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Impact of Weather Factors on *Coelaenomenodera elaiedis* MLK (Coleoptera: Chrysomelidae) in Nigeria

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Abstract

The leaf miner (*Coelaenomenodera elaeidis*) is a major pest of the oil palm. It breaks out in epidemic proportions periodically, resulting in severe leaf defoliation and consequently low fresh fruit bunch (FFA) yield. This study analyses temperature, rainfall, relative humidity, and leaf miner abundance records sampled in oil palm fields between 1976 and 1980 in the main station of the Nigerian Institute for Oil Palm Research (NIFOR). Data for temperature, rainfall, and relative humidity were obtained from NIFOR meteorological station. Mathematical relationships between the insect stages (larva, pupa, and adult) and weather factors (rainfall and temperature) were developed indicating that pest predictions can be made for different leaf miner stages using their corresponding model equations giving specific values for rainfall and temperature. Variations in the seasonal patterns of temperature and rainfall are of major significance as a cue to timing leaf miner abundance and would help in making better decisions regarding where farmer action can target pest control interventions, thereby contributing to ensure food security. The need for continuous monitoring has great potential for detection and control of insect pests in oil palm growing areas.
Keywords: Leaf miner; Weather variability; Oil palm; Pest predictions; Monitoring.

1. Introduction

The leaf miner, a hispid beetle, 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 [1]. Knowledge of past systems is necessary to evaluate future events.

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 [2, 3]. 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 [4, 5]. A comprehensive study [6] 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. According to Omoloye [7], any alteration of the physical condition of the environment in which a pest population exists; whether on the surface or under the soil, terrestrial or arboreal, will affect the pest population.

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 [8, 9]. 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 [10]. Climate change is expected to impact both crops and livestock systems [11]. The rate of insect growth is greatly influenced by the physical environment, particularly temperature [12].

Mathematical models can be categorized as mechanistic or empirical models. A mechanistic (or explanatory) model is built from knowledge of the underlying physical, chemical, or biological processes and represents the cause-and-effect relationships among the variables [13]. An empirical (or descriptive) model describes the relationship among the driving factors and response variables and is developed by statistical analysis of data collected in the field [14].

This paper focuses on the sensitivity of the leaf miner to weather variability. The objectives include:

1. Mathematical relationship between mean weather factors and leaf miner stages from 1976-1980.
2. Impacts of weather variability on *Coelaenomenodera elaeidis* abundance in the study area.

2. Materials and Methods

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.

2.1. 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.

2.2. Secondary Data Collection

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

2.3. Climate Data

Climate data (temperature, rainfall and relative humidity) were obtained from NIFOR meteorological station. The data were monthly averaged records.

2.4. Statistical Analysis

Multiple linear regressions were used to analyse the relationship between abundance of leaf miner and the following climatic variables: Temperature (°C), rainfall (mm) and relative humidity (%).Monthly means were computed.

3. Results

Relationship between the various insect stages (Larva, pupa and adult) and weather factors (rainfall, humidity and temperature) between 1976 and 1980 is presented in table 1. Larvae had a significant relationship (0.037) with rainfall, humidity and temperature in 1976. However rainfall made a more significant contribution. This was also the case for larvae, rainfall, humidity and temperature relationship (0.021) in 1977.

Table-1. Relationship between the Weather Factors and Leaf miner Stages from 1976-1980 in NIFOR

	1976		1977		1978		1979		1980	
Insect stage/Rainfall, Humidity temperature	**Gen. Sig.**	**Ind. Sig.**	**Gen. Sig.**	**Ind. Sig.**	**Gen. Sig.**	**Ind. Sig.**	**Gen. Sig.**	**Ind. Sig.**	**Gen. Sig.**	**Ind. Sig.**
Larvae vs Rainfall, humidity, temperature	Sig.037	RF	Sig. 021	None	NS	None	NS	None	NS	Temp.
Pupae vs Rainfall, humidity, temperature	NS	None	NS	None	NS	None	NS	None	NS	None
Adult vs Rainfall, humidity, temperature	NS	None	NS	None	NS	None	NS	None	NS	None

P = 0.05
Gen. Sig. – General significance
Ind. Sig. – Individual significance

Table 2 indicates a mathematical relationship between the insect stages (larva, pupa and adult) and weather factors (temperature, humidity and rainfall) between 1976 and 1980. Larva relationship with temperature, humidity and rainfall in 1976 is represented by the equation ($L=34.42-0.801X_1+ 0.015X_2- 0.156X_3$). From the equation, a unit change in X_1 (temperature) will reduce the number of larvae. A unit change in X_2 (humidity) will increase the number of larvae. In addition, a unit change in X_3 (rainfall) will reduce the number of larvae, while 35.42 is the number of larvae when temperature, humidity and rainfall are held constant. Pupa relationship with temperature, humidity and rainfall in 1976 is represented by the equation (P=20.36-0.560X_1+ 0.002X_2– 0.034X_3). From the equation, a unit change in X_1 (temperature) will reduce the number of pupa. A unit change in X_2 (humidity) will increase the number of pupa. In addition, a unit change in X_3 (rainfall) will reduce the number of pupae while 20.36 is the number of pupae when temperature, humidity and rainfall are held constant. Adult relationship with temperature, humidity and rainfall in 1976 is represented by the equation (A=6.13+0.199X_1+ 0.008X_2+0.095X_3). From the equation, a unit change in X_1 (temperature) will increase the number of adults. A unit change in X_2 (humidity) will increase the number of adults. In addition, a unit change in X3 (rainfall) will increase the number of adults while 6.13 is the number of adults when temperature, humidity and rainfall are held constant.

This implies that prediction can be made for the different leaf miner stages using their corresponding equations giving specific values for temperature, humidity and rainfall.

Table-2. Regression equations for relationship between Weather Factors and Leaf miner Stages from 1976-1980 in NIFOR

Year	Larvae	Pupae	Adult
1976	L=34.42-0.801X_1+ 0.015X_2– 0.156X_3	P=20.36-0.560X_1+ 0.002X_2– 0.034X_3	A=6.13+0.199X_1+ 0.008X_2+0.095X_3
1977	L=1.25-0.07X_1+ 0.003X_2– 0.003X_3	P=-1.44+0.08X_1- 0.02X_2+ 0.005X_3	A=40.55-0.81X_1- 0.12X_2-0.02X_3
1978	L=-9.86+0.21X_1+ 0.08X_2– 0.006X_3	P=3.39-0.18X_1+ 0.101X_2– 0.012X_3	A=-97.62+2.65X_1+ 0.66X_2-0.04X_3
1979	L=6.34-0.21X_1- 0.04X_2+0.004X_3	P=-17.7+0.29X_1+ 0.16X_2– 0.005X_3	A=67.4-0.87X_1- 0.27X_2+0.003X_3
1980	L=-57.88+1.38X_1+ 0.27X_2– 0.006X_3	P=-2.68+0.32X_1+ 0.11X_2+0.023X_3	A=-14.34+0.35X_1+ 0.43X_2-0.03X_3

X_1 – Temperature
X_2 – Humidity
X_3 – Rainfall

A mathematical relationship between the grouped insect stages (larva, pupa and adult) and mean weather factors (temperature, humidity and rainfall) between 1976 and 1980 is shown in table 3. There was a strong correlation (R=0.676) between larvae and weather factors. Pupae (R=0.488) and adult (R=0.393) had weak correlations with weather factors (Table 3). Larvae relationship with temperature, rainfall and humidity from 1976 – 1980 is represented by the equation (L = -24.527+ 0.003X_1 – 0.018X_2 + 0.519X_3). From the equation, a unit change in X_1 (temperature) will increase the number of larvae. A unit change in X_2 (rainfall) will decrease the number of larvae. In addition, a unit change in X_3 (humidity) will increase the number of larvae, while -24.527 is the number of larvae when temperature, humidity and rainfall are held constant. Pupae relationship with temperature, rainfall and humidity from 1976 – 1980 is represented by the equation (P = -57.748 + 1.140X_1 – 0.001X_2 + 0.458X_3). From the equation, a unit change in X_1 (temperature) will increase the number of pupae. A unit change in X_2 (rainfall) will decrease the number of pupae. In addition, a unit change in X_3 (humidity) will increase the number of pupae while -57.748 is the number of pupae when temperature, rainfall and humidity are held constant. Adult relationship with temperature, rainfall and humidity from 1976 - 1980 is represented by the equation (A = 64.391 + 1.715X_1 + 0.034X_2 – 0.445X_3). From the equation, a unit change in X_1 (temperature) will increase the number of adults. A unit change in X_2 (rainfall) will increase the number of adults. In addition, a unit change in X_3 (humidity) will decrease the number of adults while 64.391 is the number of adults when temperature, humidity and rainfall are held constant.

This implies that prediction can be made for the different leaf miner stages using their corresponding equations giving specific values for temperature, humidity and rainfall.

Table-3. Regression equations for relationship between mean Weather Factors and Grouped Leaf miner Stages from 1976-1980 in NIFOR

		Gen. Sig.	Ind. Sig.	Model
Larvae	R^2 = 0.457 R = 0.676	0.160	None	L = -24.527+ 0.003X_1 – 0.018X_2 + 0.519X_3
Pupae	R^2 = 0.238 R = 0.488	0.512	None	P = -57.748 + 1.140X_1 – 0.001X_2 + 0.458X_3
Adult	R^2 = 0.156 R = 0.393	0.698	None	A = 64.391 + 1.715X_1 + 0.034X_2 – 0.445X_3

P = 0.05
X_1 = Temperature
X_2 = Rainfall
X_3 = Relative humidity
Gen. Sig. = General significance
Ind. Sig. = Individual significance
R^2 = Coefficient of determination
R = Correlation coefficient

Monthly variation in temperature, humidity and rainfall with larvae, pupae and adult leaf miner in between 1976 and 1980 is presented in figures 1-9. Total seasonal distribution of the leaf miner is presented in figure 10.

As temperature decreased, larvae increased between March and June 1978. As temperature increased, larvae also increased with peaks in February and November 1980 (Fig. 1). It was observed that as temperature decreased, number of pupae also decreased with a noticeable drop in July between 1976 and 1980 (Fig. 2). Adult leaf miner peaked in the dry season months of 1977 (January), 1979 (December) and 1980 (November) respectively while it peaked in the rainy season in 1976 (July) and 1978 (September) (Fig. 3). As rainfall increased, larvae also increased in 1976 (September) and 1980 (Jan. – Mar.) (Fig. 4). As rainfall increased, pupae also increased in 1980 (May) (Fig. 5). Figure 6 indicates that peaks in rainfall in 1978 (July) and 1980 (June) showed a corresponding drop in adult leaf miner population. This could be as a result of breeding interruption and mortality. As relative humidity increased, there was a corresponding increasing increase in larvae during the period under review (Fig. 7). Figure 8 indicates that peaks in relative humidity corresponded with a decrease in pupae during the period. There was no clear trend in the change of adult population with respect to relative humidity. In 1977 (August), 1978 (July) and 1980 (August), there was a decrease in adult population. In 1976 (July) and 1979 (August), as relative humidity increased, there was an increase in adult population (Fig. 9). Leaf miner population was more abundant in the rainy season during the study period with a peak in 1978 for both leaf miner populations in both rainy and dry season (Fig. 10).

Fig-1. Monthly larval and mean temperature variation in NIFOR, 1976 - 1980

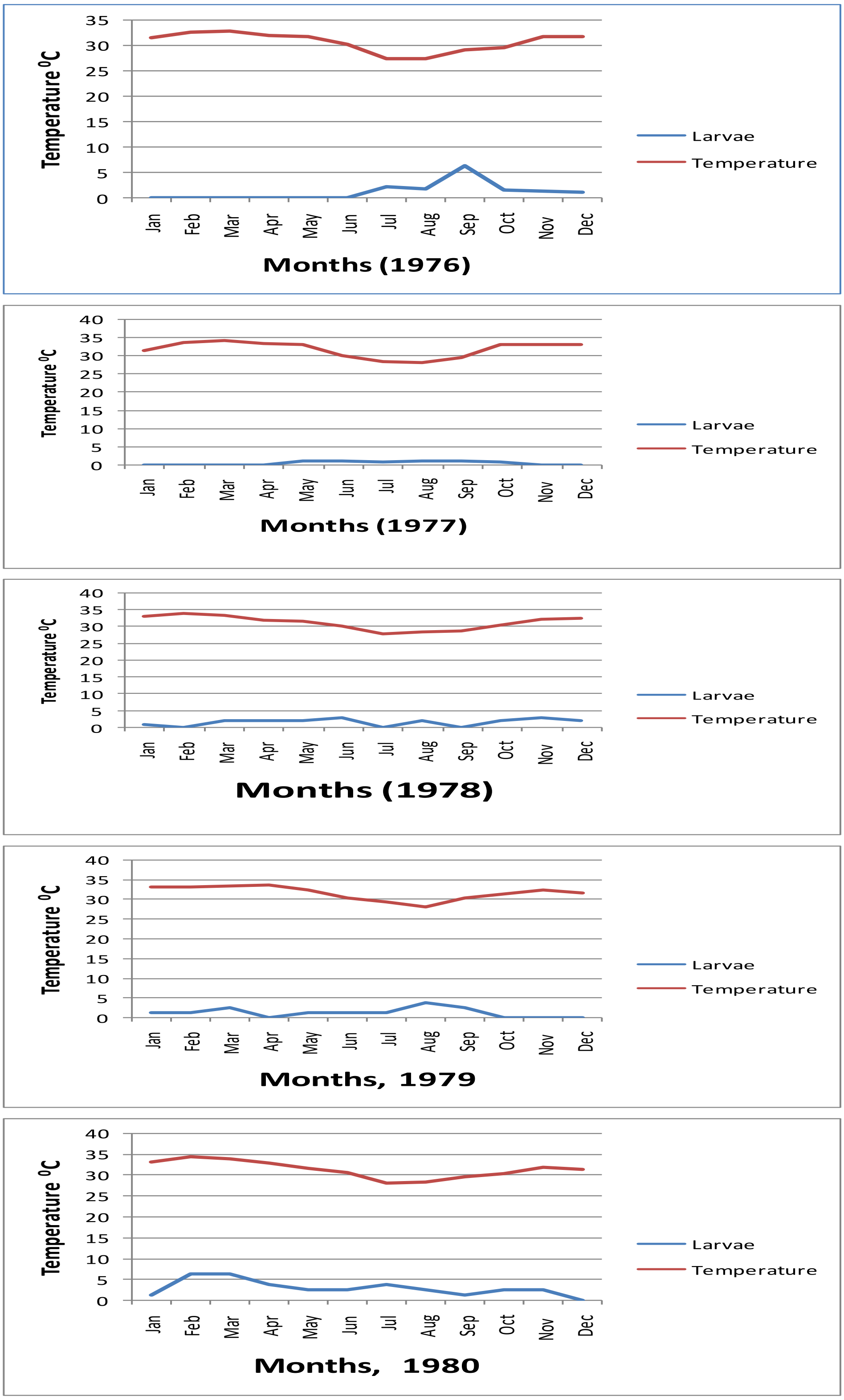


Fig-2. Monthly pupal and mean temperature variation in NIFOR, 1976 - 1980

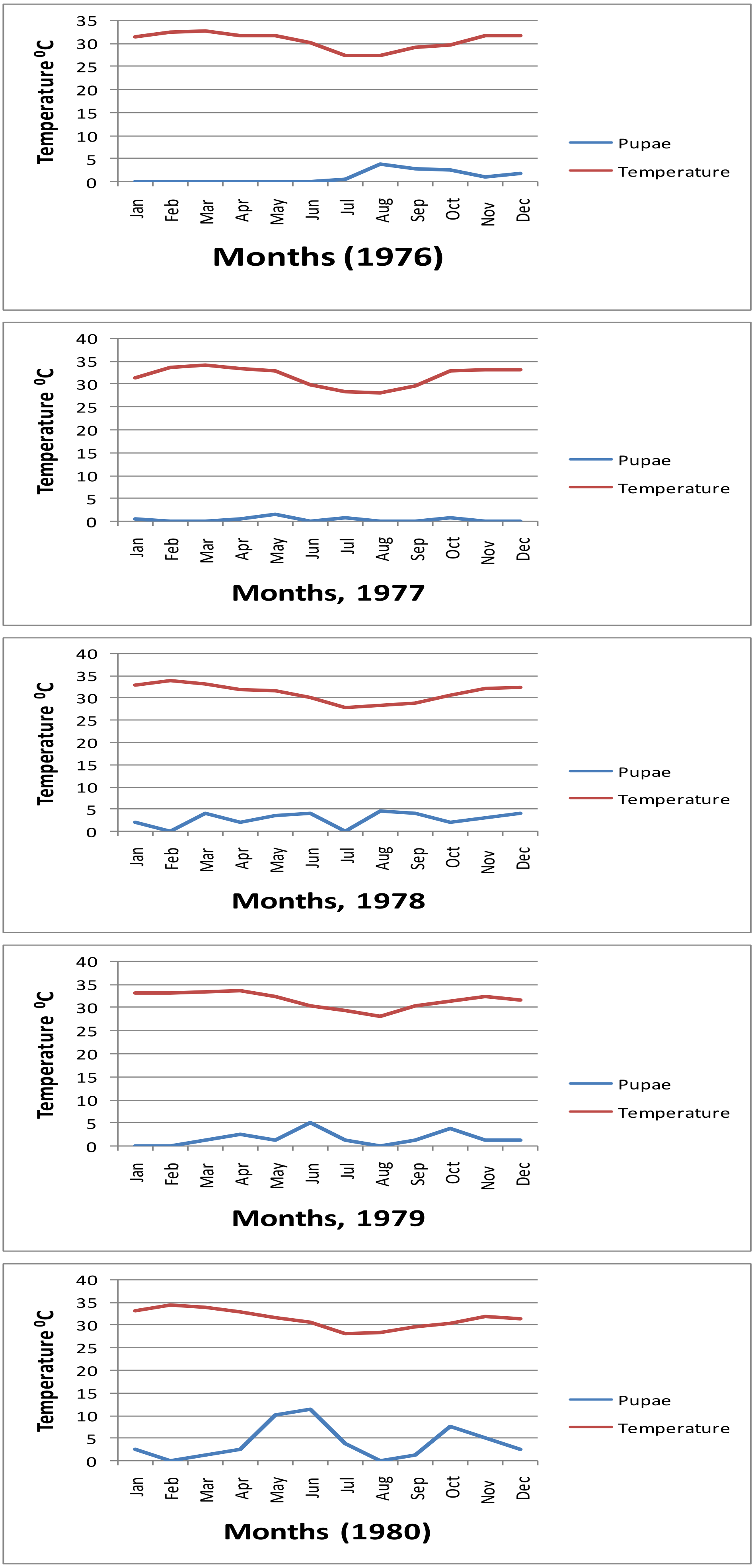


Fig-3. Monthly adult and mean temperature variation in NIFOR, 1976 - 1980

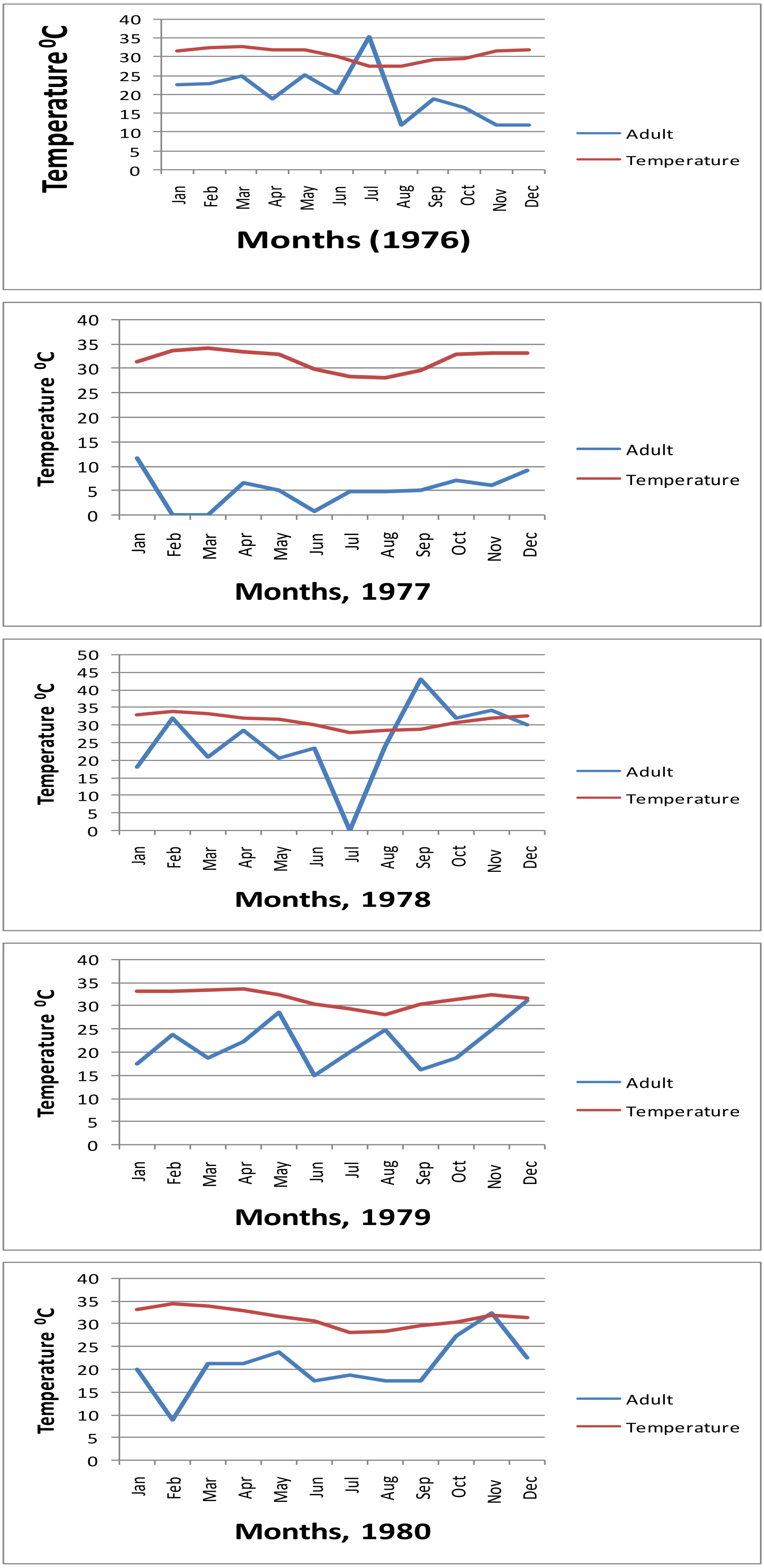


Fig-4. Monthly larval and mean rainfall variation in NIFOR, 1976 - 1980

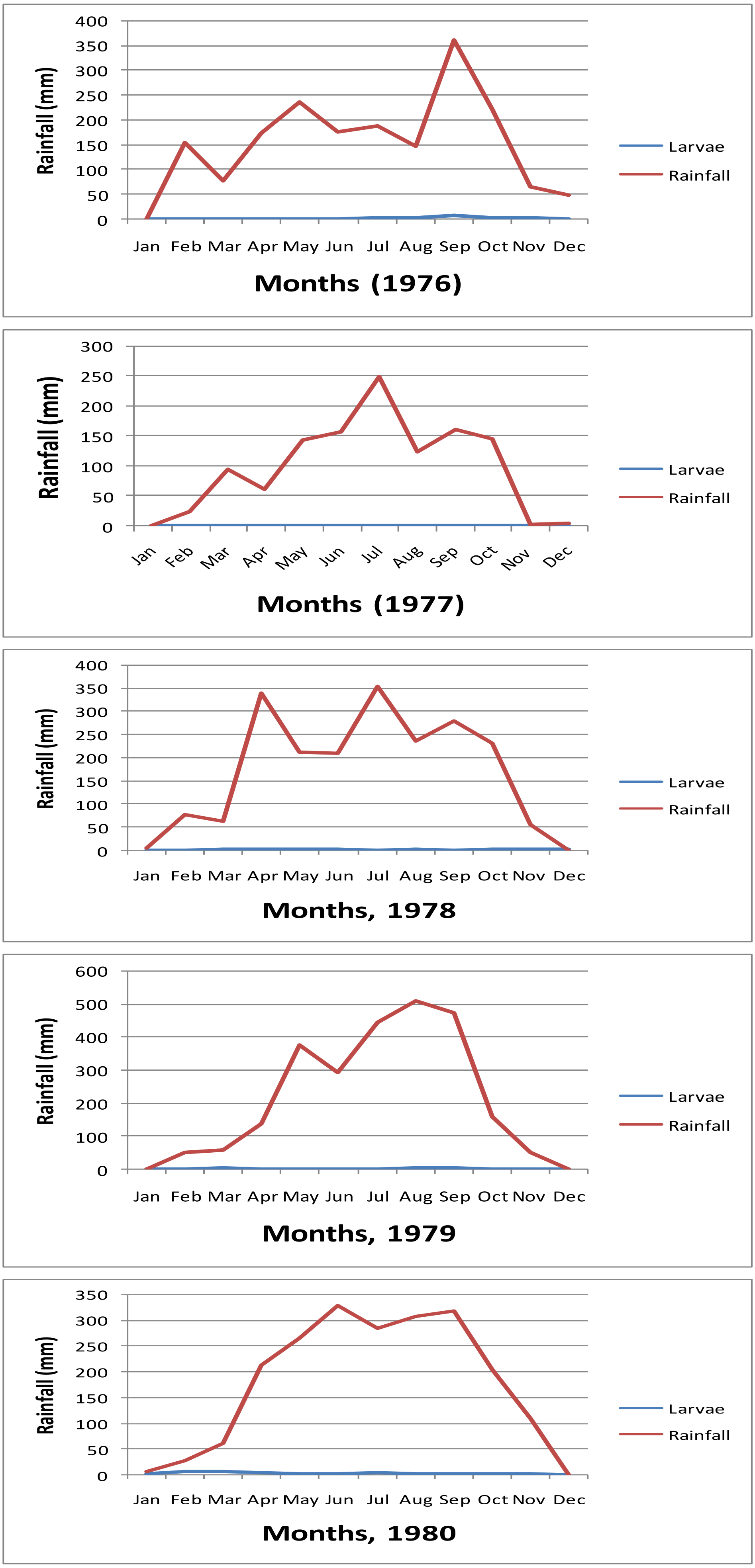


Fig-5. Monthly pupal and mean rainfall variation in NIFOR, 1976 - 1980

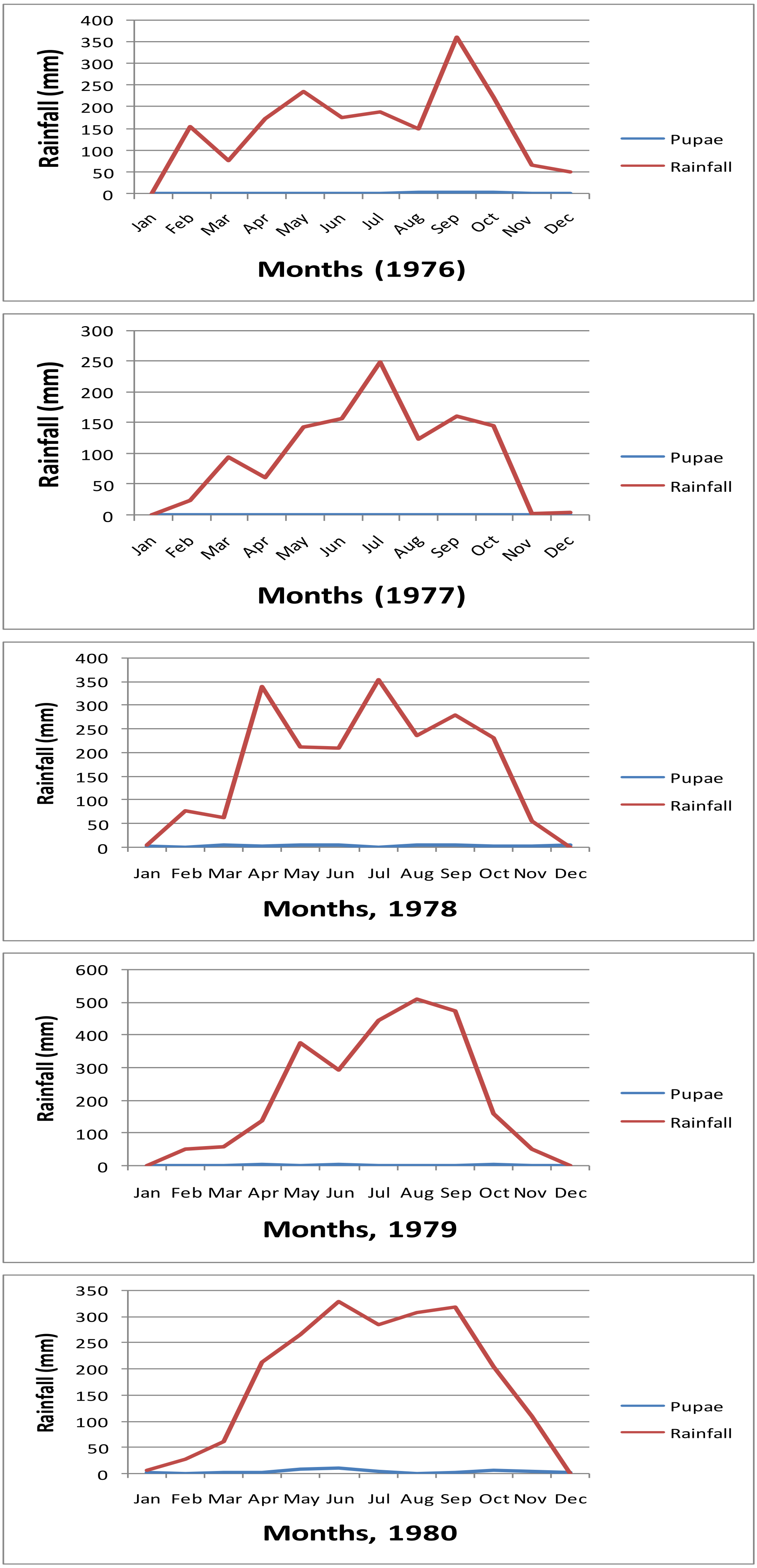


Fig-6. Monthly adult and mean rainfall variation in NIFOR, 1976 - 1980

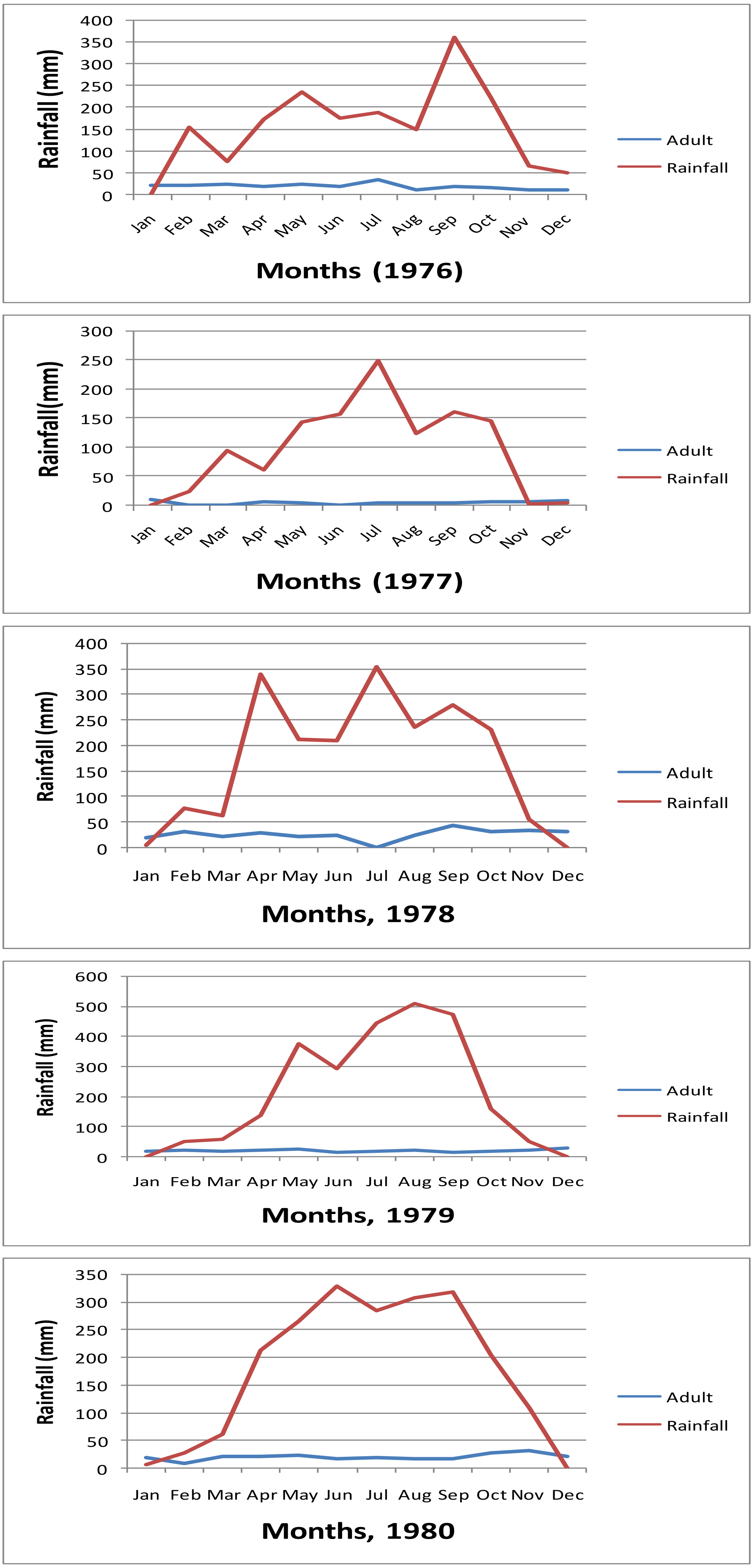


Fig-7. Monthly larval and mean relative humidity variation in NIFOR, 1976 - 1980

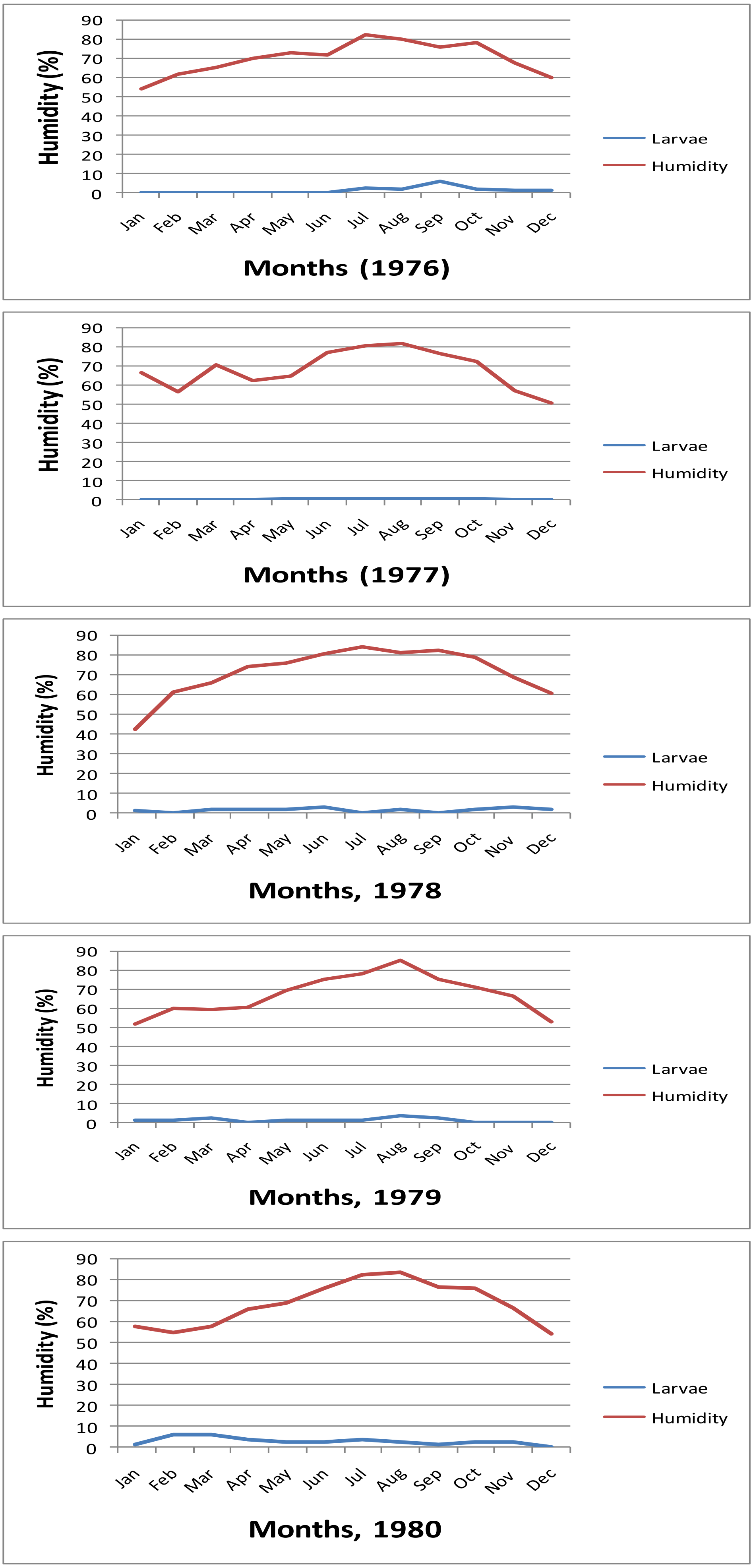


Fig-8. Monthly pupal and mean relative humidity variation in NIFOR, 1976 - 1980

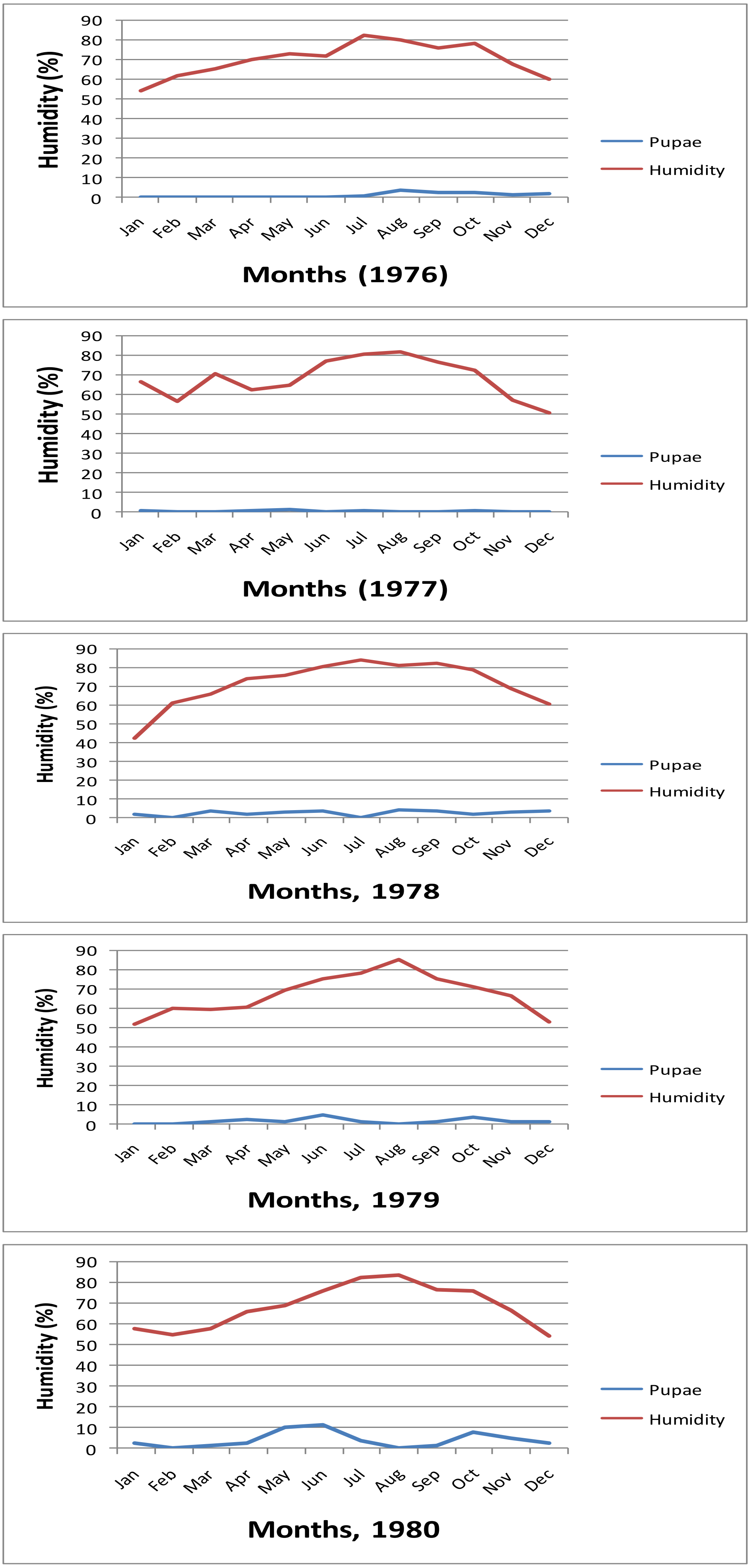


Fig-9. Monthly adult and mean relative humidity variation in NIFOR, 1976 - 1980

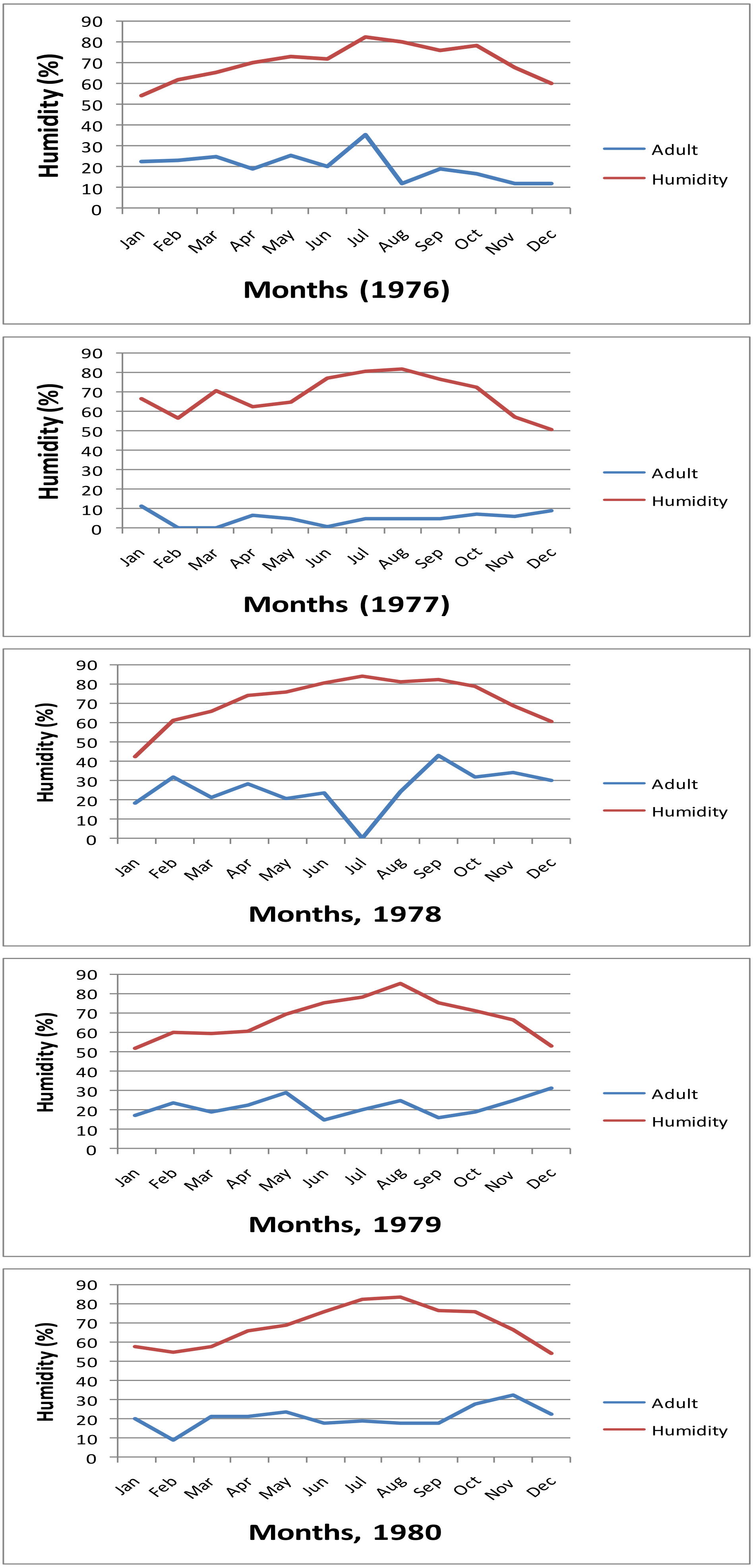
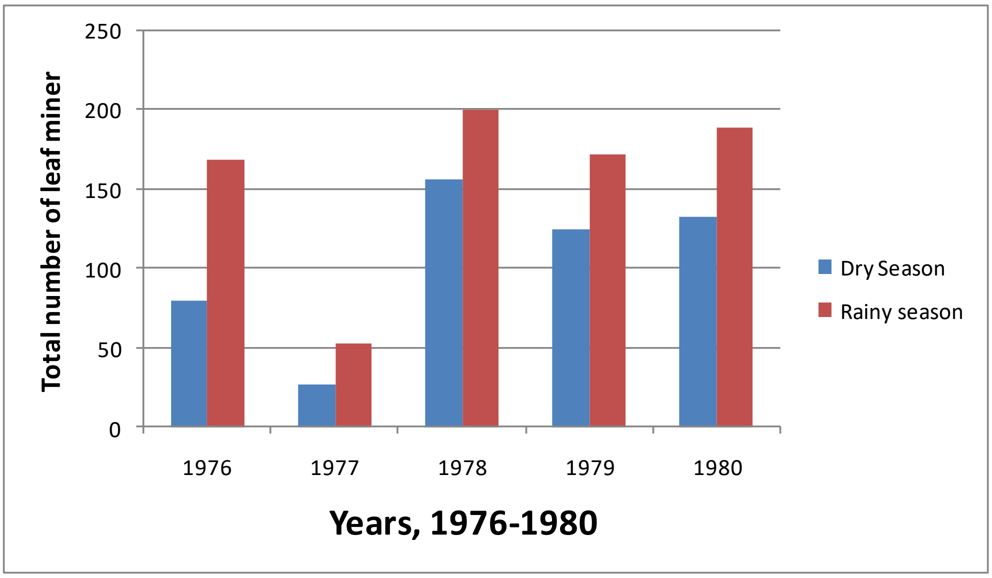


Fig-10. Seasonal distribution of leaf miner, 1976 - 1980



4. Discussion

Insect pests depend on adequate temperature (heat) and moisture (rainfall) for their growth and development. 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 [15-20]. 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. Larvae showed a gradually decreasing trend for the observed period. When this observation was correlated with the weather (temperature, rainfall and relative humidity) during these periods, it could be inferred that there was no proliferation as a result of weather. Pupae showed an increasing trend for the observed period. No feeding occurs at this stage. Adult analysis shows an increasing trend for the observed period. At this stage, the adults emerge from the leaflet mines into the environment. It could be inferred that adults are more sensitive to environmental conditions, and are more likely to proliferate than other leaf miner developmental stage. In general, most studies have concluded that future climate change is likely to produce an increased challenge to agriculture [21].

Mathematical relationships between the insect stages (larva, pupa and adult) and weather factors (rainfall and temperature) were developed indicating that pest predictions can be made for different leaf miner stages using their corresponding model equations giving specific values for rainfall and temperature. Variations in the seasonal patterns of temperature and rainfall are of major significance as a cue to timing leaf miner abundance. Climate and weather assessment is an important tool that times critical events for pest management, and would help in making better decisions regarding where farmer action can target pest control interventions, thereby contributing to ensure food security.

5. Conclusion

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. The need for continuous monitoring has great potential for control of insect pests in oil palm growing areas.

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