THE INFLUENCE OF CLIMATIC FACTORS ON THE INCIDENCE OF *CONIESTA IGNEFUSALIS* IN THE BAGAUDA AREA OF KANO STATE

BY

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DECLARATION

I hereby declare that the content of this thesis is a record of my research work. The subject matter herein has not been presented in any previous publication for a higher degree.

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CERTIFICATION

This Thesis entitled: "The Influence of Climatic Factors on the Incidence of Coniesta ignefusalis in the Bagauda area of Kano State " by EJEH Lawrence Udeh meets the regulation governing the award of the degree of Master of Science of the Ahmadu Bello University, Zaria and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my family

And

The Christian Faith

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"For none of us Liveth to himself, and no man dieth to himself" (Rom. 14:7). Our lives are all wrapped up in people and people's in ours. What we are today is a product of the various contribution(s) (be it directly, remotely, positively or negatively) of other people. Whichever way the contribution(s) are made "all things work together for good to them that love God, to them who are called according to his purpose" (Romans 8:28). I hereby, without pretence, acknowledge in order or chronologically, the immeasurable positive contributions of the people named in the following paragraphs.

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ABSTRACT

The growing problem of field pests and pesticide misuse in the savanna has been of great concern among scientists and scholars. In the Nigerian Sudan savanna, where traditional agriculture is widely practised, grain pest and use of pesticides are serious constrainsts to millet production because of:

i) low literacy rates of farmers in the study area

ii) low income of the farmers to embark on effective chemical control, and

iii) poor user understanding by the few farmers that could afford chemical control.

This work related the relationship between the incidence of Coniesta-ignefusalis (a major stemborer pest of millet) and environmental factors (weather factors) in the Bagauda area in the Sudan savanna zone of Nigeria. The pest was monitored for three cropping seasons (1995 to 1997) using pheromone traps on millet fields at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) station, Baguada, Kano, Nigeria approximately on latitude 1 l°40oN and longitude 8°30'N.

Pest and weather data for the three cropping seasons (1995 to 1997) were statistically analysed at three levels - the simple linear regression, the polynomial non-linear regression and the multiple linear regression. The pest population was predicted using the multiple linear regression approach.

The polynomial distribution was found to be the best method for determining relationship between single or individual weather parameter- and pest incidence in the study area. Results suggested that the availability of abundance of food and absence of natural

enemy has not been the only determinant in the incidence of the pests, and emphasise the importance of weather condition in assessing these effect. The incidence of the pest in the Nigerian savanna is weather dependent. Major climatic variables affecting the pest incidence in the Sudan savanna are rainfall relative humidity, radiation and temperature. The influence of rainfall was such that it correlated positively with both weekly and monthly data with r values greater than 50% in all the years of study (i.e. the higher the rainfall the higher the pest incidence). Rainfall amounts greater than 200mm were observed to hamper the pest incidence. The effect of radiation was such that it correlated negatively with the pest incidence for all the cases considered for 1995 and 1996 and 1997 monthly data with r-values greater than 50%. Radiation was, however, not statistically significant both at 5% and 1% level of significance for 1996 weekly data. Temperature influence was such that (Tavg) correlated positively with the pest for all the years of study i.e. an increase in (Tavg) leads to increase in the pest incidence (Tmin). (Tmax) is however, such that it correlated negatively with the pest incidence (i.e. an increase in (Tmax) leads to a decrease in the pest population) for 1996 data. The influence of relative humidity was such that it correlated positively with the pest incidence in all the cases for all the years of study (i.e. an increase in relative humidity leads to increase in the pest incidence). The weather variables do not work in isolation but influences the pest incidence simultaneously.

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CHAPTER ONE

1.1 GENERAL

The development of many crop pest is largely dependent on the weather of the area (Gilspier 1994). Most often the effects of adverse weather conditions on crops is viewed from the perspective of performance based on crop physiological development, growth and maturity. Little attention is given to the provision of conducive environment for field pest to thrive and cause greater damage to the crop.

The abundance of an insect pest is determined by the availability of food, fecundity, natural enemies and weather. During cropping season when food is available, the build up of any insect pest is strongly influenced by weather condition. This is because the presence and abundance of natural enemies are in themselves weather controlled. Several insect pest are known to infest millet (Peninsetum glaucum [L]) at different stages of the crop growth and development (Ajayi, 1990, Dike et. al., 1995, Youm et. al., 1993).

Coniesta Ignefusalis is a major destructive stemborer of millet most prevalent in the Sudan Savanna Agroecology (Fig. 1.1). Inspite of the extensive research on such cultural control as planting date alteration and intercropping, extensive application of insecticides, this insect pest reduce the yield and productivity of millet plant over the years. An over-view of total output of this crop in the Sudan Savanna from 1980 - 1998 (Table 1) shows a great fluctuation in production over the years. The decline in millet production in the Sudan is as a result of edaphic, socio-economic, and pest and disease.

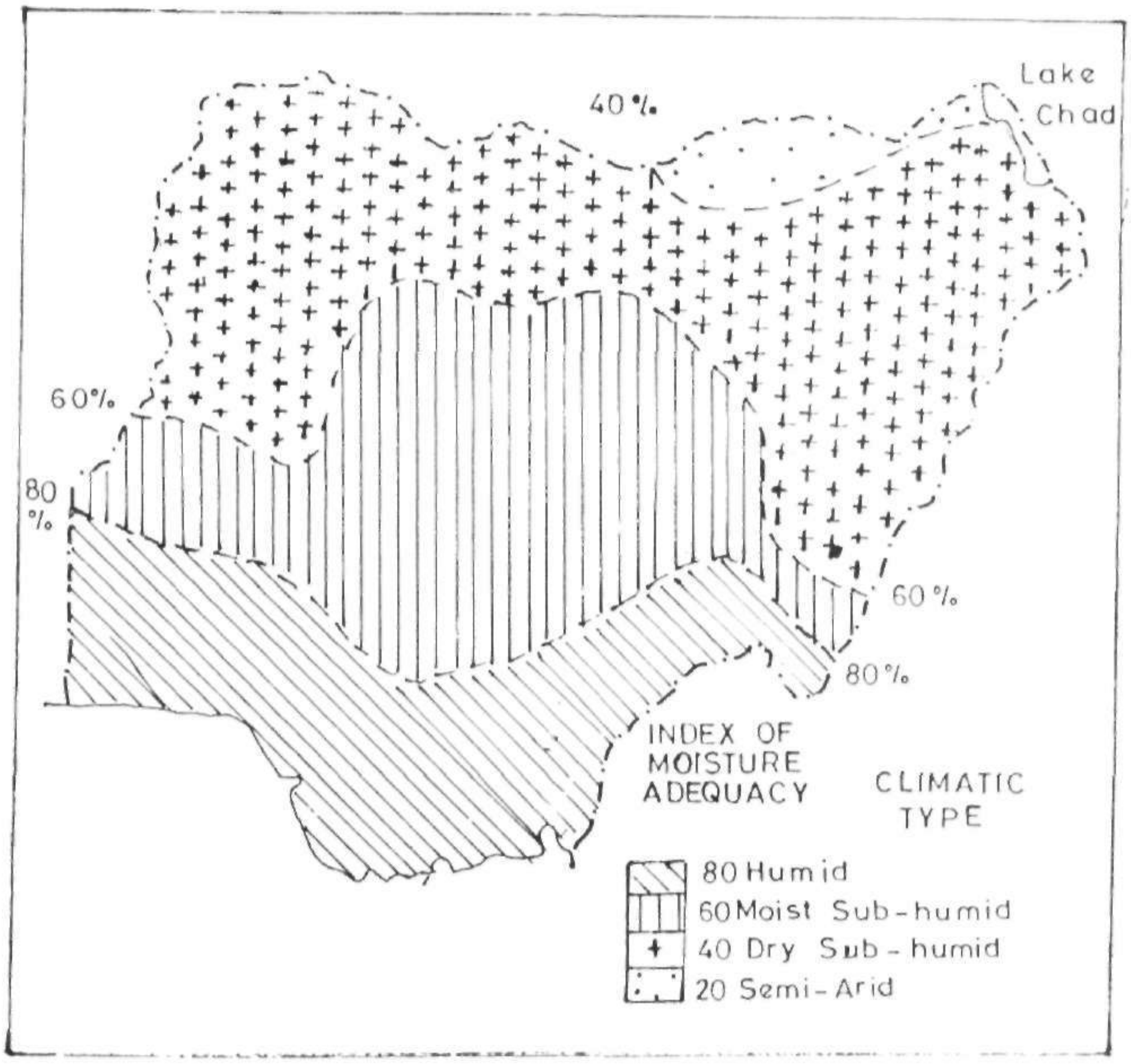

Fig 2 1 Moisture adequacy regions of Nigeria (Ayoade, 1973)

Table 1.1 **Estimated Output of Millet ('00 Tones) in Nigeria from 1980 - 1994**

Years	Total Out-put
1980	2354
1981	2682
1982	2666
1983	2783
1984	3349
1985	3684
1986	4111
1987	3905
1988	2334
1989	2905
1990	2366
1991	410
1992	4234
1993	4602
1994	4671

This current reduction in millet production is not only expensive but there is a threat to worsen this development, insect pest are quickly evolving resistance to chemical pesticides, hence a need to understand the insect population incidence/ecology. A knowledge of factors that inhibit or favour the build up of the insect population during the cropping season will enable us to manipulate the agroecosystem to the disadvantage of the pest (Singh et. al. 1974).

Pest and disease, particularly Coniesta Ignefusalis, have been a principal contraint to millet production in the Sudan Savanna zone of Nigeria (Youm, 1990). The type and symptoms of the borer depend on the stages of crop development and the borer's generation (Youm et. al. 1993). Under rainfed agriculture, weather is the most important factor affecting the incidence of any insect pest (Pedley and Belts, 1980, Renold et. al., 1982, Walker 1980). Weather directly and indirectly influences the activity and population build up of field pests.

Extensive works have been reported on the responses and development of crop insect pests to simulated weather conditions, most especially, temperature and humidity (Pruess 1983, Tamaki et. al. 1980, Yadav et. al., 1987). In the Baqauda area, the few survey works on field pests are mostly from the entomological point of view. Practically, very few attempts have been made to ascertain the effects of any physical (environmental) factor on the incidence of the adult stage of the pest coniesta.

Considering the importance of such information, both from practical utility and academic points of view, the present work was therefore initiated in the study area to monitor the incidence of the adult population of coniesta ignefusalis using climatic parameters.

1.2 AIM AND OBJECTIVE

The aim of this study is to determine the weather parameters that influences the incidence of the adult population of *coniesta ignefusalis* in the Nigeria Sudan Savanna with application to the Bagauda area of Kano, with a view to predicting future population of the pests in this area.

The objectives of this work includes:

i) To determine the conditions that may be responsible for the outbreaks of the millet pest in the Kano area of the Sudan Savanna.

ii) To estimate the level of infestation during the crops growing seasons and

iii) To recommend appropriate strategy for managing the pest.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Since the environment determines what crops are grown and what pests occur in an area climatological consideration are very essential in modern agriculture production programmes. This is because most agricultural decisions involves weather inputs from emergence through harvesting.

In any particular locations, seasonal variations in crop production are largely due to different weather patterns within and between years (Butter, 1996). For insects, such variations can be explained through understanding the insect-enabling environment. However, studies of these insects seasonal variation can be unclear and even complex because:

1. Insects are mobile and may originate from locations outside the area of immediate interest.
2. The pests also respond to their microenvironment for survival, reproduction and growth.

2.2 CLIMATE OF NIGERIA

The geographical location, size and shape of Nigeria allow it to experience most of the types of climate of West Africa. In other words, the climate of Nigeria is a microsum of that of West Africa.

The climate of Nigeria exhibits a definite wet season and marked dry season in response to the pressure patterns in West Africa. Belts of distinct weather exist from the coast to the Northern fringes, with great seasonal variations and fluctuations in response to the movement of the inter-tropical discontinuity (ITD) Fig. 2.

The ITD is the boundry between the dry tropical-continental (cT) air (Harmattan) of Northern origin, and the moist tropical-maritime (mT) air (Monsoon) of Southern origin. The dry harmattan dominates most parts of the north for a great part of the year. Each of the climate determine the crop grown and its associated pest in the area.

The climate of the area is the savanna type with alternating wet and dry seasons. The seasonal rainfall of this area is between 500mm to 1000mm per annum in only about five months (May to October) of the year. The rainfall is highly variable (in distribution, time and space) and the onset of the rains is highly erratic too. The rainfall intensity is very high between the months of July and August. As a result, apart from other constraints in millet production in the area, the crop is often lost through heavy and torrential rains (Ayoade, 1971, Ati, 1990). The rainfall of the area has been declining in the last thirty years.

The daily sunshine duration is 7 - 8 hours (Oguntoyinbo, 1983). The air temperature is consistently high with high evaporative demands. The mean annual temperatures of the area ranges between 17° and 32°C, however, high temperature of up to 42°C may occur in some months (April/May). A low temperature up to 5°C is also possible in some months (December/January). The mean monthly temperature of the study area drops slightly with

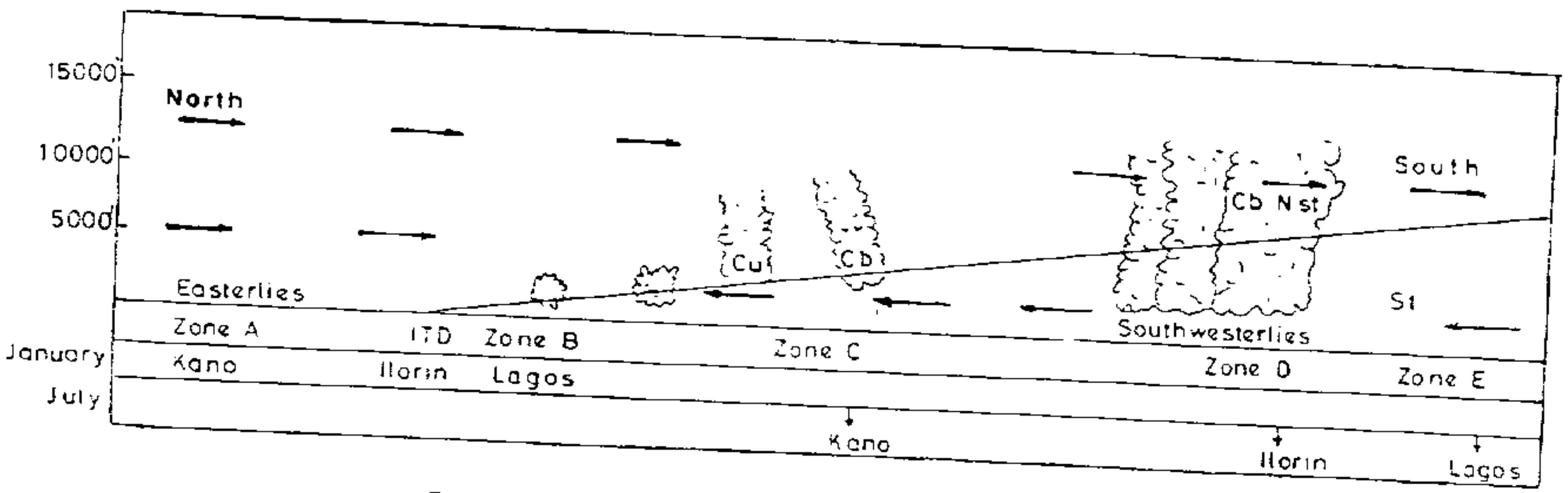

Fig. 2.2: The ITD and the weather zones

Source: Ojo, 1982

the rains in July, August and September. The high temperature have the effect of reducing activity of the pest due to increasing lassitude (Mortimore and Wilson, 1965, Sivaskulmer, et. al., 1991).

Relative humidity in the study area can be as low as 8% during the drier months, but usually high during the wet season.

2.3 THE AGROCLIMATOLOGY OF THE STUDY AREA

Bagauda, where the data for this study are collected, is located within the Sudan savanna bio-climatic zone, south of present Kano State, approximately on latitude 11°40N and longitude 8°30E.

The climate of this area is the savanna type with alternating wet and dry season which corresponds to Koppen's climate (la.....). Thus the great features of weather patterns (Rainfall, Temperature, etc) are usually in association with the inter-tropical discontinity (ITD) (Nicholson, 1981, Hayward, 1987, Kaynote, 1984).

The study area falls under zone A of the ITD between November and April (Fig. 2.1). This means that when the Northeasterly wind predominates, dry spells prevail. When the ITD moves sufficiently North by June and July, the area comes under the influence of zone B of the ITD, consequently the rain bearing wind prevails. The study area goes deeper into the ITD zone until the ITD begins its south ward retreat in response to the earth rotation. Dry condition then returns.

The movement of the ITD Northwards across this area between January and August, and its retreat from the Southern fringe of the Sahara desert after August cause this area to experience seasonal changes in rainfall vis-a-vis other climatic variables (Olaniran et. al., 1989). The rainfall of this area is less than 1,000mm per annum falling in only about five months in the year, specifically between May and October. Therefore, rain is a major determinant of the growing season and hence of the crops grown in this area.

The daily sunshine duration of the area is 7 - 8 hours (Oguntoyinbo, 1983). The air temperature is constantly high and falls slightly in the evenings hours (Ati, 1995). The mean temperature drops gradually with the rains in July, August and September.

The relative humidity can be as low as 8% during the drier months. The high temperature of the area have effect of reducing activities of the pest (Mortimore and Wilson, 1965, Silvakulmer et. al., 1991, Ati, 1995).

2.4 FARMING SYSTEM OF THE STUDY AREA

Agricultural practice in this area is a rythemic one centred on the passage of season (Yayock and Owanobi, 1986). Agriculture is largely subsistence and the land holding are small and fragmented.

The general cropping systems of the savanna are cereal-based and have evolved from shifting cultivation to continous inter-cropping (Boets, 199). Due to recent population pressure on land in the area, the amount of fallow land for this traditional cropping system has shortened. As a result, farmers are forced to adopt to the continous cropping system which enhance the population build up of grain pest in this area.

The cropping system of this area are cereal/legume mixtures mainly composed of sorghum, millet and cowpea. Millet may also be grown with sorghum in cereal/cereal mixture. In economic terms, the pearl millet (pennisetum americane [L]) is rated second most important grain crop in the study area. The predominant species is Gero (in Hausa). It matures faster than most sorghum and it requires little amount of rainfall (<310mm per annum).

The land area of millet cultivation in the savanna is estimated at over five million hectares (about 40% of the total land area) (Eghaverb, 1978) and an average yield in farmers field has been put between 300kg/ha to 1000 kg/ha. This area is leading producer of this crop. In 1993, it provided over 33% of the national output (Buker et. al., 1997). An annual production has been estimated between 1.75 million to 2.72 million tonnes (Nwasike et. al., 1982).

Most of the millet produce presently in this area is for home consumption. This area has great potential for higher output. The sustainable exploitation of this potential holds considerable promise for providing livelihood and food security for the people and meeting their increasing economic aspiration if well utilized.

2.5 SOWING OF MILLET

Two major types of millet are common in this area. These are:

1. Gero-short season millet (70 - 90 days maturity)
2. Maiwa - takes longer time to mature.

The optimum sowing date is not uniform throughout the region. The date of sowing follows the pattern of rain and the variety of millet in use. However, planting in the Sudan and Sahel savanna is latest, compared to other part of the savanna region. The middle of June is considered to be ideal time for sowing in the Sudan (Egharverb, 1978).

Millet in the area is either sole cropped or intercropped in various combination with grains and legumes. Most of the intercropped practices are either carried out as a check to the millet pest (Dike et. al., 1995) or as a supplement crop.

2.6 CONSTRAINTS TO FARMING IN BAGAUDA

Agriculture in the Bagauda area is largely rainfed and subsistence. Hence among other constraints (inputs, rainfall, pest and disease), rainfall and pest are the two major constraints faced by farmers in the area. Major source of water is the underground water being tapped through wells. The wells are generally sited at either interfluvial regions or stream beds, where water can be found at about 1 metre even at the end of the dry season or at the foot of inselbergs (Mortimore and Wilson, 1965). Thus irrigation practices are not easily within the reach of the poor farmers.

The area is predominantly a grain belt with varied pests. Over 100 pest are known to plague grain production in the savanna. Stemborers of many types constitute a major source of anxiety to farmers all over the area (Oguntoyinbo et. al., 1981).

They greatly militate against successful and profitable cultivation of many cereal crops in the area.

2.7 BRIEF BIOLOGY OF THE MILLET STEMBORER PEST CONIESTA IGNEFUSALIS

It has been observed that of the over 100 field pests of millet in the study area, *coniesta ignefusalis* is a major destructive stemborer (Harris, 1962; Brenieve, 1976).

The female moth lays about 200 eggs in a group on the leaf sheath and underside leaves. The eggs hatch within seven days. The larvae penetrate the whorl, feeds and move into the stem. The larvae, migrates from tiller to tiller and often infest all tillers in some farms. A single stand may harbour as many as 20 larvae. After completing development in about 30 to 40 days, the larvae pupates in the stem gallery. The pupal stage lasts for about seven to thirteen days.

Some second and third generation larvae go into facultative diapause in which they survive the hot dry month following the first rains. usually, the life cycle lasts for about 2 months in a single season, under condusive environment, two to three generations may occur.

Coniesta ignefusalis bores into the stem resulting in dead heart and profuse tillering with unproductive spikes. Late attacks of the pest results often in peduncle damages, plant breakage and losses of the grain. It has been observed that pearl millet tends to be immune to the stemborer attack at early stages of growth, and beccmes more susceptible to internode injury later.

Attacks from first-generation-developing larvae on small plants causes premature death with stand losses resulting from death hearth. Seconds and third generation attacks results in disruption of nutrient flow and increased susceptibility to secondary diseases transmission and incidence.

Field losses resulting from C. Ignefusalis damage range from 15% to total crop failure (Harris 1962; Ajayi, 1990; Dike et. al., 1995). Second generation larvae are destructive more to late millet (N'doye, 1991). The borers infestation on the crop does not seem to be altered by inter-cropping with sorghum or maize (Adesiyan, 1983).

In severely infested areas, for example, Ningi in Bauchi state, as reported by Dike et. al., (1996), there may be about 60% larvae per stem (ie an infestation intensity of Coniesta per plant), with 40% of tillers having crafty panicles and 60% of stalk broken or fallen to the ground (Dike, 1996).

Depending on the type of millet planted infestation may be as high as 100% on some farms (Dike, et. al., 1996).

In the Sudan savanna region, infestation has been found to be higher on millet inter-cropped with cereals than millet plus legumes.

Infestation rate and damage is usually higher on farms close to villages and where old millet stems are used for thatching and fencing using on farm counting of the pest population.

2.7.1 Other Host Crops

Coniesta ignesfusalis has been observed to attack majority of grain crops grown in the Bagauda area. It is a common pest of millet crop. When millet is inter-cropped with other grains like sorghum, the pest is found to attack sorghum and maize. Sorghum is the second (after millet) most common host crop. Infestation of sorghum is mostly in the absence of millet, especially in fields previously cropped with infested millet and/or sorghum/millet. Infestation of maize is not as severe as that of millet and sorghum.

2.7.2 The Pest Population within the Study Area

The field pests attacking millet crop are common throughout the savanna, but their incidence differs from place to place and from farm to farm. Rainfall, temperature and the vulnerable stage of the millet are among major factors responsible for the population build up in the area.

A survey on the incidence of this pest in 1995 and 1996 show an infestation percentage in the Sudan, Guinea and Sahel savanna as in Table 2.1

Table 2.1 Infestation Intensity of Coniesta within the Savanna Zone

	Zone	% Infestation
1.	Northern Guinea Savanna	52
2.	Sudan Savanna	18
3.	Sahel Savanna	4

Source: Farm Count Survey of Coniesta within the Nigeria Savanna by Ajayi, et. al., (1996), ICRISAT Nigeria (1996).

The survey also reveal that cultural practices, cropping systems and environmental factors are likely promoting factors of the pest incidence in the area. For example, it was observed that human settlements where previously infested stalks are used for fencing and thatching have severe on farm population incidence of up to 90%. This is because such practices encourage survival of large population of the pest which spend the dry and hot months in facultative larvae dispause within the stalks.

7.3 Farmers Perception of the Pest in the Study Area

Stemborers constitute a major source of anxiety to farmers all over the study area. They greatly militate against successful and profitable cultivation of the crop in the area.

Dike et. al. (1996) reported that most farmers in the area are adequately aware of the pest incidence and severity. The local name for coniesta ignefusalis among these farmers is Tsutsa. Farmers can, to some extent, describe the damage associated with the pest. They also know that the severity of infestation of the pest vary from year to year. They can tell a year of out-break. Dike, et. al. (1996) observed that despite the knowledge of the pest by farmers, they do not often apply stringent control measures like chemical treatment. This is due to the high cost of these chemicals.

However, some farmers apply some traditional measures such as:

1. Partial burning of stalks after grain harvest. This may kill about 90% of the total population.
2. Uprooting of stuble and feeding the stalks to animals before the onset of the rains. This tends to reduce the carry over of the stemborer to the next season.
3. Inter-cropping with legumes and cereals, especially with sorghum/maize. This tends to reduce the population concentration on millet as the pest also infest the legumes as alternative crop.

2.8 MANAGEMENT

Management of Coniesta Ignefusalis among farmers varies depending on the level of out-break in a particular year and the farmers financial resources.

The two major control measures often in use in the management of the pest in the study area are the use of cultural control such as residues management (burning of stalk or feeding of stalk to animals after harvest), alteration of sowing date, and inter-cropping.

Much work has been done on inter-cropping and sowing date as control methods (Ajayi, et. al., 1995, Ajayi, 1985, 1990, Elemo et. al., 1985, Luther 1993, Harris, 1965, Sharma, 1985).

Despite the extensive study in the area of cultural control, the pest has remained a major problem of pearl millet production every season. This is because most often, cultural control only attempts to reduce the severity of infestation per millet plant in the field. The use of chemical control has been proved very effective. Its major limitation is its non-availability within the reach of farmers due to high cost.

2.8.1 Monitoring

Monitoring of crop pest, can be done using numerous methods, ranging from traditional methods to more improved methods. For each particular insect, efficiency of management depends greatly on the choice of monitoring method. For most insects, entemologist have employed the use of light traps.

Generally, there are different methods of monitoring *coniesta ignefusalis* on field crops. These methods can be grouped into two major categories depending on the purpose and scope of investigation. These are:

1. Relative estimate monitoring
2. Absolute estimate monitoring

The absolute estimate monitoring is an indept investigation which is applied commonly in crop protection, it includes, egg monitoring, larval monitoring, absence and presence of death heart monitoring, and death-heart evaluation monitoring.

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In the relative estimate monitoring, pheromone traps are commonly employed. In Coniesta monitoring, the use of phenomone traps is preferred to the light trapping method because of the following limitations of the light trap:

i) The method can easily be affected by climatic factors such as wind-intensity and type of rainfall; and

ii) The light interference during moon face often hampers the attraction by the trap especially in those areas where there is clear sky that permits direct rays of the moon.

These limitations are overcome by the pheromone traps. However, monitoring system employing pheromone traps can differ in many respects such as choice of trap model, pheromone release system, trap area, trap location, and trap maintenance.

Trap elevation markedly affects the number of catches of the pest. The number of catch depends on the trap density, catch per trap increases with trap area and with the number of pest within the area. Individual pheromenon trap reflects the population level within the trap area (Tauzeane, 1980).

Apart from the substance that attracts the female pest from its hiding, the trap works with the direction of wind, hence the direction of the pest (Youm, 1983). This method is very sensitive to low density of the pest incidence and capable of detecting with great precision, on the start and end of the pest incidence.

2.9 WEATHER VARIABLES AND PEST RELATION IN THE STUDY AREA

Coniesta Ignefusalis is the most important pest of millet. The incidence of the pest, like most field pests, vary from place to place depending on the prevalent weather condition.

The two most important climatic element relevant to pest incidence in the area appears to be moisture and temperature. In general, pest does better when the temperature is high under condition of optimum water supply (Oguntoyibo, et. al., 1989). Other climatic factors which influences the incidence of field pest are; wind, rainfall, relative humidity and radiation.

2.9.1 Temperature

A lot of attempted works has been reported on the responses of organism to temperature (Singh et. al., 1988, Dolebel 1984, Pruess, 1983). The development and activity rate of field pest like other organism is proportional to temperature above the threshold (Kenneth P. Pruess, 1983). This threshold differs from field pest to field pest. This assumption is often not true in all cases (Logan et. al., 1976). This is because of the varying field condition of the different field pest.

It has been reported that both maximum and minimum temperatures significantly affect the adult fly of field pest (Lhan, et. al., 1980; Gahukar, 1987, Singh, et. al., 1988; Dolebel, 1984; Sukhatine, 1985, Nair et. al., 1993). Yadav 1986, working on some field pest reported that longer duration of pest and their activity occur in a moderately low temperature period, while pest activity is slowed down during a longer and high temperature periods. Ogunwole, et. al., 1998 working on some field pest in the Northern Guinea savanna reported that the influence of temperature on the population build up of the field pests was not significant, though an average temperature within the range of 22 to 24°C seems to favour the activities of the insects pests. A sudden drop in temperature after a higher inhibiting temperature may favour the activity of the insect pest in the study area (Oguntoyinbo, 1986, Ogunwole, and Onu, 1995).

2.9.2 Rainfall and Wind

Most authors have reported that light rains are generally favourable to adult flight of field pest and that heavy driving rains may destroy the adults (Hinds, 1928, Neiswander, 1952). Although beating rains accompanied by high winds are destructive to adults pests, the moths are able to cling to the undersides of leaves so that mild showers or storms of medium violence are endured without great mortality. The detrimental effect of high rainfall intensity is either by washing away of the eggs or mortality of the adult population. This consequently reduce the adult population (Sukhan, 1986, Gahukar, 1987, Dolebel and Lubega, 1984). However, Singh and Veuma (1986) observed that rainfall is significant for adult population and egg laying. Their observation is, however, for rainfall in general not regarding the intensity.

Thompson and Parker, 1928, Neiswander and Hibbs, 1950, Neiswander, 1952, Hibbs, 1950 and Weakman, 1957 working on the European cornborer (Ecvz) found that heavy rains causes "Abrupt end" to the second flight of the adult population.

Thomas et. al., 1983, working on the European cornborer, observed that rainfall storm accompanied by moderately violent winds (65 to 80m/h) destroy much of the adult population during flight. While relatively light precipitation with mild wind (0 to 15km/h) is favourable. Thus like rain fall, wind speed also significantly influence the population build up of field pest. ogunwole, et. al., 1998, working on some field pest in the Northern Guinea savanna of Nigeria, observed that wind speed correlated negatively with the insect pests build up. And that heavy wind seems to hinder the activity of some of the field pest. While some insect pests in the study area might not withstand wind speed above $150 km/hr^{-1}$, some can withstand a wind speed about $200 kmhr^{-1}$.

2.9.3 Relative Humidity

Moist or dry conditions have a controlling influence on pest population. High relative humidity create a conducive environment for some pest in the study area and also adversely affect the population build up of others. Shieshanghin, et. al. (1981) reported that some adult pest are more active at 70 - 80%. Relative Humidity but die off when RH reached saturation for 2 (two) consectuve days. Ogunwole, et. al., 1998, working on some field pest in the Northern Guinea savanna of Nigeria, reported that low relative humidity creates conducive environment for the build up of the insect pests, while a high relative humidity affects their population growth.

2.9.4 Sunshine

It has been reported that bright sunshine is highly significant for activity of the adult pests (Delobel and Lubega, 1984). Thus, as the bright sunshine hours increase up to 12 hours, there is corresponding increase in pest activity, especially in the morning hours. This is because increase in bright sunshine hour result in increase in canopy, plant and soil temperature which do have favurable effect on flying activity (Delobel and Lobega, 1984).

CHAPTER THREE

MATERIALS AND METHODS

3.1 LOCATION

The data for this study is collected at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Station, Baqauda, Kano approximately located on latitude 11°40N and longitude 8°30E.

The study area and its surrounding region is located within the Sudan savanna bio-climatic zone of the present Kano State.

3.2 PEST DATA COLLECTION

Population incidence of Coniesta Ignefusalis in Bagauda, Kano, Nigeria was monitored using pheromone traps. The monitoring was carried out on a millet farm of the institute.

Two traps were used for the monitoring. The traps were strategically positioned (along the rows) and spaced apart. The traps were placed at distances of 10, 30, 50, 100 and 300 metres away within the pest habitat (millet farm). The spacing of the trap was to avoid interference in the trap catches and to observe the effect of trap distance on the pest catch. The choice to position the traps within the pest habitat (within the millet farm) is to achieve maximum monitoring of the pest within the area. The monitoring covered three cropping seasons (1995, 1996, 1997).

The number of pest caught was counted daily.

The insects caught were destroyed every day after counting to avoid double counting of the population.

3.3 WEATHER DATA MEASUREMENT

The weather data was collected insitu using standard meteorological instruments. The decision to collect the data locally (i.e. on site) instead of using available data from the existing meteorological stations covering the area (Bagauda) is to obtain more precise information related to the incidence of the pest during the period of study.

The weather parameters were monitored daily covering the period 1995 through 1997. The weather parameters monitored for this study include temperature, rainfall, wind speed, radiation, and relative humidity. Each weather parameter was measured using the appropriate instruments mounted into an automatic weather station (Campbell 21x data logger) as follows:

Temperature	Temperature Sensor (Model 207, RH & Temp. Probe)
Rainfall	Tipping bucket-Rain gauge
Humidity	Humidity Sensor (Model 207, RH & Temp. Probe)
Wind speed	An Anemometer (Cup Anemometer)
Radiation	PAR Radiometer (LI2ROS Li-cor Pyron meter)

3.4 DATA ANALYSIS

Data obtained during the period were statistically analyzed using simple statistical regression analysis.

The various meteorological parameters, namely, maximum temperature (T_{max}), Minimum Temperature (T_{min}), Maximum relative humidity (RH_{max}), Minimum relative humidity (RH_{min}), average relative humidity (RH_{avg}), average temperature (T_{avg}), rainfall, radiation and wind speed were analyzed (regressing the pest population on the climatic variables), using the linear and non-linear regression statistics on weekly and monthly bases for the three cropping seasons (1995-1997) to determine the effect of the individual variable on the pest incidence. Their correlation coefficient (r) were also calculated.

A combined and step wise analysis were also done to investigate combine effect of the various climatic parameters on the pest population and to investigate possible effect of variation(s) within the climatic parameters on the pest population. Their correlation coefficient (r) was also calculated.

The simple linear regression model was used separately on each of the variables for each of the year (on weekly and monthly basis) to investigate which variable have a strong influence on the population incidence of the pest in the study area. The model is defined as;

$$Y = \beta_o + \beta_1 X_1 \quad \text{.......} \quad (1.1)$$

This mathematical expression implies, however, an exact relationship (i.e the function of X predicts a value of Y exactly equal to the observed value of the dependent variable (Croxton et. al. 1988; George, et. al. 1980), *since such relationship may not be* achieved practically, the polynomial (non-lonear regression) model which allows for error bands were employed to investigate the relationship between the pest population and each climatic variable (Jeffrey et. al., 1989, Croxten et. al., 1988). This model is defined as:

$$Y_1 = \beta_o + \beta_1 X_1 + Ei \quad \text{.......} \quad (1.2)$$

where: Y_i = Value of the dependent variable for the ith observation.

X_i = Value of the independent variable assumed to be measured without error.

$\beta_o \beta_i$ = The intercepts and slope parameters of unknown constant parameters of the system.

E_i = The error term for the ith observation which is assumed to be a random variable with a mean of zero and a variable of 02E.

In order to show the degree of association or direction of relationship between the climatic variables and pest population, the simple linear correlation coefficient or pearson product-moment correlation coefficient (r) was computed.

$$r = \frac{\Sigma X_i Y_i - \frac{\Sigma X_i \Sigma Y_i}{n}}{\sqrt{\left(\Sigma X_i^2 - \frac{(\Sigma X_i)^2}{n}\right)\left[\frac{(\Sigma Y_i^2)}{n^2}\right]}}$$

In order to find out the combination of possible climatic variable(s) strongly influencing the pest population, the multiple regression analysis was employed (Jeffrey et. al., 1989). This was done by regressing the dependent variable (Y) pest population, against the independent variable (X) climatic variable.

$\sum(Yi) = \beta_o + \beta_1 X_1 + \beta_2 X_2 \; ..... \; \beta_h X_k$ .... (1.4)

Where: K = Number of independent variables

i = The element number as before (i.e. number of observation).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 WEATHER PATTERN OF THE STUDY AREA DURING THE YEARS OF STUDY (1995-1997)

Weather pattern in the study area during 1995 to 1997 exhibited definite wet and dry seasons characteristics of the savanna region of Nigeria.

Table 4.1: Weather Pattern of the Study area during the period of Study (1995 to 1997).

	YEARS			
	1995	**1996**	**1997**	**Average**
RFsum (mm)	837	833	895	855
RFmax (mm)	103	131.30	162	132.1
RFmin (mm)	0.00	0.00	0.00	0.00
RF (mm)	22.62	22.51	24.19	23.12
Tmax (°C)	39.40	40.10	39.40	39.6
Tmin (°C)	8.90	8.20	10.20	9.10
T (°C)	32.20	18.00	32.20	27.50
RHmax (%)	81.20	65.70	50.00	65.60
RHmin (%)	7.40	6.5	7.00	7.00
RH (%)	58.00	17.0	30.00	35.0
SWmax (k/hr)	3.6	1.84	8.60	4.68
SWmin (k/hr)	0.90	0.51	1.00	0.80
SW (k/hr)	1.71	1.10	1.99	1.60
PP (Sum)	1337	1942	593	1291
PP max	335	643	227	402
PP mm	0	0	0	0
PP	36	53	16	35

From Table 4.1, the mean rainfall during the 1995-1997 period of study was 855mm. The rainfall varied slightly for each of the three years. Studies by Kowal and Knabe (1972), however, showed rainfall at nearby Kano to range from 750m to 886.5mm per year. This present variation in annual rainfall is due to recent general rainfall decline in the region (Shaib, et. al., 1997).

The temperature pattern during the period of study exhibited a constantly high temperature range (see Appendix 3). This agrees with the findings of Ati (1990), and Oguntoyibo (1983). The mean maximum temperature for the period (1995 to 1997) was 39.6°C. The highest annual maximum and minimum temperature for the same period was 40.1°C and 8.2°C respectively. The year 1996 showed slight deviation in the temperature pattern from the rest of the years (Table 4.1). The average temperature for the study period was 27.5°C. The temperature regime in 1995 and 1996 were similar.

The relative humidity (RH) condition in the study area during 1995 - 1997 study period conformed to earlier reports of workers in the area (Ogunwole and Onu, 1998, Ogunwole, et. al., 1997). The mean maximum relative humidity (RHmax) for the study period was 81.2%. According to Singh et. al., (1987), adult pest fly is more active at relative humidity of about 60 - 70%. The maximum relative humidity varied greatly within the years. The year 1995 experienced the highest RHmax (81.2%) while the lowest RHmax was recorded in 1997 (50%) see Table 4.1.

The lowest RHmin for the period was 7%. This agrees with Oguntoyinbo (1983) who reported 8%. The average relative humidity (RH) i.e. the mean ratio of actual amount of water vapour contained in the air to the amount the air would hold if it were saturated at the same temperature) for the years of study was 35%. The pattern of average relative humidity during the period of study exhibited a general variation. The year 1995 has the highest relative humidity (81.2%), while 1996 recorded the lowest relative humidity (17%).

The wind speed pattern during the years 1995 - 1997 showed great variations. The average wind speed for the period was 1.6km/hr.

From Table 4.1, it can be deduced that the general weather pattern for the period of study (1995-1997) exhibited similarities in rainfall across the years. However, temperature and wind speed varied substantially from year to year.

4.2 MICROMETEREOLOGICAL ELEMENTS AND THE PEST INCIDENCE DURING THE PERIOD OF STUDY (1995 - 1997)

From the pest and weather data processed for the three cropping seasons (1995 to 1997), the incidence of the pest begins with an initial small population at the start of the rains, and increased gradually as the rain progresses vis-a-vis changes in other weather condition and then decline with the end of the rains in October or November (see Appendix 5). At the end of the rains, the dry and harsh weather begins to set in. The air temperature increases with decreasing rainfall amount and frequency.

There seems to be a build up of the pest as the rains progress from June to October. This suggests that a humid condition is favourable for the incidence of the pest in the study area. This result agrees with the findings on other field pests else where by Ogunwole, et. al. (1985), Owonubi et. al. (1995), who both reported a high positive correlation (r->50%) between rainfall and the field pests.

Most of the parameters were found to significantly correlate positively with the pest incidence for all the years and in both cases (weekly and monthly), using the polynomia non-linear regression and the correlation matrix statistics (Table 4.2 and 4.3).

Table 4.2 **Correlation Coefficients of the Relationship of the Pest Incidence and the Weather Variables using the Polynomial non-Linear Regression**

			1996		1997	
Weather Variable	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Tavg	0.3817**	0.6609*	0.2205*	0.9780**	0.2916*	0.5037^NS
Tmin	0.4598**	0.6690*	0.3933**	0.6144**	0.3582**	0.5514^NS
Tmax	0.5214**	0.5214^NS	0.5214**	0.5215^NS	0.5215**	0.5215**
RHavg	0.5133**	0.7072**	0.5383**	0.9989**	0.4381**	0.6926**
RHmin	0.6792**	0.9704**	0.3964**	0.6127*	0.3234*	0.5072^NS
RHmax	0.4588**	0.6900	0.5412**	0.7868**	0.4400**	0.7231**
Rainfall	0.9923**	0.9923**	0.9923	0.9923**	0.9923**	0.9923**
Wind speed	0.8143**	0.8143**	0.8143**	0.8143**	0.8143**	0.8143**
Radiation	0.7672**	0.6851**	0.2464^NS	0.5925*	0.1435^NS	0.4455^NS
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.3 **Correlation Coefficients of the Relationship of the Pest Incidence and the Weather Variables Using the Correlation Matrix Statistics**

Weather Variable	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Tavg	0.6241**	0.5206NS	0.5210**	0.8971**	0.6581**	0.6302*
Tmax	0.7319**	0.7604**	0.5659**	0.6912**	0.3442*	0.8650*
Tmin	0.2289^NS	0.4297^NS	0.2544^NS	0.4077^NS	0.4112**	0.3164^NS
RHavg	0.5668**	0.6613*	0.5745**	0.9997**	0.5390**	0.7205**
RHmin	0.7040	0.8536**	0.4151**	0.6334*	0.7103**	0.8256**
RHmax	0.3693**	0.6454*	0.5875**	0.8107**	0.4355**	0.7052**
Radiation	0.8220**	0.8477**	0.3336*	0.6885**	0.5002**	0.7085**
SW	0.5238**	0.1746^NS	0.4342**	0.5863*	0.5001**	0.3500^NS
Rainfall	0.695**	0.9909**	0.5042**	0.6259*	0.5321**	0.7286**
T0.05	0.277	0.553				
T0.01	0.351	0.684				

4.2.1 Relationship between Rainfall and Pest Incidence

Using both the polynomial statistics and the correlation matrix the relationship of rainfall and the pest incidence was such that rainfall correlated positively with the coniesta pest throughout the three years of the study with r-values greater than 50% (Table 4.4).

Table 4.4 **Rainfall Correlation Table for Weekly and Monthly Pest Incideace during 1995 to 1997**

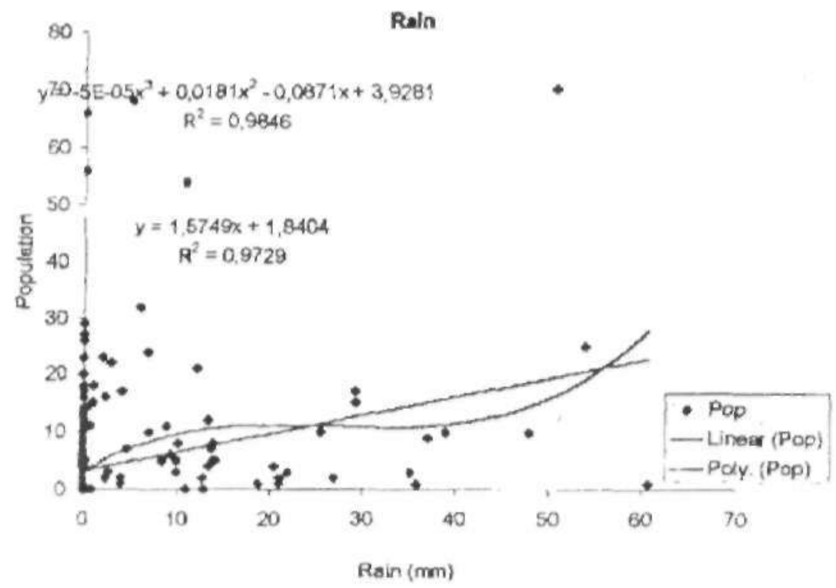
Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.9923**	0.9923**	0.9923**	0.9923**	0.9924**	0.9923**
Correlation Matrix	0.9923**	0.9923**	0.9923**	0.9923**	0.9923**	0.9923**
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

The influence of rainfall was such that it correlated positively on both weekly and monthly data in all the years of study (Fig. 4.1). These results are in agreement with the finding of Ajayi (1996) who reported a correlation coefficient greater than 50%. However, this does not agree with Dolebel (1984) using rainfall intensity.

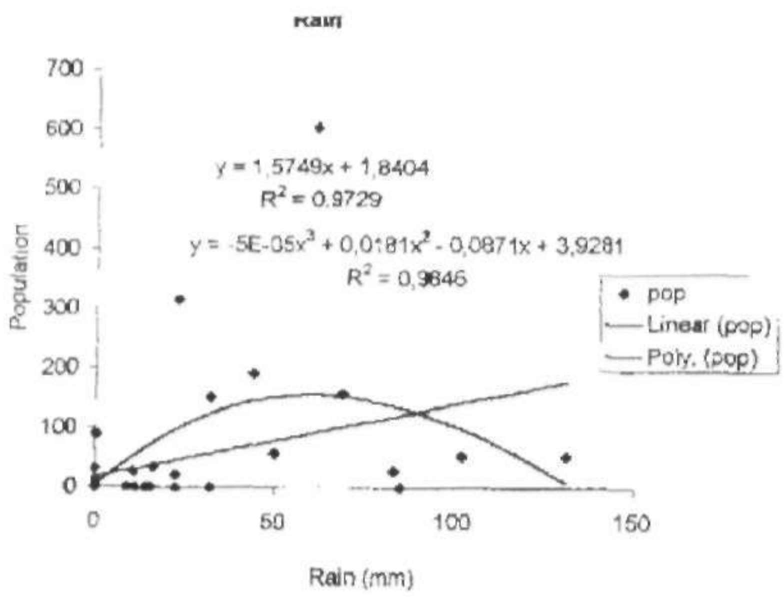
It was observed that rainfall amount greater than 200mm probably from a consecutive rainfall, tends to hampered the pest incidence and build up. This might have explained the fluctuation or inconsistences in the daily count of the pest within the rainy months (Appendix 5). The days of erratic populations are periods of rain breaks (normally > 2 days). Similar results have been reported else where on other field pest by Singh and Balan (1986), Sukhani 1986.

Fig. 4.1: Weekly and Monthly Rainfal and Pest Relation Graphs

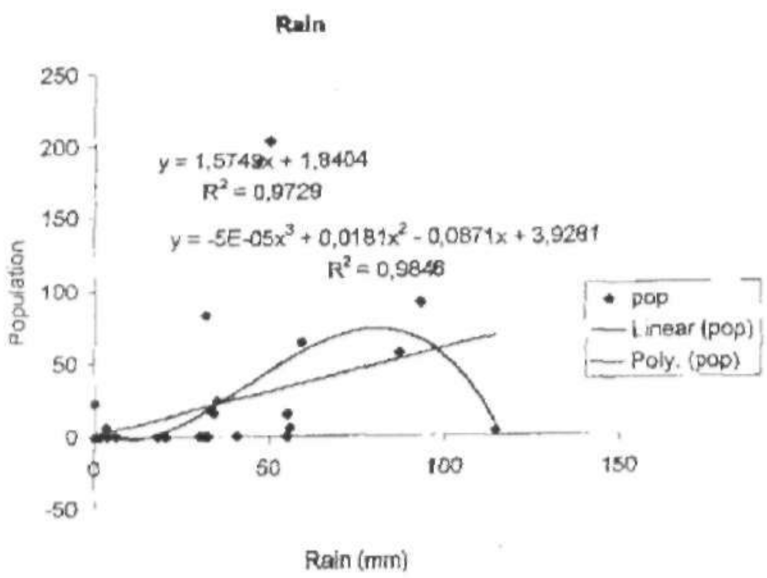
Weekly 1995



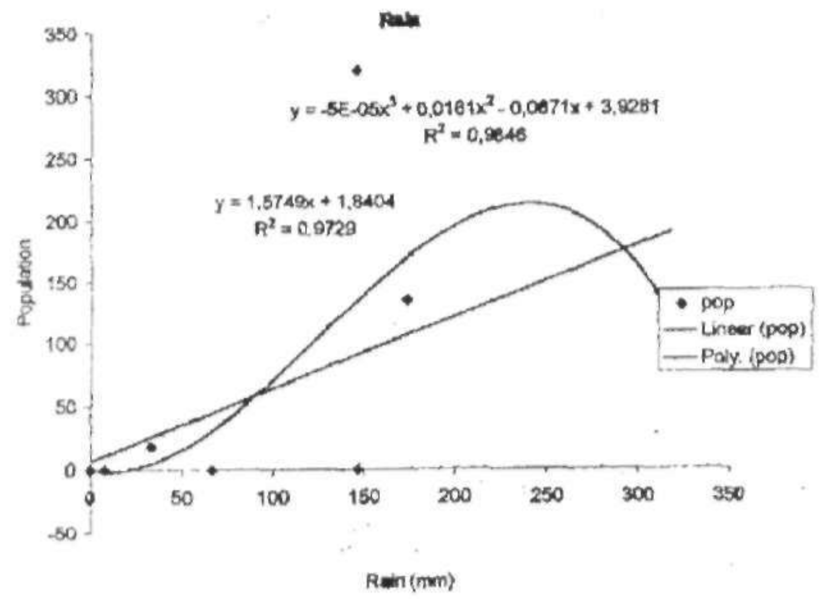
Weekly 1996



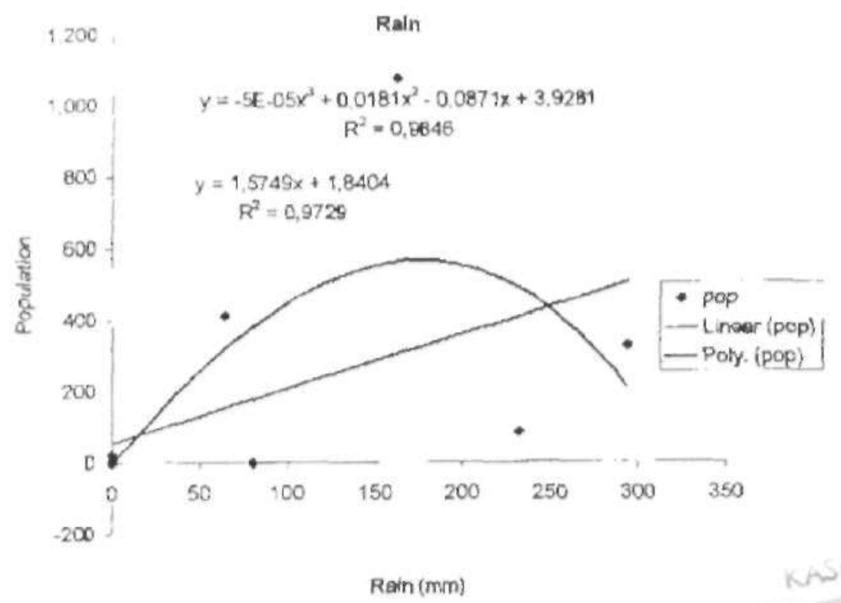
Weekly 1997



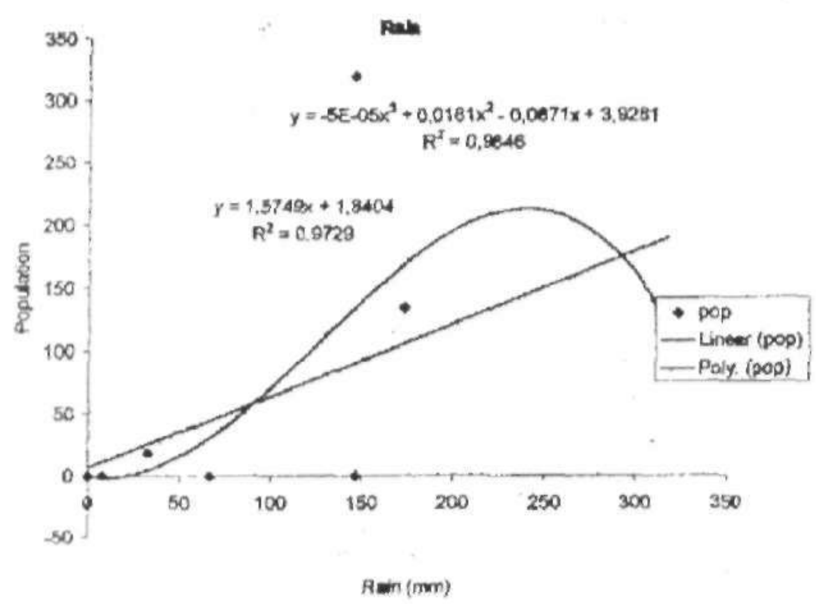
Continuation of Fig. 4.1



Monthly 1995



Monthly 1996



Monthly 1997

The high correlation between rainfall and pest count is explained by the fact that rainfall increases humidity and lowers the soil temperature of the pest environment which provides favourable condition for the pest. However, high rainfall frequency may hamper adult fly, lead to death of younger population or washing away of eggs of the pest.

4.2.2. Relationship Between Radiation and Pest Incidence

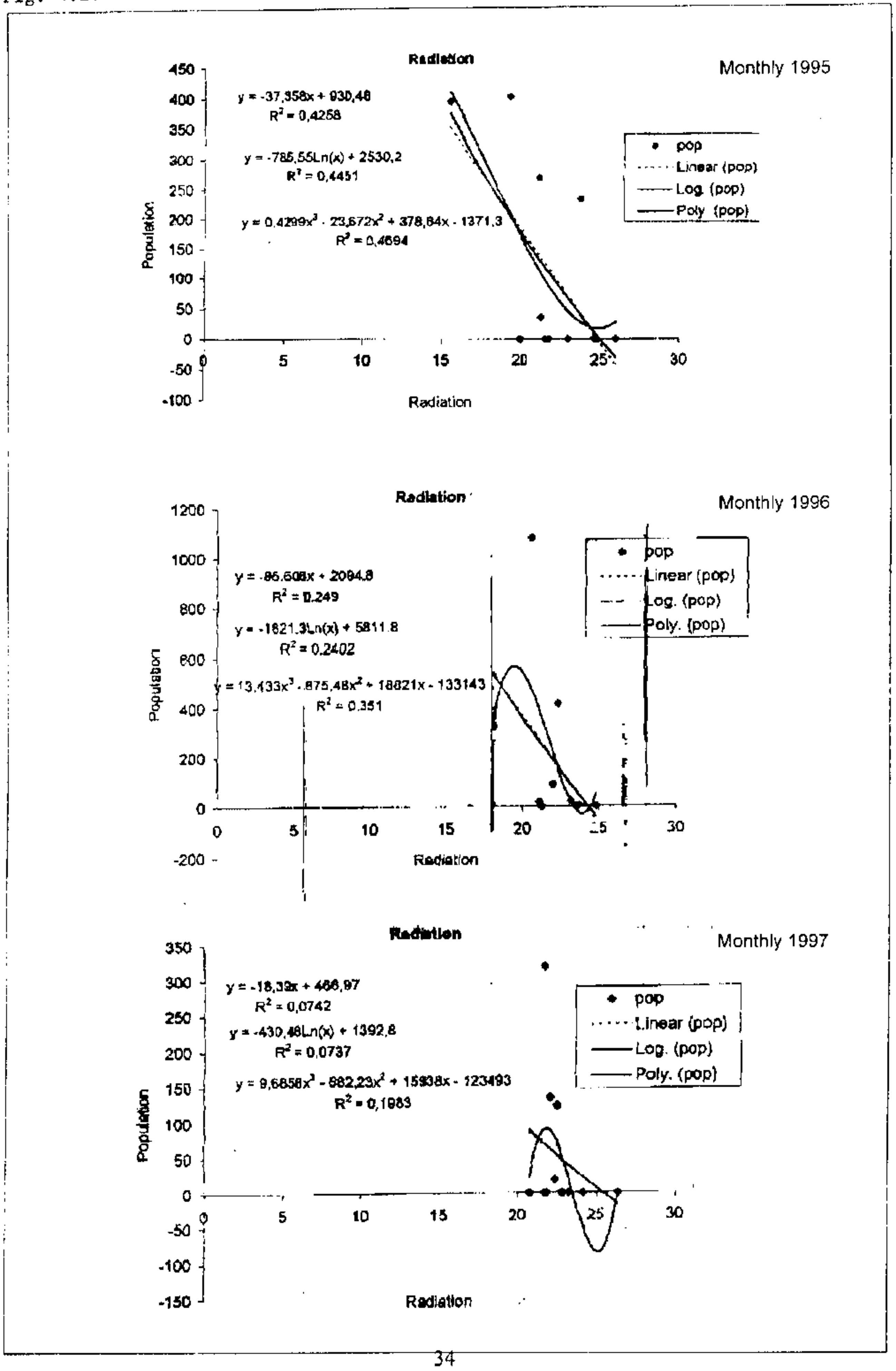
It was observed that radiation showed a highly negative correlation with the pest incidence using both the polynomial and correlation matrix statistics both on weekly and monthly basis throughout the years of study with r values greater than 50%. The influence of radiation was however, not statistically significant for 1996 monthly data using the correlation matrix and in most of the cases using the polynomial statistics (Table 4.5).

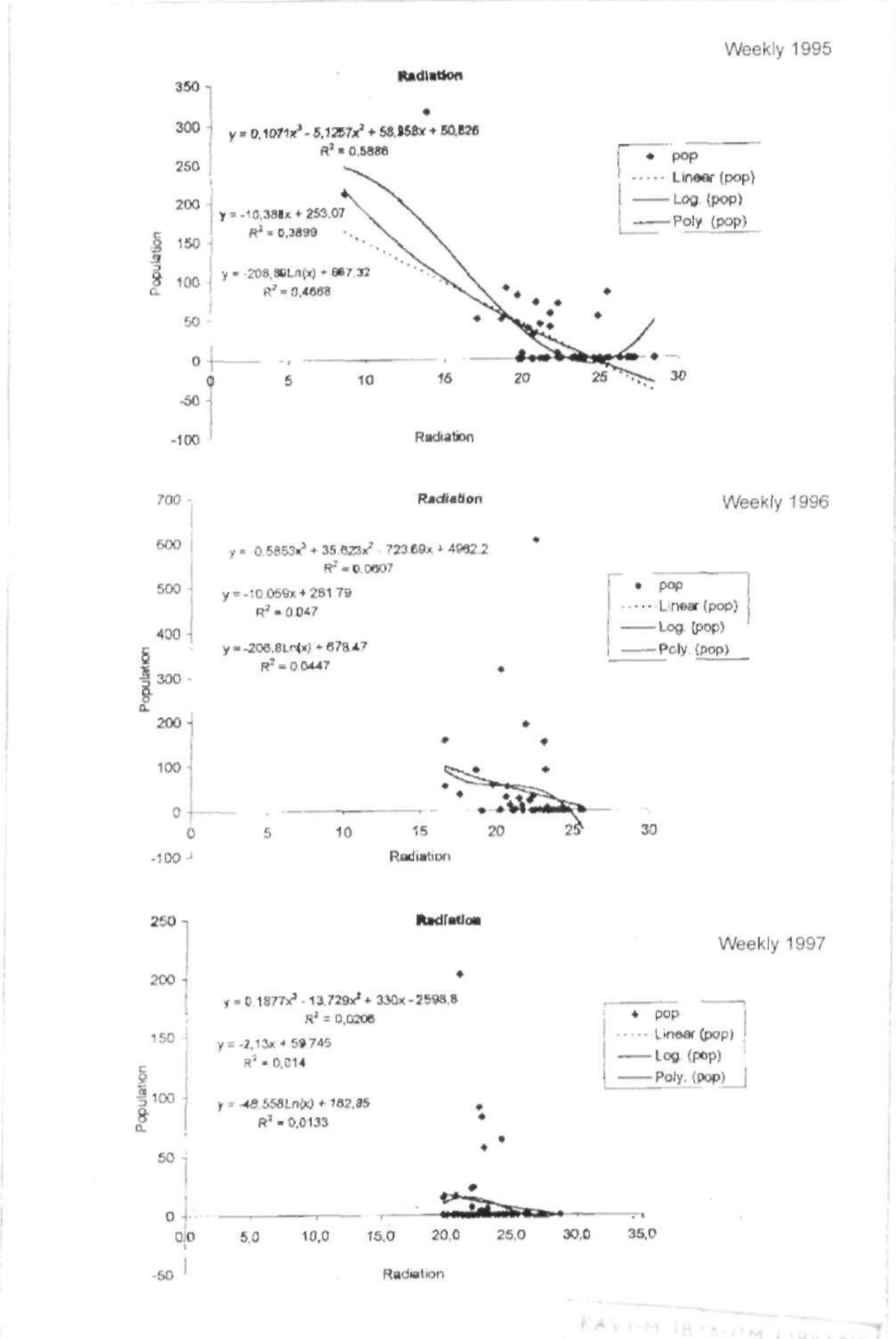
The effect of radiation was probably because increase in radiation resulted in increase in soil temperature which consequently affects the micro or immediate environment of the pest. This agrees with the findings of Dolebel and Lubega (1984). A practical importance of this, is that meaningful effect of pesticide may be achieved at mid day when the temperature and radiation of the pest environment is high (Fig. 4.2).

Table 4.5 Radiation Correlation Table for weekly and Monthly Pest Incidence during 1995 to 1997

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.7672**	0.6851**	0.2464^{NS}	0.5925*	0.1435^{NS}	0.4453^{NS}
Correlation Matrix	0.8220**	0.8477**	0.3336*	0.6855**	0.5002*	0.7085*
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Fig. 4.2: Radiation and Pest Relation Graphs for Weekly and Monthly Data




Weekly 1995
Radiation
y = 0,1071x³ - 5,1257x² + 58,358x + 50,826
R² = 0,5886
y = -10,388x + 253,07
R² = 0,3899
y = -208,89Ln(x) + 667,32
R² = 0,4668
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Radiation
Weekly 1996
Radiation
y = 0.5853x³ + 35.823x² - 723.69x + 4962.2
R² = 0.0607
y = -10.059x + 281.79
R² = 0.047
y = -206.8Ln(x) + 678.47
R² = 0.0447
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Radiation
Radiation
Weekly 1997
y = 0.1877x³ - 13.729x² + 330x - 2598.8
R² = 0,0206
y = -2,13x + 59.745
R² = 0,014
y = -48,558Ln(x) + 182,85
R² = 0,0133
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Radiation

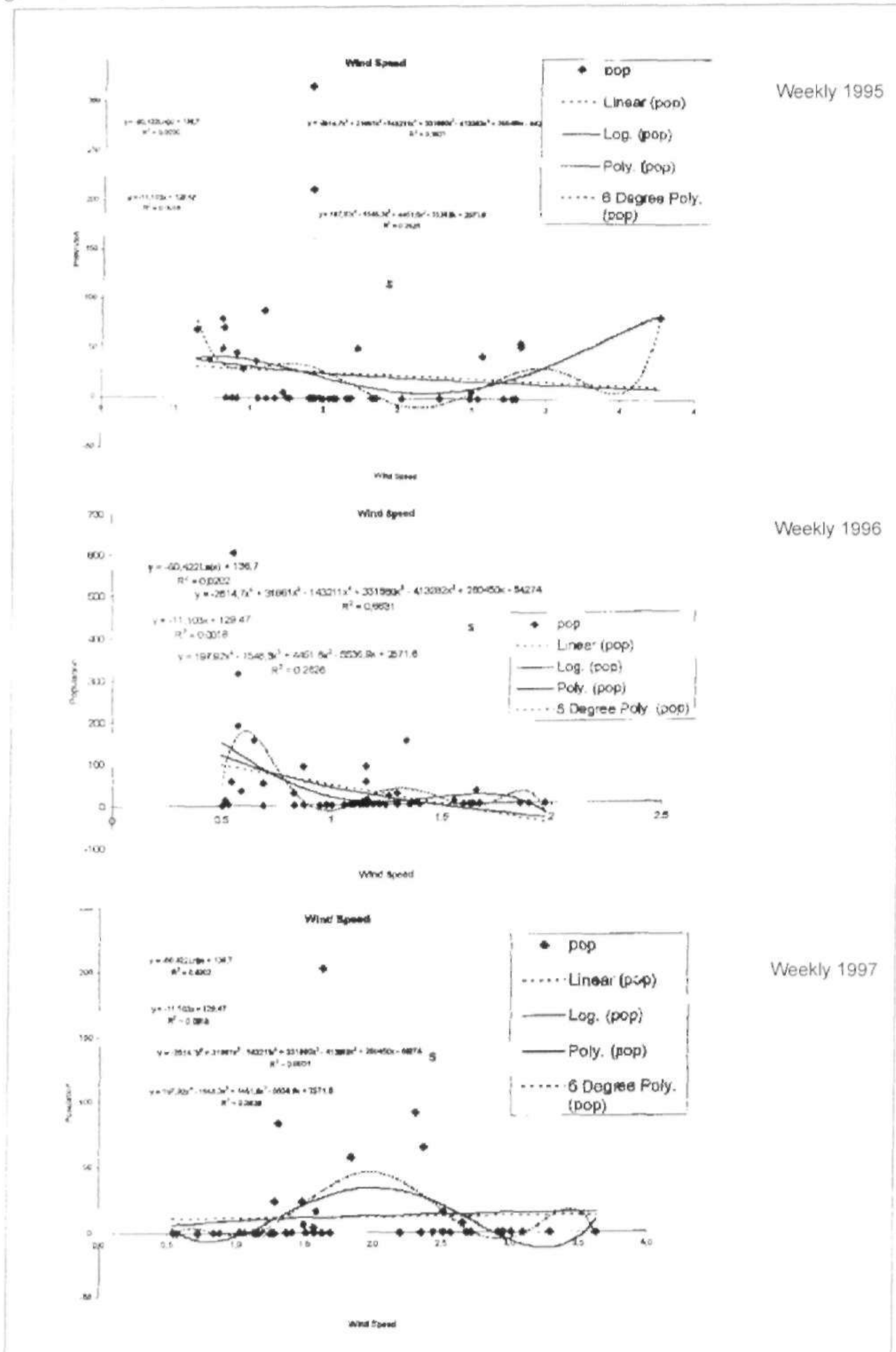
4.2.3 Relationship Between Wind Speed and Pest Incidence

Table 4.6 Wind speed Correlation Table for Weekly and Monthly Pest Incidence during 1995 to 1997

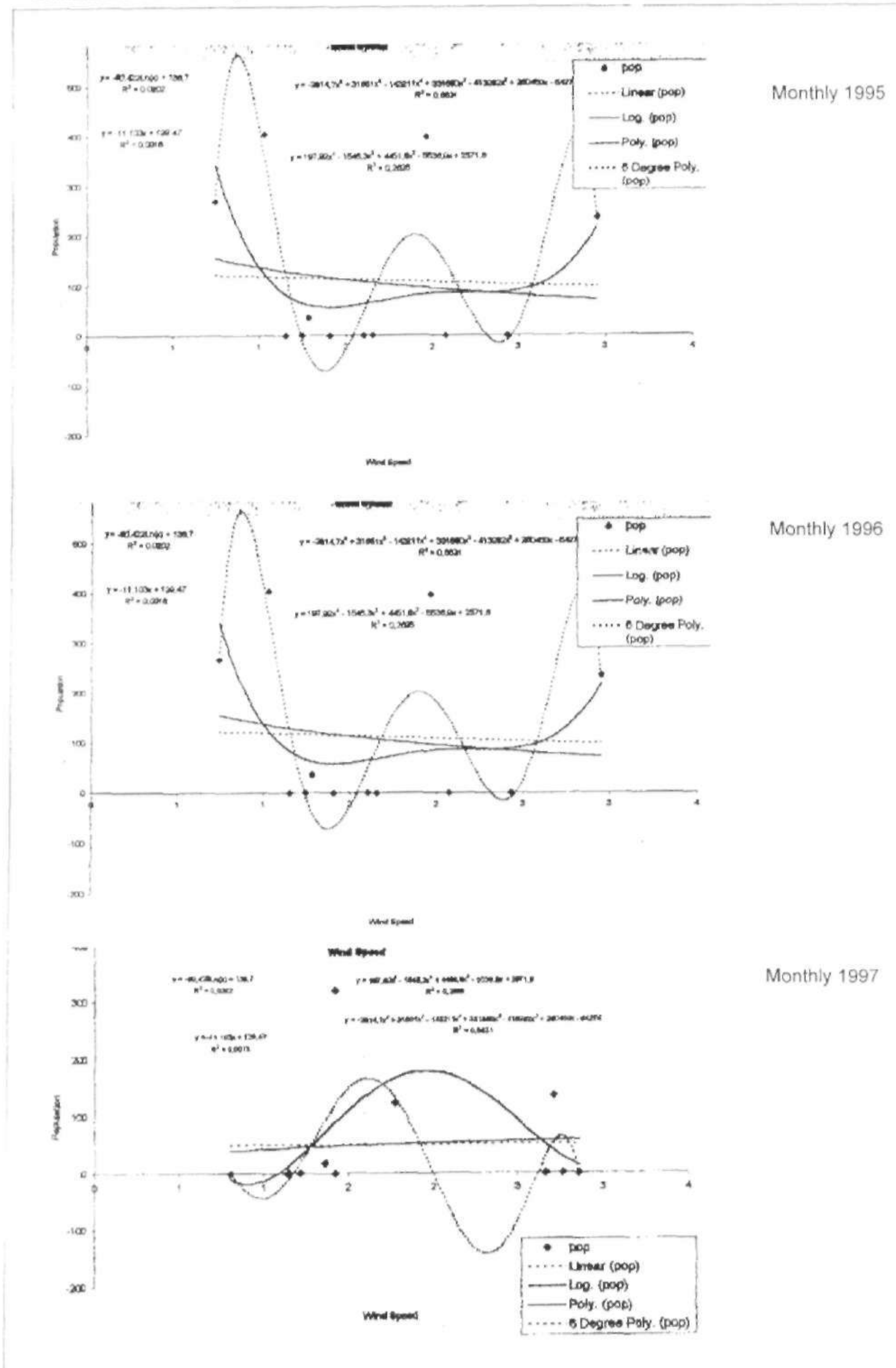
Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.8143**	0.8143**	0.8143**	0.8143**	0.8143**	0.8143**
Correlation Matrix	0.5238**	0.1746NS	0.4342**	0.5863*	0.5001**	0.3500^{NS}
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

For all the years and in all cases (weekly and monthly), Wind speed showed a highly negative correlation with the pest incidence with r values of 0.81 both at 5% and 1% levels of significant using the polynomial statistics (Table 4.6 and Fig. 4.3). Using the correlation matrix, wind speed was shown not to be statistically significant for the monthly date of 1995 and 1997 with r values (0.18 and 0.35). This agrees with the finding of Owonubi, et. al., 1995 on some field pests in Samaru. In all the cases, wind speed above 150km/day tends to have adverse effect on the adult pest while a wind speed of < 100km/day seems to favour the pest activity.

Fig. 4.3: Windspeed and Pest Relation Graphs for Weekly and Monthly Data



Continuation of Fig. 4.3



4.2.4 Relationship Between Temperature and Pest Incidence

Table 4.7a Temperature Minimum Correlation Table for Weekly and Monthly Test Incidence for 1995 to 1997.

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.4698*	0.6690**	0.3933*	0.6144	0.3582*	0.5514*
Correlation Matrix	0.2289^{NS}	0.4297^{NS}	0.2544^{NS}	0.4077^{NS}	0.4112**	0.3164^{NS}
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.7b Temperature Maximum Correlation Table for Weekly and Monthly Pest Incidence for 1995 to 1997.

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomia	0.5214**	0.5214^{NS}	0.5215**	0.5215^{NS}	0.5215**	0.5215^{NS}
Correlation Matrix	0.7319**	0.7604**	0.5659**	0.6912**	0.3442*	0.8650**
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.7c **Temperature Average Correlation Table for Weekly and Monthly Pest Incidence for 1995 to 1997**

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.3817**	0.6609*	0.2205^{NS}	0.9780**	0.2916*	0.5036^{NS}
Correlation Matrix	0.6214**	0.5206NS	0.5210**	0.8971**	0.6581**	0.6302*
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

From Table 4.7 a-c Appendix 5, it was observed that temperature generally showed a negative correlation with the incidence of the pest in most of the cases throughout the period of the study both on weekly and monthly basis. In all the cases, the relationship between pest incidence and temperature was statistically significant (both at 5% and 1% levels), with only little variations in the monthly data especially with maximum temperature (Tmax).

From the results, Tmin, showed highly positive correlation with the pest incidence on monthly basis, and a highly negative correlation on weekly basis with r values greater than 50%.

Maximum temperature (T_{max}) showed a negative correlation to the pest incidence both on weekly and monthly basis. T_{max} is however not statistically significant on monthly basis for all the years using the polynomial statistics both at 5% and 1% levels of significant. This may be due to the fact that temperature at short time intervals better reflects pest behaviour than monthly averages.

Average temperature (T) statistically correlated positively with the pest incidence for all the years and in both cases (weekly and monthly). However, T (Temperature average) was shown to correlate negatively with the pest using the correlation matrix statistics with r values < 50% both at 5% and 1% levels of significant. Overall, we found that Tmax, Tmin and Tavg significantly affected the pest incidence in all the cases examine (weekly and monthly).

An average temperature within the range of 15 to 20°C seems to favour the incidence of the pest in the area while temperatures > 28° to 30°C seems to hamper the pest incidence (see Appendix 53).

It may be deduced from the analysis of temperature and pest data that predicting the pest activity using temperature average as a climatic variable is possible. The high correlation of maximum temperature to the pest incidence may help determine the best time to apply pesticide for chemical control of the adult population. Thus, maximum efficiency of pesticide control may be achieved at mid-day hours when high temperature hamper the activity of the pest. This result agrees with the finding of Mortimore, et. ai. (1965). Also such application could be below the canopy where the pest shelters during hours of harsh temperature condition. This result is supported by the findings of Gahukar (1987), Verma, et. al., (1988) Singh et. al. (1980), and Ogunwole, et. al., (1988).

4.2.5 Relationship between Relative Humidity and Pest Incidence

Table 4.8a **Relative Humidity (Minimum) Correlation Table for Weekly and Monthly Pest Incidence for 1995 to 1997**

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.6792**	0.9004**	0.3964**	0.6127*	0.3234*	0.5072^{NS}
Correlation Matrix	0.7040**	0.8536**	0.4151**	0.6334*	0.7103**	0.8256**
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.8b **Relative Humidity (Maximum) Correlation Table for Weekly and Monthly Pest Incidence for 1995 to 1997**

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.4338**	0.6900**	0.5412**	0.7868**	0.4400*	0.7230**
Correlation Matrix	0.3693**	0.6454*	0.5875**	0.8107**	0.4355**	0.7052**
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.8c **Relative Humidity (Average) Correlation Table for Weekly and Monthly Pest Incidence for 1995 to 1997**

Types of Statistics	1995		1996		1997	
	Weekly	Monthly	Weekly	Monthly	Weekly	Monthly
Polynomial	0.5133**	0.7072**	0.5383**	0.9989**	0.4381**	0.6926**
Correlation Matrix	0.5668**	0.6673*	0.5745**	0.9997**	0.5390**	0.7205**
T-0.05	0.277	0.553				
T-0.01	0.351	0.684				

Table 4.8a-c, show that relative humidity has a highly positive correlation with the pest incidence with r values > 50% using both the polynomial and the correlation matrix statistics, for all the years and in both cases (weekly and monthly). Relative humidity was also shown to be statistically significant both at 5% and 1% level of significant, except for the monthly data of 1997 using the polynomial statistics.

The results further reveal that low relative humidity tends to create a conducive environment for the pest incidence. However, pest activity was shown to be hampered at high relative humidity between 80% to 90% (see Appendix 2).

Thus it can be concluded that humid conditions tends to enhance the pest activity, however if there are a consecutive days of high humidity the pest mortality may rise. This results agree with Shiang-Lin et. al., (1981) Marwa (1984), who reported that relative humidity between 75% to 80% favours the activity of field pest.

From the above results on individual environmental parameters effects on the pest incidence in the study area, it can be deduced that rain, temperature, radiation and relative humidity influence the incidence of coniesta igniefusalis in the study area. Therefore, climate is a major factor in the pest incidence and should be taken into focus for any meaningful control programme for the pest. If this proper understanding of the pest-weather relationship can be utilized alongside other cultural and scientific control methods already in place, the probability of reducing the rate of the pest incidence visa-a-vis the pest damage to millet and other grain crops (hosts crops of the pest) in the area will be greatly increased.

4.3 WEATHER CONDITIONS AND THE PEST INCIDENCE IN THE STUDY AREA.

Table 4.3 Critical Weather Conditions Favourable and Unfavourable levels for the Incidence of the Pest.

Critical Period	CONDITIONS		Pest Incidence
	Favourable Weather Condition	Unfavourable Weather Condition	
Initial Incidence to full colony March-May	Cool weather with well distributed rainfall and decrease in temperature	Abnormally prolonged dry period with high temperature (Tmax 39°C, low RHmax 35% and a high wind speed	47
Full colony to beginning of the Pest retreat Sept-June	Cool weather with well distributed rainfall with high RHmin > 50%	Excessively hot weather or a prolonged dry spell with high wind speed.	325
Pest retreat to complete disappearance Oct-Nov.	Calm dry weather	Windy and high temperature (Tmax 52°C) condition	36

From Table 4.9, it is observed that the monthly count of the pest incidence fluctuates with the change in average weather condition from the onset of the rain vis-a-vis changes in other weather element condition, to end of the raining season. A complete conclusion may not be drawn on this observation as the availability of food and lack of major predators may also be a contributing factor. However, weather can be say to be greatly responsible for the incidence, thrive and retreat of the pest in the study area.

4.4 COMBINED EFFECT OF THE WEATHER VARIABLES AND THE PEST INCIDENCE

The possible combine effect of the various meteorological parameters excluding average temperature and average relative humidity was investigated using the SPSS (statistical package for social science) multiple linear regression.

1995 $POP = 0.67x_1 + 1.53x_2 + 1.71x_3 + 0.23x_4 - 0.40.80$ 5a

1996 $POP = 6.69x_1 + 0.04x_2 + 11.69x_3 + 63.89x_4 - 64.20$ 5b

1997 $POP = 129.73x_1 - 2.95x_2 - 156.65x_3 + 98.12x_4 + 1627$ 5c

Their Correlation Coefficient (r) is presented in Table 4.8 below:

Table 4.8 **Correlation Coefficient of the Combined effect of rain, temperature, relative humidity and radiation on the pest incidence.**

	YEARS				
	1995	1996	1997	5%	1%
r	0.876**	0.775**	0.581^{NS}	0.533	0.684
R^2	0.666	0.600	0.337		
SE	46.91	90.32	40.400		

The combine effect of the variables acting simultaneously on the pest incidence was shown to be statistically significant for all the years (1995, 1996, 1997). The year 1995 and

1996 data in particular showed a highly significant correlation with the pest incidence both at 5% and 1% levels of significance. This result agrees with the finding of Nair et. al. (1993). However, the work excluded radiation which is integrated in this present work.

4.5 EFFECT OF SELECTED WEATHER VARIABLES AND THE PEST INCIDENCE

The effect of some major influencing meteorological variables (rain, radiation, temperature, relative humidity) in the study area was investigated to see their possible effect on the population incidence of the pest in the study area. Their correlation coefficient is presented in Table 4.9.

Table 4.9 Coefficient of Correlation of Pest Incidence and the Combine Influence of Rain, Radiation, Temperature and Relative Humidity

Meteorological Parameters	1995	1996	1997
Rain and Radiation	0.71*	0.45^{NS}	0.49^{NS}
Rain and Tmin	0.66*	0.45^{NS}	0.49^{NS}
Rain and T	0.66*	0.45^{NS}	0.54*
Rain and RH	0.69**	0.46^{NS}	0.51^{NS}
Radiation and T	0.65*	0.20^{NS}	0.29^{NS}
Radiation, RHmax and RHmin	0.73**	0.47^{NS}	0.55^{NS}
Radiation, RHmax and RHmin	0.71*	0.37^{NS}	0.56^{NS}
Rain, RHmax and RHmin	0.72**	0.49^{NS}	0.58*
Rain, Tmax and Tmin	0.67*	0.46^{NS}	0.51^{NS}

From Table 4.9, average temperature and average relative humidity showed a high correlation with the pest incidence for 1995 and 1996 at 5% and 1% levels of significance. The data for 1997, however, is not statistically significant both at 5% and 1% levels of significance. It may therefore, be concluded that T and RH significantly affect the population incidence of the pest in the savanna.

It was observed that rainfall and relative humidity showed high correlation for 1995 data. Other selected combinations (radiation and temperature) are statistically related only at 5% level of significance. These result is supported by Ajayi (1997) although he reported only for rain fall and radiation. The data for 1996 was not statistically significant for all the meterorlogical data selected both at 5% and 1% levels of significance.

4.6 MODEL DEVELOPMENT

Simple regression model were developed for those weather variables that consistently correlated with the pest incidence in the study area and with correlation coefficients greater than 50%. Their correlation coefficient is presented in Table 4.11.

Table 4.11: Regression Model of Weather Variables on Pest Incidence for 1995, 1996 and 1997

Years	Model	R^2
1995	$POP = 1.317x_1 + 1.428x_2 + 1.264x_3 + 0.862x_4 - 0.781_5 + 15.172$	0.97
1996	$POP = 415.119x_1 + 7.371x_2 + 715.864x_3 - 256.080x_4 + 39.744_5 + 10793.638$	0.99
1997	$POP = 56.696x_1 - 1.328x_2 - 106.629x_3 + 107.191x_4 - 0.773x_5 + 5660.426$	0.86

Radiation = X_1 Rain = X_2

RHmin = X_3 Tmax = X_4

RHmax = X_5

The model was developed based on uniform variables with highest correlation coefficient frequency. Thus radiations rain, relative humidity minimum, temperature maximum and relative humidity maximum was observed to consistently influence the pest incidence in the study area.

The model was used to attempt predicting the future pest incidence in the study area.

4.7 COMPARISM OF PREDICTED AND OBSERVED RESULTS

In an attempt to verify fitness of the models used in predicting the pest incidence in the study area, contingency tables were prepared. The contigency tables were prepared on decade basis to keep a breast with current standard of the W.M.O. (Franz. 1997, Pedgloy et. al. 1980, Jones, 1980). The contingency tables were prepared staring from when the pest population was shown to be greater than one (>1) i.e. a colony. The probability of occurrence of good agreement between the predicted population and observed population (applying the X^2 test) is shown below in Table 4.12).

Table 4.12: Contingency Table of Predicted and Observed Population, Incidence of Coniesta Ignefusalis (Based on 10 days Incidence)

Years	Predicted	Observed	X^2 Calculated
1995	1374	1337	0.9964^{NS}
1996	1934	1942	0.0330^{NS}
1997	493	593	20.2839**

From the contingency table (Table 4.12) it could be observed that 1995 and 1996 were not different statistically from the observed. For 1997, the predicted value was significantly higher than the observed. Since the number of discrepancies between the predicted and the observed populations of the pest were low, especially for 1995 and 1996, and the differences insignificant statistically (using the X^2 test for fitness), the models for 1995 and 1996 can be said to be reliable for predicting future population incidence of the pest in the study area. The 1996 model proved to be more reliable with lesser difference between the observed and the predicted population.

However, the level of forecast achieved for 1997 data was found to be lower than the observed population and also highly significant statistically (X^2 Cal 20.28). Hence, the model for 1997 cannot be said to be reliable or accurate.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 SUMMARY AND CONCLUSION

The ability to effectively predict the level of damage of grain pest is of paramount importance. This is because an epidemic year or period can be conveyed to farmers ahead of real time, thereby, making them prepare to combat such devastation. Hence, a good model/method for determining possible behaviour of field pest holds a key to optimum production of rain fed grains in this environment.

The three years data of pest population and meteorological factors used in this study is analysed using two statistical methods. The simple linear and multiple regression method and the polynomial (non-linear) regression method. Their correlation coefficient (r) were calculated by regressing the pest population (Y) against the climatic variables (X). It was observed that the polynomial method performed better than the rest methods with respect to pest population and climatic variables relationship and the pest prediction, in all the cases considered and in all the years.

Using the polynomial, most of the climatic parameters, with the exception of wind speed and maximum temperature in all the cases (weekly and monthly) and in all the years (1995 to 1997) correlated significantly with the pest incidence with r-values greater than 50% (>50%). In this work, therefore, determining the effect of an individual climatic variable on the pest incidence in the study area, the polynomial non linear regression is suggested. This is because unlike the other methods which may tend to ignore the contributing effect of some weather variables, the polynomial curve takes into account these effects however small they are. Furthermore,, the polynomial curve is significantly higher than those based on simple linear regression and it explains about 98% of the relationship better than the simple linear regression (Croxton et. a. 1988).

Using the SPSS multiple linear regression model to investigate the possible combine effect of the climatic variables acting simultaneously on the pest, it was observed that, the combined effect were statistically significant both at 5% and 1% levels of significant for the 1995 and 1996 data. The 1997 data was statistically significant only at 5% level of significance. Predicting the pest incidence using the same model (equation 5a-c) for all the season and applying the chi-square test to test the fitness of the model in predicting the pest incidence, the models of 1995 and 1996 were found to be more reliable. This is because their predictions were not statistically different from the observed.

Based on this study, the following inferences can be drawn:

1. The polynomial statistics is best for determining relationship between single or individual weather parameter and Coniesta ignefusalis incidence in the study area.
2. The incidence and activity of Coniesta ignefusalis in the Nigerian savanna is weather dependent.
3. Major climatic variables affecting the pest incidence in the savanna are rainfall, relative humidity, radiation and temperature.
4. These weather variables do not work or affect the pest in isolation, hence a multiple regression analysis could be employed in related research as this.

5. Predicting the pest incidence using all the weather parameter is observed to do better compared to predictions using individual or few selected weather parameter.

$$E(Y_1) = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_k X_k \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

6. It was observed that records on the pest in the savanna region was very limited and as such, do not permit extensive projection in which long term prediction can be embarked upon. Hence, further study in which long - term prediction can be embarked on can be attempted in the future with larger data base.

7. It was observed that catches by trap increase with increase in distance of traps. This information is important in considering the pheromone detection thresh-hold range of the pest.

8. It was observed that most male fly distances of about 300m to mate with the female pest. Thus as part of an integrated control strategy traps may be placed at certain distances to attract adult males while other control measures may be simultaneously carried out.

5.2 RECOMMENDATION

The work done in this study is location and pest specific, hence, conclusions reached here could be tested in different areas with similar or different ecological setting, and different pest problem.

The 1996 model used in predicting the pest incidence could be used for farmers taking decision on the pest.

Periodical observations to supply sufficient information for detailed work for possible integrated control methods less harmful to the environment and the host crop can be carried out in the future.

Research such as this should be extended to other field crops and pests. Findings from such work should be pieced together with other control methods for a good selective and purposeful pest control programme.

Available information from adult monitoring of field pest such as this can be used as supplementary guide for forecast and advices on the need for control measures.

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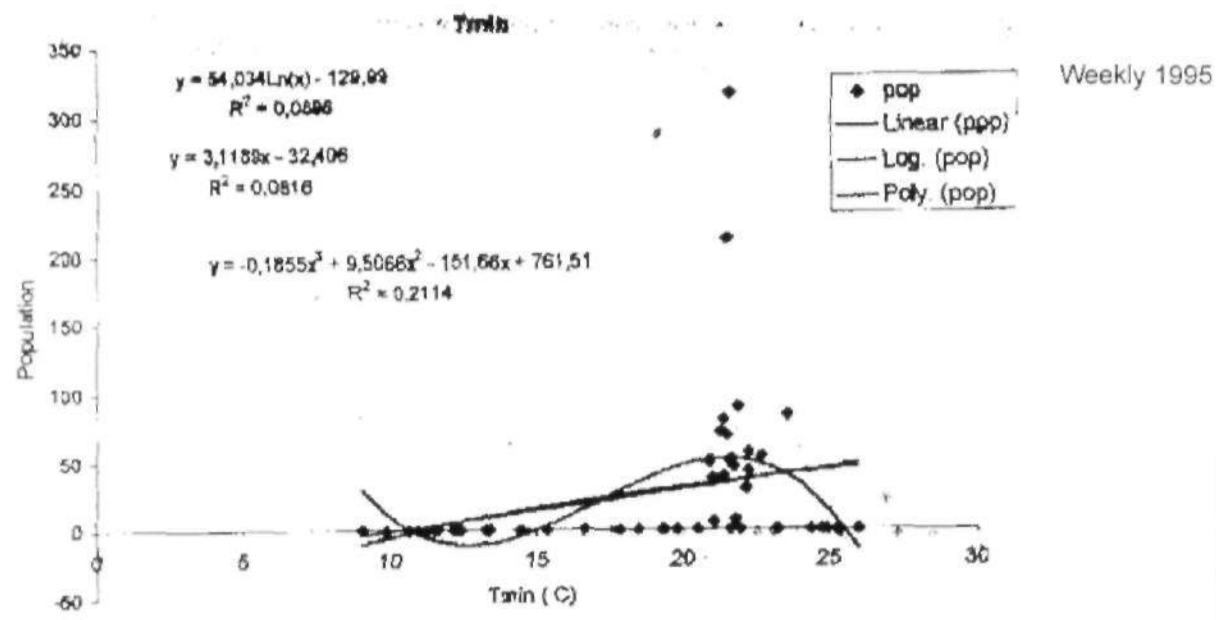
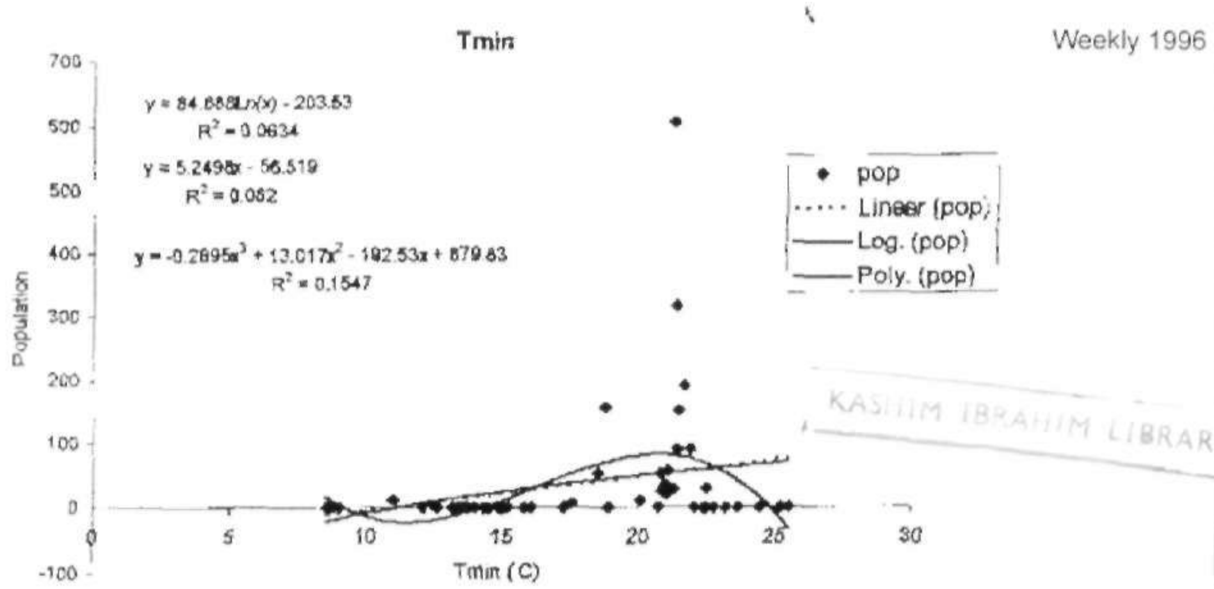
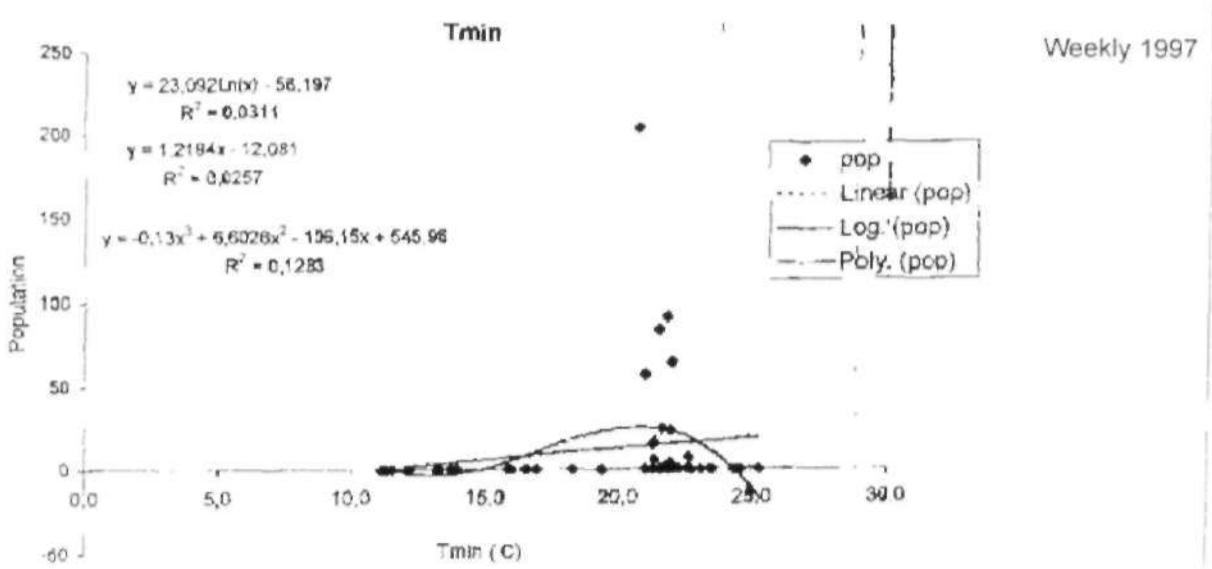
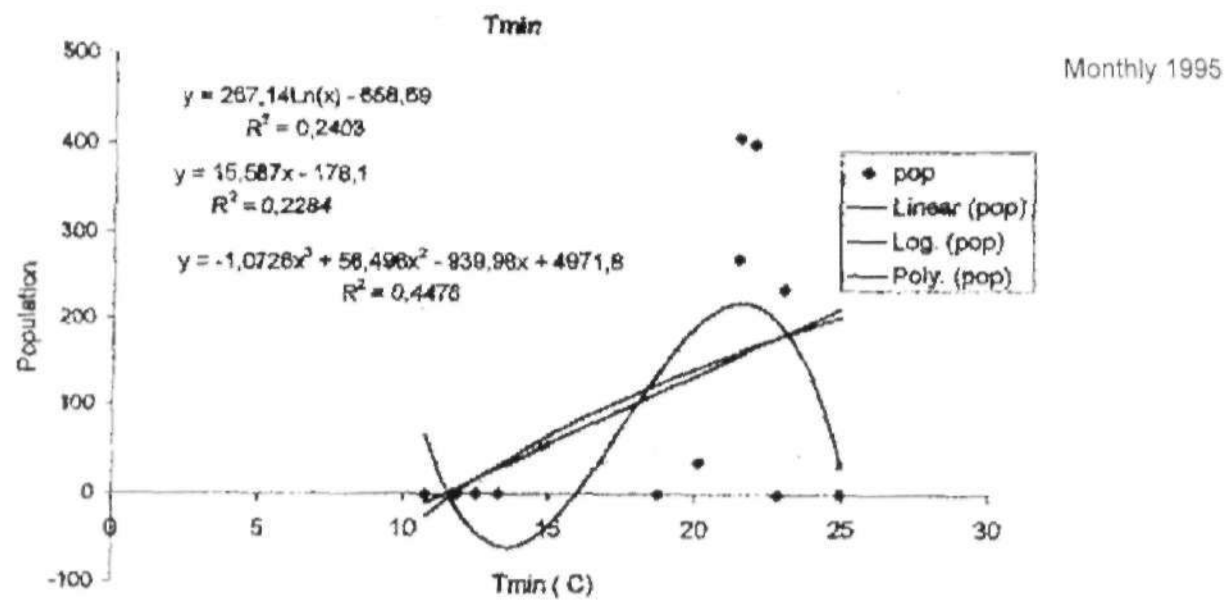
Appendix. 1. Temperature and pest relation graphs for weekly and monthly data.

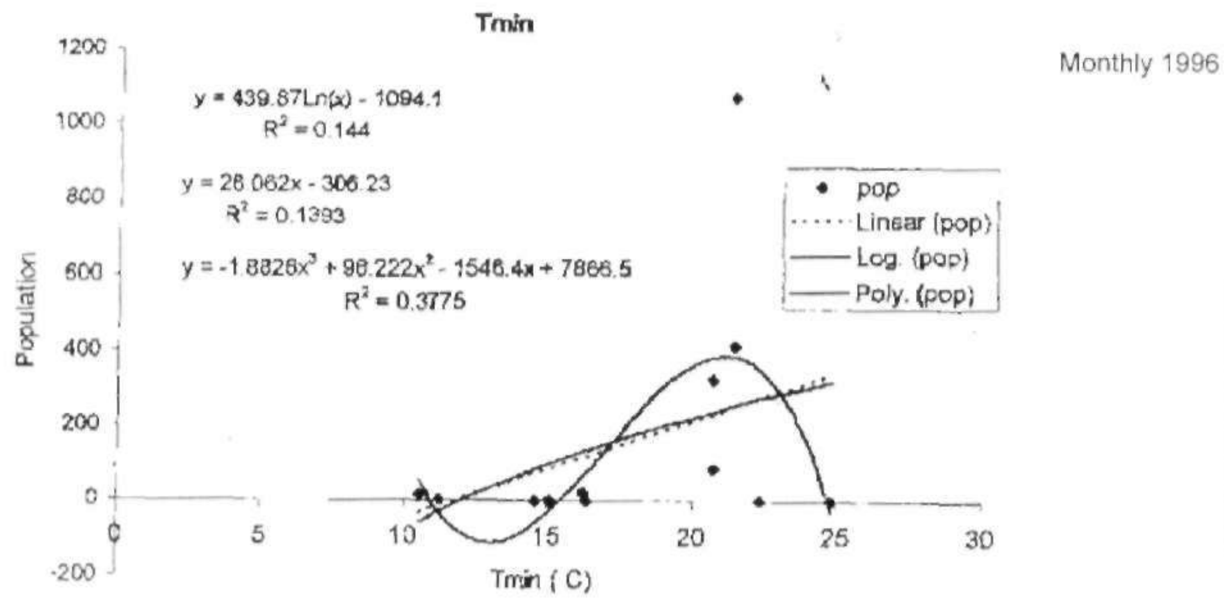


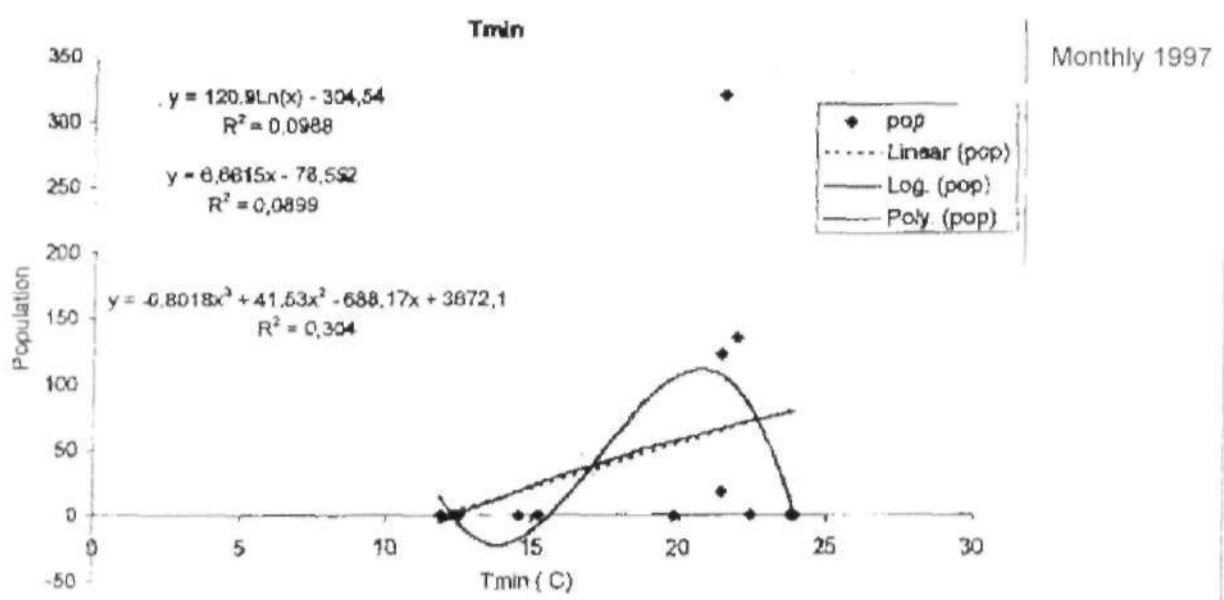


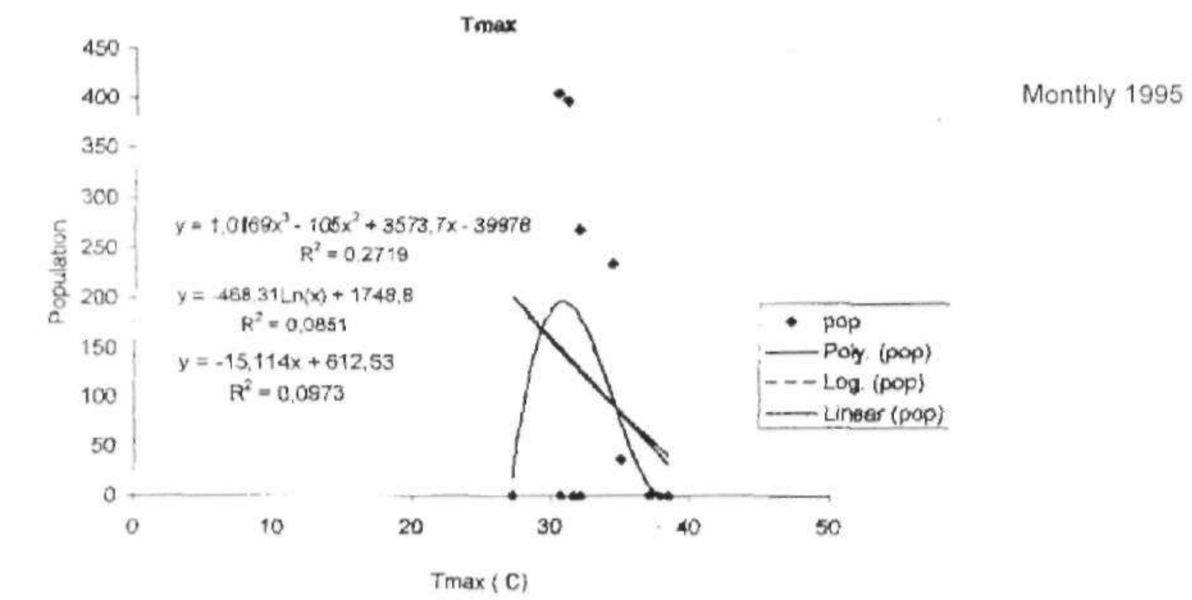


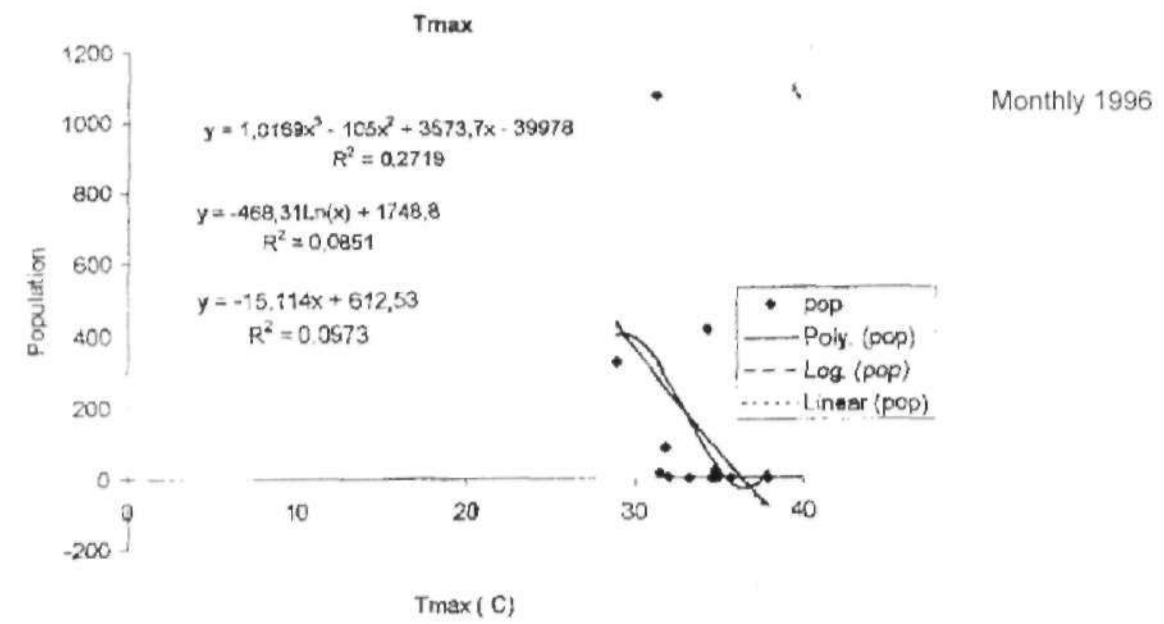
Appendix I:

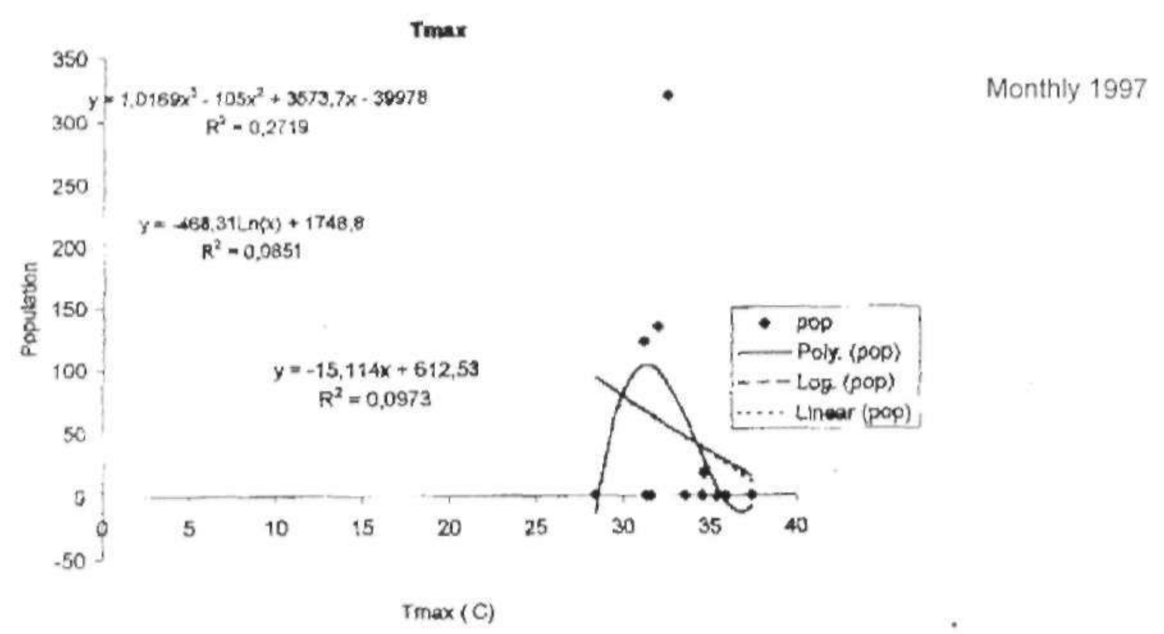

Tmin
Monthly 1995
y = 267,14Ln(x) - 668,69
R² = 0,2403
y = 15,587x - 178,1
R² = 0,2284
y = -1,0726x³ + 56,496x² - 939,98x + 4971,8
R² = 0,4476
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
500
400
300
200
100
0
-100
0
5
10
15
20
25
30
Tmin (C)


Tmin
Monthly 1996
y = 439.87Ln(x) - 1094.1
R² = 0.144
y = 26.062x - 306.23
R² = 0.1393
y = -1.8826x³ + 98.222x² - 1546.4x + 7866.5
R² = 0.3775
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
1200
1000
800
600
400
200
0
-200
0
5
10
15
20
25
30
Tmin (C)

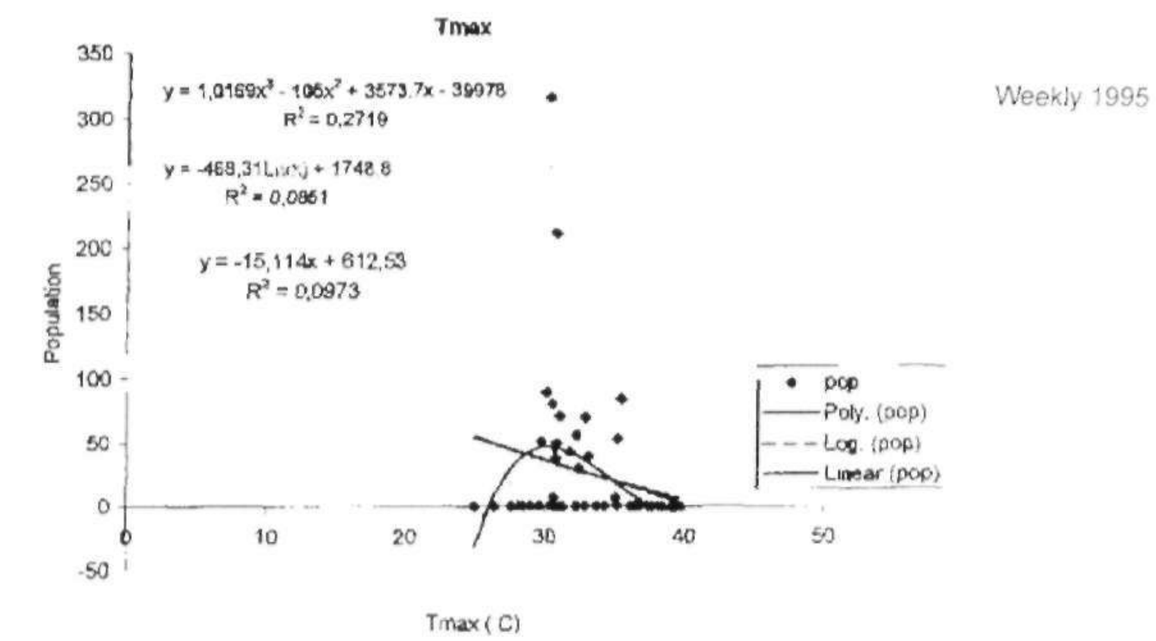

Tmin
Monthly 1997
y = 120,9Ln(x) - 304,54
R² = 0,0988
y = 6,6615x - 78,592
R² = 0,0899
y = -0,8018x³ + 41,53x² - 688,17x + 3672,1
R² = 0,304
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
350
300
250
200
150
100
50
0
-50
0
5
10
15
20
25
30
Tmin (C)

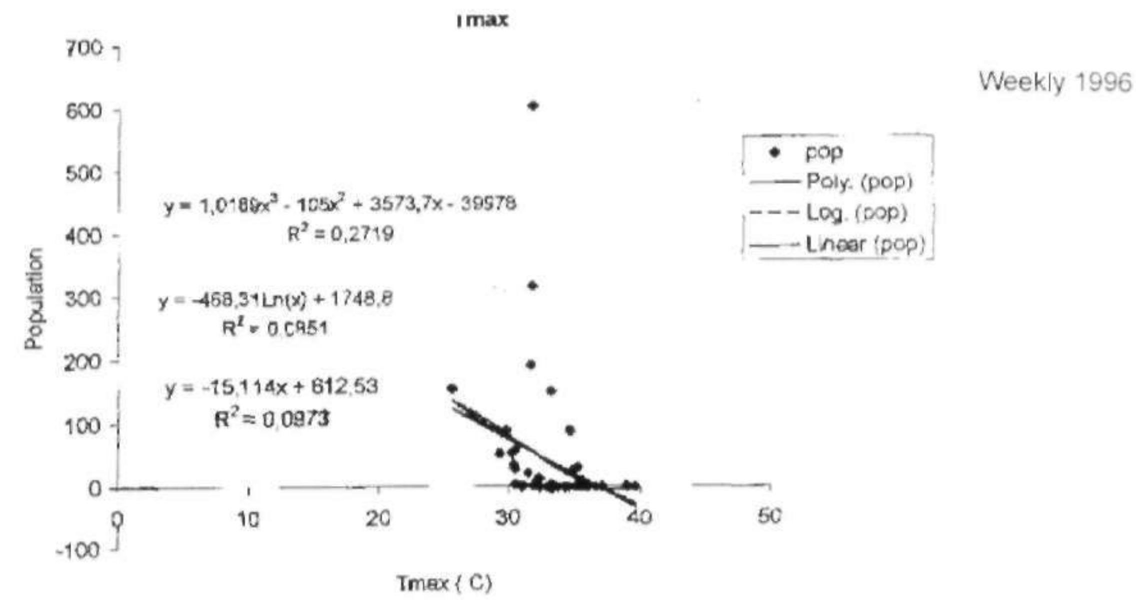

Tmax
Monthly 1995
y = 1,0169x³ - 105x² + 3573,7x - 39978
R² = 0,2719
y = -468,31Ln(x) + 1748,8
R² = 0,0851
y = -15,114x + 612,53
R² = 0,0973
Population
Tmax (C)
pop
Poly. (pop)
Log. (pop)
Linear (pop)

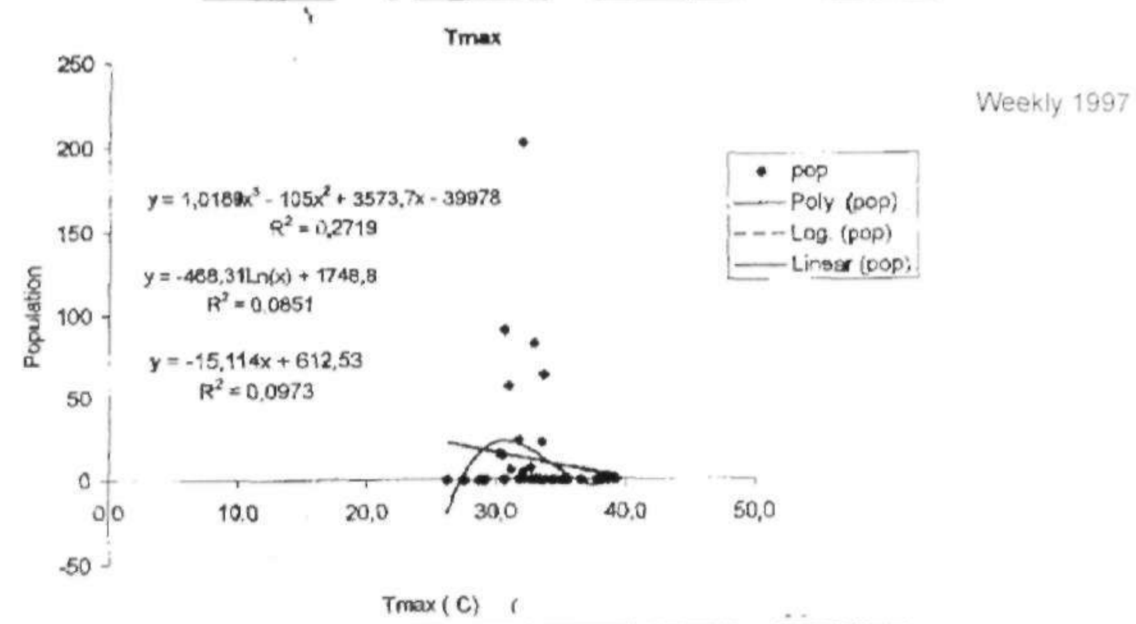

Tmax
Monthly 1996
y = 1,0169x³ - 105x² + 3573,7x - 39978
R² = 0,2719
y = -468,31Ln(x) + 1748,8
R² = 0,0851
y = -15,114x + 612,53
R² = 0,0973
Population
Tmax (C)
pop
Poly. (pop)
Log. (pop)
Linear (pop)


Tmax
Monthly 1997
y = 1,0169x³ - 105x² + 3573,7x - 39978
R² = 0,2719
y = -468,31Ln(x) + 1748,8
R² = 0,0851
y = -15,114x + 612,53
R² = 0,0973
Population
Tmax (C)
pop
Poly. (pop)
Log. (pop)
Linear (pop)

Continuation of Appendix 1.







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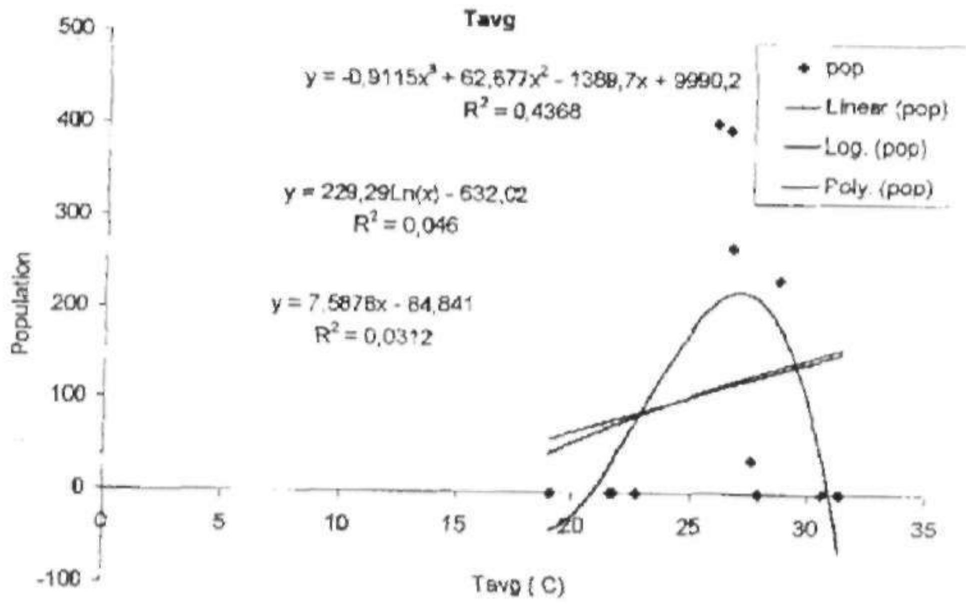
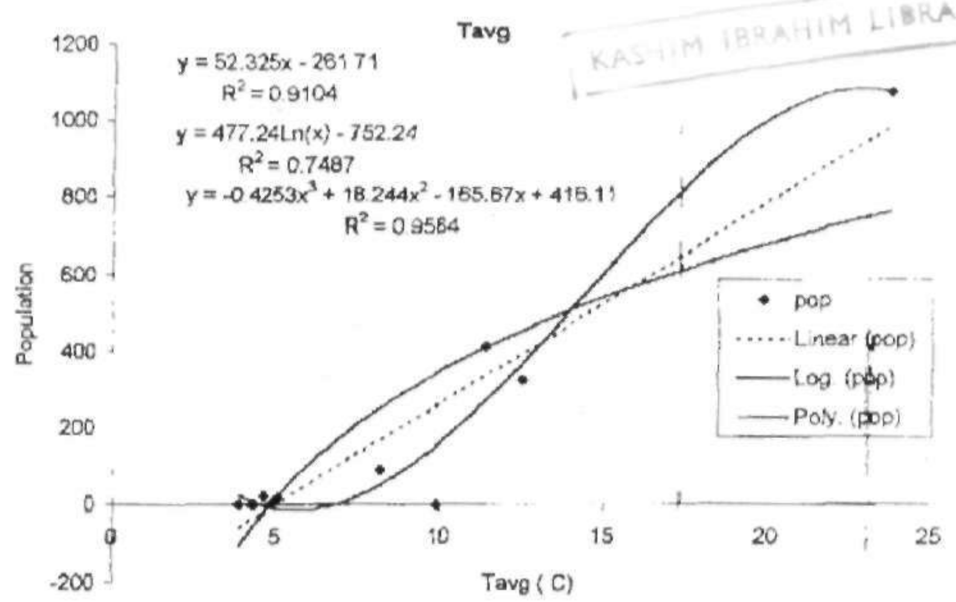
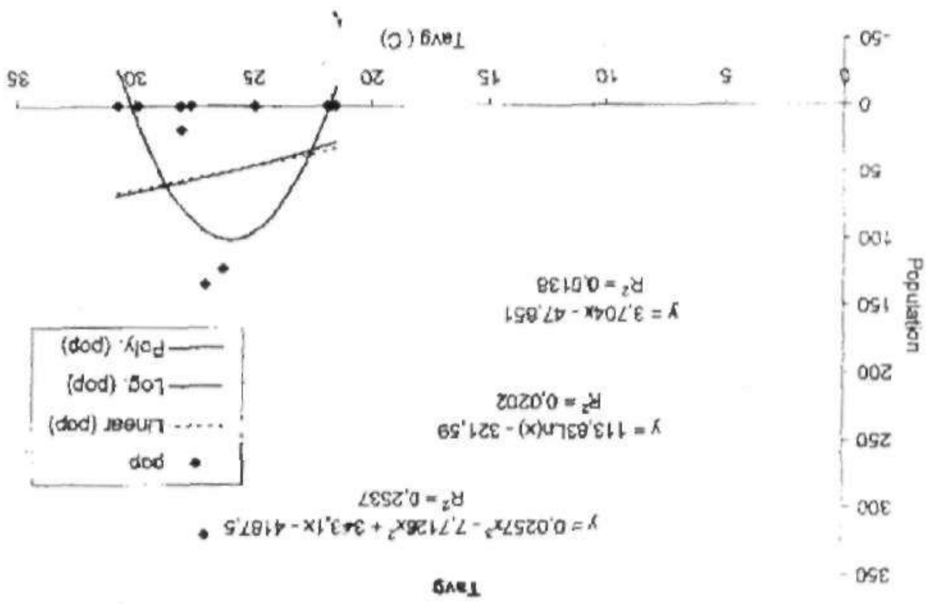


Monthly 1995

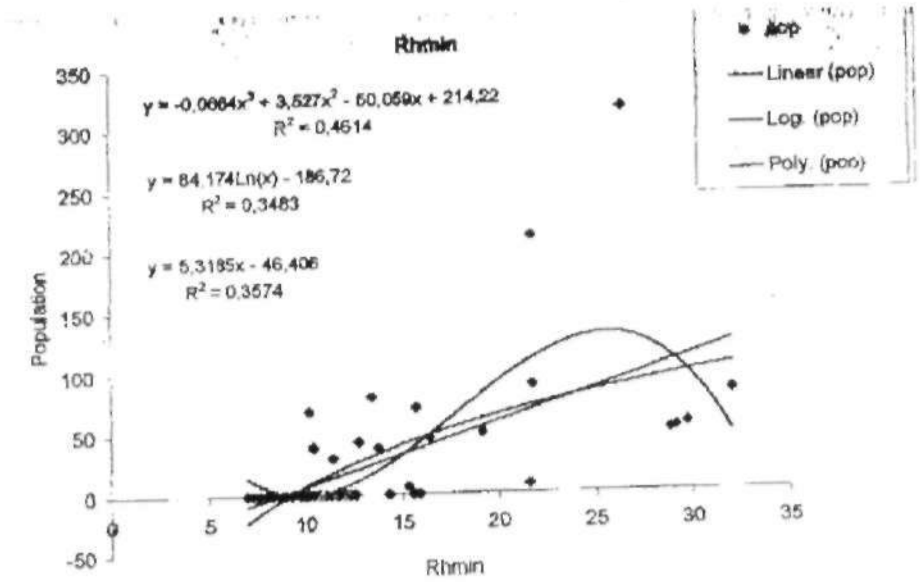


Monthly 1996

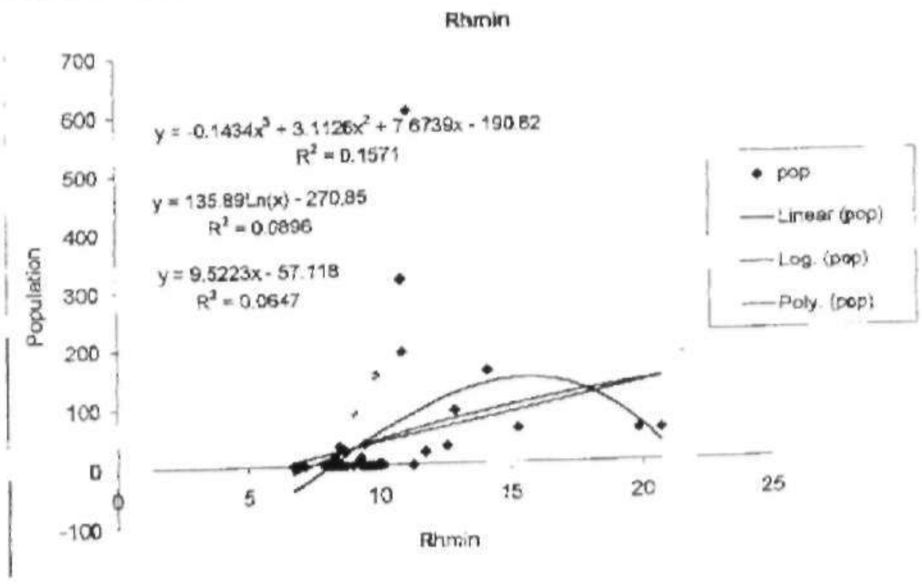


Monthly 1997

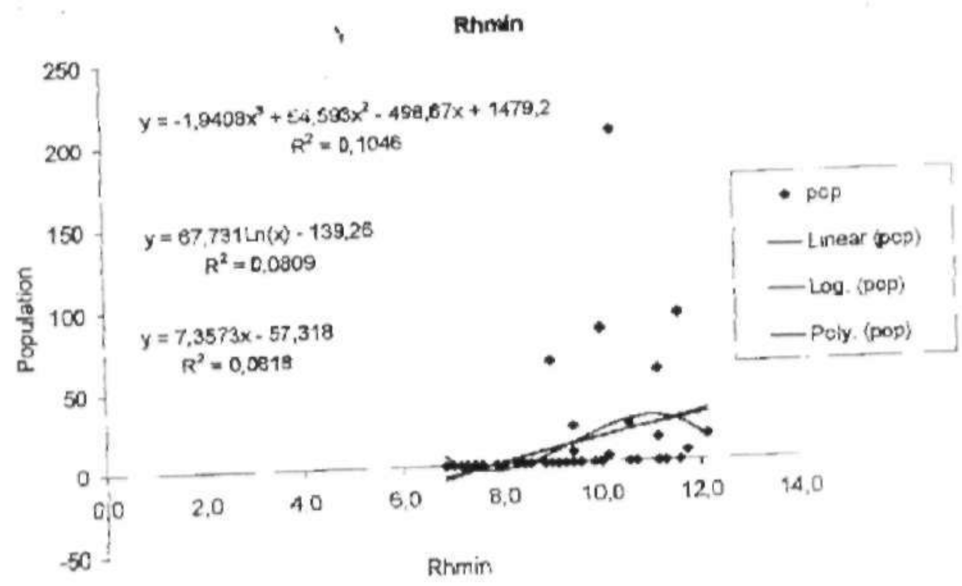
Weekly 1995



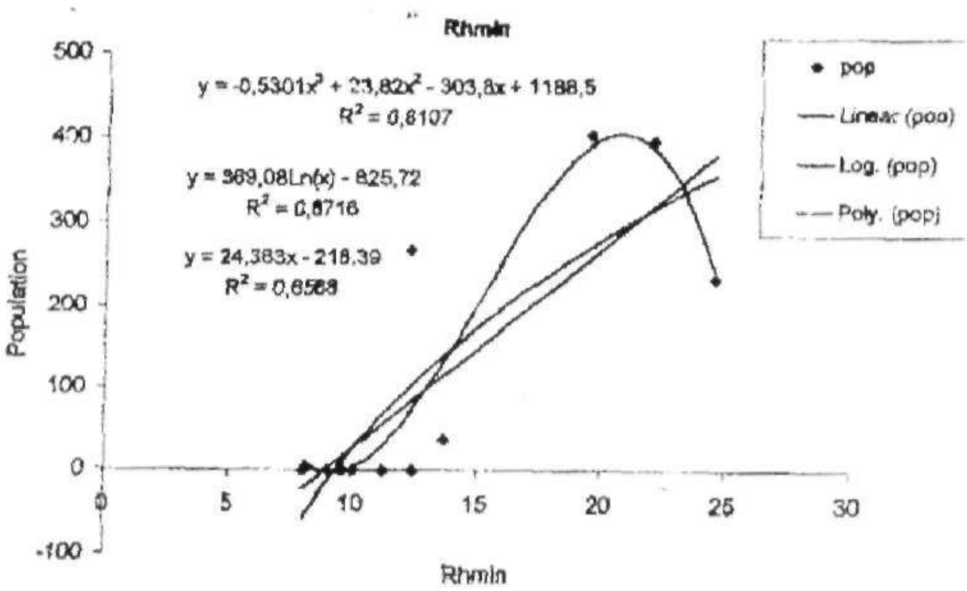
Weekly 1996



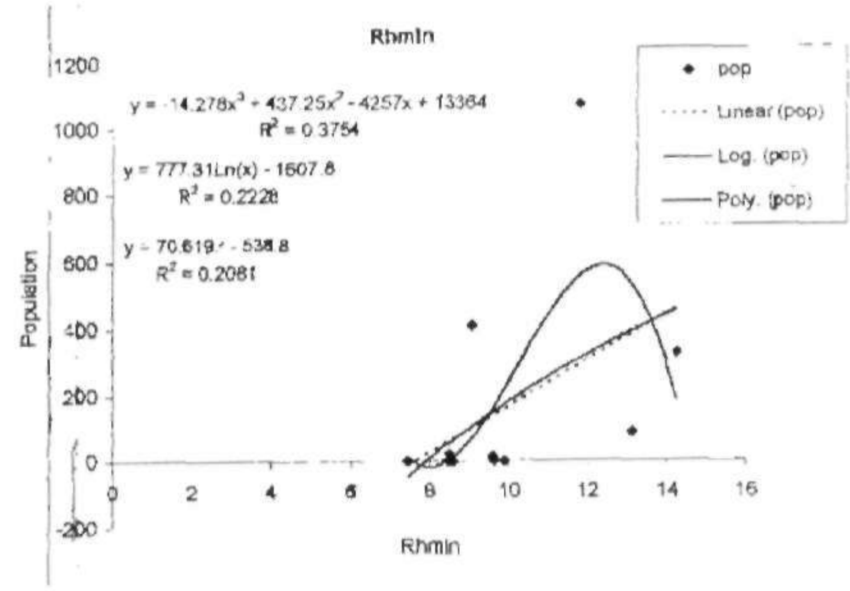
Weekly 1997



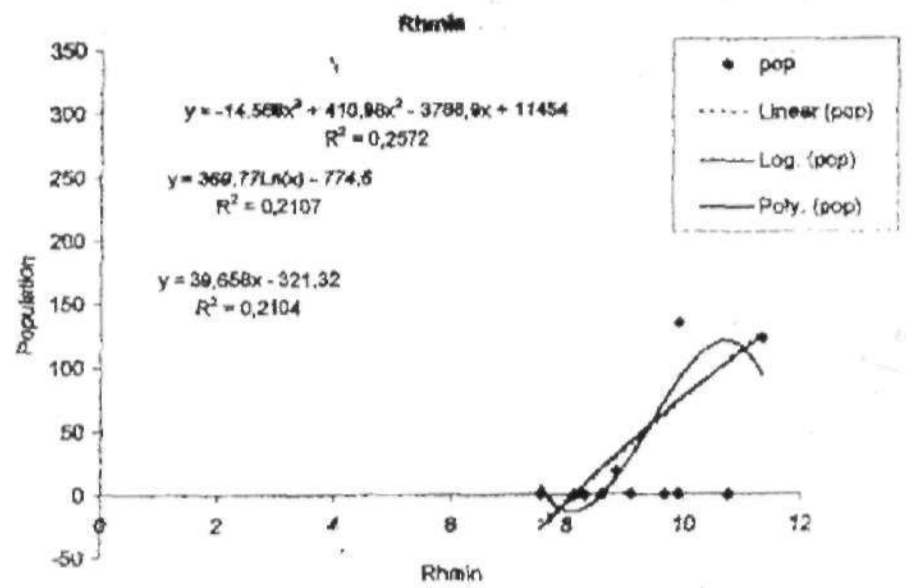
Appendix 2: Relative humidity and pest relation graphs for weekly and monthly data.



Monthly 1995

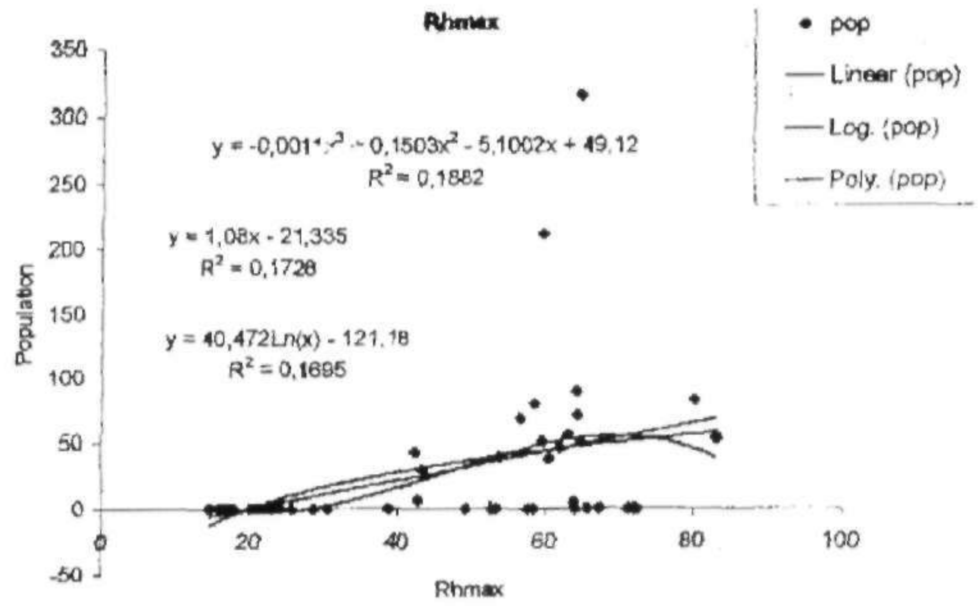


Monthly 1996

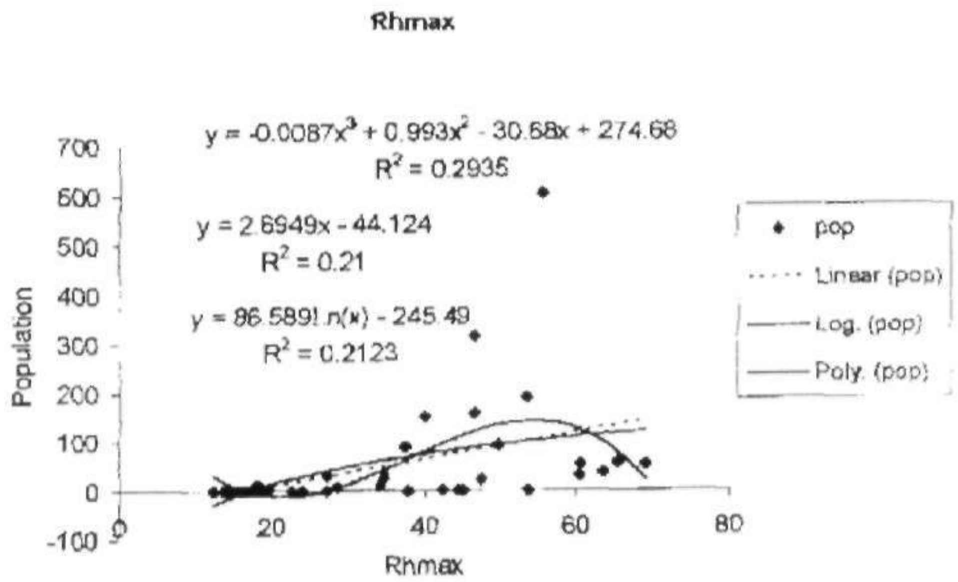


Monthly 1997

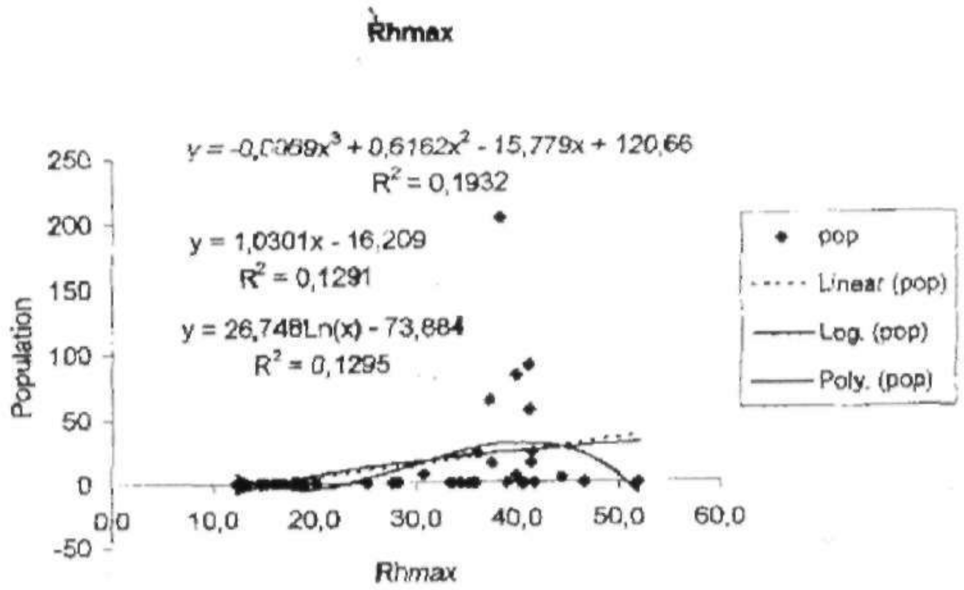
Weekly 1995



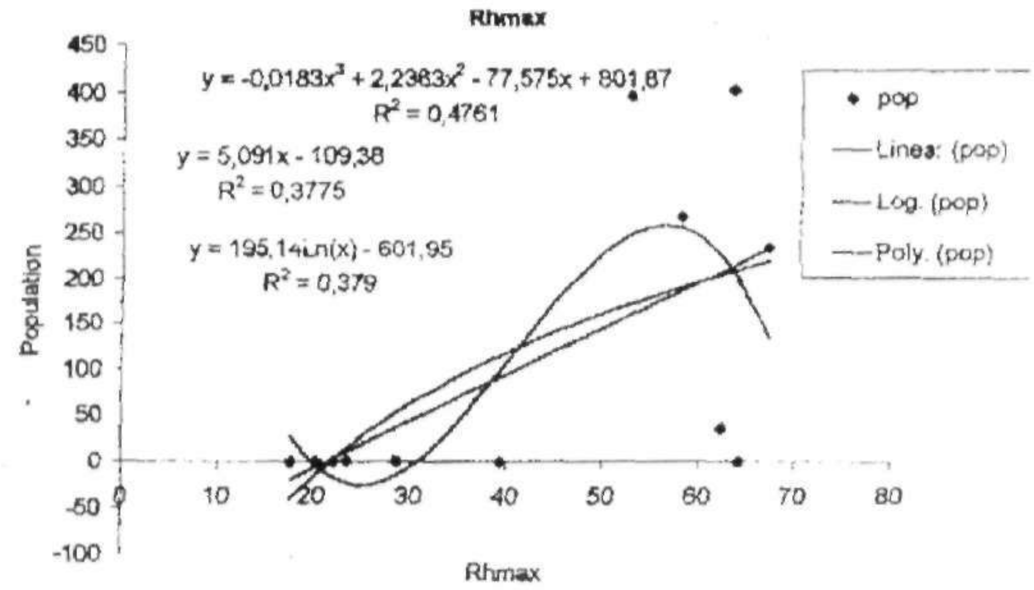
Weekly 1996



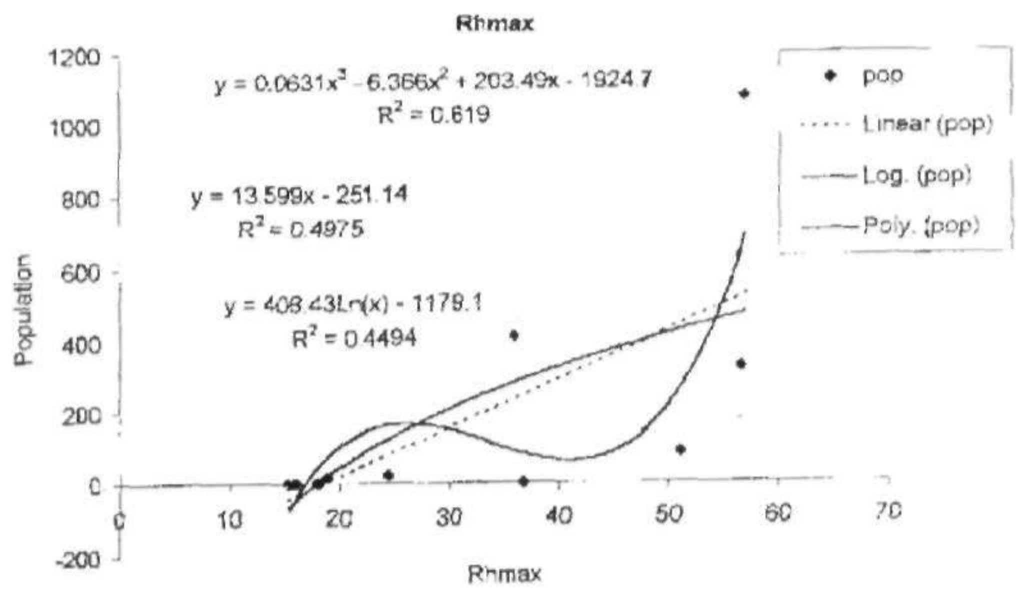
Weekly 1997



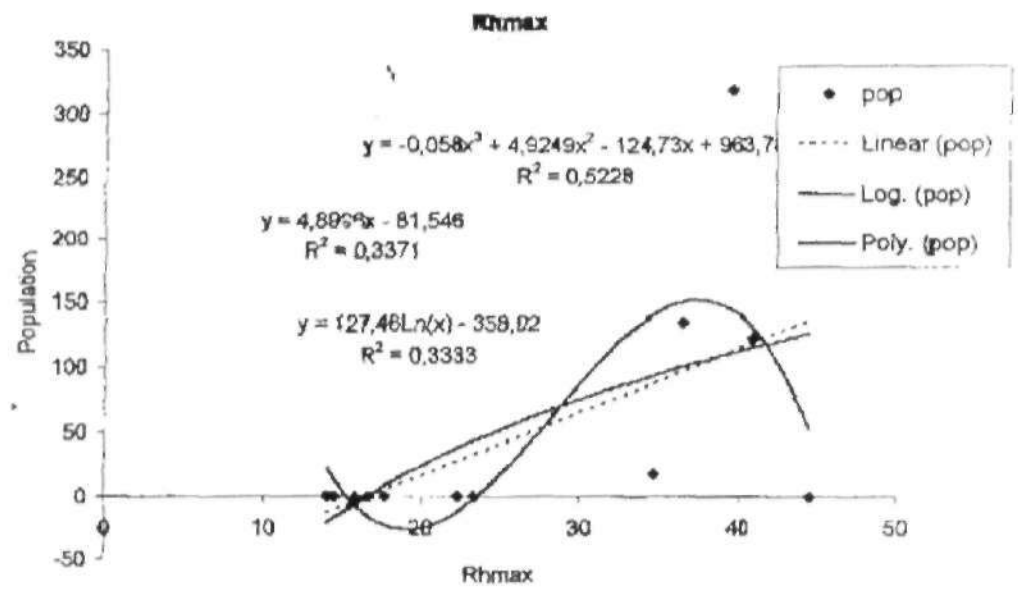
Continuation of Appendix 2.



Monthly 1995

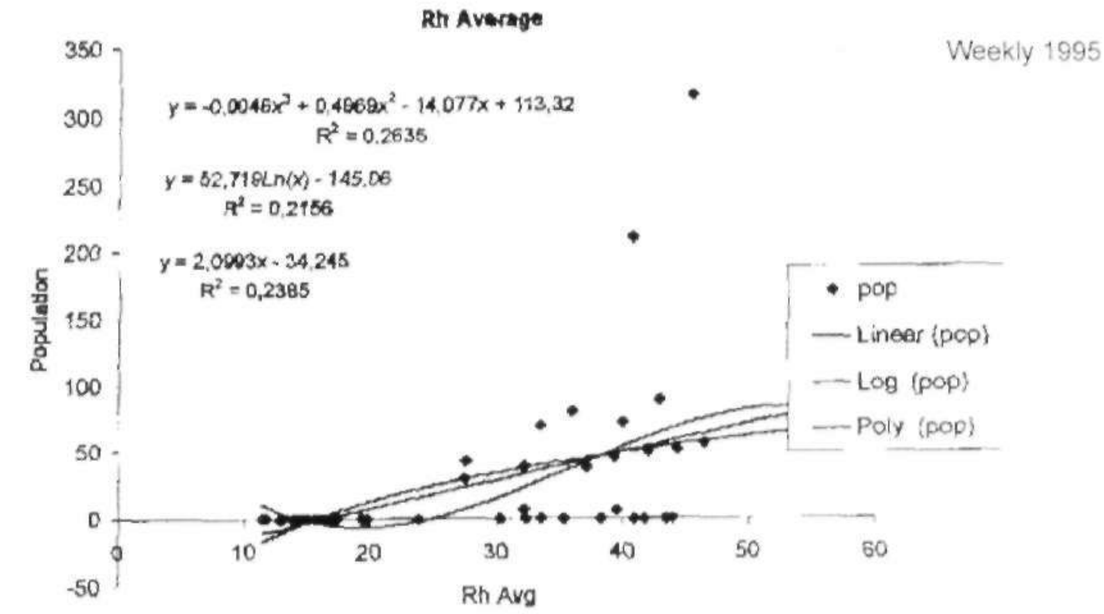


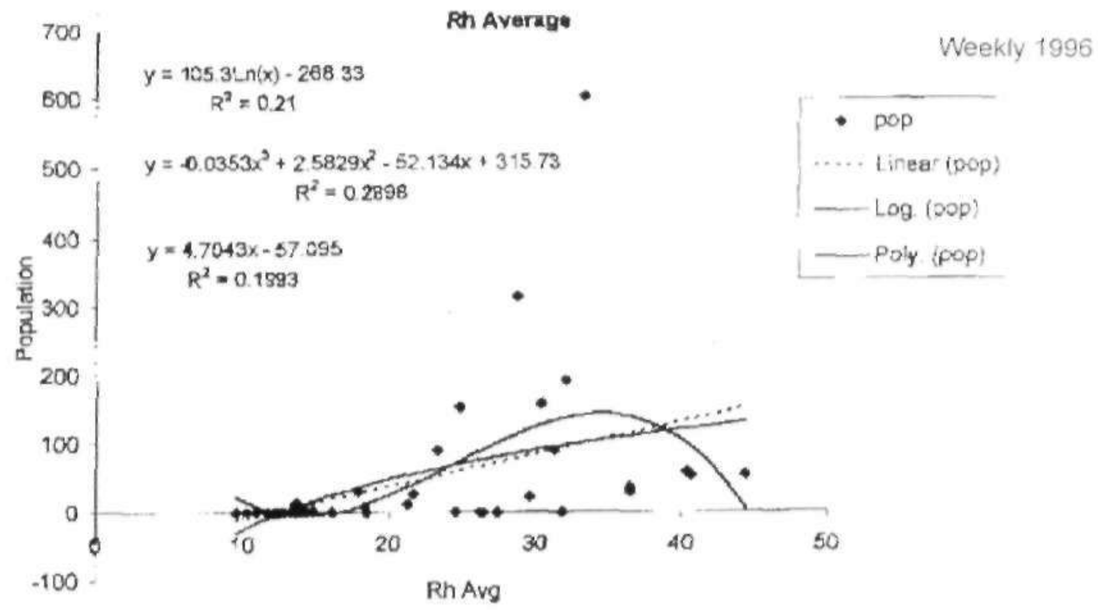
Monthly 1996

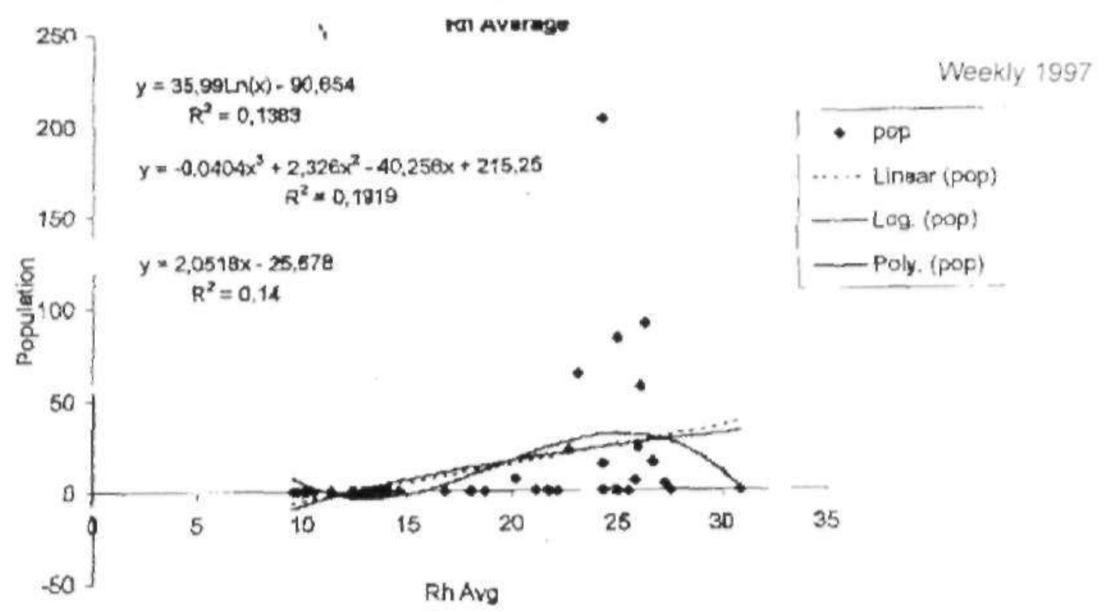


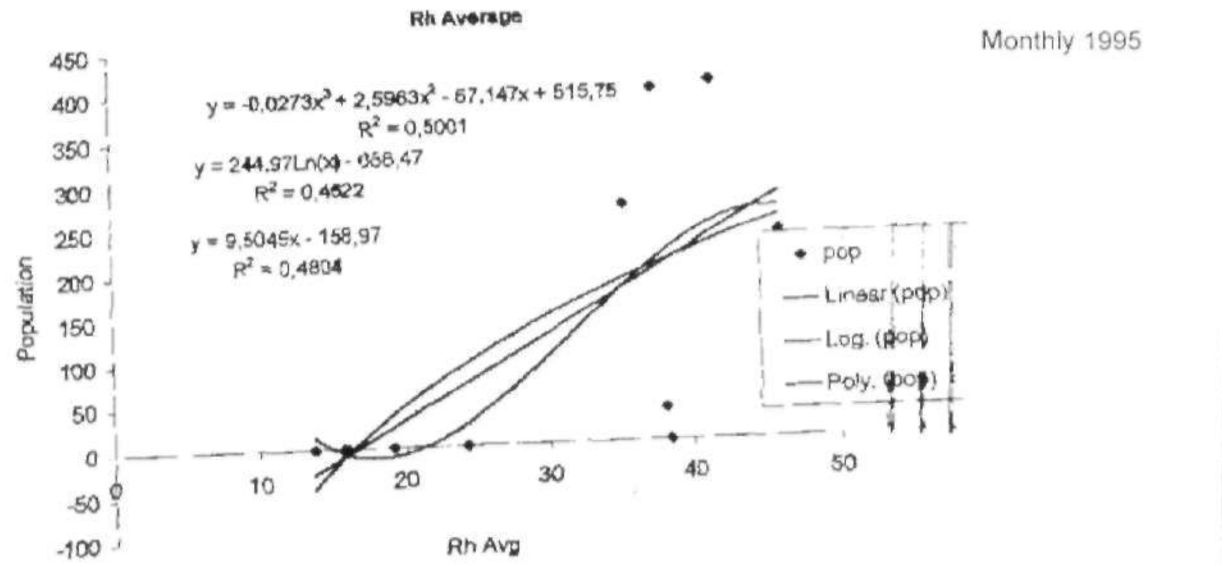
Monthly 1997

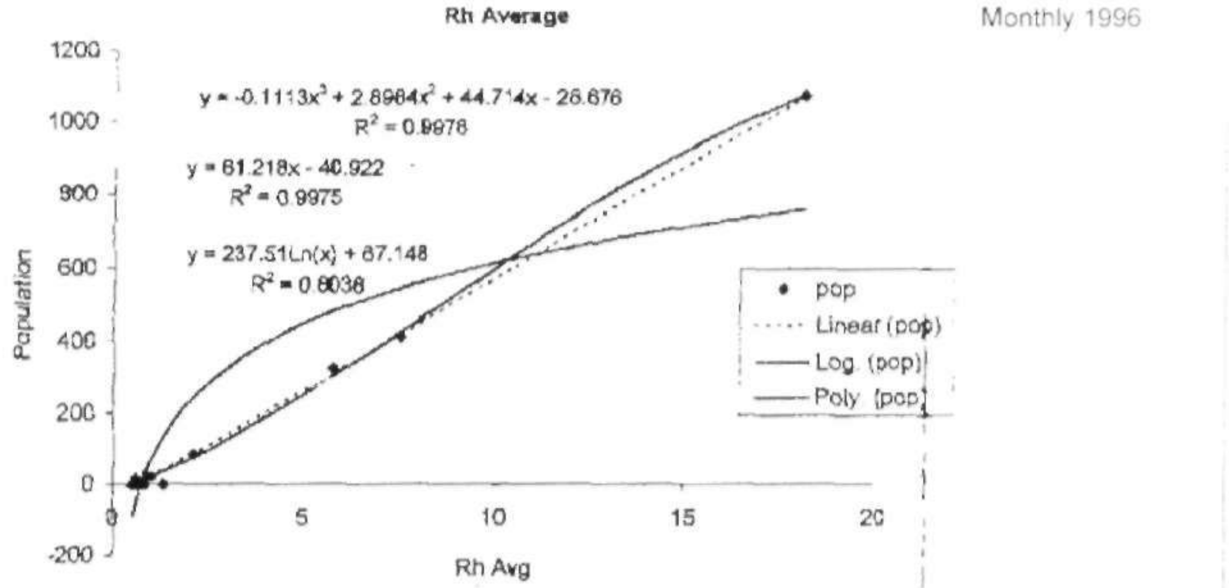
Continuation of Appendix 2.

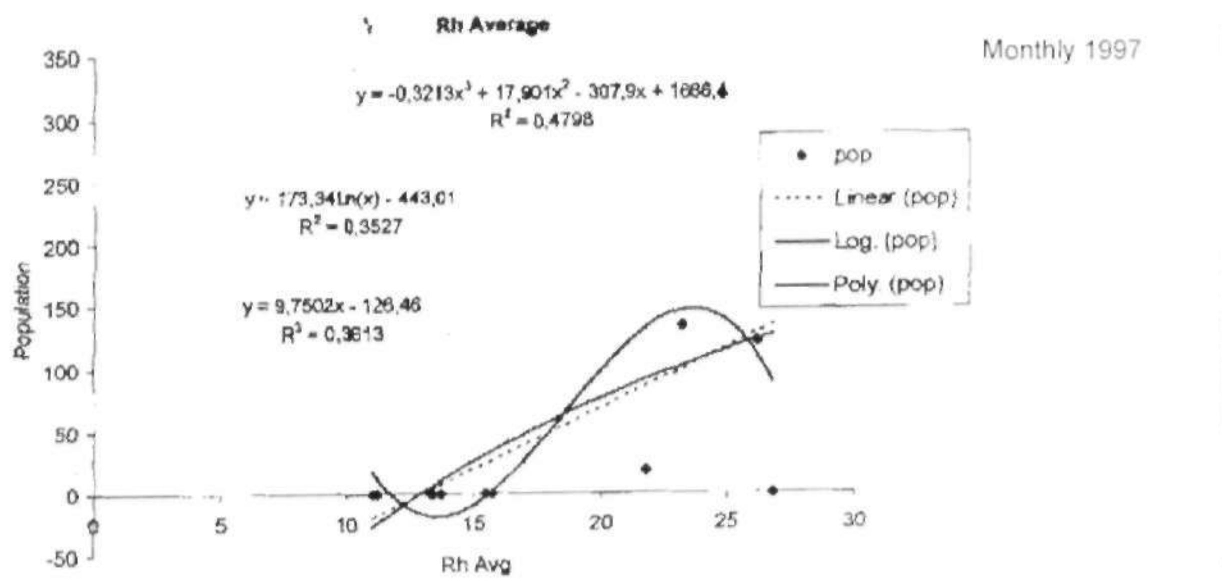







Rh Average
Monthly 1995
y = -0,0273x³ + 2,5963x² - 67,147x + 515,75
R² = 0,5001
y = 244,97Ln(x) - 656,47
R² = 0,4622
y = 9,5045x - 156,97
R² = 0,4804
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Rh Avg
450
400
350
300
250
200
150
100
50
0
-50
-100
10
20
30
40
50


Rh Average
Monthly 1996
y = -0.1113x³ + 2.8984x² + 44.714x - 26.676
R² = 0.9976
y = 61.218x - 40.922
R² = 0.9975
y = 237.51Ln(x) + 67.148
R² = 0.8036
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Rh Avg
1200
1000
800
600
400
200
0
-200
5
10
15
20


Rh Average
Monthly 1997
y = -0,3213x³ + 17,901x² - 307,9x + 1666,4
R² = 0,4798
y = 173,34Ln(x) - 443,01
R² = 0,3527
y = 9,7502x - 126,46
R² = 0,3813
pop
Linear (pop)
Log. (pop)
Poly. (pop)
Population
Rh Avg
350
300
250
200
150
100
50
0
-50
5
10
15
20
25
30

Appendix 4. Weekly and Monthly Correlation Matrixes for Pest and Climatic Data PROCESS

1995Wk

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	-0.7424	-0.1351	-0.0173	0.5702	-0.4976	-0.1593	-0.5604	0.2433	0.4781
TMAX	-0.7424	1.0000	0.4395	0.2173	-0.4316	0.6463	0.4696	0.8932	-0.0345	-0.5356
TMIN	-0.1351	0.4395	1.0000	0.1669	0.0610	0.2711	0.4983	0.7860	0.1336	-0.0524
RH MAX	-0.0173	0.2173	0.1669	1.0000	0.4545	0.1292	0.0910	0.2625	0.9150	0.1364
RH MIN	0.5702	-0.4316	0.0610	0.4545	1.0000	-0.2725	0.2651	0.2605	0.7667	0.4956
RAD	-0.4976	0.6463	0.2711	0.1292	-0.2725	1.0000	0.5109	0.5879	-0.0367	-0.6757
WS	0.1593	0.4696	0.4983	0.0910	0.2651	0.5109	1.0000	0.5497	0.1874	-0.2744
T AVG	-0.5604	0.8932	0.7860	0.2625	-0.2605	0.5879	0.5497	1.0000	0.0656	-0.3895
RH AVG	0.2433	-0.0345	0.1336	0.9150	0.7667	-0.0367	0.1874	0.0656	1.0000	0.3212
POP	0.4781	-0.5356	-0.0524	0.1364	0.4956	-0.6757	-0.2744	-0.3895	0.3212	1.0000

1996Wk

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	-0.6218	-0.1284	0.7342	0.8094	-0.5015	-0.2225	-0.4688	0.7780	0.2542
TMAX	-0.6218	1.0000	0.3772	-0.7545	-0.7452	0.7725	0.2788	0.8528	-0.7840	-0.3202
TMIN	-0.1284	0.3772	1.0000	-0.0799	-0.2543	0.0295	-0.0114	0.7744	-0.1131	-0.0647
RH MAX	0.7342	-0.7545	-0.0799	1.0000	0.7181	-0.5997	-0.2039	-0.5302	0.9927	0.3452
RH MIN	0.8094	-0.7452	-0.2543	0.7181	1.0000	-0.6365	-0.2332	-0.6372	0.7968	0.1723
RAD	-0.5015	0.7725	0.0295	-0.5997	-0.6365	1.0000	0.0966	0.5448	-0.6313	-0.1113
WS	-0.2225	0.2788	-0.0114	-0.2030	-0.2332	0.0966	1.0000	0.1742	-0.2173	-0.1885
T AVG	-0.4688	0.8528	0.7744	-0.5302	-0.6372	0.5448	0.1742	1.0000	-0.5705	-0.2714
RH AVG	0.7780	-0.7840	-0.1131	0.9927	0.7968	-0.6313	-0.2173	-0.5705	1.0000	0.3301
POP	0.2542	-0.3202	-0.0647	0.3452	0.1723	-0.1113	-0.1885	-0.2714	0.3301	1.0000

1997Wk

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	-0.2136	-0.1701	0.6002	0.5859	-0.1745	-0.1718	-0.4986	0.5577	0.2831
TMAX	0.2136	1.0000	0.2962	0.0097	-0.1383	-0.0966	0.2411	-0.0024	-0.0346	-0.1185
TMIN	-0.1701	-0.2962	1.0000	-0.4698	-0.4358	0.5244	0.6539	0.7673	-0.3920	-0.1691
RH MAX	0.6002	0.0097	-0.4698	1.0000	0.7132	-0.6004	-0.3778	-0.7274	0.9042	0.1897
RH MIN	0.5859	-0.1383	-0.4358	0.7132	1.0000	-0.6638	-0.3835	-0.8544	0.6971	0.5046
RAD	-0.1745	-0.0966	0.5244	-0.6004	-0.6638	1.0000	0.3996	0.7310	-0.4921	-0.2502
WS	0.1718	-0.2411	0.6539	-0.3778	-0.3835	0.3996	1.0000	0.5384	-0.4008	-0.2501
T AVG	-0.4986	-0.0024	0.7673	-0.7274	-0.8544	0.7310	0.5384	1.0000	-0.6984	-0.4331
RH AVG	0.5577	0.0346	0.3920	0.9042	0.6971	0.4921	0.4008	0.6984	1.0000	0.2905
POP	0.2831	-0.1165	-0.1691	0.1897	0.5046	-0.2502	-0.2501	-0.4331	0.2905	1.0000

Continuation of Appendix 4.

1995 Monthly

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	-0.6019	0.2169	0.3783	0.7112	-0.7419	0.0912	-0.2335	0.4119	0.9818
TMAX	-0.6019	1.0000	0.1054	0.1928	-0.2718	0.2725	-0.1170	0.3797	-0.0090	-0.5782
TMIN	0.2169	0.1054	1.0000	0.6827	0.2970	0.1247	0.5890	0.8840	0.5230	0.1846
Rhmax	0.3783	0.1928	0.6827	1.0000	0.5732	-0.1357	0.2658	0.4261	0.8252	0.4165
RHmin	0.7112	-0.2718	0.2970	0.5732	1.0000	-0.4135	0.5245	-0.0296	0.8279	0.7288
RAD	0.7419	0.2725	0.1247	-0.1357	-0.4135	1.0000	0.3422	0.4811	0.0186	-0.7186
WS	0.0912	-0.1170	0.5890	0.2658	0.5245	0.3422	1.0000	0.5957	0.6049	0.0305
Tavg	0.2335	0.3797	0.8840	0.4261	-0.0296	0.4811	0.5957	1.0000	0.3022	-0.2710
Rhavg	0.4119	-0.0090	0.5230	0.8252	0.8279	0.0186	0.6049	0.3022	1.0000	0.4454
POP	0.9818	-0.5782	0.1846	0.4165	0.7288	-0.7186	0.0305	-0.2710	0.4454	1.0000

1996*Monthly*

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	0.9093	0.4542	0.9195	0.9880	0.8602	0.9228	0.0702	0.3787	0.3918
TMAX	-0.9093	1.0000	-0.1348	-0.8959	-0.9491	0.8977	0.8699	-0.1652	-0.4644	-0.4777
TMIN	0.4542	-0.1348	1.0000	0.4429	0.3363	-0.3942	-0.1702	0.1088	0.1789	0.1662
RH MAX	0.9195	-0.8959	0.4429	1.0000	0.9207	-0.8464	-0.8117	0.4212	0.6523	0.6573
RH MIN	0.9808	-0.9491	0.3363	0.9207	1.0000	-0.8494	-0.9483	0.1000	0.3875	0.4012
RAD	*-0.8602*	*0.8977*	*-0.3942*	*-0.8464*	*-0.8494*	*1.0000*	*0.6695*	*-0.0804*	*-0.4662*	*-0.4740*
WS	-0.9228	0.8699	-0.1702	-0.8117	-0.9483	0.6695	1.0000	-0.0571	-0.3234	-0.3437
T AVC	0.0702	-0.1652	0.1088	0.4212	0.1006	-0.0804	-0.0571	1.0000	0.8199	0.8048
RH AVG	0.3787	-0.4644	0.1789	0.6523	0.3875	-0.4662	-0.3234	0.8199	1.0000	0.9993
POP	0.3918	-0.4777	0.1662	0.6573	0.4012	-0.4740	-0.3437	0.8048	0.9993	1.0000

1997*Monthly*

	RAIN	TMAX	TMIN	RH MAX	RH MIN	RAD	WS	T AVG	RH AVG	POP
RAIN	1.0000	-0.8772	0.1676	0.7361	0.8496	-0.3692	0.1364	-0.0721	0.7637	0.5308
TMAX	0.8772	1.0000	0.1182	-0.7976	-0.9682	0.6897	0.2023	0.3227	-0.8184	0.7483
TMIN	0.1676	0.1182	1.0000	0.0339	-0.2320	0.3589	0.6441	0.4641	0.0355	0.1001
RH MAX	0.7361	-0.7976	0.0339	1.0000	0.7216	-0.7432	-0.1234	0.1852	0.9979	0.4973
RH MIN	0.8496	-0.9682	-0.2320	0.7216	1.0000	-0.6360	-0.3133	-0.4333	0.7454	0.6816
RAD	-0.3692	0.6897	0.3589	-0.7432	-0.6360	1.0000	0.5182	0.3053	-0.7459	-0.5020
WS	0.1364	0.2023	0.6441	-0.1234	-0.3133	0.5182	1.0000	0.5919	-0.1379	-0.3500
T AVG	-0.0721	0.3227	0.4641	0.1852	-0.4333	0.3053	0.5919	1.0000	0.1467	-0.3972
RH AVG	0.7637	0.8184	0.0355	0.9979	0.7454	0.7459	0.1379	0.1467	1.0000	0.5189
POP	0.5308	-0.7483	0.1001	0.4973	0.6816	-0.5020	-0.3500	-0.3972	0.5189	1.0000

Appendix 5 : Population and Climatic data processd for 1995

	[illegible]	[illegible]	[illegible]	RHMAX	RHMIN	[illegible]	[illegible]	[illegible]	[illegible]	POP	PRE_1	ZPR_1	PRE_2	ZPR_2	PRE_3	ZPR_3	PRE_4
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28.90	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.74	[illegible]	[illegible]	28.90	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-24.56	-1.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-38.66	-1.26	[illegible]	[illegible]	-8.99	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-37.69	-1.24	[illegible]	[illegible]	-24.14	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-16.62	-0.94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.66	-0.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.73	[illegible]	[illegible]	-0.96	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.62	[illegible]	[illegible]	-4.99	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-16.13	-0.62	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.49	-0.41	[illegible]	[illegible]	34.14	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-6.03	[illegible]	[illegible]	[illegible]	-9.23	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-22.35	-0.96	[illegible]	[illegible]	[illegible]	[illegible]	9.67
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45.00	49.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38.93
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.37	[illegible]	[illegible]	27.99	[illegible]	54.34
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45.77	0.16	[illegible]	[illegible]	82.73	1.09	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.00	98.67	1.05	[illegible]	[illegible]	125.99	[illegible]	139.55
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.00	130.43	1.59	[illegible]	[illegible]	103.22	1.30	87.78
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	186.95	2.54	[illegible]	[illegible]	154.50	[illegible]	95.36
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	335.00	185.21	2.51	[illegible]	[illegible]	[illegible]	0.26	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	114.00	138.31	[illegible]	[illegible]	[illegible]	81.76	1.88	62.08
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	63.00	105.11	1.16	[illegible]	[illegible]	132.59	1.86	143.08
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	64.00	62.51	0.44	[illegible]	[illegible]	92.97	1.10	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	95.00	110.44	1.25	[illegible]	[illegible]	[illegible]	1.63	132.33
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.03	-0.04	[illegible]	[illegible]	18.99	-0.33	25.82
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61.00	[illegible]	0.47	[illegible]	[illegible]	48.14	[illegible]	37.34
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.00	46.18	[illegible]	43.41	[illegible]	12.99	-0.45	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	28.04	-0.14	44.43	[illegible]	16.02	-0.39	6.99
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	13.90	-0.37	44.66	[illegible]	27.38	-0.17	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	.90	-0.48	[illegible]	-0.58	9.20	-0.52	4.53
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	6.87	-0.49	[illegible]	-0.63	16.77	-0.37	3.30
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	19.89	-0.27	6.03	-0.52	16.77	-0.37	3.76
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.00	1.52	-0.58	-3.80	-0.78	9.20	-0.52	4.37
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.24	-0.55	-2.91	-0.72	14.50	-0.42	[illegible]
	[illegible]	[illegible]	10.20	17.40	10.80	21.60	1.00	19.60	[illegible]	0.00	17.77	-0.31	5.91	-0.56	16.77	-0.37	2.84
Average	[illegible]	[illegible]	18.52	43.14	13.51	21.94	1.71	25.82	28.57	36.14	36.14	0.00	36.14	0.00	36.14	0.00	36.14
Maximum	[illegible]	35.40	25.70	81.20	34.40	27.60	3.60	32.20	58.00	335.00	186.95	2.54	156.20	2.22	154.50	2.29	143.08
Minimum	[illegible]	[illegible]	6.90	15.20	7.40	12.00	0.90	15.70	12.10	0.00	-58.86	-1.26	-38.53	-1.38	-30.20	-1.28	[illegible]
Sum	[illegible]	[illegible]	685.30	1596.10	500.00	811.80	63.20	955.40	1057.10	1337.00	1337.00	0.00	1337.00	0.00	1337.00	0.00	1337.00
Std	[illegible]	3.44	5.19	21.43	5.81	3.14	0.65	3.94	12.83	72.82	59.42	1.00	54.04	1.00	51.79	1.00	47.88
Var	[illegible]	[illegible]	26.94	459.33	33.79	9.88	0.43	[illegible]	164.54	5302.95	3530.45	1.00	[illegible]	1.00	2682.10	1.00	2292.69

Continuation of Appendix 5.

ZPR_4	PRE_5	ZPR_5	PRE_6	ZPR_6	PRE_7	ZPR_7	PRE_8	ZPR_8	PRE_9	ZPR_9	PRE_10	ZPR_10	PRE_11	ZPR_11
-0.70	-2.41	[illegible]	33.95	-0.05	32.66	-0.07	12.62	-0.48	-6.34	-0.87	-1.79	-0.79	2.75	-0.63
-0.70	-6.71	-0.88	29.95	-0.13	38.44	0.04	39.65	0.07	17.66	-0.38	0.15	-0.75	8.84	-0.52
-0.70	-6.71	-0.88	31.95	-0.09	37.28	0.02	50.57	0.30	26.00	-0.21	1.36	-0.72	7.84	-0.54
-0.70	-5.18	-0.82	0.58	-0.76	17.42	-0.35	11.06	-0.51	10.53	-0.52	0.43	-0.74	6.31	-0.57
-0.67	-1.88	-0.76	-29.39	-1.39	-13.21	-0.93	-23.79	-1.23	0.70	-0.72	1.54	-0.72	-0.77	-0.70
-0.65	-8.51	-0.89	-50.22	-1.84	-35.92	-1.36	-43.48	-1.63	-3.31	-0.81	3.21	-0.69	-4.67	-0.77
-0.63	-4.77	-0.82	-51.35	-1.86	-50.22	-1.62	-67.76	-2.13	-21.76	-1.18	3.39	-0.68	-12.25	-0.92
-0.58	0.09	-0.72	5.56	-0.65	-25.07	-1.15	-4.43	-0.83	-0.28	-0.74	9.96	-0.54	-8.82	-0.85
-0.61	-10.87	-0.94	3.69	-0.69	-18.98	-1.04	10.97	-0.52	12.12	-0.49	6.57	-0.57	-7.14	-0.82
-0.60	-9.78	-0.92	-37.35	-1.56	-51.84	-1.65	-44.30	-1.65	-9.29	-0.93	7.65	-0.59	-12.67	-0.93
-0.54	7.23	-0.88	25.70	-0.22	-18.22	-1.02	17.01	-0.39	7.25	-0.59	13.74	-0.47	-9.11	-0.86
-0.57	23.14	-0.28	56.07	0.42	25.08	-0.21	53.49	0.36	18.63	-0.36	13.29	-0.48	8.85	-0.52
-0.18	48.49	0.25	74.78	0.82	57.11	0.39	67.96	0.65	33.98	-0.04	31.07	-0.11	37.18	0.02
-0.56	21.19	-0.31	23.15	-0.28	-6.40	-0.80	24.16	-0.25	13.59	-0.46	13.78	-0.47	-0.15	-0.69
-0.57	13.85	-0.23	47.48	0.24	24.67	-0.21	43.13	0.14	15.29	-0.43	12.55	-0.49	12.35	-0.45
0.06	61.43	0.81	9.09	-0.57	54.51	0.35	17.96	-0.37	38.51	0.05	41.50	0.11	72.57	0.69
1.38	90.21	1.28	12.69	-0.50	138.61	1.93	28.43	-0.16	56.83	0.42	56.34	0.42	150.32	2.17
1.68	118.53	1.44	35.09	0.04	62.87	0.50	59.51	0.48	114.36	1.60	116.52	1.60	109.91	1.40
2.16	121.36	1.72	69.46	0.71	85.48	0.93	85.75	1.02	134.09	2.00	138.82	2.14	128.41	1.75
1.18	99.63	1.27	101.30	1.38	116.42	1.51	106.65	1.44	95.06	1.20	88.96	1.10	107.38	1.35
1.24	100.30	1.30	188.31	3.23	175.78	2.63	168.37	2.71	101.54	1.34	96.11	1.25	119.23	1.58
1.13	141.47	2.08	123.59	1.86	150.11	2.14	124.61	1.81	135.05	2.02	136.98	2.10	153.86	2.23
1.54	73.81	0.78	91.23	1.17	102.78	1.25	106.61	1.44	82.22	0.94	64.22	0.58	81.74	0.87
2.23	140.43	2.08	72.55	0.77	80.78	0.88	83.95	0.98	133.37	1.98	141.37	2.19	121.60	1.62
1.80	106.16	1.40	47.73	0.25	37.84	0.03	65.97	0.61	108.11	1.47	118.57	1.51	75.36	0.74
[illegible]	[illegible]	1.82	83.68	1.01	79.32	0.81	96.94	1.24	129.77	1.91	131.38	1.98	106.61	1.34
-0.22	31.81	-0.27	27.94	-0.17	7.81	-0.34	41.40	0.11	37.60	0.03	28.11	-0.27	10.86	-0.48
0.03	37.07	[illegible]	60.33	0.51	33.04	-0.06	70.91	0.71	51.65	0.32	39.84	0.08	24.83	-0.21
-0.61	19.66	-0.13	45.61	0.20	45.18	0.17	39.01	0.06	11.81	-0.50	9.31	-0.56	23.28	-0.24
-0.61	18.51	-0.18	49.18	0.28	38.85	0.05	25.75	-0.21	-1.14	-0.76	7.28	-0.60	14.77	-0.41
-0.61	14.25	-0.24	65.43	0.71	45.83	0.18	39.36	0.07	-1.38	-0.77	6.63	-0.61	10.33	-0.49
-0.66	-2.54	-0.77	11.52	-0.52	4.61	-0.59	2.94	-0.68	-0.81	-0.75	1.56	-0.70	-2.76	-0.74
-0.69	-7.81	-0.88	14.68	-0.46	16.37	-0.37	11.79	-0.50	3.39	-0.67	1.71	-0.74	1.34	-0.66
-0.65	-7.13	-0.86	19.19	-0.36	13.78	-0.42	0.15	-0.74	-7.25	-0.89	-1.13	-0.75	-1.19	-0.71
-0.66	-9.21	-0.90	10.02	-0.55	1.04	-0.66	-8.98	-0.92	-9.96	-0.94	1.26	-0.73	-4.66	-0.77
-0.67	-8.93	-0.91	16.64	-0.41	12.50	-0.44	14.64	-0.44	5.60	-0.62	0.11	-0.71	0.35	-0.68
-0.70	-7.96	-0.88	10.18	-0.55	19.74	-0.31	8.42	-0.57	3.82	-0.66	-1.89	-0.76	4.34	-0.60
0.00	36.14	0.00	36.14	0.00	36.14	0.00	36.14	0.00	36.14	0.00	36.14	0.00	36.14	0.00
2.23	141.47	2.08	188.31	3.23	175.78	2.63	168.37	2.71	135.05	2.02	141.37	2.19	153.86	2.23
-0.70	-10.87	-0.94	-51.35	-1.86	-51.84	-1.65	-67.76	-2.13	-21.76	-1.18	-1.79	-0.79	-12.67	-0.93
0.00	1337.00	0.00	1337.00	0.00	1337.00	0.00	1337.00	0.00	1337.00	0.00	1337.00	0.00	1337.00	0.00
1.00	50.12	1.00	47.06	1.00	53.16	1.00	48.85	1.00	48.99	1.00	48.04	1.00	52.72	1.00
1.00	2511.68	1.00	2214.67	1.00	2826.50	1.00	2385.87	1.00	2399.54	1.00	2317.80	1.00	2779.15	1.00

Appendix 6. Population and Climatic data processed for 1996

	RAIN	TMAX	TMIN	RHMAX	RHMIN	RAD	WS	TAVG	RHAVG	POP	PRE_1	ZPR_1	PRE_2	ZPR_2	PRE_3	ZPR_3	PRE_4	ZPR_4	PRE_5
	.00	[illegible]	8.24	18.30	9.90	24.46	1.13	9.90	1.20	1.00	-49.57	-1.03	-25.73	-.86	24.18	-.45	-14.03	-.97	21.36
	.00	[illegible]	12.44	18.30	9.80	22.46	.99	9.80	1.00	1.00	8.26	-.44	-7.03	-.65	12.01	-.65	-11.58	-.93	22.45
	.00	[illegible]	13.11	17.30	9.40	24.08	1.14	9.40	1.11	.00	9.14	-.44	-7.18	-.66	21.75	-.49	-1.77	-.79	21.91
	.00	[illegible]	13.58	16.70	8.30	23.19	1.02	8.30	1.20	.00	.99	-.52	60.19	.08	16.45	-.58	25.18	-.40	21.36
	.00	[illegible]	15.11	15.90	8.80	23.48	1.07	8.80	1.20	.00	37.59	-.15	29.66	-.25	18.22	-.55	12.93	-.58	21.36
	.00	[illegible]	14.88	15.90	8.50	24.21	.97	8.50	1.11	.00	63.70	.11	67.39	.16	22.66	-.48	20.28	-.47	21.91
	.00	[illegible]	14.90	16.00	9.00	24.20	1.00	9.00	1.00	.00	37.05	-.16	38.92	-.15	22.60	-.48	8.03	-.65	22.45
	.00	[illegible]	14.90	16.00	9.00	24.20	1.00	9.00	1.00	.00	37.05	-.16	38.92	-.15	22.60	-.48	8.03	-.65	22.45
	.00	[illegible]	19.19	14.10	8.00	25.61	1.54	8.00	1.50	.00	14.03	-.39	-10.21	-.69	31.18	-.34	32.54	-.29	19.72
	.00	[illegible]	14.63	14.10	8.20	23.76	1.12	8.20	1.20	.00	-3.10	-.56	49.37	-.03	19.92	-.52	27.64	-.36	21.36
	.00	[illegible]	15.11	15.90	8.80	23.48	1.07	8.80	1.11	.00	37.59	-.15	29.66	-.25	18.22	-.55	12.93	-.58	21.36
	.00	[illegible]	14.88	15.90	8.50	24.21	.97	8.50	1.11	.00	63.83	.11	67.39	.16	22.66	-.48	20.28	-.47	21.91
	.00	[illegible]	15.58	16.10	6.50	24.51	1.84	6.50	1.90	.00	-27.36	-.80	-6.76	-.65	24.49	-.45	69.30	.24	17.53
	.00	[illegible]	15.01	16.60	7.40	23.78	1.75	7.40	1.80	.00	-20.60	-.74	-35.28	-.97	20.04	-.52	47.24	-.08	18.08
	.00	[illegible]	13.88	[illegible]	8.40	22.66	1.41	8.40	1.60	.00	37.29	-.15	-23.00	-.83	13.22	-.63	21.73	-.43	19.17
	[illegible]	[illegible]	12.43	24.50	10.00	20.08	1.62	10.00	17.00	.00	-21.42	-.74	-65.31	-1.30	51.54	-.02	70.57	.26	-16.30
	[illegible]	[illegible]	12.41	37.40	10.80	20.57	1.17	10.80	11.00	.00	7.02	-.46	-60.56	-1.24	20.85	-.51	4.06	-.70	-13.88
	40.47	[illegible]	12.43	46.00	9.00	22.94	1.35	9.00	17.00	.00	126.85	.75	95.27	.47	89.67	.60	128.47	1.11	2.41
	[illegible]	[illegible]	12.14	43.70	10.00	23.65	1.08	10.00	3.11	.00	147.58	.96	55.57	.06	60.51	.13	50.00	-.04	48.22
	[illegible]	[illegible]	[illegible]	51.50	10.70	21.54	1.58	10.70	1.80	18.00	147.57	.96	211.66	1.75	182.17	2.08	249.59	2.87	176.80
	[illegible]	[illegible]	15.94	57.40	18.00	20.83	1.29	18.00	1.40	56.00	-16.99	-.70	8.14	-.49	214.29	2.59	129.41	1.12	211.90
	[illegible]	[illegible]	15.80	47.20	13.80	17.04	.75	13.80	[illegible]	188.00	171.11	1.20	110.38	.64	106.67	.87	103.45	.74	137.73
	[illegible]	[illegible]	11.32	61.00	17.50	17.20	.66	17.50	1.00	108.00	138.94	.87	191.02	1.52	222.91	2.73	191.15	2.02	241.82
	[illegible]	[illegible]	11.18	61.80	13.30	19.95	.84	13.30	[illegible]	39.00	215.34	1.64	219.99	1.84	170.08	1.89	181.99	1.88	179.00
	[illegible]	[illegible]	[illegible]	65.70	12.80	18.24	.52	12.80	.70	52.00	85.83	.34	62.38	.11	46.44	-.10	19.14	-.49	78.39
	[illegible]	[illegible]	11.30	57.00	11.20	21.99	.57	11.20	1.11	643.00	368.94	3.19	341.18	3.17	164.19	1.79	203.94	2.20	162.46
	[illegible]	[illegible]	11.73	51.10	10.60	22.52	.59	10.60	.90	352.00	304.65	2.54	217.26	1.81	97.48	.72	105.96	.78	99.85
	[illegible]	[illegible]	11.19	41.70	10.20	21.44	1.09	10.20	1.11	298.00	166.44	1.15	160.74	1.19	103.85	.82	136.63	1.22	110.46
	.80	34.88	11.94	34.60	8.90	22.61	1.25	8.90	1.20	100.00	31.70	-.21	-12.90	-.72	13.85	-.62	11.97	-.59	22.19
	.00	35.16	11.16	31.70	8.50	22.58	1.48	8.50	1.50	42.00	-40.59	-.94	-41.26	-1.03	12.74	-.64	20.28	-.47	19.72
	[illegible]	35.34	15.81	35.00	8.20	21.79	1.22	8.20	1.11	15.00	-1.52	-.54	59.69	.05	27.35	-.40	38.94	.09	39.45
	.00	34.15	15.36	20.80	8.70	23.32	1.56	8.70	1.70	11.00	-99.03	-1.53	-61.26	-1.25	17.24	-.87	15.38	-.54	18.62
	.00	[illegible]	14.54	19.40	8.60	23.80	1.30	8.60	1.30	.00	-44.13	-.97	-3.20	-.61	20.16	-.52	17.83	-.50	20.81
	.00	32.52	11.61	19.00	9.30	21.53	1.03	9.30	1.50	1.00	-44.39	-.98	1.22	-.56	6.35	-.74	.68	-.75	19.72
	.00	31.94	11.09	17.90	9.50	20.60	.51	9.50	1.00	13.00	40.95	-.12	86.23	.37	.68	-.83	-4.23	-.83	22.45
	.00	31.45	8.59	19.20	10.00	21.23	.61	10.00	1.00	3.00	12.78	-.40	48.36	-.05	4.52	-.77	-16.48	-1.00	22.45
	.00	31.75	9.63	18.17	10.00	20.20	.58	10.00	.83	.00	-1.55	-.54	47.09	-.06	-1.75	-.87	-16.48	-1.00	23.36
Average	22.51	33.35	17.76	30.03	9.92	22.27	1.10	9.92	2.38	52.49	52.49	.00	52.49	.00	52.49	.00	52.49	.00	52.49
Maximum	131.30	40.11	25.58	65.70	18.00	25.61	1.84	18.00	17.00	643.00	368.94	3.19	341.18	3.17	222.91	2.73	249.59	2.87	241.82
Minimum	.00	26.53	8.24	14.10	6.50	17.04	.51	6.50	.70	.00	-99.03	-1.53	-65.31	-1.30	-1.75	-.87	-16.48	-1.00	-16.30
Sum	832.90	1233.89	656.96	1111.07	367.20	823.92	40.69	367.20	88.23	1942.00	1942.00	.00	1942.00	.00	1942.00	.00	1942.00	.00	1942.00
Std	37.43	2.58	4.76	16.67	2.39	2.03	.35	2.39	3.91	128.15	99.26	1.00	90.94	1.00	62.35	1.00	68.74	1.00	65.19
Var	1401.82	6.67	22.65	277.84	5.71	4.12	.12	5.71	15.27	16422.65	9851.84	1.00	8269.49	1.00	3887.98	1.00	4725.08	1.00	4250.31

Continuation of Appendix 6

ZPR_5	PRE_6	ZPR_6	PRE_7	ZPR_7	PRE_8	ZPR_8	PRE_9	ZPR_9	PRE_10	ZPR_10	PRE_11	ZPR_11
-.48	43.47	-.14	2.74	-.71	48.29	-.06	-8.25	-.93	-8.45	-.97	-26.17	-1.06
-.46	50.11	-.76	-10.10	-.89	59.22	.09	20.59	-.49	3.58	-.78	-23.59	-1.02
-.47	38.61	-.37	-.91	-.76	59.55	.10	8.81	-.67	5.53	-.75	-16.61	-.93
-.48	27.90	-.66	.00	-.75	-48.92	-1.43	-10.47	-.96	6.79	-.73	9.81	-.57
-.48	33.19	-.52	-7.09	-.85	25.62	-.38	9.45	-.66	11.11	-.66	-5.80	-.78
-.47	26.42	-.70	.72	-.74	3.09	-.69	-2.93	-.85	10.49	-.67	1.96	-.68
-.46	32.90	-.53	-3.44	-.80	1.85	-.71	-3.05	-.85	10.64	-.67	-10.63	-.85
-.46	32.90	-.53	-3.44	-.80	1.85	-.71	-3.05	-.85	10.64	-.67	-10.63	-.85
-.50	14.42	-1.13	5.03	-.68	40.73	-.17	4.57	-.73	22.93	-.47	8.83	-.59
-.48	14.34	-.76	1.53	-.73	-45.18	-1.37	-11.90	-.99	9.66	-.68	10.38	-.56
-.48	33.19	-.52	-7.09	-.85	25.62	-.38	9.45	-.66	11.11	-.66	-5.80	-.78
-.47	26.42	-.70	.72	-.74	1.62	-.71	-3.25	-.85	10.49	-.67	1.96	-.68
-.54	-.54	-1.43	22.50	-.43	-37.60	-1.27	8.10	-.68	41.25	-.18	54.33	.02
-.53	13.96	-1.14	11.88	-.58	5.13	-.67	23.78	-.44	39.61	-.20	32.74	-.26
-.51	31.29	-.57	20.39	-.46	59.27	.10	44.37	-.12	36.37	-.26	22.34	-.40
-1.06	62.15	.16	6.05	-.66	75.95	.33	93.13	.62	75.89	.37	43.82	-.12
-1.12	66.65	.38	76.33	.34	85.66	.47	75.19	.35	48.61	-.06	41.96	-.14
-.77	37.91	-.39	154.31	1.45	113.54	.86	88.79	.56	92.64	.64	161.73	1.47
-.07	47.97	-.22	137.14	1.21	159.90	1.51	77.75	.39	64.74	.19	96.07	.58
1.91	65.37	.35	153.81	1.44	135.33	1.16	152.24	1.53	171.77	1.88	229.66	2.38
1.45	161.15	1.96	119.31	.95	149.45	1.36	174.38	1.87	193.78	2.25	99.04	.62
1.31	119.33	1.81	78.49	.37	195.92	2.02	178.10	1.93	127.07	1.19	100.12	.64
[illegible]	170.13	3.18	118.94	.95	91.42	.55	210.19	1.42	225.40	2.75	153.48	1.36
1.94	135.14	1.41	181.38	1.84	161.37	1.53	170.88	1.81	168.71	1.85	198.10	1.95
.40	111.67	1.33	194.68	1.18	107.74	.78	116.56	.98	76.98	.39	123.42	.95
1.69	[illegible]	.47	188.33	1.94	170.21	1.66	147.55	1.46	154.36	1.62	218.72	2.23
.73	60.19	.11	159.28	1.51	179.26	1.78	112.45	.92	99.11	.74	144.06	1.23
.59	59.33	.18	114.51	.88	111.89	.83	109.38	.87	117.93	.88	141.95	1.20
-.46	37.93	-.39	89.73	.53	78.13	.36	45.71	-.10	31.86	-.33	55.31	.04
-.51	32.90	-.53	77.15	.35	39.11	-.19	33.90	-.28	25.88	-.38	55.02	.03
-.20	32.17	-.55	91.81	.57	-13.92	-1.07	30.90	-.33	41.41	-.19	92.47	.54
-.51	30.53	-.54	19.91	-.46	15.95	-.51	8.91	-.67	11.95	-.65	13.24	-.53
-.49	29.34	-.60	16.39	-.51	-7.22	-.84	-2.80	-.85	9.60	-.66	11.13	-.56
-.50	47.37	-.14	-7.57	-.86	-16.97	-.98	9.41	-.66	4.07	-.77	-8.31	-.82
-.46	53.65	.03	-22.34	-1.07	-46.77	-1.40	6.24	-.71	-.28	-.84	-17.18	-.93
-.46	57.59	.14	-25.44	-.97	-1.96	-.77	6.79	-.70	-7.48	-.95	-25.74	-1.05
-.45	61.56	.25	-28.16	-1.15	-32.33	-1.19	10.01	-.65	-4.46	-.91	-29.21	-1.10
.00	52.49	.00	52.49	.00	52.49	.00	52.49	.00	52.49	.00	52.49	.00
1.90	170.13	3.18	198.68	2.08	195.92	2.02	210.19	2.42	225.40	2.75	229.66	2.38
-1.06	-.54	-1.43	-28.16	-1.15	-48.92	-1.43	-11.90	-.99	-8.45	-.97	-29.21	-1.10
.00	1942.00	.00	1942.00	.00	1942.00	.00	1942.00	.00	1942.00	.00	1942.00	.00
1.00	37.08	1.00	70.18	1.00	71.12	1.00	65.24	1.00	62.64	1.00	74.52	1.00
1.00	1375.19	1.00	4924.79	1.00	5057.78	1.00	4256.29	1.00	3946.26	1.00	5553.71	1.00

Appendix 7: Popufaiton and Climatic data processed for 1997

	RAIN	TMAX	TMIN	RHMAX	RHMIN	RAD	WS	TAVG	RHAVG	POP	PRE_1	ZPR_1	PRE_2	ZPR_2	PRE_3	ZPR_3	PRE_4	ZPR_4	PRE_5
	.00	33.10	11.50	17.10	9.30	20.60	1.00	22.30	13.40	.00	6.95	-.35	8.37	-.36	8.00	-.40	4.94	-.56	1.31
	.00	32.50	14.10	16.30	9.40	20.70	1.10	23.40	13.20	.00	9.86	-.24	8.85	-.34	7.81	-.41	4.67	-.57	1.04
	.00	29.80	12.10	16.80	10.80	21.60	1.30	20.50	14.10	.00	3.53	-.48	2.39	-.64	6.16	-.49	5.40	-.54	2.26
	.00	26.70	13.90	16.00	11.30	20.20	1.30	20.30	13.90	.00	-.09	-.62	6.05	-.47	8.73	-.36	5.45	-.53	1.99
	.00	28.60	13.80	16.20	10.80	23.30	1.40	21.10	13.80	.00	-1.44	-.68	-2.52	-.87	3.03	-.65	5.25	-.54	1.86
	.00	30.40	16.10	15.20	10.10	21.00	1.10	23.30	10.80	.00	6.10	-.38	7.51	-.40	7.26	-.44	4.69	-.57	.50
	.00	30.60	16.90	15.10	10.00	20.90	1.40	23.80	10.90	.00	8.09	-.31	7.15	-.42	7.44	-.43	4.57	-.58	.64
	.00	37.20	19.60	14.30	7.70	25.10	1.00	28.20	11.20	.00	1.32	-.57	.89	-.71	-.29	-.81	3.46	-.63	-1.66
	.00	38.60	23.70	12.70	7.10	23.40	1.00	31.00	10.00	.00	7.24	-.34	8.39	-.36	2.84	-.66	2.76	-.67	-3.29
	.00	37.20	21.90	13.20	7.60	28.00	2.40	29.40	10.80	.00	-11.53	-1.06	-12.77	-1.35	-5.62	-1.08	3.16	-.65	-2.20
	.00	39.40	25.60	12.20	7.00	26.90	3.00	32.20	9.90	.00	1.53	-.56	-9.51	-1.19	-3.60	-.98	2.46	-.68	-3.42
	8.00	36.10	24.50	18.10	8.00	19.70	8.60	27.40	10.50	.00	-8.07	-.93	-16.59	-1.53	13.54	-.12	7.64	-.42	.11
	20.00	35.10	23.60	25.80	8.60	22.80	2.60	29.20	17.40	.00	14.93	-.04	14.42	-.07	13.67	-.12	13.16	-.14	13.54
	.00	38.20	24.70	13.40	7.30	26.20	2.80	31.50	10.70	.00	-2.37	-.71	-6.77	-1.07	-2.31	-.91	2.63	-.67	-2.34
	46.00	34.70	23.30	31.90	8.40	23.70	2.90	29.00	20.40	.00	.15	-.61	22.66	.31	24.66	.33	26.14	.51	26.45
	29.00	35.10	23.00	37.50	8.60	24.00	2.70	29.10	13.30	.00	10.89	-.20	18.74	.13	15.84	-.01	17.66	.08	24.59
	93.00	32.70	22.10	50.00	9.50	22.00	2.70	27.50	30.00	.00	23.49	.29	52.70	1.72	50.64	1.72	49.90	1.71	55.45
	26.00	33.50	22.70	44.10	9.00	23.60	2.80	28.10	26.80	.00	3.57	-.48	19.96	.18	15.12	-.05	16.42	.02	28.30
	18.00	31.90	22.10	36.80	9.60	21.60	3.30	27.00	23.50	.00	6.96	-.35	16.28	.01	14.91	-.06	12.72	-.17	21.11
	56.00	32.10	22.10	32.80	9.90	20.90	3.00	26.90	21.70	18.00	29.87	.53	33.40	.81	35.65	.96	30.64	.84	32.30
	59.00	32.60	22.10	37.70	9.90	22.60	2.30	27.20	23.90	68.00	34.94	.73	34.24	.85	33.00	.84	33.06	.86	35.62
	162.00	31.10	21.70	41.50	11.40	22.80	2.20	26.20	26.60	115.00	84.08	2.63	74.61	2.74	82.72	3.32	84.56	3.45	74.35
	42.00	31.50	21.60	40.70	11.90	21.20	1.80	25.80	16.70	49.00	86.96	2.74	34.66	.87	27.31	.56	24.96	.45	33.62
	67.00	31.70	21.70	39.90	11.30	23.30	1.70	26.80	25.80	6.00	79.10	2.44	39.09	1.08	35.60	.97	37.15	1.06	40.92
	151.00	31.90	21.90	44.50	10.40	21.90	1.60	26.90	27.90	10.00	58.15	1.63	77.22	2.86	78.54	3.11	79.44	3.14	72.03
	55.00	32.10	21.00	39.00	10.50	21.50	1.40	26.50	24.90	227.00	54.33	1.48	39.98	1.12	33.08	.85	31.25	.77	35.61
	19.00	33.50	21.80	38.20	9.60	22.80	1.50	27.60	24.20	93.00	33.87	.69	26.57	.49	19.05	.10	18.04	.10	25.81
	30.00	33.60	21.70	39.10	9.50	22.70	1.50	27.60	24.70	7.00	31.67	.60	28.43	.58	19.55	.18	19.53	.18	27.51
	1.00	34.50	20.20	33.00	8.50	22.40	1.30	28.30	21.20	.00	19.29	.13	16.26	.01	5.17	-.54	3.93	-.61	12.21
	.00	35.10	21.10	32.40	8.50	22.10	1.50	28.10	20.80	.00	10.03	-.23	15.27	-.04	5.24	-.54	3.49	-.63	11.33
	.00	35.70	19.20	34.30	8.20	22.00	1.00	27.40	21.40	.00	5.66	-.40	17.46	.07	5.42	-.53	3.66	-.62	12.14
	.00	33.80	18.10	20.30	9.80	24.10	1.70	24.30	14.80	.00	-9.57	-.99	-1.32	-.81	1.55	-.72	4.44	-.58	3.21
	.00	34.90	14.70	18.80	8.60	23.60	1.40	24.80	13.70	.00	-.13	-.62	1.22	-.69	2.47	-.67	4.32	-.59	1.72
	.00	33.20	11.70	20.10	9.20	21.90	1.40	22.50	14.90	.00	-.26	-.63	4.26	-.55	5.60	-.52	4.89	-.56	3.34
	.00	33.40	12.20	17.40	9.00	22.60	1.40	22.60	15.30	.00	-6.29	-.86	1.01	-.70	4.32	-.58	4.87	-.56	1.18
	.00	30.70	13.10	16.40	10.00	21.90	1.50	21.80	12.50	.00	-1.67	-.68	1.74	-.67	5.60	-.52	5.07	-.55	1.45
	.00	28.60	10.20	17.40	10.80	21.60	1.00	19.60	14.20	.00	1.85	-.55	2.70	-.62	6.16	-.49	5.62	-.52	2.40
Average	24.19	33.25	19.18	26.65	9.36	22.63	1.99	26.08	18.18	16.03	16.03	.00	16.03	.00	16.03	.00	16.03	.00	16.03
Maximum	162.00	39.40	25.60	50.00	11.90	28.00	8.60	32.20	30.00	227.00	86.96	2.74	77.22	2.86	82.72	3.32	84.56	3.45	74.35
Minimum	.00	26.70	10.20	12.20	7.00	19.70	1.00	19.60	9.90	.00	-11.53	-1.06	-16.59	-1.53	-5.62	-1.08	2.46	-.68	-3.42
Sum	895.00	1230.10	709.60	986.20	346.40	837.20	73.60	965.10	672.80	593.00	593.00	.00	593.00	.00	593.00	.00	593.00	.00	593.00
Std	40.19	2.90	4.54	11.71	1.26	1.79	1.32	3.23	6.19	44.54	25.87	1.00	21.38	1.00	20.11	1.00	19.86	1.00	20.64
Var	1615.38	8.39	20.64	137.02	1.59	3.19	1.74	10.42	38.37	1984.28	669.48	1.00	457.08	1.00	404.37	1.00	394.29	1.00	426.09