation occurred in D2 (CV - 5.9%). Temperature also increased by 1.15^{o}C between D1 and D5 with highest temperature observed in D5. Also, temperature observed across the years in D1 varied by 1.80^{o}C and 1.90^{o}C in D5 respectively.

Table 8: Summary Statistics for average Seasonal Temperature from 1961-2010

	Dry Season (^{o}C)				**Rainy Season (^{o}C)**			
	Mean	**Std**	**Variance**	**CV (%)**	**Mean**	**Std**	**Variance**	**CV (%)**
D1	32.03	1.80	3.245	5.6	29.85	1.80	3.15	6.09
D2	32.83	0.96	0.915	2.9	30.35	1.78	3.15	5.9
D3	33.07	1.68	2.83	5.1	30.85	1.84	3.39	6.0
D4	33.41	1.21	1.46	3.6	30.41	1.91	3.66	6.3
D5	33.78	1.74	3.03	5.2	31.0	1.90	3.62	6.13

Seasonal relative humidity between 1961 and 2010 is presented in table 9. In the dry season, highest variation occurred in D4 (CV=17.8%) while lowest variation occurred in D2 (CV=10.4%). Relative humidity decreased by 0.71% between D1 (1961-1970) and D5 (2001=2010) with D4 (1991-2000) as the most humid period. Also, relative humidity across the years varied by 6.97% in D1 and 7.84% in D5 respectively. In the rainy season, highest variations occurred in D1 (CV=13.9%) while lowest variation occurred in D2 (CV=8.3%). Relative humidity decreased by 2.28% between D1 and D5 with D4 as the most humid period. Also, in the rainy season, relative humidity across the years in D1 varied by 10.50% and 6.40% in D5 respectively.

Table 9: Summary Statistics for average Seasonal Relative Humidity from 1961-2010

	Dry Season (%)				**Rainy Season (%)**			
	Mean	**Std**	**Variance**	**CV (%)**	**Mean**	**Std**	**Variance**	**CV (%)**
D1	59.54	6.97	48.52	11.7	75.59	10.50	110.25	13.9
D2	58.85	6.09	37.033	10.4	75.27	6.25	39.01	8.3
D3	56.64	8.63	74.43	15.2	72.08	6.75	45.56	9.4
D4	65.39	11.64	135.43	17.8	77.49	8.08	65.28	10.4
D5	58.83	7.84	61.43	13.3	73.31	6.40	40.95	8.7

DISCUSSION

Environmental change issues are rapidly increasing in relevance for pests of agriculture. Oil palm – pest interactions will change significantly with climate variability and change leading to impacts on pest abundance and crop loss. Studies of effects of weather and climate on ecology and evolution at the population level are numerous (Hoffmann and Parsons, 1997; Saether, 1997; Weiss et al., 1988; Precht et al., 1973; Wiesel 1973; Singer, 1972). There was no observed relationship between mean weather factors and leaf miner stages between 1976 and 1980. This could be attributed to relatively low weather values and low leaf miner population during the period. However, between 2009 and 2010, there was a significant relationship between mean weather factors and leaf miner stages. This could be attributed to relatively higher weather values and consequently, higher leaf miner population.

TEMPERATURE

The results reported in IPCC (2001a,b) suggest temperature changes over the coming decades for Africa of between 0.2 and 0.5°C per decade, with the greatest warming in interior regions. Rising temperatures were observed between 1961 and 2010 with 2001 – 2010 being the warmest period. Average temperature recorded between D1 (1961-1970) and D5 (2001-2010) increased by 1.56^{0}C. This indicates incremental warming between the study periods. It was also observed that there was temperature increase across seasons with highest increase in the dry season, and suitable for leaf miner control.

RAINFALL

The water available on earth continually cycles through the atmosphere, oceans, and terrestrial environments, mainly, through evaporation, transpiration and precipitation. A decline in mean rainfall was observed between 1961 and 2010. This decrease was in both the dry and rainy seasons with a higher variation in the dry season. Between D1 (1961 – 1970) and D5 (2001 – 2010), there was a decline in rainfall values by 33.76mm. Using 159.66mm average annual rainfall for NIFOR (Hartley, 1988) as baseline, 1969 (211.63mm); 1979 (213.33mm) and 1994 (209.79mm) could be described as years of flooding, attributed to climate variability. During the 1979 - 1980 periods, there was no dominant weather effect on the leaf miner. However, the 2009 - 2010 periods has shown rainfall to be the dominant variable implying that its decrease could contribute to increase in abundance of the leaf miner. High rainfall could also lead to disruption in leaf miner breeding and mortality, and decrease in rainfall levels leads to increased leaf miner abundance.

RELATIVE HUMIDITY

Generally, high relative humidity provides a moist environment and favors increase in insect pests and diseases. A decline in mean relative humidity was observed during the study period. It is evaluated that between D1 (1961 – 1970) and D5 (2001 – 2010), there was a decline in relative humidity values by 2.3%. A decrease in relative humidity would increase the growth of the leaf miner.

CONCLUSIONS

A crucial issue in ecology is to determine how environmental variations associated with global climate change and variability, especially changing temperatures, affects trophic interactions in various ecosystems. The assessment of the sensitivity of leaf miner to variability in weather conditions is important in view of evidence that show expansion of pest ranges as a result of climate variability impacts. Given the heavy dependence of livelihoods on natural resources in Nigeria, efforts should be directed to implementing effective and longer-term agro-meteorological programmes to adapt production systems to climatic resources. The consequences of climate variability and change affect the leaf miner and could have significant effects on its distribution and abundance. Given the population base of the leaf miner, increases in temperature could create favorable conditions for population growth and thus substantial oil palm yield losses. The study indicates that the leaf miner is capable of adapting to a wide range of temperature, rainfall and relative humidity variation. The need for continuous monitoring has great potential for control of insect pests in oil palm growing areas.

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