IMPACT OF TEMPERATURE ON THE RATE OF GROWTH OF COTTON INSECT PESTS' DEVELOPMENT

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Abstract

Climate has a profound effect on the distribution and abundance of invertebrates such as insects, and the mathematical description of the climatic influence on insect development has been of considerable interest among entomologists. Additionally, as temperature exerts great influence among the climate variables, by directly affecting insect phenology and distribution, most of the models that describe insect development are temperature driven.

More than a dozen different species of insect pests attack the cotton crop in Egypt. Cotton insect pests i.e. *Agrotis ipsilon, Thrips tabaci, Aphis gosypii, Tetranychus urticae, Bemisia tabaci, Spodoptera littoralis, Earis insulana, Pectinophera gossypiella and Helicoverpa armigera.* Zero of development as well as the summation of heat units (DD'S) required for the completion of one generation of these insect pests' were calculated.

INTRODUCTION

More than a dozen different species of insect pests attack the cotton crop in Egypt. Each of these pests is capable of causing economic yield loss, and some, such as the Pink bollworm (PBW), *Pectinophora gossypiella* and Cotton leafworm, (CLW), *Spodoptera littoralis*, are capable of totally destroying a crop. Cotton growers may invest large sums of money per acre in producing cotton. And all of this investment is potentially at risk to insect damage. The cost of controlling insects is one of the larger items in the crop production budget.

1-Agrotis ipsilon (Hufnagel)

The black cutworm is a cosmopolitan pest that poses an economic threat to many agricultural plant species. In Egypt field crops, it is most often a pest of the cotton crop. It will also attack some vegetable crops, including sweet corn, and can be problematic in turf grasses. While black cutworm has the potential to be a very serious pest, it is sporadic with major outbreaks being relatively rare (1980 was a particularly bad year in Pennsylvania with at least 5,000 acres of corn being decimated). Nevertheless, it warrants attention because losses can be severe if it infests fields at the right time.

Black cutworms exhibit two types of feeding patterns depending upon the amount of moisture in the soil and size of plants. Where soil moisture is adequate and plants are small, the larvae hide in the soil during the day and move to the soil surface at night where they cut off plants just above the soil surface. This is typical damage for most cutworm species. One larva will cut off an average of five cotton plants during its development. In situations of dry soil conditions, the larvae do not move to the surface to feed, but instead, they chew into the plant just below the soil surface. This causes the cotton plants to wilt and usually die. Loss of plants in infested fields will vary from 10 to 80 percent. Seldom is a field completely destroyed, rather severe damage is usually confined to portions of the field.

2- **Thrips tabaci**

The most consistent insect-related challenge for cotton growers is thrips. These tiny, barely visible, splinter-like insects are important pests during the first couple of weeks after plants emerge. They can retard growth, but also are sometimes blamed for more damage than they cause.

Most thrips problems in cotton seem to be related to thrips migrating from wheat as it matures in the spring. This may cause a burst of thrips activity that is particularly damaging if it occurs when the cotton plants emerge from the soil.

Thrips cause most damage to seedling cotton. They rasp tender leaves and terminal buds with their sharp mouthparts and feed on the juices. Leaves may turn brown on the edges, develop a silvery color, or become distorted and curl upward. Light thrips infestations tend to delay plant growth and retard maturity. Heavy infestations may kill terminal buds or even entire plants. Damaged terminal buds cause's abnormal branching patterns. The duration and intensity of thrips infestations vary greatly according to season and geographic location. Once cotton plants are four to six weeks old, they outgrow thrips damage and recover.

3- Aphis gosyepii

The cotton aphid may be troublesome during the seedling stage when its feeding may result in plants being stunted. At the boll-opening stage, the honeydew produced by the insect and the associated fungal molds can foul the cotton lint. This lowers the quality of the crop and can cause harvesting difficulties.

The different forms of the cotton aphid differ in their ability to cause population outbreaks and plant damage, therefore it is important to be aware not only of the number of aphids present, but also of their color form. The small yellow aphids develop slowly from newborn nymph to adult and do not produce many offspring; thus, their populations rarely increase rapidly. The larger, darker aphids (green and black) are quite different; they develop more rapidly, produce many more offspring in a rapid burst, and can generate rapid population growth rates.

Additionally, damage caused by cotton aphid varies seasonally with the growth stage of the plant.

Heavy populations of seedling cotton can cause crinkling and cupping of leaves, failing to expand, defoliation, and a severe stunting of seedling growth. In addition, honeydew contamination on leaves may make the leaves appear wet and shiny. Cotton appears to be able to compensate fully for early season damage as long as the aphid feeding ceases.

Low aphid numbers (<25/leaf) on mid-season cotton often do not generate any obvious damage symptoms. High aphid numbers (>50/leaf) create the same symptoms as observed on seedling cotton (cupped, crinkled leaves, honeydew accumulations, sooty mold, and in extreme cases, limited defoliation). High aphid numbers at this time can decrease the size of bolls, stunt plant growth, and may increase square and boll shedding.

The cotton crop is more sensitive to cotton aphid damage at this time because honeydew can contaminate the exposed cotton lint, creating "sticky cotton". Aphid populations as low as 5/leaf can result in honeydew deposition on lint.

4- Tetranychus urticae

All mites have needle-like piercing-sucking mouthparts. Spider mites feed by penetrating the plant tissue with their mouthparts and are found primarily on the underside of the leaf. All spider mites spin fine strands of webbing on the host plant — hence their name the mites feeding causes graying or yellowing of the leaves. Necrotic spots occur in the advanced stages of leaf damage. Mite damage to the open flower causes a browning and withering of the petals that resembles spray burn.

When twospotted spider mites remove the sap, the mesophyll tissue collapses and a small chlorotic spot forms at each feeding site. It is estimated that 18 to 22 cells are destroyed per minute. Continued feeding causes a stippled-bleached effect and later, the leaves turn yellow, gray or bronze. Complete defoliation may occur if the mites are not controlled.

Spider mites are the most common mites attacking woody plants and the twospotted spider mite is considered to be one of the most economically important spider mites. This mite has been reported infesting over 200 species of plants

5- Bemisia tabaci

Several species of whiteflies may infest cotton. Proper identification of Sweetpotato whitefly is important because other whitefly species do not usually cause economic damage in cotton. Use a hand lens to examine both immatures and adults.

Sweetpotato whitefly adults are tiny (0.06 inch or 1.5 mm long), yellowish insects with white wings. Their wings are held somewhat vertically tilted, or rooflike, over the body and generally do not meet over the back but have a small space separating them.

Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, oval eggs hatch into a first nymphal stage that has legs and antennae and is mobile. The legs and antennae are lost after the first molt and subsequent stages remain fixed to the leaf surface. The last nymphal stage, often called the pupa or the red-eye nymph, is the stage that is easiest to identify. Sweetpotato whitefly pupae are oval and yellowish with red eye spots. The edge of the pupae tapers down to the leaf surface and has little to no long waxy filaments around the edge. In contrast, greenhouse whitefly and banded-winged whitefly pupae have many long waxy filaments around the edge and the edge is somewhat vertical where it contacts the leaf surface.

Sweetpotato whitefly is a multi host pest. Problems in cotton develop from Sweetpotato whiteflies that overwinter in cole crops, ornamentals, and weeds. Numbers often increase in spring melons. Once these alternative host crops are harvested or destroyed, whiteflies migrate into adjacent cotton fields. As temperatures warm up, numbers, rapidly increase, with the highest numbers occurring in mid- to late summer.

Whiteflies are sucking insects and their feeding removes nutrients from the plant. Feeding by high populations may result in stunting, poor growth, defoliation, boll shed and reduced yields. As they feed, whiteflies produce large quantities of honeydew which, if deposited on fibers, will reduce cotton quality and may interfere with picking, ginning, and spinning. Honeydew also supports the growth of black sooty molds that stain lint, lowering its quality.

6- Spodoptera littoralis

Among all cotton pests in Egypt, the cotton leaf worm (CLW), *Spodoptera littoralis* is the most important. It is extremely polyphagous, and always apt to inflict excessive damage when it occurs in masses during certain years, commonly referred-to as "cotton worm monsoons." The fluctuations in the acuteness of its attack and in its population density depend on ecological and physiological factors, which, up to the present, are not precisely determined. In contrast to the biology of this insect, which has been adequately studied, the ecological knowledge, notwithstanding the attempts rendered by several workers, is still incomplete. This lack of ecological information is mainly due to several factors; the first and most momentous is that the insect becomes more reproductive under alternating physical conditions rather than under constant or artificial ones. Ecological studies are made more difficult by the fact that *Spodoptera littoralis* is a poly-phagous insect known to invest approximately 112 host plants belonging to 44 different plant families. Thereupon, its diet preferences and its microclimatic relationships of the host plants are far from precise or complete

7- Erias insulana

Spiny bollworm: A serious pests of cotton and plants of the Malvaecae family, such as okra, hollyhock etc. Larvae bore into terminal shoots of young plants, flower buds and young bolls, leading to death of shoots and shedding of flower buds and bolls. Presence of larval frass at the entrance of the bore-hole is a characteristic symptom.

8- Pectinophora gossypiella

The Pink bollworm (PBW), *Pectinophora gossypiella* is remaining the most destructive pests causing significant losses to the yield. Larvae feeding within boll basis most economic losses caused by these pests. PBW and CLW are a major cotton pest in Africa and the Middle East (Pearson, 1958; Avidov & Harpaz, 1969). Since the larvae penetrate the bolls soon after hatching, efficient control by insecticides is hard to achieve. In addition, application of toxic insecticides may result in increased pest resistance to insecticides, interference with the activity of beneficial insects, environmental pollution, and hazards to public health. The reduction of insecticidal applications in cotton is, therefore, of great correspondence. Cotton bollworm has a number of difficult problems regarding sampling techniques, I. e. (A) - Larvae feed inside the green bolls causes special difficulty in estimation the population density in the developmental stages of these insect pests. (B)- PBW and CLW have variable numbers of annual generations. Amin et al (1999) found that PBW showed four generations. CLW found to have seven overlapping generations annually by many authors (Bishara 1926, Abdel-Badie 1977 and Dahi 1997). The indiscriminate use of insecticides has caused a number of problems to various ecological niches around the world including Egypt. Hence there is a growing necessity and interest in the use of Ecological approaches to manage these pests.

9-Helicoverpa armigera (Hübner)

Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae) is a major pest affecting a wide range of economically important plants, including field and horticultural crops in Iran (Naseri et al. 2011) and throughout the world (Jallow et al. 2004; Reddy et al. 2004; Mironidis and Savopoulou- Soultani 2008; Yu et al. 2008). In northern Egypt, cotton plants are subjected to attack by several insect pests, the most serious of which is the budworm, *H. armigera.* Recently, it has been observed in increasing numbers. In cotton cultivated fields, *H. armigera* predominantly damages young leaves and bolls, causing whole leaves to be destroyed during the crop's reproductive stage. The destruction of the leaves results in considerable loss of yield at harvest.

Cotton bollworm larvae (*Helicoverpa*) damage bolls and squares. Larvae chew holes into the base of bolls and may hollow out locks. Moist frass usually accumulates around the base of the boll. Larvae may also chew shallow gouges in the boll surface, which can become infected with rot organisms. Squares injured by cotton bollworm usually have a round hole near the base. Fifth-instar larvae are the most destructive; they not only damage more fruit than do earlier investors, but they damage, larger fruit that is harder for the plant to replace.

The rates of development in insects under natural conditions are largely determined by temperature. In most micro environments, temperature is characterized by daily and seasonal cyclic variations with superimposed irregular fluctuations. However, studies of insect development rate most often involve experiments performed under constant temperatures. In the development and application of development-rate models, it is always assumed that development rate at a given temperature is independent of thermal regime, whether the model is linear or nonlinear in relation to temperature. This assumption is also inherent in efforts to derive development-rate models from data obtained under varying temperatures, such as the work by Dallwitz & Higgins (1978). According to this assumption, development rate follows a definite function with respect to temperature, when other factors are equal, and the amount of development can be calculated by accumulating the fraction of development per unit time; i.e., rate summation (Kaufmann 1932). The procedure may be expressed as:

$$D = \int r\,[T(t)]\,DT$$

Where development D is a function of temperature, T, which in turn is a function of time, t, and the development rate, r; adjust instantaneously to temperature. The above assumption is fundamental to the formulation of development-rate functions for phenological models. Attempts to study the validity of this assumption are numerous in entomological literature, and both positive and negative results have been reported (Hagstrum & Hagstrum 1970, Ratte 1984). Life table studies are fundamental to not only demography but also too general biology. In such studies, development tunes and survival rates of each stage, longevity of adults, and the daily fecundity of females are recorded for every individual. Using elementary statistics, means and standard deviations can be calculated. In traditional life-table analysis, these means are used to calculate age-specific survival rates and age-specific fecundity using either the Leslie matrix (Leslie 1945) or Birch's method (Birch 1948). These procedures have been widely used by researchers in many different fields (Laing 1969, Shib et al. 1976, Cave & Gutierrez 1983, Vargas et al. 1984, Carey & Vargas 1985). However, variation in development rate is well known, even when a population is kept under constant laboratory conditions. The range of variation depends on many factors (for example, temperature and food). To assume that all individuals have the same development rate is biologically unrealistic and may be misleading. Therefore, ignorance of such variation when using either the Leslie matrix or Birch's method should be carefully considered. The method of incorporating this variation is the use of distributed delay theory in modeling (for example, Gutierrez et al. 1984, Plant & Wilson 1986). On the other hand, Chi & Liu (1985) developed an age-stage life table theory for both sexes, incorporating variable developmental rates among individuals. In comparison with the distributed de-lay models, Chi & Liu's model is different in that both sexes were included, and variation in development rates was integrated sequentially for all stages and expressed in the form of a stage distribution. The stage structure of a population can also be calculated in Chi & Liu's model. Furthermore, most life-table analyses have been concerned only with the "female" population. Most lepidopteran, coleopterast, and orthopteran pests are not parthenogenetic, however, and both males and females are economically important. Moreover, the development rate may differ between the sexes. Susceptibility to either chemical or biological control agents may be quite variable among stages and sexes. These and many other differences between stages and sexes explicitly point out the inadequacy of the female age-specific life table. In addition, whether to calculate the intrinsic rate of increase of a "female" population or of the population as a whole is a central question in ecology. In the theoretical model of Chi & Liu (1985), the population parameters are calculated with respect to both sexes and incorporating variable developmental rates among individuals. However, the major obstacle in taking the variable developmental rates and tire male population into account is the difficult and tedious work of applying the age-stage, two-sex life table theory to the raw data analysis.

The number of days between observable events, such as cotton seedling emergence and first squares of the duration of insect generations can characterize the growth and development of plants and insects. The number of days between events, however, may be misleading because growth rates vary with temperatures. The measurement of events can be improved by expressing development units in terms of the temperature and time. The deviation between events is then based on accumulated degrees per unit time above a lower temperature re-presenting a threshold of growth.

The current work highlights the importance of the relationship between insect development and its vital thermal requirements and outlines important constraint and challenges regarded to model selection and applicability in pest management and insect ecology. Within our aims, building on previews, reviews, was to provide a simple account for applying entomologists and field ecologists by avoiding complex and technical details. Furthermore, efforts are also made to present a short example of the linear model and to propose a simple three parameter non-linear equation for modeling temperature effects on insect developmental rates.

The present work aimed to set the basic temperature (zero of development) and thermal requirements and accumulation, heat units of most common cotton insect pests'. This work helps the entomologists to construct their empirical models for the prediction of critical times of infestation as a part of IPM' programs.

MATERIALS AND METHODS

In this investigation 9 cotton insect pests were reared in the laboratory at four constant temperatures.I.e. 15, 20, 25, and 30 °C. Duration in days was observed and recorded daily in each temperature degree.

Rearing insects

1-Agrotis ipsilon (Hufnagel)

Under controlled conditions (four constant temperatures .i.e. 15, 20, 25, and 30 °C and 65 ± 5 % R. H.), one hundred newly hatched larvae of BCW were confined individually in plastic tubes (7 X 3.5 cm) with punctured plastic covers. Larvae were provided daily with the required food. Ten pairs of newly emerged moths for each temperature degree were coupled and fed on 20 % sucrose solution under the above-mentioned constant conditions. One hundred newly deposited eggs from each temperature degree taken to collect data from it. Egg hatchability percentage, and incubation periods were recorded. The newly hatched larvae were reared individually in plastic tubes (7 X 3.5 cm) with punctured plastic covers. The larvae were provided daily with the required food. Larval and pupal duration as well as mortality percentage were recorded daily. One-day old pupae of each temperature degree were sexed and the sex ratio was determined. The newly emerged moths in each case were coupled and fed on 20 % sucrose solution. Females' longevity, preoviposition period, oviposition period, and no. of eggs deposited daily per female were recorded daily.

2- **Thrips tabaci**

The populations of *T. tabaci* were collected from cotton fields in Nile Delta (Lower Egypt) in April. Germinated broad bean seeds (*Vicia faba*
L.). Broad bean seeds were allowed to germinate in running tap water for 3–4 days at room temperature. After their seed coats had been removed, they were used for rearing thrips larvae. A tight box (120 × 98 × 46 mm, box cage), with a hole (10 mm diameter) in the lid sealed with gauze for ventilation was used for rearing. Adult females (300 to 400 per cage) one bean per cage per day, were supplied for the adults. Bean seeds were replaced every single or alternate day at the time of egg collection. Although humidity in the cage was above 90% R. H., this did not affect egg production. Adult females deposited eggs in the water as well as in the beans. Eggs laid in water were collected on a filter paper (Toyo, No. 2, 55 mm diameter) using a water suction bottle or an aspirator. The time when eggs could be collected varies from 1 h up to the maximum of a total egg developmental period (3 to 4 days). The filter paper with eggs and a little moisture was placed in a closed Petri dish until hatching.

Depending on the incubation temperature, the eggs hatched over a period of several days. The emerging larvae moved in the Petri dish from where they could be picked up individually with a fine brush.

This procedure was repeated under controlled conditions (for constant temperatures. I. e. 15, 20, 25, and 30 °C

3- Aphis gosyepii

Cotton aphids were collected from different cotton crop fields and reared on cotton plants inside the screen house insect rearing facility for use in further experiments Under controlled conditions (for constant temperatures. I. e. 15, 20, 25, and 30 °C. Aphids were gently surface sterilized with 0.001% Sodium hypochlorite in water (v/v) for 1 minute and rinsed with sterilized tap water in a fine mesh sieve. Fresh leaves of Cotton were taken and surface sterilized with 0.005% Sodium hypochlorite for 2 minutes, dipped in 200 ppm solution of penicillin in sterilized water for 1 minute, and then rinsed with sterilized water. A leaf portion (approx: 2"X1" inches), altered by its margins and keeping the mid rib intact, was placed at the center of each Petri plate. Wet and sterilized cotton was placed around the midrib initial end of the leaf for humidity and protection of leaf from dehydration in the Petri plate chamber. Initially a brush was used to infest the leaves with aphids, but it was observed that insect transfer though brush may also move some dead insects resulting in variable pathogenicity results. Therefore, each leaf was kept with a large number of surfaces sterilized aphids in a 18 cm Petri plate for 30 minutes to allow the active and alive adult insects to move on to the test leaves.

4- Tetranychus urticae

T. Utica was maintained and reared continuously on a food supply consisting of baby lima bean plants (also called Henderson baby lima beans or bush beans; *Phaseolus lunatus* L.), provided by Buckeye Seed Supply, Canton, OH, under conditions of 15, 20, 25 and 30 ± 1°C, 70±5 RH, and a 16 h light: 8 h dark photoperiod (Figure 1). New, uninfected baby lima bean plants were rotated into the mite colony every seven days. About 12 bags of plants were grown in the greenhouse every week, each bag with 60 ml of seeds sowed shallowly (1-2 cm deep) in medium grade

Vermiculite. Cotyledons emerged within 3-5 days at 25±2°C 13 and were fully expanded within one week. Beans were kept in the greenhouse for a total of two weeks, until they were mature enough to be transferred to a *T. urticae* colony. Cut leaf samples from the susceptible colony were first examined for predators (i.e. Western flower thrips or predator mites), to confirm an absence of contamination. The leaves were then laid on top of the clean replacement bean plants. As the cut leaves dry, the active stages of spider mites disperse onto the replacement plants. A handful of leaves (about 20 leaves, estimated to be around 300-500 mites total), were transferred to each new tray of plants (each tray consists of four vermiculite bags of planted beans), *T. urticae* usually colonize most parts of the replacement plant within three days, and within one week plants reach exhaustion and are no longer viable hosts for the spider mites.

5- Bemisia tabaci

To establish a stock culture of *B. tabaci* to be used in this study, plant leaves infested with B. tabaci were collected from infested cotton plants from Nile Delta (Lower Egypt) in June. Infested leaves with pupae of whitefly population were placed with the petioles immersed in water. After 24 h, 50 male and female adults were collected using an aspirator.

Adults were checked under a stereomicroscope and male were separated from females based on their smaller size and narrower end of their abdomen. After 24 h, the adults were transferred on caged cotton and rape seed plants for oviposition, approximately 100 - 200 eggs were kept for studying development and survival of the nymphs of *B. tabaci*.

This experiment was conducted in four repetitions thoroughly randomized. All of the experiments were carried out in a growth chamber, under 15, 20, 25 and 30 ± 1°C, 55 ± 3% RH and 16:8 h (L: D) photoperiod on cotton, *Gossypium hirsutum* L. and on rapeseed (*Brassica napus* L.).

6- Spodoptera littoralis

Colonies of the cotton leafworm *S. Littoralis* were raised in the laboratory on a semi artificial diet (Salama, 1970). For assessing the effects of temperature effects on growth, newly hatched larvae of the cotton leafworm were taken from the colony and reared individually in plastic cups on the artificial diet. Four temperature degrees15, 20, 25 and 30 ± 1°C, 65 ± 5% RH. Daily records on the living and dead individuals were made. The larval and pupal durations were estimated. Pupae were weighted on its first day. Deformalities in both pupae and the emerged moths were recorded. To determine the number of eggs laid by each female and longevity (days) of adults, pairs of newly emerged moths were confirmed to glass jars (1-liter) containing *Nerium oleander* leaves as an egg deposition site and provided with 10 % of sugar cane solution for adult nutrition.

Cotton Bollworms

7- Erias insulana

The freshly hatched larvae used in these studies were drawn from a culture of the spiny bollworm maintained on okra fruits at 28 + 1°C. Although humidity was not controlled, it ranged between 60% and 80%.

Larvas were transferred to the artificial diet described by Poitout et al. (1972). The tested four temperature degrees i.e. 15, 20, 25 and 30 ± 1°C, 65 ± 5% RH were used in this test. In all the experiments observations were recorded on (a) duration of larval and pupal stages, (b) number of larvae reaching pupal and adult stages, (c) weight of adults after emergence and their sex, and (d) number of eggs laid by the females and their viability.

8- Pectinophora gossypiella

The proper diet for maintaining a mass culture *of Pectinophora gossypiella* was followed according to the method described by Abd El-Hafez et al. (1982). The newly hatched larvae of pink bollworm were kept at 70+5% RH, 15, 20, 25 and 30 ±1°C with a photoperiod of L: D 16:8. Biological aspects were recorded daily in the four tested temperature degrees.

9-Helicoverpa armigera (Hübner)

A colony of *H. armigera* was initiated from 2 pairs of adults collected from the wild environment and reared on the agar-based diet used in the current study (Ahmed et al. 1998). Experiments were conducted on the second generation of that wild collected pair. The experimental conditions were kept at 70+5% RH, 15, 20, 25 and 30 ±1°C with a photoperiod of L: D 16:8.

Eggs were collected from the lab colony on layers of cotton wool oviposition pads and enclosed in polyethylene bags. Eggs were allowed to develop at room temperature. After the larvae started hatching they were transferred to glass vials containing the diet.

To study the larval stage a glass vial (2.5cm in diameter and 5.5cm in height) was used. Diet (7 ml) was placed into sterilized vials and a newly hatched first instar larva was added using a camel hair brush. In order to provide an air exchange a sterilized cotton wool plug was used which also prevented drying of the diet before the developing larva pupated. Four replicates of 25 vials each for agar and tapioca-based diets were run simultaneously.

Adult emergence was studied using plastic Petri plates (1.5cm high with 9cm diameter). After larvae pupated, the pupae were placed on a circular piece of blotting paper in the Petri dish with 1 pupa on each plate. After emergence, the adults were placed in individual vials for egg laying. Briefly, medium sized lamp glasses 10.2 cm high having 7.9 cm lower end and 6.6 cm upper end diameter were used as oviposition cages for single pairs of adults, and plastic jars having 10 cm lower ends and 12cm upper end diameter were used as oviposition cages for two to three pairs of adults.

One popular method of estimating the zero of development parameters is to use a linearizing transformation of the duration by calculating the rate of development y = *100/D* for the day variable resulting to the observation Arnold C. Y.(1959 &1960) and Schoolfield et al (1981).

The X-intercept method, which is simply derived after a growth rate fitting to a simple linear equation and then extrapolated to zero, The lower theoretical temperature threshold (i.e., base temperature) is derived from the linear function as whereas 1/slope is again the average duration in degree days or thermal constant.

RESULTS AND DISSCUSSION

Climate has a profound effect on the distribution and abundance of invertebrates such as insects, and the mathematical description of the climatic influence on insect development has been of considerable interest among entomologists. Additionally, as temperature exerts great influence among the climate variables, by directly affecting insect phenology and distribution, most of the models that describe insect development are temperature driven.

This first effort for a formal description of the relation between temperature and developmental rate was taken by botanists, to model the effect of temperature on plant growth and development. However, similar modeling procedures extended to most of the poikilothermic organisms, including insects as well. To date, the earliest experiment that related the velocity of insect development and heat, was made by Bonnet (1779) on the study of the reproduction rate of *Aphis evonymi*, F. , while the major assumption and principles that have been brought out by these earlier works, constituted the basis for all future research. Nevertheless, since then, several theoretical and experimental works have been carried out and current progress in entomology, mathematics and computation offers new means in describing the relation of temperature to insect development.

Thus, although simple predictive models have been developed during the last century, the development and broader availability of personal computers in the 70s and 80s resulted in the rapid development of computer-based models to predict responses of insects in relation to climate.

Determination the basic temperature (Zero of Development)

All the nine cotton insect pests were reared on at four constant temperatures.i.e. 15, 20, 25, and 30 °C. Duration in days was observed and recorded daily in each temperature degree.

Figures (1-9) show the zero of development degrees for the nine tested insect pests. Simple linear regressions equation ***y=a+bx*** was used for calculation this degree. The rate of development y ***= 100/D*** for the day variable resulting to the observation vs. temperature were used in the linear regression equation.

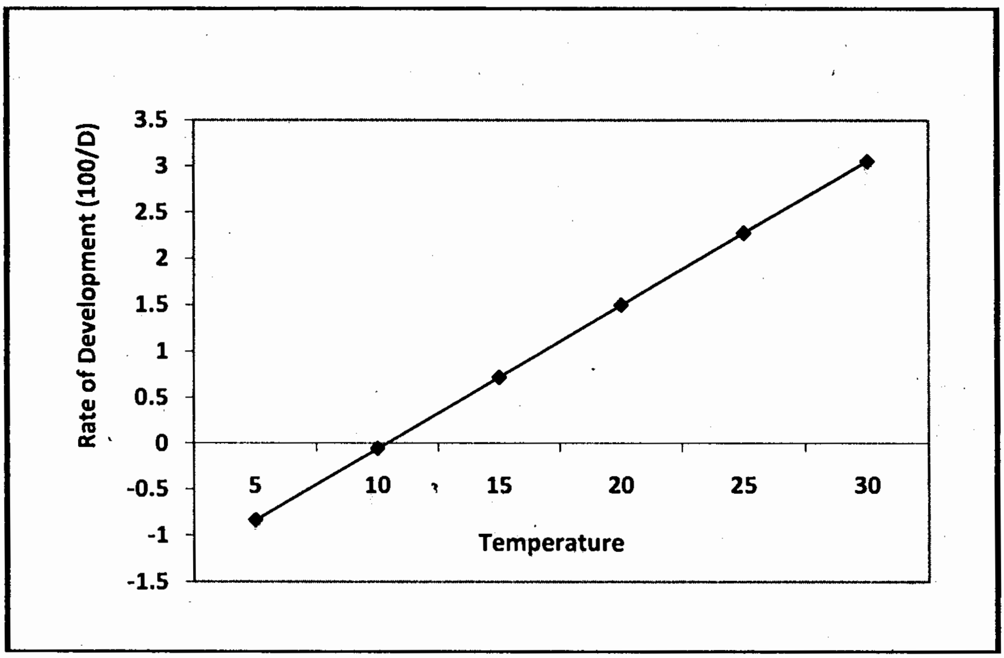

Fig. (1) Zero of development degree for the black cutworm, *Agrotis ipsilon*

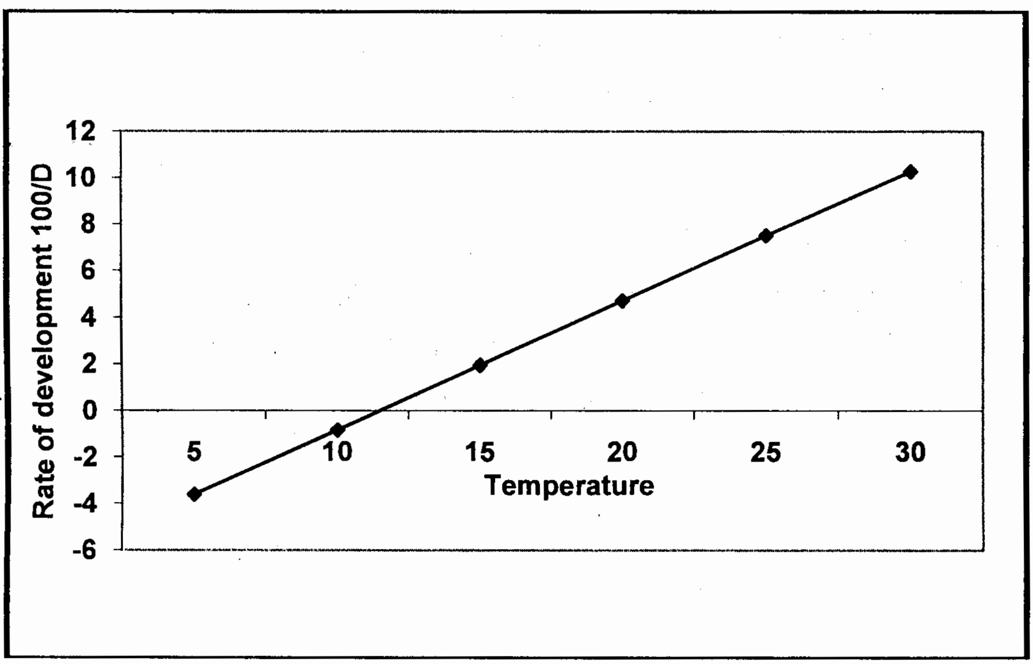

Fig. (2) Zero of development degree for the cotton thrips *Thrips tabaci*

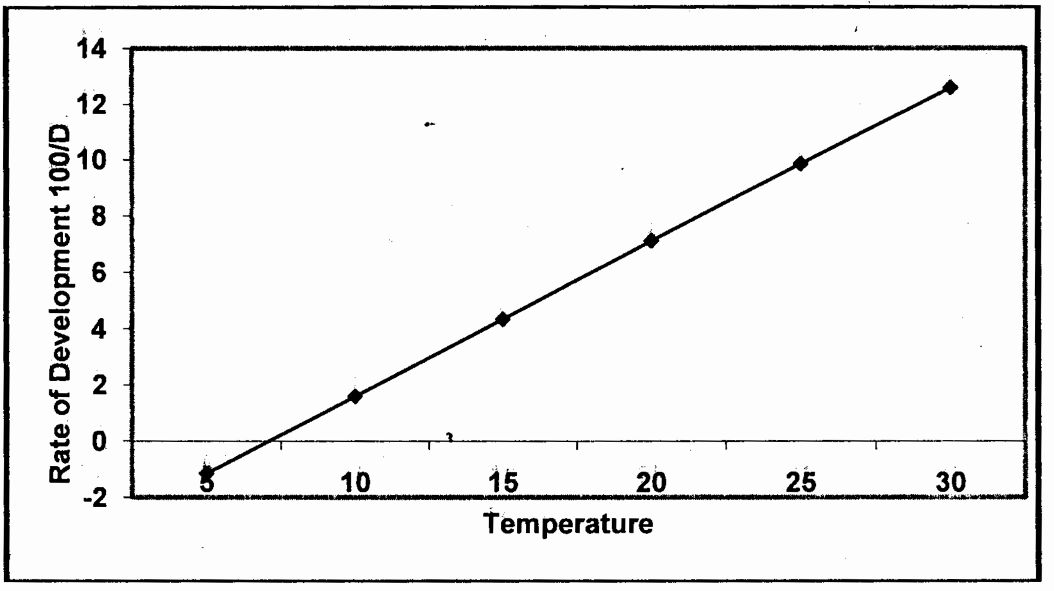

Fig. (3) Zero of development degree for the cotton aphid *Aphis gosypii*

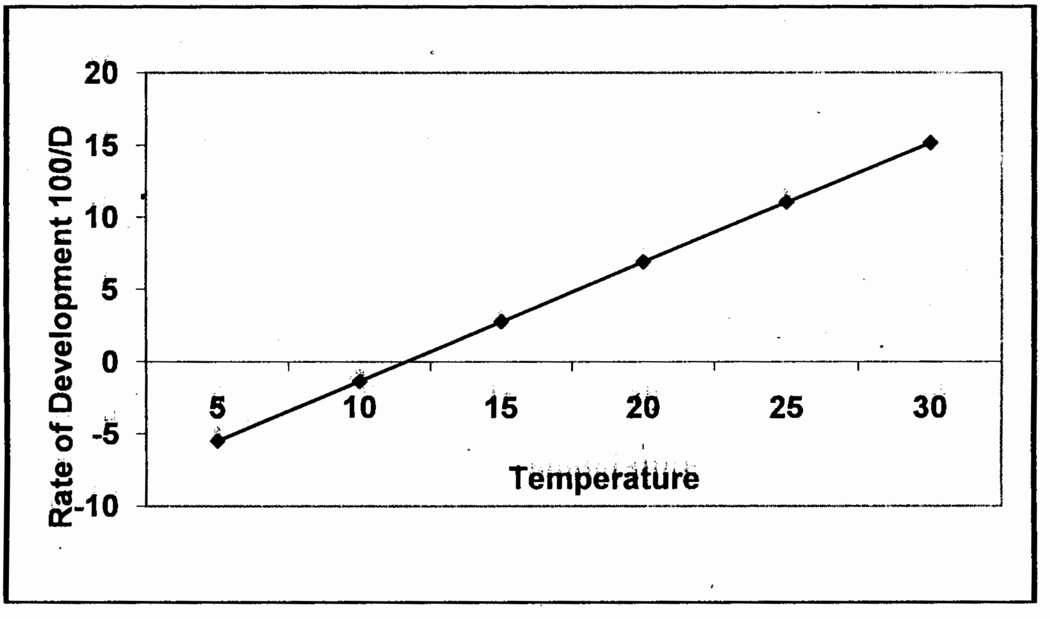

Fig. (4) Zero of development degree for the spider mite *Tetranychus urticae*

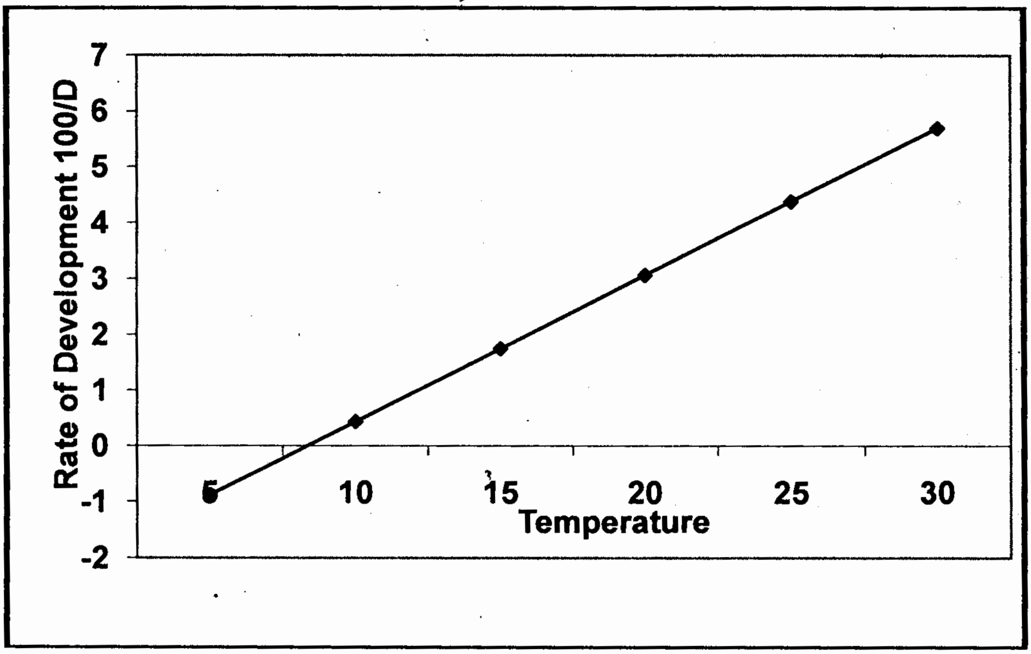

Fig. (5) Zero of development degree for the cotton whitefly *Bemisia tabaci*

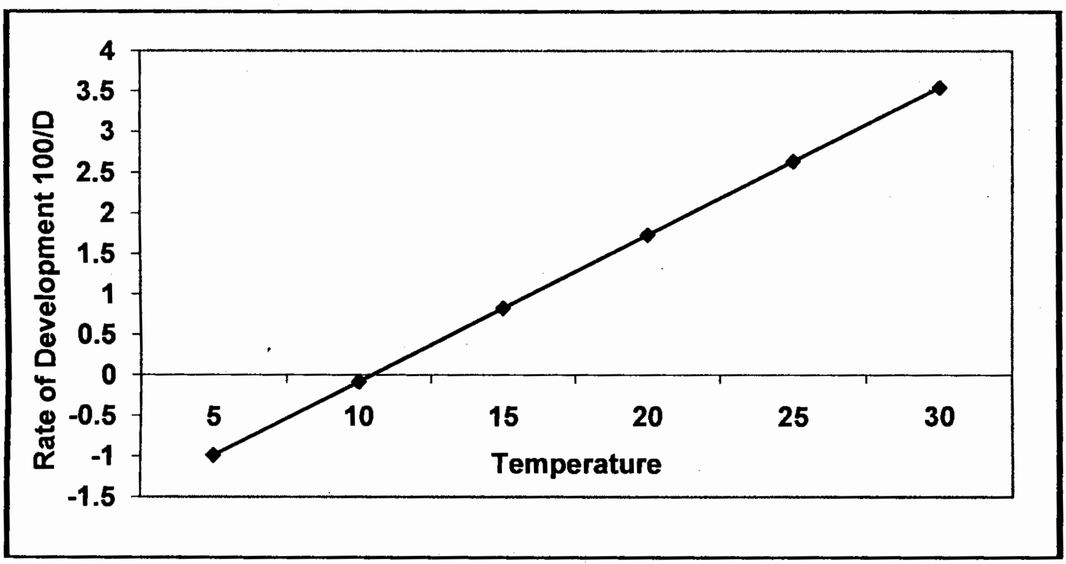

Fig. (6) Zero of development degree for the cotton leafworm *Spodoptera littoralis*

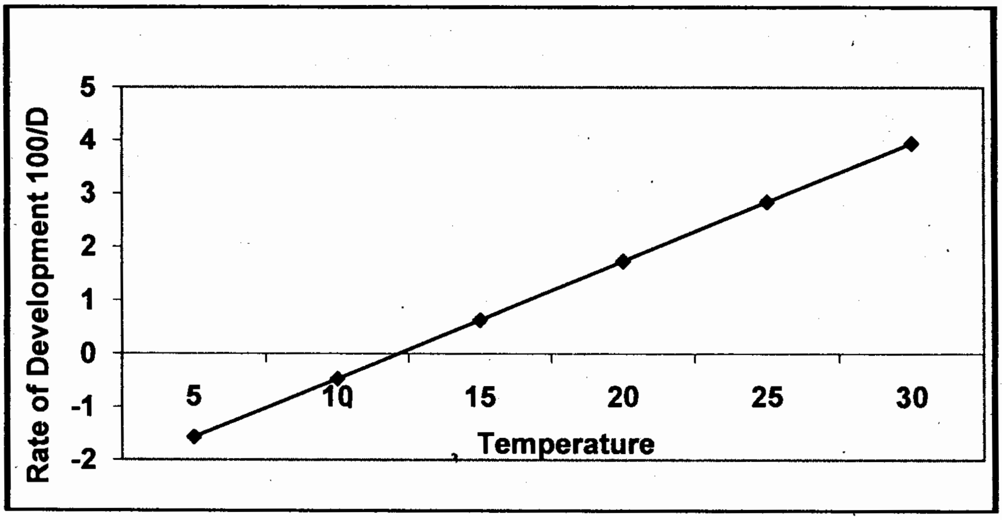

Fig. (7) Zero of development degree for the cotton spiny bollworm *Erias insulin*

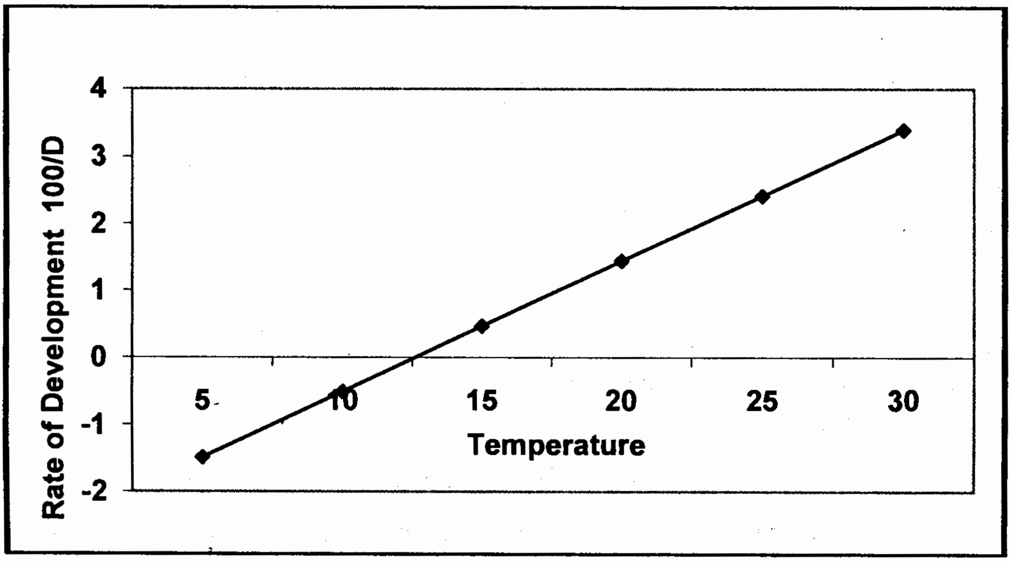

Fig. (8) Zero of development degree for the cotton pink bollworm *Pectinophora gossypiella*

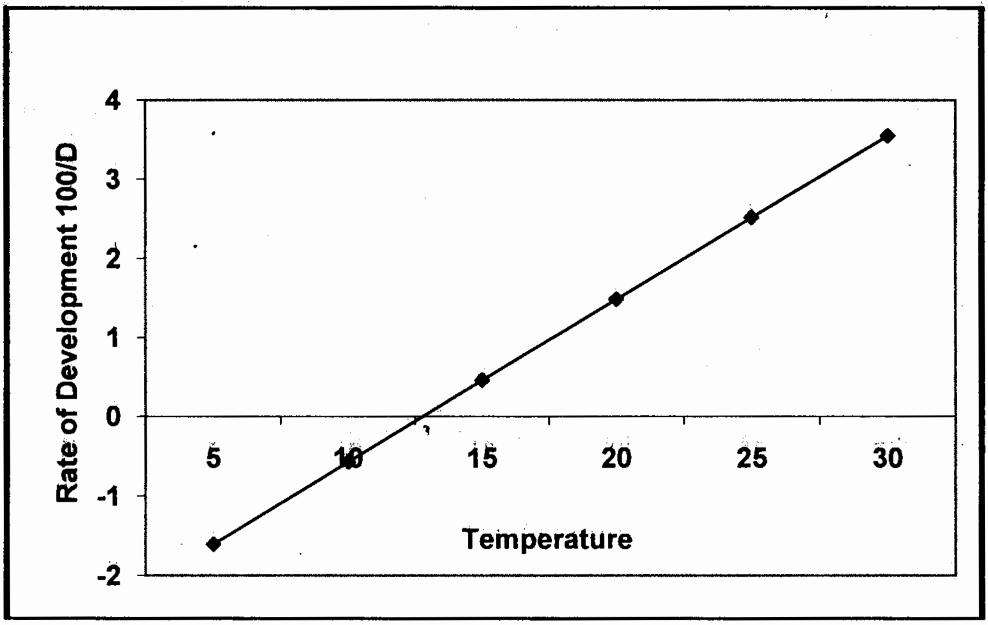

Fig. (9) Zero of development degree for the cotton budworm *Helicoverpa armigera*

Heat units Summation

According to the law of total effective temperatures, it is possible to estimate the emergence and number of generations for a given duration, of the organism of interest, according to the following fundamental equation: $K = D (T-T_0)$ where k is the species (or stage-specific) thermal constant of the poikilothermic organism, T temperature and T_0 developmental zero temperature. This thermal constant provides a measure of the physiological time required for the completion of a developmental process and is measured in degree-days (DD).

Table (1) represents the zero of development of the nine investigated cotton insect pests i.e *Agrotis ipsilon, Thrips tabaci, Aphis gosypii, Tetranychus urticae, Bemisia tabaci, Spodoptera littoralis, Earis insulana, Pectinophera gossypiella and Helicoverpa armigera* aswell as the summation of heat units (DD'S) required for the completion of one generation.

The effect of a climatic factor, such as temperature, for instance, sets the tolerance limits for a species, and this has been acknowledged by earlier studies (i.e., Shelfold, 1913: The Law of Tolerance). Later studies discuss how the species-specific "environmental boundaries" are determined by the ultimate tolerance factor (i.e., temperature) which may further restrict geographic distribution.

Based on such linear relationships, between thermal constants and lower temperature thresholds, for several cold-blooded species, it is suggested that there is an inverse relationship between lower temperature thresholds and the thermal constant associated with latitude and/or habitat that adapts each species

Table (1) Zero of development of the nine investigated cotton insect pests as well as the summation of heat units (DD'S) required for the completion of one generation

Insect Pest	Zero of Development	Heat unit summation (DD'S)
Agrotis ipsilon	10.36	643
Thrips tabaci	11.51	180
Aphis gosypii	7.1	182
Tetranychus urticae	11.65	121
Bemisia tabaci	8.35	380
Spodoptera littoralis	10.46	551
Earis insulana	12.62	512
Pectinophera gossypiella	12.14	453
Helicoverpa armigera	12.79	485

also based on the particular morphology and size of the species. For example, size at maturity is a function of the rate and duration of growth, and large size at maturity implies a long generation time and a correspondingly large requirement.

Thus, any model which provides biologically important parameters is useful in modeling population dynamics under several temperature regime alterations. In addition, by incorporating more factors in the equations, climate-driven models have the potential to describe the general ecological behavior, abundance, distribution, and outbreaks of insects on a regional or even global scale, with important practical applications.

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تأثير درجة الحرارة على معدل نمو تطور آفات القطن الحشرية

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يتعرض القطن فى مصر للإصابة بالعديد من الآفات الحشرية طوال حياته وتتسبب هذه الآفات فى خسارة كبيرة للمحصول ومن اهم هذه ألحشرات الدودة القارضة – التربس– المن – العنكبوت الأحمر الذبابة البيضاء – دودة ورق القطن – دودة اللوز الشوكية – دودة اللوز القرنفلية ودودة اللوز الامريكية.

و لما كان للمناخ تأثير عميق على التوزيع ووفرة اللا فقريات مثل ألحشرات ولقد كان للوصف الرياضي للتأثير المناخي على تطور ونمو الحشرات موضع اهتمام كبير بين علماء الحشرات بالتعاون مع علماء الرياضيات وعلوم الكمبيوتر لحل مشاكل مكافحة تلك الحشرات باستخدام النماذج الرياضية والتنبؤ ، لذلك كان من الضرورى تحديد اهم الظواهر البيولوجية فى حياه تلك الحشرات وهى عتبة النمو وكمية الوحدات الحرارية المتجمعة التى تحتاجها الحشرة لإتمام جيل.

وفى البحث قد تم تحديد صفر النمو وكمية الوحدات الحرارية المتجمعة التى تحتاجها أفات القطن السابق ذكرها لإتمام جيل.