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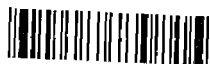
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EFFECT OF DIFLUBENZURON ON SOME PHYSICAL PROPERTIES  
OF INSECT CUTICLE

PUTCHAKAYALA ARJUNA RAO

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Division of Entomology,  
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New Delhi - 110012

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EFFECT OF DIFLUBENZURON ON SOME PHYSICAL PROPERTIES  
OF INSECT CUTICLE

By

PUTCHAKAYALA ARJUNA RAO

A thesis

submitted to the Post-Graduate School,  
Indian Agricultural Research Institute, New Delhi,  
in partial fulfilment of the requirements  
for the degree of

DOCTOR OF PHILOSOPHY

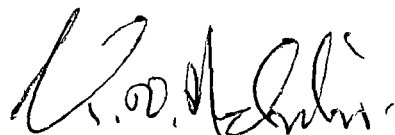
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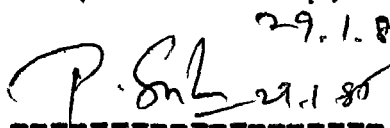
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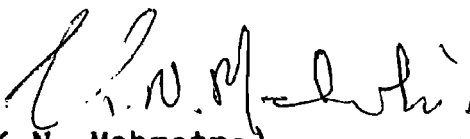
  
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C E R T I F I C A T E

This is to certify that the thesis entitled,  
'Effect of diflubenzuron on some physical properties of  
insect cuticle' submitted in partial fulfilment of the  
requirements for the award of the degree of DOCTOR OF  
PHILOSOPHY in Entomology to the Post-Graduate School,  
Indian Agricultural Research Institute, New Delhi, is a  
faithful record of the bona fide research work carried  
out by Mr. Putchakayala Arjuna Rao under my guidance and  
supervision. No part of the thesis has been submitted  
for any other degree or diploma. All the assistance and  
help received during the course of investigation have  
been fully acknowledged by him.

  
(K.N. Mehrotra)  
Chairman  
Advisory Committee

New Delhi  
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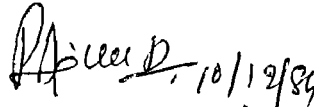
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New Delhi  
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(P. Arjuna Rao)

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## INTRODUCTION

The introduction of DDT and chlorinated hydrocarbons, organophosphates, carbamates and other synthetic insecticides, led to a renewed interest in the structure, function and properties of insect cuticle. As this tissue not only serves as a skeleton, but is also exposed to the vagaries of nature, the insecticide must cross this tissue before it can reach the target organ/organs. During the post embryonic growth and development of an insect, the cuticle is periodically shed - the insect undergoes moulting a necessary consequence of having an exoskeleton which is rigid to allow growth in size. The insect is most vulnerable during the period of moulting process and the insect cuticle thus forms an attractive target for the control of insects. Efforts have been directed to interfere with moulting, either through hormonal system or interfering with the deposition of various chemical components of the cuticle (Hollingworth, 1975).

The premise of this investigation is that the benzophenyl urea analogues are a group of novel insecticides which effect the deposition of chitin, (Ker, 1977; Saxena and Kumar, 1981a; and Mitsui et al., 1984) so characteristic of an insect cuticle. The exact mode of action of the compounds is as yet not known (Beeman, 1982). The interference

in chitin deposition during the development of new cuticle by the benzophenyl urea compounds might also lead to some effects on the physical properties of the cuticle.

In an age so characterised by impressive advances in electronics, and application of electronics to many fields, it is quite remarkable that integument has escaped closer scrutiny with this tool. The present investigations were, therefore, taken up to study the electrical properties of the cuticle of Schistocerca gregaria Forskal and the effect of diflubenzuron on -

- (a) the AC resistance of the cuticle;
- (b) the potential difference across the two surfaces of the cuticle;
- (c) the capacitance of the cuticle; and
- (d) the chitin content of the cuticle and its relation to the electrical properties of the cuticle.

## REVIEW OF LITERATURE

Since the present investigations were mainly concerned with the effect of diflubenzuron, on the physical properties of the cuticle, the present review restricts itself to (a) the structure, biochemistry and physical properties of insect cuticle and (b) the mode of action and related areas of benzoylphenyl urea insecticides.

### Physical properties of insect cuticle

The cuticle of insects, functions both as an exoskeleton and as a barrier between the living tissue and environment. It also, to a large extent determines the shape and appearance of insects (Anderson, 1979). Because of the physiological importance of cuticle, it has been extensively studied, histologically (both by light and electron microscopy) and biochemically along with its physical properties (Wigglesworth, 1948, 1957 and 1972; Richards, 1951 and 1958; Rudall, 1963 and 1976; Hackman, 1974 and 1976; Locke, 1974; Neville, 1975; Anderson, 1979; Vincent and Hillerton, 1979; Reynolds, 1980; and Vincent, 1980).

### Histological organization of the cuticle

The insect cuticle consists of three main layers. These are epicuticle, exocuticle and endocuticle (Wigglesworth,

1972; and Neville, 1975). The outer most layer of the cuticle is epicuticle. It is a layer distinct from the rest, consisting of several layers such as cement layer, wax layer, cuticulin layer and protein epicuticle (Locke, 1966 and 1974; Filshie, 1970; and Neville, 1975). Hydrocarbons are the major components in epicuticle followed by proteins. An important feature of epicuticle is the absence of chitin (Wigglesworth, 1972 and 1976; Neville, 1975; and Zacharuk, 1976).

The region located between the epicuticle and epidermal cells is known as procuticle. It constitutes the main part of the cuticle and can be subdivided into several layers with different staining properties as exocuticle, mesocuticle, and endocuticle (Richards, 1951; Locke, 1974; and Neville, 1975). Most of the properties of the cuticle depend upon the amount and organization of the individual components as well as upon the interaction between the various components in procuticle (Locke, 1974; Neville, 1975; and Hepburn and Joffe, 1976). Procuticle is also known as chitin/protein layer of the cuticle.

#### Chemical composition:

##### Chitin:

Chitin is the main constituent of endocuticle, of which it forms about 60 per cent of the dry weight in Periplaneta. In exocuticle of Periplaneta it constitutes nearly 22 per cent. In the entire abdominal sclerites of

Periplaneta 35 to 38 per cent of weight is due to chitin (Campbell, 1929). Candy and Kilby (1962) reported that in the adult Schistocerca gregaria about 8 mg chitin is present in hind legs and 16 mg in the wings. Chitin content in the cuticle of insects can range from < 10 per cent to about 60 per cent (Richards, 1951; and Jeuniaux, 1971). An average value of chitin for the entire cuticle of a wide variety of insects is 33 per cent (Wigglesworth, 1972).

Chitin is present in the cuticle as long microfibrils, about 2.8 nm thick and of variable length (Rudall, 1963 and 1976; and Neville, 1975). Each microfibril contains 18 to 21 chitin molecules, which are arranged nearly parallel to each other (Rudall and Kenchington, 1973; and Neville, 1975). Because of this arrangement only the peripheral molecules in a chitin microfibril are in intimate contact with proteins (Anderson, 1979). Chitin is a polymer of  $\beta$ -(1,4)-2-acetamido-2-deoxy-D-Glucose. The chitin microfibrils are imbedded in protein matrix and the relative amounts of chitin and protein vary from cuticle to cuticle (Rudall, 1963; and Neville, 1975). The chitin microfibrils can be reorganized in various patterns and the organization is important for the mechanical properties of the cuticle (Hepburn and Joffe, 1976).

### Proteins:

The other important component of cuticle is protein. It has been suggested that proteins are covalently linked to chitin (Hackman and Goldberg, 1958, and 1971;

Hackman, 1974 and 1976; Neville, 1975; and Hepburn and Joffe, 1976). The covalent linking between protein molecules is of importance for physical properties of insect cuticle (Anderson, 1977). One of the most dramatic features of the life of any arthropod is ecdysis. Proteins play a very important role in the sclerotization after ecdysis. Proteins are cross linked by phenols and chitin is bound to proteins as glycoprotein in the hardening process (Hackman and Goldberg, 1971; Hepburn and Joffe, 1974; Anderson, 1976; and Vincent and Hillerton, 1979).

#### Lipids:

Besides chitin and proteins, lipids are present as major components in insect cuticle. Hydrocarbons are present in epi, exo and meso cuticle (Neville, 1975; Hackman, 1974; and Wigglesworth, 1976). Hydrocarbons comprise a significant portion of cuticular lipids that prevent desiccation and are important in chemical communication (Blanquist and Jackson, 1979; and Howard and Blanquist, 1982). The cuticular lipids play an important role in water and ion permeation (Richards, 1951; Beament, 1961a, 1964, 1965, and 1976; and Nemenz, 1976). The wax layer of the epicuticle is responsible for the very low permeability of the cuticle to water (Richards, 1951; and Beament, 1961a, 1964 and 1965).

#### Mechanical properties of the cuticle:

Being an exoskeleton the cuticle in insects has acquired mechanical properties best suited for the

environment in which insects live. The mechanical properties of the cuticle of selected insects have been studied and amply reviewed (Neville, 1975; Reynolds, 1975; Hepburn and Joffe, 1974 and 1976; and Vincent, 1980). The insect cuticle can be classified into three different types depending upon the mechanical properties. (a) Plastically deformable (soft), (b) brittle (hard) and (c) a hybrid of these two (Hepburn and Chandler, 1975; Hepburn and Joffe, 1974, and 1976; and Vincent, 1980).

(a) The cuticle from a number of Lepidoptera and Coleoptera larvae belong to the plastic type. It is characterized by low stiffness, low tensile strength, large breaking strain and limited strain recovery. In these cuticles the tensile force is mainly carried by chitin filament system, whereas the protein matrix acts as the plasticizing material (Hepburn and Chandler, 1975; Hepburn and Joffe, 1976; Anderson, 1979; and Vincent, 1980).

(b) The hard cuticles are characterized by high stiffness, high tensile strength, and low breaking strain. Introduction of covalent bonding between proteins result in a stiff and less extensible cuticles. Most of the beetles and weevils have the hard cuticle (Hepburn and Joffe, 1976; Anderson, 1979; and Vincent, 1980).

(c) Hybrid cuticle is seen in majority of insect. It is a typical solid cuticle as in S. gregaria with a brittle outer matrix (the exocuticle) and a softer and plastic inner

portions (the endocuticle) (Hepburn and Joffe, 1976).

The main factors contributing to the mechanical properties of the insect cuticle are, the organization of chitin microfibrils, length of chitin microfibrils, protein conformations, chitin-protein interactions, and protein-protein interactions (Neville, 1975; Hepburn and Joffe, 1976; Anderson, 1979 and Vincent, 1980).

#### Permeability to water and water proofing

Experiments by Hurst (1941, 1948) and Beament (1945, 1948) indicated that under certain conditions water would pass through an isolated piece of insect cuticle more rapidly in one direction than the other. Water passes more rapidly inwards than outwards in Cockroach, Rhodnius and blowfly (Beament, 1948; Hurst, 1941 and 1948; and Richards et al., 1953). The asymmetry ratio varies between 100:1 and 2:1 (the inwards figure first) (Hurst, 1948).

Lipid layer is responsible for water proofing in the insects (Richards, 1951; Chefurka and Pepper, 1955; Beament, 1958 and 1964). Change in permeability of cuticular lipids are brought about by thermal agitation due to the change in organization of the molecules in the monolayer (Chefurka and Pepper, 1955; and Beament, 1961a and 1964).

Some insects are able to imbibe water from atmosphere and the cuticle of these insects is permeable to water. The water can be taken from atmosphere having a relative humidity of 70 per cent or more (Beament, 1964).

The absorption of liquid water into the cuticle is accomplished by temporary reorganization of lipids. The cuticle protein is under active control by the epidermis which modifies the hydration of the cuticle (Beament, 1961a, 1964 and 1965; and Winston, 1967). Staddan (1969) also reported that in aquatic hemiptera water enters the body through cuticle. Insects maintain active transport of water through the cuticle (Nemenz, 1976).

#### Electrical properties of insect cuticle

The four basic electrical properties which have been studied on insect cuticle are potential difference, direct current (DC) Resistance, alternating current (AC) impedance and capacitance (Scheie, 1980). Potential difference indicates the presence of ion pumps, concentration differences and selective permeabilities to ions. DC current resistance gives information about ion channels and water routes through the integument. Capacitance provides data on the barriers to ion movements through the integument. AC impedance can be used to deduce capacitive, inductive and resistive values (Scheie, 1980).

#### Resistance:

The impedance of isolated sections of Melanoplus egg coverings at 1 KC/S was measured by John (1936). It was reported that, there was several fold increase in resistance and capacitance at the time of cuticle formation, during embryonic development. A change in specific resistance

from  $84 \Omega \text{-cm}^2$  to  $8400 \Omega \text{-cm}^2$  was observed. Cole and Jahn (1937) measured the variation of impedance with frequency. They reported that the resistance of the egg coverings depends on the resistivity of the medium until the cuticular membrane was formed. Richards (1957) reported that in larval Sarcophaga bullata the average value for specific resistance of the excised cuticle was  $40,000 \Omega \text{-cm}^2$  and suggested, the outer epicuticle as the main barrier to electrolytes with a calculated thickness of 75 to 300  $\text{\AA}$ . It was further reported that intact integument was more permeable to ions than isolated cuticle. In Blattella, it was observed that the resistance went up in the cuticle, when separated by epidermal cells by a factor of two.

Scheie and Smyth (1967) reported that cuticles exhibited linear and symmetrical relations between current and potential difference at current densities less than  $30 \mu\text{A/cm}^2$ , in adult Periplaneta. At greater current densities the resistance was observed to decrease with increasing current. It was further stated that there was a large increase in the resistance and decrease in capacitance with time after moult. Values of resistance at 2000 C/S changed from  $12 \pm 6 \times 10^3 \Omega \text{-cm}^2$  for freshly moulted cuticle to  $50 \pm 16 \times 10^3 \Omega \text{-cm}^2$  for cuticles excised 2 weeks after moult. It was suggested that dermal gland ducts are the morphological conduits for the current although pore canals were not conclusively ruled out (Scheie and Smyth, 1967).

The resistance on live intact integument of adult Periplaneta was measured by Scheie and Smyth (1968). This was more pertinent to the normal physiological state of the insect. A resistance of  $7 \pm 2 \times 10^4 \Omega\text{-cm}^2$  across the pronotum of Periplaneta has been reported for both male and female insects (Scheie and Smyth, 1968). The resistance was reported to decrease by a ratio of  $0.5 \pm 0.1$  by disrupting outer layers of cuticle mechanically with emery powder. The mechanical damage to the epidermal layer reduces the resistance of insect cuticle by a factor of three (Scheie and Smyth, 1968). It was further suggested that integument resistance increases tremendously just after moulting and after several months of isolation. It was also suggested that either the ducts of dermal glands or pore canals are the major paths for ions moving across the cuticle.

A dramatic increase in DC resistance of the cuticle preceeds the ecdysis in Periplaneta (Scheie, 1969). It was indicated that the outer ends of old dermal gland ducts are plugged resulting in the increase in resistance of the cuticle prior to moulting. The voltage current characteristics from various portions of the integument of Supella has been reported by Scheie and Smyth (1972). In these studies the presence of Ohmic response, rectification and an active response for current, in the integument has been observed. It was further suggested that with change in the direction of the current, there was about 8 fold change in the specific resistance. The specific resistance was  $9 \times 10^5 \Omega\text{-cm}^2$  for inward current and  $1.2 \times 10^5 \Omega\text{-cm}^2$  for outward current (Scheie and Smyth, 1972).

Cuticular resistance in relation to feeding, temperature and illumination have also been reported. Bernays et al. (1972) reported that the resistance dropped by about 25 per cent during the first few hours after feeding, across the maxillary palps of Locusta migratoria. They reported that feeding, reflected alterations in the permeability of terminal sensilla. Bernays and Chapman (1972) reported that the resistance across the tips of maxillary palps is not affected by stimulation of palps but increased to the normal level found after feeding as a result of distension of the foregut with agar or injection of corpus cardiaca homogenates into the haemolymph. It suggested that distension of foregut stimulates receptors and cause the release of hormone from corpora cardiaca, which acts on the terminal sensilla of the palps causing them to close and hence increase in resistance across the palps.

Short term irradiations invariably resulted in an increase of the integument resistance in social wasps (Ishay and Croitoru, 1978). An essential difference between the yellow and brown parts in resistance was also observed. The resistance reversed in yellow strips in 10-20 minutes while in brown parts it took very long time. Croitoru et al. (1978) reported that a 2 minute exposure to white light produced an increase in resistance in all the wasps.

Ishay and Shinoy (1982) and Ishay et al. (1982a, 1982b) reported that resistance of cuticle to electricity

in social wasps was temperature dependent. In Vespa craba (the European hornet), V. orientalis (the oriental hornet) and Dolichovespula saxonica (the wasp), the resistance of the integument first decreases with increased temperature which differs according to species and then raises upto 40°C (Ishay et al., 1982a). It was suggested that the cuticular changes in resistivity at different temperatures reflects that the wasp is able to detect and regulate the temperature. No difference in the electrical resistivity of the cuticle has been observed between yellow and brown areas in oriental hornet (Ishay et al., 1982b). It was further reported that the oriental hornet, Vespa orientalis when fed on Colchicine reach a minimum resistance at a higher temperature while those fed on purine reach a minimum resistance at a lower temperature.

#### Potential difference

Jahn (1935) measured the potential difference across membranes of grasshopper, Melanoplus eggs during early diapause, when the eggs were immersed in a solution of various salts at different concentrations and at various pH and used these measurements to determine the relative ionic mobilities. Beament (1961b, 1964) measured a potential difference of 0.2 V between the two sides of nymphal cuticle of P. americana, when both sides were perfused with 0.1 M NaCl. Similar results were obtained with dead cuticle and also with a model consisting of

cockroach grease spread on a hydrated membrane. It was suggested that the electrical field, which gave rise to this effect was destroyed by lipid solvents and detergents, and indicated that the lipid layer was responsible for the potential difference. However, Scheie and Smyth (1967) did not observe any potential difference across the cuticle of P. americana when the same electrolyte was placed on each side (0.1 M NaCl). A diffusion potential was however, measured when different concentrations of the same electrolyte were placed on either side of the cuticle.

#### Capacitance:

Jahn (1936) reported that there was several fold increase in capacitance of grasshopper egg coverings at the time of cuticular formation. Richards (1957) measured a capacitance of  $0.3000 \pm 0.0124 \mu\text{F}/\text{cm}^2$ , from the isolated cuticles of Sarcophaga larvae. These measurements combined with calculations indicated an approximate thickness of 75 to 300  $\text{\AA}$  for the barrier to electrolytes in the cuticle of Sarcophaga. Scheie and Smyth (1967) observed a large decrease in capacitance on excised cuticle of Periplaneta, with time after moult. At 2000 C/S the capacitance was found to change from  $0.045 \pm 0.001 \mu\text{F}/\text{cm}^2$  for freshly moulted cuticle to  $0.005 \pm 0.003 \mu\text{F}/\text{cm}^2$ , for cuticles excised two weeks after moulting. Chefurka and Pepper (1955) in their studies on the physical nature of the transition region of insect waxes observed that initially the dielectric constant

of the wax decreased with increase in temperature. After 35°C there was a sharp increase in dielectric constant suggesting a change in the structure of wax from one with relatively immobile to one with mobile dipoles.

All these studies on electrical properties of insect cuticle indicate that changes in the physiological state of insects, result in changes in the electrical properties. Scheie and Smyth (1968) and Richards (1957) observed the changes in the cuticle resistance by mechanical damage. Till now no work has been done on the effect of chitin synthesis inhibitors or cuticle inhibitors on the electrical properties of insect cuticle, inspite of the fact that normal deposition of cuticle is severely interfered, with these chemicals. Hence the present investigations were taken up with the aim of studying the effect of the chitin synthesis inhibitor, diflubenzuron on AC resistance, capacitance, potential difference and chitin content of the insect cuticle.

#### Toxicity and Mode of action of Diflubenzuron

Before understanding the mode of action of diflubenzuron, it would be better to know about its toxicity to insects. The toxicity of diflubenzuron against most of the insects has been extensively studied. The literature available has been presented in the Table given below:

| S. No.            | Name of the Insect                  | Chemical                     | Dose              | Efficacy                                                         | Authors                         |
|-------------------|-------------------------------------|------------------------------|-------------------|------------------------------------------------------------------|---------------------------------|
| <u>Orthoptera</u> |                                     |                              |                   |                                                                  |                                 |
| 1.                | <u>Chrotogonus trachypterus</u>     | Di flubenzuron and Penfluron | 20 µg/nymph       | -                                                                | Saxena and Kumar, 1981a, 1981b. |
| 2.                | <u>Locusta migratoria</u>           | Di flubenzuron               | 100 ppm           | -                                                                | Hunter and Vincent, 1974        |
| 3.                | <u>Melanoplus sanguinipes</u>       | "                            | 10 ppm            | LC <sub>90</sub> for continuous exposure for 8 days              | Elliot and Iyer, 1982           |
|                   |                                     |                              | 2.4 ppm           | 12 days                                                          |                                 |
|                   |                                     |                              | 0.8 ppm           | 20 days                                                          |                                 |
| 4.                | <u>Oxya japonica</u> (Will.)        | "                            | 0.6±0.06 µg/nymph | LD <sub>50</sub> by topical application                          | Lim and Lee, 1982               |
|                   |                                     |                              | 13 µg/nymph       | LD <sub>95</sub>                                                 |                                 |
|                   |                                     |                              | 2.8±0.1 µg/nymph  | LD <sub>50</sub> by injection                                    |                                 |
|                   |                                     |                              | 50 µg/nymph       | LD <sub>95</sub>                                                 |                                 |
| 5.                | <u>poekilocerus pictus</u>          | Di flubenzuron and Penfluron | 2 and 20 µg/adult | Adversely affected oviposition, hatching and nymphal development | Saxena and Mathur, 1981         |
| 6.                | <u>Schistocerca gregaria</u> Forsk. | DU 19111                     | 30 ppm            | 100 % mortality at 7 days                                        | van Daalen et al., 1972         |
|                   |                                     |                              | 10 ppm            | 66 % mortality at 7 days                                         |                                 |
|                   |                                     | Di flubenzuron               | 100 ppm           | -                                                                | Ker, 1977                       |

| S. No.             | Name of the insect                         | Chemical      | Dose                                   | Efficacy                                                    | Authors                            |
|--------------------|--------------------------------------------|---------------|----------------------------------------|-------------------------------------------------------------|------------------------------------|
| 6.                 | <u>Schistocerca gregaria</u>               | Diflubenzuron | 0.24±0.01 µg/nymph                     | LD <sub>50</sub> for fourth instar } by topical application | Marly et al., 1981                 |
|                    |                                            |               | 0.70±0.01 µg/nymph                     | LD <sub>50</sub> for fifth instar                           |                                    |
|                    |                                            |               | 0.5 µg/egg                             | eggs failed to hatch                                        |                                    |
|                    |                                            |               | 100 mg AI/litre                        | LC <sub>95</sub>                                            |                                    |
|                    |                                            |               |                                        |                                                             | Grosscurt, 1978a                   |
| <u>Lepidoptera</u> |                                            |               |                                        |                                                             |                                    |
| 1.                 | <u>Achaea janata</u> Linn.                 |               | 0.05 g/litre                           | 96% mortality                                               | Rabindra and Balasubramanian, 1981 |
|                    |                                            |               | 10 and 100 ppm to 4th instar           | None of the larvae reached adult stage                      | Subrahmanyam et al., 1980          |
| 2.                 | <u>Bucculatrix thurberiei</u> <u>Bueck</u> |               | 0.22 and 2.2 kg AI/ha in cotton fields | gave excellent control                                      | Flint et al., 1977                 |
| 3.                 | <u>Ceramica picta</u>                      |               | 10 and 100 ppm                         | Effective against the larvae                                | Tamaki and Turner, 1974            |
| 4.                 | <u>Choristoneura fumiferana</u>            |               | 1.0%                                   | gave > 80% deformity in 5th and 6th instars                 | Retnakaran and Smith, 1975         |
|                    |                                            |               | 3.7 ppm in diet                        | EC <sub>50</sub> for 6th instar                             | Granett, 1977                      |
|                    |                                            |               | 8.3 "                                  | " 5th "                                                     |                                    |
|                    |                                            |               | 15.0 "                                 | " 4th "                                                     |                                    |
|                    |                                            |               | 36.0 "                                 | " 3rd "                                                     |                                    |
|                    |                                            |               | 91.0 "                                 | " 2nd "                                                     |                                    |

| S. No. | Name of the Insect                | Chemical                  | Dose           | Efficacy                                                   | Authors                         |
|--------|-----------------------------------|---------------------------|----------------|------------------------------------------------------------|---------------------------------|
| 4.     | <u>Choristoneura fumiferana</u>   | EL-494 and diflubenzuron  | 0.205 ppm      | EC <sub>50</sub> for 3rd instar                            | Retnakaran, 1979                |
|        |                                   |                           | 0.249 ppm      | " 4th "                                                    |                                 |
|        |                                   | EL-494                    | 0.287 ppm      | " 5th "                                                    |                                 |
|        |                                   |                           | 0.486 ppm      | " 6th "                                                    |                                 |
| 5.     | <u>Choristoneura occidentalis</u> | Diflubenzuron and TH 6038 | 406 g AI/ha    | 84% mortality at 6 weeks                                   | Gillette et al., 1978           |
| 6.     | <u>Choristoneura rosaceana</u>    | Diflubenzuron             | 100 ppm        | Toxic to 1st instar and reduced adult longevity            | Anderson and Elliott, 1982      |
| 7.     | <u>Cnaphalocrosis medinalis</u>   | "                         | 200 ppm        | Larvae unable to moult and 80 % of population deformed.    | Natesan et al., 1980            |
| 8.     | <u>Ergolis merione</u>            | "                         | 52.50 µg/larva | LD <sub>50</sub> when treated                              | Chockalingam and Krishnan, 1984 |
|        |                                   | "                         | 27.76          | 24 hr                                                      |                                 |
|        |                                   | "                         | 13.60          | 48 hr                                                      |                                 |
|        |                                   | "                         | 8.70           | 72 hr                                                      |                                 |
| 9.     | <u>Lasperisia pomonella</u>       | "                         | 0.027 mg/lit.  | LC <sub>50</sub> for eggs                                  | Hoying and Riedl, 1980          |
| 10.    | <u>Lymantria dispar</u>           | "                         | 0.052 ppm      | EC <sub>50</sub> for failure of 3rd instar to moult to 4th | Abdelmonem and Mumma, 1981      |
|        |                                   | "                         | 0.122 ppm      | EC <sub>50</sub> for failure of 5th instar to moult        |                                 |
| 11.    | <u>Malacosoma dissitria</u> Hbn.  | "                         | 70 g AI/ha     | Gave effective control                                     | Retnakaran et al., 1979         |

| S. No. | Name of the insect                                   | Chemical | Dose                                   | Efficacy                                                   | Authors                                |
|--------|------------------------------------------------------|----------|----------------------------------------|------------------------------------------------------------|----------------------------------------|
| 12.    | <u>Nepantlis serinopa</u> <u>Meyr.</u>               | "        | 0.2-4.0 gm/litre                       | 27.5 to 75% inhibition of moulting                         | Sundaramurthy and Santhakrishnan, 1979 |
|        |                                                      | II       | 2.5-20 g AI/10 lits                    | Entire field population of larvae eliminated in 14-18 days | Sundarmurthy, 1980                     |
| 13.    | <u>Operophtera</u> <u>brumata</u>                    | "        | 165 ppm                                | Effective for control                                      | Pree, 1976                             |
| 14.    | <u>Orygia</u> <u>pseudotsugata</u>                   | "        | 0.028 ppm in diet<br>0.056 ppm in diet | LC <sub>50</sub><br>LC <sub>90</sub>                       | Gillette et al., 1978                  |
|        |                                                      |          | 0.25 lb AI/gal/acre                    | gave effective control and foliage protection              | Neisess et al., 1979                   |
| 15.    | <u>Ostrinia</u> <u>nubilalis</u> <u>Hbn.</u>         | "        | 2.5 ppm in diet                        | 95.6% larval mortality                                     | Buchi, 1978                            |
|        |                                                      | "        | 0.2% G or 0.28, 0.56 and 1.12 kg AI/ha | Effectively checked the population                         | Berry et al., 1980                     |
|        |                                                      | "        | 500 ppm - eggs dipping                 | 93.1% eggs did not hatch                                   | Faragalla et al., 1980                 |
| 16.    | <u>Pectinophora</u> <u>gossypiella</u> <u>Saund.</u> | "        | 10,000 ppm spray or 1 ppm in diet      | Effective                                                  | Flint and Smyth, 1977                  |
| 17.    | <u>Porthetria</u> <u>dispar</u>                      | "        | 0.013 ppm in artificial diet           | EC <sub>50</sub> for 3rd instar                            | Granett and Dunbar, 1975               |

| S. Name of the No. insect             | Chemical                               | Dose                                   | Efficacy                                                                                             | Authors                 |
|---------------------------------------|----------------------------------------|----------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------|
| 18. <u>Spodoptera exigua</u> Hbn.     | Penfluron                              | 0.013 µg/larva                         | LD <sub>50</sub>                                                                                     | Granett et al., 1983    |
|                                       |                                        | 0.29 ppm                               | LC <sub>50</sub>                                                                                     |                         |
|                                       | Diflubenzuron                          | 0.53 µg/larva                          | LD <sub>50</sub>                                                                                     |                         |
|                                       |                                        | 1.5 ppm                                | LC <sub>50</sub>                                                                                     |                         |
|                                       | BAYSIR 8514                            | 0.12 µg/larva                          | LD <sub>50</sub>                                                                                     |                         |
|                                       |                                        | 1.7 ppm                                | LC <sub>50</sub>                                                                                     |                         |
| 19. <u>Spodoptera frugiperda</u>      | Diflubenzuron and two of its analogues | 0.01 to 100 ppm in diet                | Effective                                                                                            | De Milo et al., 1978    |
| 20. <u>Spodoptera mauritia</u> Boisd. | Diflubenzuron                          | 1, 10, 100, 1000 ppm                   | Early instars more susceptible                                                                       | Beevi and Dale, 1980    |
| 21. <u>Spodoptera littoralis</u>      | Diflubenzuron                          | Eggs dipped in 0.00025%                | 100 % kill of eggs                                                                                   | Ascher and Nemny, 1974  |
|                                       | "                                      | 2.5 to 10,000 µg/g in wheat bran baits | 70-90 % larval mortality                                                                             | Ascher and Nemny, 1976a |
|                                       | "                                      | 0.04 µg/larva and 0.66 µg/larva        | ED <sub>50</sub> for cumulative mortality upto adult stage for 100 mg and 200 mg larvae respectively | Ascher and Nemny, 1976b |
|                                       | "                                      | 5 ppm dipping of the eggs              | 100 % kill of eggs                                                                                   | Salama and El-Din, 1977 |
|                                       | "                                      | 30-50 ppm to larval food               | Larval mortality                                                                                     |                         |
|                                       | "                                      | 100 or 1000 ppm soil treatment         | No adult emergence                                                                                   | Abo-Elghar et al., 1982 |

| S. No.            | Name of the insect                | Chemical      | Dose                                                               | Efficacy                                                         | Authors                                        |
|-------------------|-----------------------------------|---------------|--------------------------------------------------------------------|------------------------------------------------------------------|------------------------------------------------|
| 22.               | <u>Spodoptera litura</u>          | Diflubenzuron | 0.1% to leaves                                                     | 46-96% inhibition of moulting and various deformities            | Sundarmurthy, 1977                             |
| "                 | "                                 | "             | 0.01% spray                                                        | 90.6% reduction of larvae at 7 days                              | Santharam and Balasubramaniam, 1980            |
| "                 | "                                 | "             | Dipping pupae in solution of 100,250, 500 and 1000 ppm/ 10 seconds | Pupal mortality, partial Natesan and Balasubramaniam, 1980       |                                                |
| 23.               | <u>Trichoplusia ni</u> Hubner     | "             | 0.22 and 2.2 kg AI/ ha in cotton fields                            | gave excellent control                                           | Flint et al., 1977                             |
| <u>Coleoptera</u> |                                   |               |                                                                    |                                                                  |                                                |
| 1.                | <u>Agelastica alni</u>            | "             | 0.5, 50 and 100 ppm                                                | Number of fertilized eggs and number of larvae hatched decreased | Weiss, 1977                                    |
| 2.                | <u>Anthonomus grandis</u> Boheman | "             | Dipping in 0.1% as sprayable bait at 0.25 and 0.5 lbs AI/acre      | Fertility reduced<br>Adult emergence reduced by 98%              | Moore and Taft, 1975<br>Taft and Hopkins, 1975 |
| "                 | "                                 | "             | 431 ppm                                                            | ED <sub>50</sub> at 72 hrs                                       | ]To inhibit egg hatch                          |
| "                 | "                                 | "             | 2797 ppm                                                           | ED <sub>50</sub> at 216 hrs                                      |                                                |
| "                 | "                                 | "             | 141, 282 and 564 g AI/ha                                           | > 99% of reduction in reproduction                               | Ganyard et al., 1977                           |
| "                 | "                                 | "             | 0.25 lb AI/acre                                                    | Prevented egg hatch or killed larvae in 1st instar               | Lloyd et al., 1977                             |

| S. No. | Name of the insect                    | Chemical      | Dose                                                       | Efficacy                                                  | Authors                    |
|--------|---------------------------------------|---------------|------------------------------------------------------------|-----------------------------------------------------------|----------------------------|
| 2.     | <u>Anthonomus grandis</u><br>Boheman  | Diflubenzuron | 0.14 kg AI/ha<br>9-10 times                                | > 90 % control of reproduction                            | Ganyard et al., 1978       |
|        | "                                     | "             | 35,70 and 140 g AI/ha                                      | 62.3, 77.8 and 84.2% reduction in population respectively | House et al., 1978         |
|        | "                                     | "             | 141.8 g AI/ha                                              | egg hatch significantly inhibited                         | Johnson et al., 1978       |
|        | "                                     | "             | Fed for 6 days in diet and sterile ones released in fields | Population did not establish in fields                    | Mitchell et al., 1980      |
| 3.     | <u>Dermestes maculatus</u><br>De Geer | "             | 100-500 mg m <sup>-2</sup> spray to polypropylene          | Effective for 12 weeks                                    | Webly and Airey, 1982      |
| 4.     | <u>Diaprepes abbreviatus</u>          | "             | 283 g AI/acre                                              | egg hatch reduced from 71 to 15%                          | Schroeder et al., 1976     |
|        | "                                     | "             | 350 g AI/ha                                                | Viability of eggs reduced by > 95%                        | Schroeder and Sulton, 1978 |
| 5.     | <u>Epilachna varivestis</u>           | "             | 0.01, 0.1 and 1.0%                                         | Parasites were not effected                               | Zungoli et al., 1983       |
|        | "                                     | "             | 0.018, 0.053 and 0.088 kg AI/ha                            | 70 % control achieved                                     |                            |
| 6.     | <u>Hypera postica</u>                 | "             | 1 lb. AI/acre                                              | High mortality in 4th instar                              | Ngai, 1974                 |
| 7.     | <u>Leptinotarsa decemlineata</u>      | "             | 1000 ppm                                                   | -                                                         | Grosscutt, 1978b           |
|        | "                                     | "             | 50,100, 300 and 500 mg/litre                               | Suppressed 3rd and 4th instars                            | Tamaki et al., 1984        |

| S. Name of the No. Insect                                                                                     | Chemical      | Dose                                                           | Efficacy                                             | Authors                                              |
|---------------------------------------------------------------------------------------------------------------|---------------|----------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|
| 8. <u>Mylocerus undecimpustulatus</u>                                                                         | Diflubenzuron | Females fed with treated leaves                                | 90.2 % sterile eggs were laid                        | Thangavelu, 1982                                     |
| 9. <u>Rhizopertha dominica</u>                                                                                | "             | 1-10 ppm                                                       | effectively controlled                               | McGregor and Kramer, 1976; and Mian and Mulla, 1982. |
| 10. <u>Sitophilus oryzae</u>                                                                                  | "             | 5 and 10 ppm                                                   | gave 100 % control                                   |                                                      |
| 11. <u>S. granarius</u><br><u>S. zeamais</u><br><u>tribolium confusum</u><br><u>Oryzaephilus surinamensis</u> | "             | 1 or 10 ppm                                                    | prevented progeny development                        | McGregor and Kramer, 1976                            |
| <u>Diptera</u>                                                                                                |               |                                                                |                                                      |                                                      |
| 1. <u>Glossina moritans</u>                                                                                   | "             | 0.5-5 µg/fly                                                   | > 80 % reduction in adult emergence from off springs | Jordan and Trewn, 1978                               |
| "                                                                                                             | "             | 1 µg/fly                                                       | 77 to 83% inhibition in development of progeny       | Kaplanis et al., 1978                                |
| 2. <u>Haematobia irritans</u>                                                                                 | "             | 0.5 or 1.0 % spray to cattle                                   | Development was inhibited                            | Kung et al., 1977                                    |
| 3. <u>Musca autumnalis</u>                                                                                    | "             | 0.1 ppm                                                        | 100 % kill of larvae                                 | Miller, 1974                                         |
| "                                                                                                             | "             | Fed in diet to the adults, and also exposed to treated surface | Egg hatch inhibited                                  | Pickens and De Milo, 1977                            |

| S. No.                       | Name of the insect                                                                                                                                                                             | Chemical                                                                                                                                                      | Dose                            | Efficacy                                                          | Authors                 |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|-------------------------------------------------------------------|-------------------------|
| 4.                           | <u>Musca domestica</u><br>L.                                                                                                                                                                   | Di-flubenzuron                                                                                                                                                | 1.00 ppm                        | 100 % mortality of larvae                                         | Miller, 1974            |
|                              | "                                                                                                                                                                                              | "                                                                                                                                                             | 10, 2.5 and 1.25 ppm            | 90 % mortality of the larvae                                      | Ables et al., 1975      |
| 5.                           | <u>Simulium vittatum</u>                                                                                                                                                                       | "                                                                                                                                                             | 0.7, 0.2 and 0.03 ppm           | LC95 for larvae exposed to 15 min, 60 min and 24 hrs respectively | Lacy and Mulla, 1977    |
| 6.                           | <u>Stomoxys calcitrans</u> L.                                                                                                                                                                  | "                                                                                                                                                             | 0.17%                           | LC <sub>50</sub> for inhibition of egg hatch                      | Wright and Harris, 1976 |
| <u>Other insects</u>         |                                                                                                                                                                                                |                                                                                                                                                               |                                 |                                                                   |                         |
|                              | <u>Oncopeltus fasciatus</u>                                                                                                                                                                    | "                                                                                                                                                             | 2.4 µg/gm body weight           | LD <sub>50</sub>                                                  | Hajjar and Casida, 1978 |
|                              | <u>Phyllocoptruta oleivora</u>                                                                                                                                                                 | "                                                                                                                                                             | 0.04-0.3 g AI/lit               | Moulting inhibited in 2nd nymphal stage                           | McCoy, 1978             |
|                              | "                                                                                                                                                                                              | "                                                                                                                                                             | 0.15 g AI/lit field application | gave excellent control of the population                          |                         |
| <u>Beneficial Arthropods</u> |                                                                                                                                                                                                |                                                                                                                                                               |                                 |                                                                   |                         |
|                              | <u>Geocoris punctipes</u><br><u>Nabis</u> spl.,<br><u>Hippodamia convergens</u> ,<br><u>Coleomegilla maculata</u> ,<br><u>Orius insidiosus</u> ,<br><u>Chrysopa</u> sp. and<br><u>Araneida</u> | Di-flubenzuron at 140 g AI/ha from June to August 9 times in cotton fields<br><br>No significant reduction in predator populations except <u>G. punctipes</u> |                                 |                                                                   |                         |

| S. No. | Name of the insect         | Chemical      | Dose         | Efficacy                              | Authors                 |
|--------|----------------------------|---------------|--------------|---------------------------------------|-------------------------|
|        | <u>Apis mellifera</u>      | Diflubenzuron | 100 ppm      | production of brood almost eliminated | Barker and Waller, 1978 |
|        |                            | "             | 3.7 ppm      | LC <sub>50</sub>                      | Wittmann, 1981          |
|        | Mammalian toxicity on mice | "             | > 3160 mg/kg | Acute oral LD <sub>50</sub>           | van Daelen et al., 1972 |

### Mode of action of diflubenzuron

The mode of action of benzophenyl urea compounds has been studied by various workers (reviews by Misata et al., 1979; Hammock and Quistad, 1981; and Beeman, 1982).

Benzophenyl urea compound 1-(2,6-dichlorobenzoyl)-3-(3,4-dichlorophenyl)-urea (DU 19111) was observed to cause death in the larvae during next moult after treatment. The mode of action of the compound was suggested to be connected with moulting (van Daalen et al., 1972). Post and Vincent (1973) and Post et al. (1974) reported that DU 19111 prevented incorporation of  $^{14}\text{C}$ -glucose into larval endocuticle resulting in accumulation of labelled N-acetyl glucosamine. It was suggested that DU 19111 blocks the synthesis of cuticular chitin in the larvae of Leptinotarsa and Pieris.

Diflubenzuron (1-(4-Chlorophenyl)-3-(2,6-difluorobenzoyl) urea) and related compounds are slow acting poisons which specifically affect insect cuticle. Their action results in failure of treated insect to moult or pupate; resulting in death due to impairment in cuticle deposition (Mulder and Gijswijt, 1973; Wellinga et al., 1973a and 1973b). In Pieris apolysed larvae often cannot free themselves from the old cuticle. Histological examinations showed severe lesions in the endocuticular tissue (Mulder and Gijswijt, 1973). Sowa and Marks (1975) reported that diflubenzuron and Polyoxin-D were potent

inhibitors of  $\beta$ -ecdysone dependent N-acetyl glucosamine incorporation into chitin chain in regenerating tissue from cockroach legs. It was further reported that insect tissue has affinity to diflubenzuron and hence has the higher efficacy. Kaska et al. (1980) have also reported that in Heliothis zea pupae, diflubenzuron and Polyoxin-D resulted in a 75 per cent reduction in the incorporation of  $^{14}\text{C}$  labelled N-acetyl-D-glucosamine and suggested that the two chemicals are inhibitors of chitin synthesis. Most of the workers reported that diflubenzuron and other benzophenyl ureas prevent incorporation of glucose or N-acetyl glucosamine into larval cuticle and suggested that the chemicals are inhibitors of chitin synthesis (Verloop and Ferrel, 1977; Abdel-Monem et al., 1980; and Mitsui et al., 1980, 1981, and 1984). Unlike in DU 19111, diflubenzuron treatment results in accumulation of Uridine diphospho-N-acetyl glucosamine in treated larvae (Deul et al., 1978; Hajjar and Casida, 1979; van Eck, 1979; and Turnbull and Howells, 1982).

Chitin biosynthesis inhibition by diflubenzuron and other benzophenyl ureas resulting in abnormal cuticle formation has been reported by Hunter and Vincent (1974), in Locusta migratoria; Ishaaya and Casida (1974) in Musca domestica; Salama et al. (1976) in Lymantria dispar; Clarke et al. (1977) in Locusta migratoria; Ker (1977 and 1978) in Schistocerca gregaria; Grosscurt (1978b) and Grosscurt and Anderson (1980) in Leptinotarsa; Nishioka

et al. (1979) in larval cuticle tissue of Chilo suppressalis; Mitsui et al. (1980) in Manduca larvae; and Saxena and Kumar (1981a and 1981b) in Chrotogonus trachypterus.

Reduction in the mechanical resistance of the elytra of Leptinotarsa decemlineata has been observed by administering diflubenzuron (Grosscurt, 1978b; and Grosscurt and Anderson, 1980). It was suggested that diflubenzuron interferes with chitin-protein bonding which results in reduction of mechanical resistance. It was further reported that the yield of keto catechols, a parameter which has been related to tanning was inhibited by 50%. Hunter and Vincent (1974) reported that in locusts treated with diflubenzuron, the rigidity of cuticle was about one half of that of the normal. Salama et al. (1976) and Ker (1977 and 1978) reported that endocuticle formed after treatment with diflubenzuron was not properly attached to epidermis and showed globules in endocuticle. It was also suggested that diflubenzuron by interfering with rate of deposition of chitin, makes the endocuticle less rigid which can not withstand the internal pressure during ecdysis and hence the affected insects were unable to cast the exuviae during moulting.

Diflubenzuron and DU 19111 were observed to have no effect on chitinase activity in Pieris brassicae (Deul et al., 1978). However, Ishaaya and Casida (1974) earlier reported that diflubenzuron increases the cuticular chitinase and phenol oxidase activities. An alternate proposal

for the mode of action of diflubenzuron is that it reduces the activity of  $\beta$ -ecdysone metabolizing enzyme, resulting in accumulation of  $\beta$ -ecdysone; which stimulates chitinase that degrades chitin (Yu and Terriere, 1975 and 1977). Hajjar & Casida (1979) suggested that diflubenzuron does not alter in vivo metabolism of either  $\alpha$  or  $\beta$  ecdysone in 5th instar milk weed bug nymphs. Diflubenzuron did not inhibit chitin synthetase activity (Cohen and Casida, 1980, and 1982; and Mayer et al., 1980, and 1981). However, Leighton and Marks (1981) reported that benzophenyl urea insecticides are apparently not direct acting chitin synthetase inhibitors but inhibit serine-protease and thus block the conversion of chitin synthetase zymogen into active enzyme.

The morphological manifestations of diflubenzuron and related compounds in the cuticle of insects due to reduced chitin content have been reported by various workers. The morphological manifestations such as an imperfect cuticle at the time of ecdysis, incomplete tanning, retention of exuviae, retention of larval characters, and death at the time of moulting have been reported by Retnakaran and Smith (1975) in Choristoneura fumiferana; Fytizas (1976) in Dacus oleae; Fogal (1977) in Diprion similis; Sundarmurthy (1977) and Sundarmurthy and Balasubramaniam (1978) in Spodoptera litura; Sundarmurthy and Santhakrishnan (1979) in Nephantis serinopa; Gijswijt et al. (1979) and Bene and Porcinai (1980) in Pieris brassicae; Subrahmanyam et al. (1980) in Achaea janata;

Bene and Porcinai (1981) in Thaumtopoea pityocampa; Zomer and Lipke (1981) in Aedes aegypti; Mariy et al. (1981) in Schistocerca gregaria; Lim and Lee (1982) in Oxya japonica; and Soltani et al. (1983 and 1984) in Tenebrio molitor.

Clarke et al. (1977) reported that in peritrophic membrane of Locusta migratoria chitin production was partially blocked by diflubenzuron. Reduction in chitin leads to reduction in protein incorporation in the same proportion. The protein incorporation is affected by the stability of the protein in the matrix such that unbound protein tends to inhibit the addition of further protein. Ker (1977, and 1978) reported that the cuticle of locusts treated with diflubenzuron is prone to fracture in characteristic ways. Chitin is reduced to a sufficient extent for the structural coherence and optical properties of the cuticle to be dependent on the proteins. It was further observed that only in some regions is a stable layer of cuticle formed after treatment with diflubenzuron. Many workers however, reported that diflubenzuron and other benzophenyl ureas do not effect proteins in insect cuticle (Post and Vincent 1973; Hunter and Vincent, 1974; Ishaaya and Casida, 1974; Salama et al., 1976; Mitlin et al., 1977; and Saxena and Kumar, 1981a). Diflubenzuron has no effect on amino acids and peptides of the haemolymph (Baumler and Salama, 1976). Lipid content was found to be increased in treated insects with diflubenzuron and other benzophenyl ureas (Salama et al., 1976, and Saxena and Kumar, 1981a).

Saxena and Kumar (1981b) reported that treatment of Chrotozonus trachypterus nymphs with diflubenzuron and penfluron resulted in increased levels of glucose and glycogen, decreased level of fructose while the levels of glucosamine and N-acetyl glucosamine were unaffected in the integument. Partial blockage of chitin synthesis at initial stage of conversion of glucose to fructose-6-phosphate was suggested. Baumler and Salama (1976) have also reported a sudden increase in glucose content of haemolymph, 7-8 days after treatment with diflubenzuron in gypsymoth larvae.

Inhibition of biosynthesis of DNA by diflubenzuron treatment in boll weevils, pupae of stable fly and Tenebrio molitor was reported by Mitlin et al. (1977); De Loach et al. (1981a, and 1981b); and Soltani et al. (1984). However, synthesis of neither RNA nor proteins were reported to be effected. Meola and Mayer (1980) reported that in stable fly pupae diflubenzuron in addition to preventing N-acetyl glucosamine incorporation into chitin, suppressed the development of epidermis by a cytostatic action in vivo by preventing the proliferation of the undifferentiated imaginal cells. Soltani et al. (1984) have also reported that diflubenzuron affects mitosis in the sternal cuticle of Tenebrio molitor. Reduction of thickness of cuticle by diflubenzuron treatment has also been reported by Mitsui et al. (1980) and Soltani et al. (1984). Pheromone production was said to be significantly reduced by diflubenzuron in male boll weevils (Villavaso et al., 1983).

Diﬂubenzuron also affects reproduction in insects. The affects such as sterility in adults, reduced fecundity, reduced hatching, larval mortality after hatching has been reported by various workers in different insects (Wright and Spates, 1976; Arambourg et al., 1977; McCoy, 1978; McLaughlin, 1978; Otten and Tood, 1979; Chang and Borkovec, 1980; Mariy et al., 1981; Saxena and Mathur, 1981; Lim and Lee, 1982; and Thakur and Ashok Kumar, 1984).

Despite the fact that a very extensive work has been done on the mode of action of diﬂubenzuron, its action is still not clearly understood. Even though most of the workers agreed that chitin biosynthesis is inhibited, it is still uncertain about at what stage in the chitin formation chain, the inhibition occurs. There are no explanations for its secondary and miscellaneous effect. The exact cause of death is also not known. Hence the present studies were taken up to throw some light on the mode of action of diﬂubenzuron, by studying the effects of diﬂubenzuron on the physical properties of insect cuticle.

## MATERIAL AND METHODS

### Rearing of the insects:

The 5th instar hoppers and adults of desert locust Schistocerca gregaria used in the present studies, were obtained from a laboratory colony maintained according to Mehrotra and Rao (1966). The insects were fed with cabbage, cauliflower and maize leaves and dry wheat bran daily. Periodically vitamin E and yeast mixed with wheat bran was fed to boost the strength of the colony.

### Treatment with the chemical

#### Test chemical:

Diflubenzuron (1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl) urea) technical grade (100 % powder) was a gift from Dr. A.B. Borkovec, Insect Chemosterilants Laboratory, USDA, USA.

#### Preparation of standard solution

A mixture of acetone and dimethyl formamide in 1:1 ratio was used as solvent to dissolve diflubenzuron. Diflubenzuron, 50 mg was dissolved in 10 ml of solvent to give 0.5 per cent solution. This was used as the standard solution. The standard solution was diluted in such a way that the various doses as given below were administered in 2  $\mu$ l solution. These solutions were kept

in vials and stored in a refrigerator and used for one week. Fresh solutions were prepared after every week.

### Treatments

|    | <u>Dose</u>      | <u>Concentration</u> | <u>Qty. of solution injected/nymph</u> |
|----|------------------|----------------------|----------------------------------------|
| 1. | 10.0 µg AI/nymph | 0.5 %                | 2 µl                                   |
| 2. | 5.0 ''           | 0.25 %               | ''                                     |
| 3. | 1.0 ''           | 0.05 %               | ''                                     |
| 4. | 0.5 ''           | 0.025 %              | ''                                     |
| 5. | 0.1 ''           | 0.005 %              | ''                                     |
| 6. | Control          | Only solvent         | ''                                     |

### Treatment procedure

Difflubenzuron solution was injected in the hoppers with the help of an electrically operated microapplicator (ISCO 5624 - Lincoln, Nebraska, USA) driven tuberculin syringe. Prior to this, the syringe was standardized for the quantity of the liquid delivered, with the time scale of the microapplicator. The syringe delivered 0.875 µl solution/second. Two to three day old fifth instar hoppers were injected with the chemical on the ventro-lateral side, just behind the left hind leg by piercing the intersegmental membrane between the first and the second abdominal sternites. The hoppers were handled without giving any anaesthesia. The hoppers, following the treatment were maintained in the laboratory on normal diet. Observations were recorded daily

for mortality and moulting abnormality until all the nymphs moulted into adults.

### Data analysis

The data on bioassay were analysed by Finney's probit (1947) method. The log-dose probit mortality and moulting abnormality, regression line was constructed and the  $ED_{50}$  value was calculated.

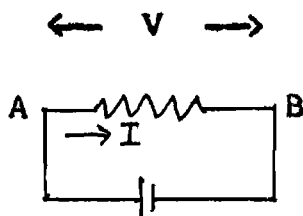
### Studies on the effect of Diflubenzuron on the physical properties of the insect integument

For the studies on the effect of diflubenzuron on the physical properties of insect integument, the hoppers were treated in batches with 5.0  $\mu$ g of diflubenzuron in 2  $\mu$ l of solution/nymph. Simultaneously control was also maintained for comparative studies by injecting 2  $\mu$ l of the solvent/nymph.

### Electrical Resistance

According to Ohm's law, under similar physical conditions the electrical current passing through a conductor would be proportional to the potential difference between the two ends of the conductor. In other words we can say some resistance is offered by the conductor to the flow of current.

|                      |                          |
|----------------------|--------------------------|
| $I \propto V$        | I - current              |
| or $IR = V$          | V - Potential difference |
| or $R = \frac{V}{I}$ | R - Resistance           |



The unit of resistance is Ohm. The electrical resistance of a conductor depends upon its dimensions and the specific nature of the substance. In metallic conductors the current is carried by the free electrons. But in case of electrolytes the charge is carried by ions. The electrical resistance or conductivity depends upon the density of ions, nature of ions, viscosity of the medium etc. The electrical conductivity measurement of solutions is an useful tool for the estimation of salt concentration in solutions.

In the present investigations AC resistance was measured across the insect cuticle according to the method of Scheie and Smyth (1968) with slight modifications. The resistance was calculated from simultaneous measurements of the potential difference 'V' developed between the two electrode positions and the current 'I' passing through the circuit, with the help of a Type 502 A' dual beam oscilloscope, Tetronix, U.S.A.

#### Electrodes and Electrolyte solution

Insects are known to contain a layer of grease on the outer surface of the cuticle (Wigglesworth, 1972) which is highly resistant for the flow of current. Hence 0.1 M NaCl was used as an electrolyte solution to facilitate

the flow of current. Stainless steel pins were used as electrodes. Copper wires soldered to the pins worked as connecting wires. These electrodes did not change the overall resistance of the circuit. The tips of the electrodes were made blunt to prevent any accidental injury to the cuticle while experimentation. Whenever measurements were conducted by keeping one electrode in haemolymph, an electrode with pointed tip was used. The stainless steel pins were preferred over the glass filled electrodes (described by Scheie and Smyth, 1968) due to the ease with which they could be prepared.

#### Measuring Technique:

The adult locusts on which the measurements were carried out, were restrained on a soft plastic sponge in a plastic case. Holes were cut on the lid of the plastic case to expose the areas of integument, for taking resistance measurements (Plate-1A). Two drops of 0.1 M NaCl (Electrolyte solution), were placed with the help of a 5  $\mu$ l pipette, on the integument at a small distance from one another. The diameter of the circular drops was measured with the help of an ocular micrometer, under a stereomicroscope. The ocular micrometer was standardised with the stage micrometer before the measurements were made, as given below:

75 divisions of stage micrometer = 13 division of  
ocular micrometers

A



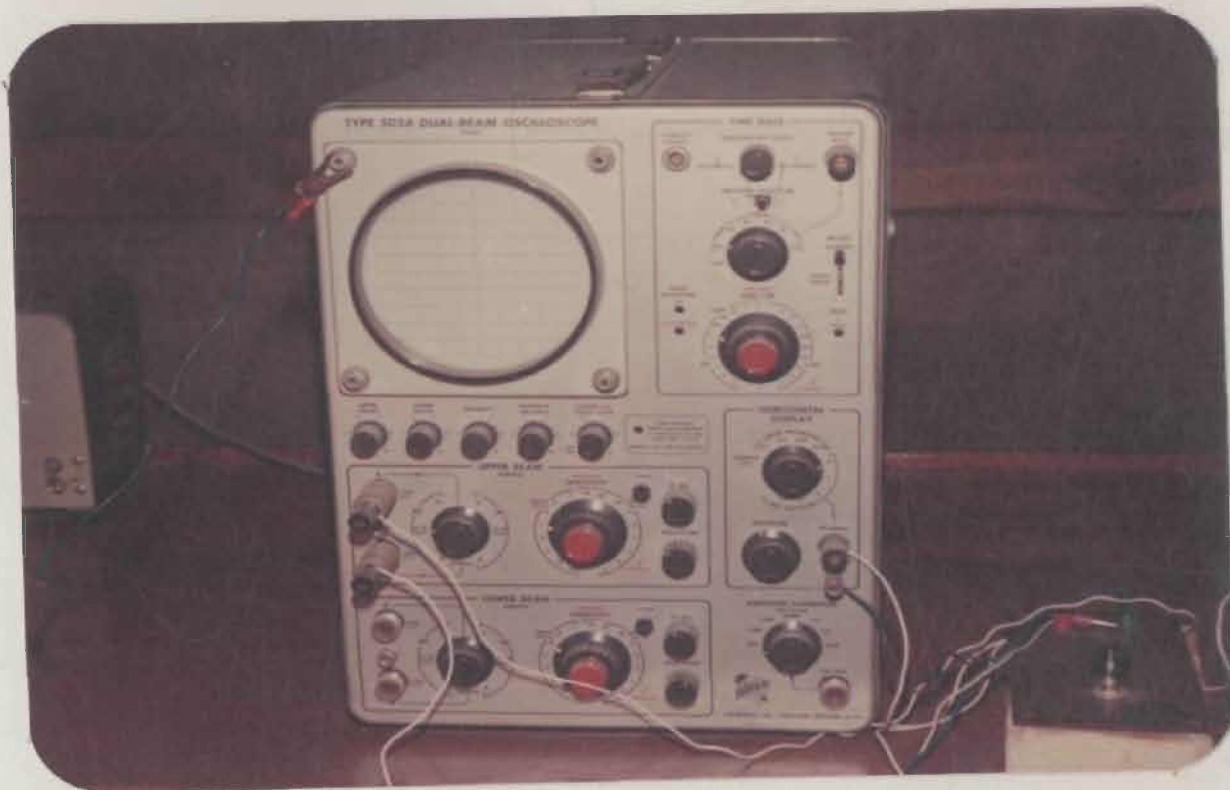
B



PLATE - II

- A. Type 502 A dual beam oscilloscope
- B. L.C.R. Bridge.

A

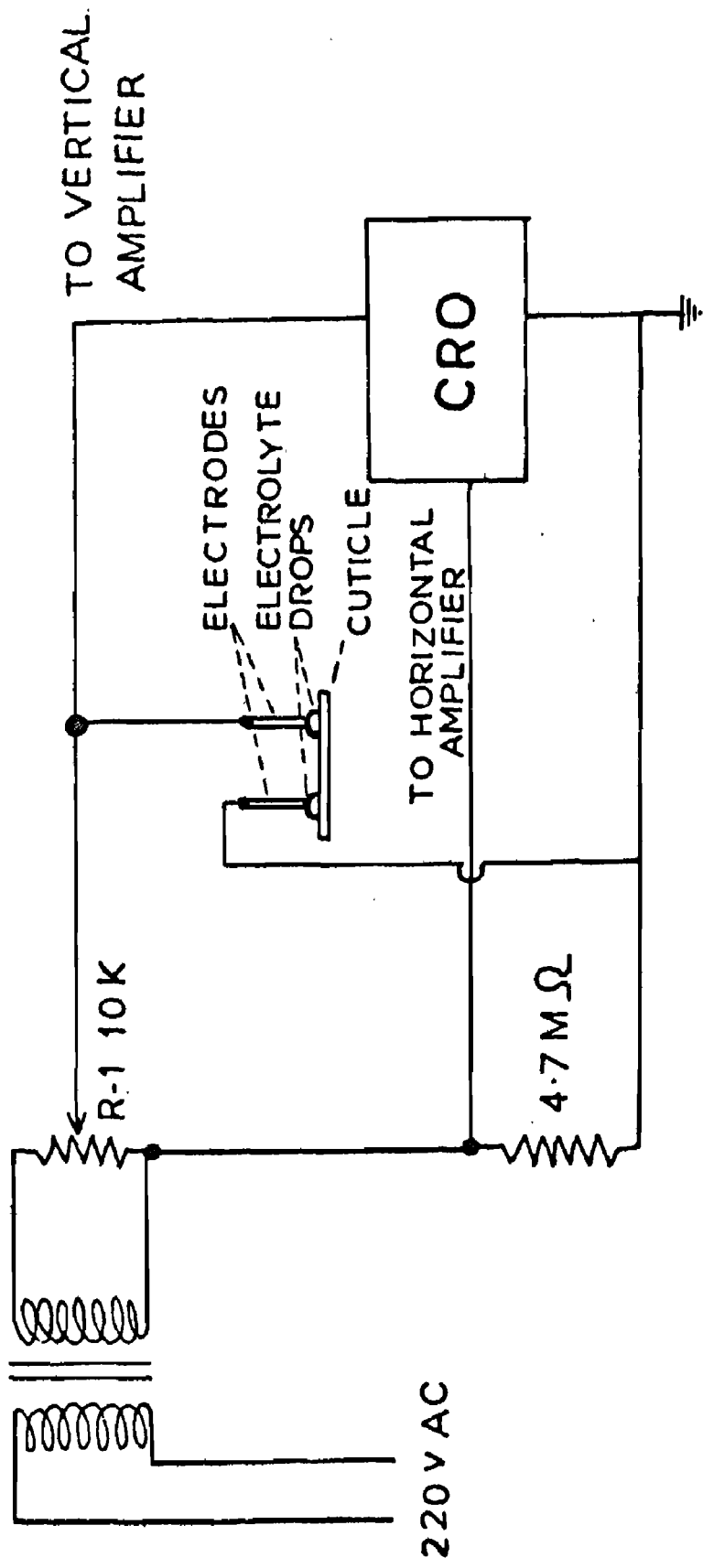


B



Fig.1. Schematic diagram of the electrical arrangement for measuring AC resistance of the cuticle of S. gregaria

STEPDOWN  
6.3v AC TRANSFORMERS



One division of stage micrometer = 0.01 mm

Hence one ocular micrometer divi. =  $\frac{0.75}{13}$  mm

= 0.058 mm

The two electrodes fixed to a movable stand, were lowered to make contact with the electrolyte drops on the integument of the insect (Plate-1B). The schematic diagram of the electrical set up is given in Figure-1. The electrical resistance between the two electrode positions was calculated with the help of Ohm's law from simultaneous measurements of the potential difference and current passing through circuit. The potential difference was detected by the vertical deflection of the upper beam on a Tetronix 502A dual beam Cathode Ray Oscilloscope (Plate-2A). The current was adjusted with the help of a potentiometer (R-1) and the potential difference developed across a  $4.7\text{ M}\Omega$  resistor was fed to the input terminals of the horizontal amplifier of the CRO. A 'V' vs 'I' curve was obtained on the Oscilloscope screen and the corresponding 'V' and 'I' measurements were recorded at different currents.

The horizontal scale of the Oscilloscope was calibrated for current, with the known,  $4.7\text{ M}\Omega$  resistor and 6.3 V AC transformer, prior to experimentation. The horizontal deflection of the lower beam, when the two electrodes were short circuited, was recorded and the horizontal scale was calibrated for current as given below:

Voltage of the step down AC transformer - 6.3 V

Resistance used in the circuit - 4.7 M $\Omega$

Internal resistance in C.R.O. - 1.0 M $\Omega$

Total resistance in the circuit -  $\frac{1}{R} = \frac{1}{1} + \frac{1}{4.7}$

$$R = \frac{4.7}{5.7} = 0.8246 \text{ M}\Omega$$

Current passing through the circuit when the electrodes were

$$\text{short circuited} = \frac{6.3}{0.82456 \times 1000 \times 1000} \text{ A}$$

$$= \frac{6.3}{0.825} \mu\text{A} = 7.6404 \mu\text{A}$$

Horizontal deflection of the lower beam when the electrodes were short circuited = 9.8 cm

Hence, 1 cm of horizontal deflection of the lower beam

$$= \frac{7.6404}{9.8} \mu\text{A}$$

$$= 0.7796 \mu\text{A}$$

Measurements of resistance were conducted on pronotum, abdominal sternites and excised pronotum at current densities of 0.78, 1.56 and 2.34  $\mu\text{A}$ , corresponding to the 1.0, 2.0 and 3.0 cm horizontal deflections of the lower beam, after cycling the current five times, at least twice the highest value of the current. For the measurements of resistance on wings, current densities of 0.625, 1.25 and 1.87  $\mu\text{A}$  corresponding to 0.8, 1.6 and 2.4 cm horizontal deflections of the lower beam, were used. On pronotum the electrolyte drops were placed one on either side of the mid dorsal line and on abdominal sternites the electrolyte drops were placed on the mid-ventral line. On forewings they were placed at the middle of the wing close to the anal margin, while on hind wings they were placed near the apical margin.

After completion of the measurements both the electrodes were raised, the electrolyte drops blotted off, and the insects released from the holder.

The specific resistance ( $R_s$ ) was calculated from the resistance obtained by Ohm's law, by multiplying the resistance with the contact area of one of the electrolyte drop.

Resistance when both electrodes were on outer surface of the cuticle ( $R$ ) =  $\frac{V}{I} \times \frac{1}{2}$ . The corresponding specific resistance ( $R_s$ ) =  $\frac{V}{I} \times \frac{A}{2}$ . Resistance when one electrode was in haemolymph and the other on outer surface of the cuticle ( $R$ ) =  $\frac{V}{I}$ . The corresponding specific resistance ( $R_s$ ) =  $\frac{V}{I} \times A$  (Scheie and Smyth, 1967, and 1968), where 'V' is the voltage; 'I' is the current; and 'A' is the area of the electrolyte drop.

AC resistance on normal adult locusts was measured with two different sizes of the electrolyte drops by placing 5  $\mu$ l and 10  $\mu$ l of the 0.1 M NaCl solution. On abdominal sternites, the resistance was measured across 2-3, 2-4, 2-5 and 2-6 sternites to know the effect of distance between the two electrode positions on the resistance. Also for certain measurements the resistance was determined by keeping one electrode in the haemolymph and the other on the outer surface of the cuticle to provide justification for using the denominator '2' when the resistance was measured between two external electrolyte drops on live insects. Since it was stated that the current encounters two resistances (cuticle) when both the electrodes are on outer surface of the cuticle i.e. while the current is passing, from one electrolyte drop to the

haemolymph and from haemolymph to the other electrolyte drop (Scheie and Smyth, 1968).

#### Repeated measurements on the same insect

To know whether repeated measurements cause any damage to the cuticle two batches of insects were used. In one batch the same insects were repeatedly used for measuring resistance of the cuticle from 1 to 10 days after moulting, while in the other batch fresh insects of the same age were used. Similarly diflubenzuron treated and solvent treated insects were also measured for the cuticle resistance.

#### Resistance on excised pronotum

The pronotums of the deformed and normal insects were excised at various ages after moulting, cleared from the adhering tissue and floated on a pool of 0.1 M NaCl solution in a 50 ml glass beaker, with the lower side of the pronotum coming in contact with the electrolyte pool. One drop of the same electrolyte was placed on the upper side of the pronotum. The 'V' vs 'I' measurements were recorded as detailed earlier, after lowering the electrodes, such that one comes in contact with the electrolyte pool and the other with the electrolyte drop on the upper surface of the pronotum. The electrolyte was changed after every measurement.

The electrodes were changed at regular intervals, however, all the measurements in a particular group were carried out with the same pair of electrodes.

#### Measurement of Bio-potential across the pronotum

The bio-potential (electrical) upto the order of

Fig.2. Schematic diagram of the electrical arrangement for  
measuring potential difference of the excised pronotum  
of S. gregaria

TO VERTICAL AMPLIFIER

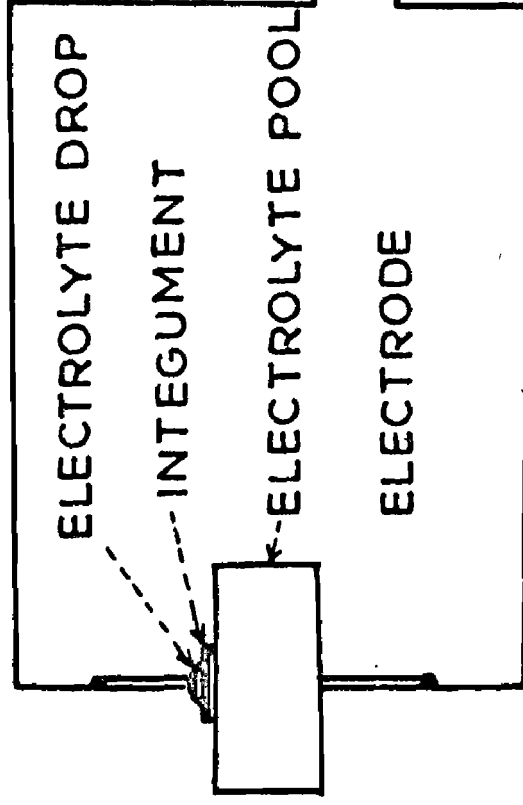
ELECTROLYTE DROP

INTEGUMENT

ELECTROLYTE POOL

ELECTRODE

CRO



several volts has been reported to occur in many living tissues (Enyikwola and Burton, 1983).

Since the bio-potential is an intrinsic property of the living tissues, the present investigations were carried out without applying external current. The basic set up for measurement of the bio-potential across the pronotum of S. gregaria is given in Figure-2.

The pronotums of the adults obtained from diflubenzuron treated and solvent treated hoppers were excised at the various ages and cleared from the adhering tissues. The pronotum was floated on a pool of 0.1 M NaCl electrolyte in a 50 ml beaker so that its lower surface comes in contact with the electrolyte. One drop of the same electrolyte was placed on the outer surface of the pronotum. The two electrodes were lowered such that one electrode makes contact with the electrolyte pool in the beaker and the other electrode with the electrolyte drop on the upper surface of the pronotum. The potential difference across the pronotum was fed to the vertical amplifier of the C.R.O. via the electrodes and the connecting copper wires. The vertical deflection of the spot on the oscilloscope was recorded after adjusting the scale of the vertical amplifier to a convenient position. From the Oscilloscope readings the bio-potential in DC volts across the pronotum was determined. The electrolyte was changed after every measurement.

#### Capacitance

The electrical charge has been found to accumulate in

many cases. The holding of electrical charge by any medium is the basic property of the medium, known as the dielectric property. The charge holding capacity of a condenser (which depends upon its dimensions) is called the capacitance of the condenser. Capacitance is expressed in farads. Since farad is a very large unit, micro farads and piko farads are commonly used. The condenser can be formed in various geometrical configurations, but the simplest is a parallel plate condenser. A special type of parallel plate condenser was used in the present studies to measure the capacitance of the insect cuticle.

#### Preparation of cuticle:

The ventral abdominal sclerites of the adult S. gregaria were excised and the adhering muscles and tissues removed. The epidermal layer and other tissues were removed with the help of a cotton swab. Following this, the sternites were separated from one another. The intersegmental membrane was also removed. The cuticle pieces were then washed, and dried before measuring capacitance.

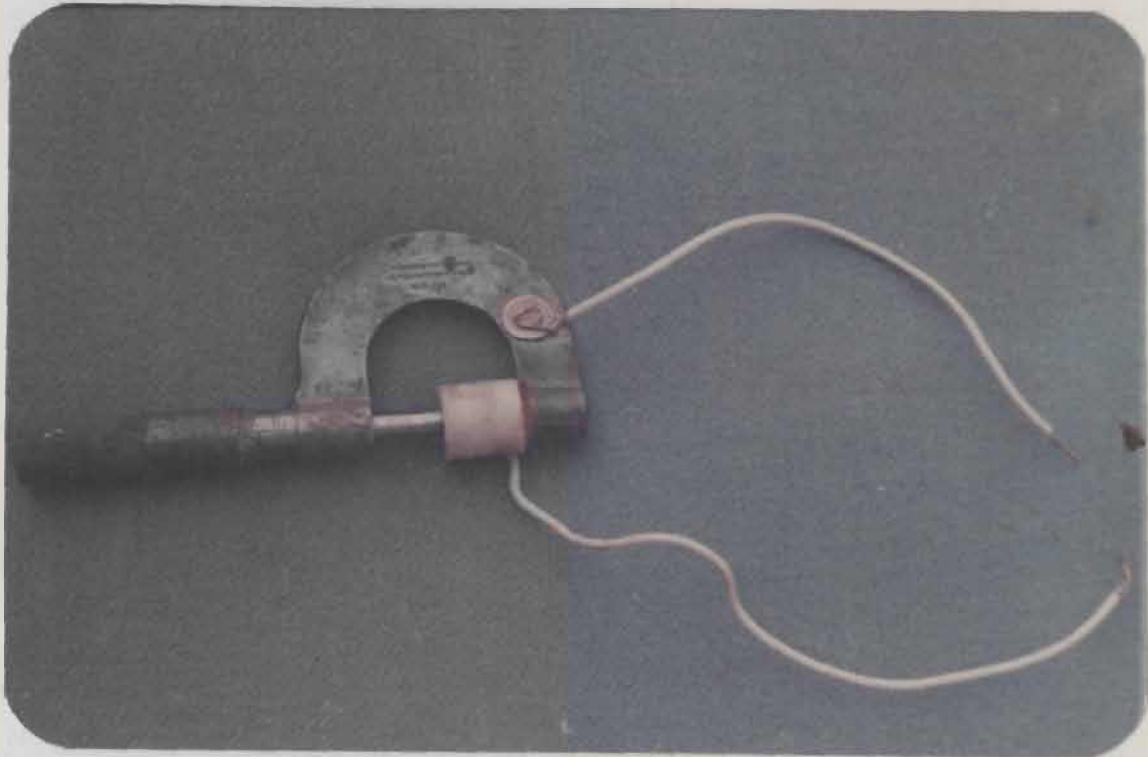
#### Measuring technique for capacitance of the cuticle of S. gregaria

A cylindrical teflon sample holder with a conductor plate at the bottom was used, to hold the sample. The sample holder was fixed to the immovable end of a micrometer (Plate-3A) which was specially used for maintaining constant distance between the two conductor plates. The circular and flat end of the movable cylinder was used as the detecting

PLATE - III

- A. Sample holder attached to micrometer.
- B. Holder cell with micrometer connected to L.C.R. bridge.

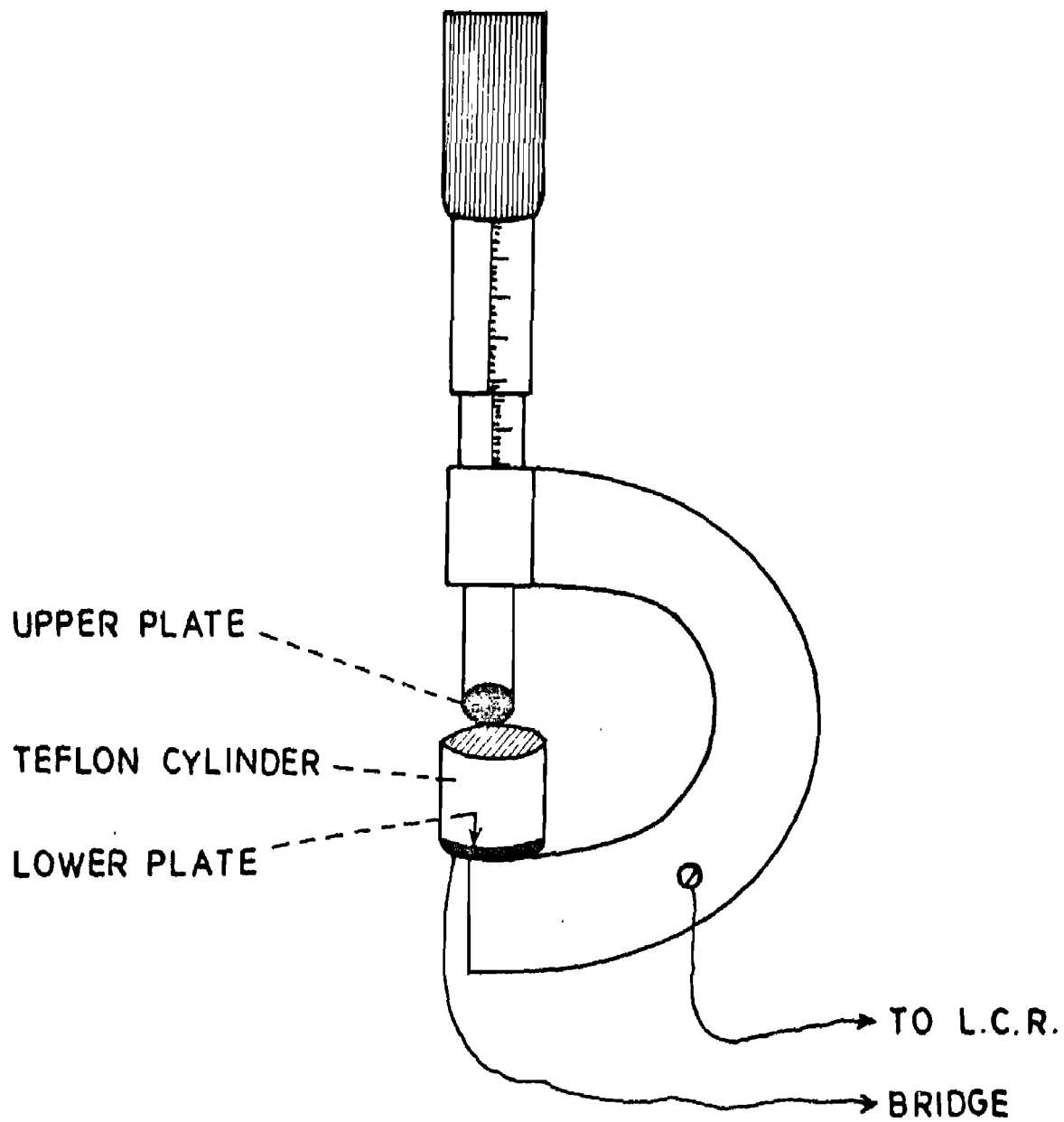
A



B



Fig.3. Schematic diagram for measuring the capacitance  
of the cuticle of S. gregaria



upper plate. The two plates were connected with very short shielded copper wires (15 cm) to an Inductance - Capacitance - Resistance bridge (L.C.R. bridge)(Plate-3B). The capacitance measurements were carried out with the L.C.R. bridge, model 1203, Eastern Electronics (Plate-2B) at a frequency of 10KHZ. The basic set up for the capacitance measurement is given in Figure-3.

The cuticle portion was kept in the sample holder, with the inner surface making contact with the conductor plate, present at the bottom of the sample holder. The movable end of the micrometer was then rotated such that the distance between the two conductor plates was 0.05 mm. The L.C.R. bridge was balanced and the corresponding reading of the capacitance was recorded. Capacitances of the cuticles of the deformed and normal adults were measured from '0' to 15 days after moulting, on 20 cuticle portions.

The dielectric constant of the cuticle was calculated from the observed capacitance values using the formula:

$$C = \frac{K\epsilon_0 A}{d} \quad (\text{Semat, 1945})$$

$$\text{or } K = \frac{Cd}{\epsilon_0 A}$$

Where 'C' is the observed capacitance; 'K' is the dielectric constant;  $\epsilon_0$  is a constant (the absolute permittivity -  $0.85 \times 10^{-12} \text{ C}^2\text{N}^{-1}\text{M}^{-2}$ ); 'A' is the area of the cuticle portion (upper plate); and 'd' is the distance between the two conductor plates.

#### Estimation of chitin content in the wings

Chitin in the wings of the locusts was determined

gravimetrically according to the method of Grosscurt (1978b). A set of four wings of the locust was used as one unit with four replications.

The wings of the adults were removed and cut into small pieces. The initial weight of the set of four wings was recorded and then the small pieces were placed in a test tube with rim. Five milli-litres of 30 % potassium hydroxide, was added to the test tube with the help of a pipette. The test tube was then covered with a small piece of nylon mesh, firmly held with a rubber band. The test tube was then boiled in a water bath for 15 to 20 minutes to digest the proteins present in the integument. It was removed from water bath, cooled and the KOH decanted off. This treatment removed the proteins. The remaining material in the test tube was washed six times with distilled water to remove any traces of KOH. Following this the material was washed twice with 96 per cent alcohol and twice with diethyl ether to remove lipids and also moisture. Finally the material was dried overnight at 50°C in an incubator and the weight of the chitin (the dried material left over in the test tube) was recorded. From these values the percentage of chitin to the fresh weight of the wings was calculated. Similarly chitin was also determined in fore and hind wings individually.

## RESULTS

### Electrical resistance of the cuticle of *S. gregaria*

Preliminary experiments were conducted on mature adult locusts, to measure the resistance of the cuticle to AC currents at various sites. The main purpose of this was to have some idea about the resistance of cuticle to electric currents and the effect of (a) the area of contact of the electrolyte drop, (b) the distance between the two electrode positions, (c) the position of the electrodes (i.e. either both electrodes on outer surface of the cuticle or one electrode on outer surface and the other in haemolymph) on the observed resistance. Repeated measurements for the resistance of cuticle on the same insects were also made and compared with those of the same age, but used only once to observe whether repeated observations cause any damage to the cuticle or not. The electrical resistance of the cuticle was measured on pronotum, abdominal sternites, and fore wings. The resistance values are expressed in  $K \Omega$  and the specific resistance ( $R_s$ ) value in  $K \Omega\text{-cm}^2$ .

#### A. AC resistance of pronotum

The data on the observed resistance on the pronotum of mature adult males are presented in Table-1. The data suggest that the average resistance across the pronotum of adult males, using 5  $\mu$ l of 0.1 M NaCl electrolyte drop and

both the electrodes on the outer surface was  $604.2 \pm 73.4$  (range 481.0 to 737.6). The corresponding  $R_s$  of the pronotum was  $25.58 \pm 2.28$  (range 21.48 to 28.78). Using 10  $\mu$ l electrolyte drop, the average resistance of the pronotum of adult males was observed to be  $438.8 \pm 47.4$  (range 352.7 to 513.1). The corresponding  $R_s$  was calculated to be  $25.85 \pm 2.44$  (range 21.26 to 28.99). The average  $R_s$  across the pronotum with one electrode in haemolymph and the other on the outer surface, was  $25.44 \pm 1.89$  (range 22.08 to 27.92).

The data presented in Table-1 suggest that the average resistance of the pronotum of adult females was  $623.1 \pm 80.0$  (range 509.5 to 801.7) using 5  $\mu$ l electrolyte drop and both the electrodes on outer surface. The corresponding  $R_s$  was observed to be  $25.79 \pm 2.33$  (range 21.48 to 28.71). Using 10  $\mu$ l electrolyte drop and again with both the electrodes on outer surface of the pronotum, the average resistance was found to be  $458.3 \pm 57.1$  (range 334.9 to 538.0). The corresponding  $R_s$  of the pronotum of adult females was  $26.22 \pm 2.41$  (range 21.26 to 28.99). Keeping one electrode in haemolymph and the other on outer surface of the pronotum the average  $R_s$  of the pronotum of the adult females was  $25.95 \pm 2.20$  (range 21.90 to 29.09).

These results suggest that the resistance of the cuticle depends on the size of the electrolyte drop. The larger the electrolyte drop, the lower the resistance and the smaller the drop the higher the resistance. However,  $R_s$  did not change significantly with the size of the

Table-1: AC resistance of the cuticle of mature adult S. gregaria.

| S. No. | Both electrodes on outer surface          |                             |                                           |                             | One electrode on outer surface and one in haemolymph |
|--------|-------------------------------------------|-----------------------------|-------------------------------------------|-----------------------------|------------------------------------------------------|
|        | With smaller electrolyte drop (5 $\mu$ l) |                             | With larger electrolyte drop (10 $\mu$ l) |                             |                                                      |
|        | Resistance                                | Specific Resistance         | Resistance                                | Specific Resistance         |                                                      |
|        | K $\Omega$                                | K $\Omega$ -cm <sup>2</sup> | K $\Omega$                                | K $\Omega$ -cm <sup>2</sup> | Specific Resistance                                  |
|        |                                           |                             |                                           |                             | K $\Omega$ -cm <sup>2</sup>                          |

I On Pronotum - male

|                 |                 |                 |                 |                 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| 604.2<br>(73.4) | 25.58<br>(2.28) | 438.8<br>(47.4) | 25.85<br>(2.44) | 25.44<br>(1.89) |
|-----------------|-----------------|-----------------|-----------------|-----------------|

II On Pronotum - female

|                 |                 |                 |                 |                 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| 623.1<br>(80.0) | 25.79<br>(2.33) | 458.3<br>(57.1) | 26.22<br>(2.41) | 25.95<br>(2.20) |
|-----------------|-----------------|-----------------|-----------------|-----------------|

III On Fore wings - male

|                  |                 |                 |                 |                 |
|------------------|-----------------|-----------------|-----------------|-----------------|
| 1053.0<br>(96.0) | 45.20<br>(2.76) | 797.0<br>(68.0) | 45.66<br>(2.08) | 45.23<br>(2.11) |
|------------------|-----------------|-----------------|-----------------|-----------------|

IV On Fore wings - female

|                  |                 |                 |                 |                 |
|------------------|-----------------|-----------------|-----------------|-----------------|
| 1080.0<br>(96.0) | 45.77<br>(2.80) | 802.0<br>(51.0) | 45.90<br>(2.59) | 45.48<br>(2.14) |
|------------------|-----------------|-----------------|-----------------|-----------------|

Table-2: Average  $R_s$  across abdominal sternites of mature adult S. gregaria (K $\Omega$ -cm<sup>2</sup>)

| Abdominal sternites | Male            | Female          |
|---------------------|-----------------|-----------------|
| 2-3                 | 22.56<br>(1.54) | 22.84<br>(2.23) |
| 2-4                 | 22.84<br>(1.22) | 22.89<br>(2.04) |
| 2-5                 | 22.68<br>(1.51) | 22.86<br>(1.99) |
| 2-6                 | 22.84<br>(1.54) | 23.17<br>(2.18) |

Each datum is an average of 16 observations - Appendix I - VI.

Figures in parentheses are standard deviations.

electrolyte drop. The average  $R_s$  was always slightly higher in females than in males.

#### B. AC resistance of fore wings

The data presented in Table-1 suggest that the average resistance of fore wings of the adult males using 5  $\mu$ l electrolyte drop and both the electrodes on outer surface was  $1053 \pm 96$  (range 882 to 1243). The corresponding average  $R_s$  was observed to be  $45.20 \pm 2.76$  (range 40.69 to 49.44). Using 10  $\mu$ l electrolyte drop the average resistance on fore wings of the adult males was found to be  $797 \pm 68$  (range 681 to 953) with both the electrodes on outer surface. The corresponding average  $R_s$  was observed to be  $45.66 \pm 2.08$  (range 42.65 to 50.49). The average  $R_s$  of fore wings of adult males with one electrode in haemolymph and the other on the outer surface was  $45.23 \pm 2.11$  (range 40.92 to 50.02).

The data on the resistance of the fore wings of the adult females are also presented in Table-1. From the data it would be seen that the average resistance on the fore wings of the adult females using 5  $\mu$ l electrolyte drop was  $1080 \pm 96$  (range 922 to 1265) with both the electrodes on outer surface. The corresponding average  $R_s$  was observed to be  $45.77 \pm 2.80$  (range 38.59 to 49.74). Using 10  $\mu$ l electrolyte drop and both the electrodes on outer surface the average resistance on the fore wings of the adult females was observed to be  $802 \pm 51$  (range 722 to 882). The corresponding average  $R_s$  of the fore wings of the adult females was  $45.90 \pm 2.59$  (range 40.81 to 49.16). The average  $R_s$  of the

fore wings of adult females when one electrode was in haemolymph and the other on the outer surface was observed to be  $45.48 \pm 2.14$  (range 41.20 to 48.81).

These results suggest that as in case of pronotum, the resistance on fore wings also depends on the size of the electrolyte drop, and that the resistance is inversely proportional to the size of the electrolyte drop. The  $R_s$  measured on forewings was slightly higher in females than in males. The  $R_s$  did not change significantly with the size of the electrolyte drop.

From the studies on the resistance of pronotum and fore wings it was observed that the  $R_s$  did not change significantly with the position of electrodes, i.e. either when both the electrodes were on outer surface or one electrode in haemolymph and the other on outer surface. This obviously suggest that the resistance when measured between two external electrolyte drops was exactly twice to that when measured between one external electrolyte drop and the haemolymph, since the denominator '2' was always used to obtain the  $R_s$  when measured between two external electrodes, the area of electrolyte drop being the same. Further this also justifies the use of the denominator '2' for arriving the  $R_s$ , when measured between two external electrolyte drops on live insects. These findings give credence to the results of Schele and Smyth (1967, and 1968) who also observed that when both the electrodes were placed on outer surface of the cuticle, the electrical current encounters two resistances in series, first while the current passes from one electrode to the

haemolymph and the other when the current passes from haemolymph to the other electrode. The resistance to AC current measured at the two different areas showed that the forewings offered higher resistance than pronotum, the  $R_s$  of forewings was 2-fold higher than that of pronotum. This was true for both the sexes. It may however, be mentioned that the  $R_s$  measured was always slightly higher in case of females than that of males, although the differences were not significant.

### C. AC resistance of abdominal sternites

Resistance of the cuticle to AC current was measured on ventral side of abdomen, between 2-3, 2-4, 2-5 and 2-6 sternites (Table-2). The average  $R_s$  across 2-3 abdominal sternites for adult males was  $22.56 \pm 1.54$  (range 20.05 to 24.50). It was observed to be  $22.84 \pm 1.22$  (range 21.15 to 24.25) across 2-4 sternites,  $22.68 \pm 1.51$  (range 20.70 to 25.50) across 2-5 sternites and  $22.84 \pm 1.54$  (range 20.05 to 25.20) across 2-6 sternites. The corresponding average  $R_s$  values for adult females were found to be  $22.84 \pm 2.23$  (range 20.05 to 26.84) across 2-3 sternites,  $22.89 \pm 2.04$  (range 20.05 to 26.84) across 2-4 sternites,  $22.86 \pm 1.99$  (range 20.13 to 26.54) across 2-5 sternites and  $23.17 \pm 2.18$  (range 21.05 to 27.88) across 2-6 sternites.

The observed  $R_s$  on abdominal sternites suggest that unlike in most of the conductors and semi-conductors, the resistance of the insect cuticle did not depend on the distance between the two electrodes. The average  $R_s$  across 2-3



abdominal sternites did not differ significantly with the  $R_s$  across 2-4, 2-5 or 2-6 abdominal sternites either in males or in females. The distance between the two electrode positions when the resistance was measured across 2-6 abdominal sternites was more than 3 times (1.8 cm) than that when the resistance was measured across 2-3 abdominal sternites (0.5 cm). This observation also confirms that there was no transverse path of the current through the cuticle. The current had to pass from one electrolyte drop to the haemolymph and from haemolymph to the other electrolyte drop. Since the haemolymph was found to offer no significant resistance to the total measured resistance of the system, the distance between the electrode positions did not have any effect on the resistance of the cuticle.

The average  $R_s$  across the abdominal sternites was found to be slightly lower than that of pronotum in both the sexes. As in case of pronotum and forewings, the  $R_s$  measured across abdominal sternites was always slightly higher in case of females than males, although the differences were not significant.

#### D. effect of repeated observations for AC resistance on *S. gregaria*

The electrical resistance of the cuticle of adult locusts across pronotum and forewings was measured repeatedly on the same insects from 1 to 10 days after moulting and compared with those of the same age but used only for one measurement of cuticle resistance.

The average  $R_s$  for the group of insects which were repeatedly used from 1 to 10 days, was  $19.23 \pm 1.68$  across pronotum of adult males on the 2nd day (Table-3, Figure-4A). It increased to  $22.31 \pm 1.83$  by 6th day and  $23.40 \pm 1.89$  by 10th day after moulting. The corresponding average  $R_s$  values for those insects on which the observations were taken only once, were  $18.74 \pm 1.37$  on 2nd day,  $21.93 \pm 1.68$  on 6th day and  $23.51 \pm 1.98$  on 10th day after moulting. In adult females the average  $R_s$  of pronotum for the repeatedly measured insects was  $19.39 \pm 1.48$  on 2nd day,  $22.45 \pm 1.65$  on 6th day and  $23.59 \pm 1.67$  on 10th day after moulting (Table-3, Figure-4B). The corresponding average  $R_s$  values for those insects, on which the observations were taken only once, were  $19.51 \pm 1.56$  on 2nd day,  $22.56 \pm 1.89$  on 6th day and  $23.80 \pm 1.90$  on 10th day after moulting.

The data on the resistance of fore wings of the locusts from 1 to 10 days after moulting are presented in Table-4 and Figures-4A and 4B. The average  $R_s$  of the fore wings for the adult males which were repeatedly used, was  $34.11 \pm 2.15$  on 2nd day,  $40.26 \pm 2.53$  on 6th day and  $42.72 \pm 2.29$  on 10th day after moulting. The average  $R_s$  for the adult males on which the observations were taken only once was  $33.41 \pm 2.33$  on 2nd day,  $40.03 \pm 2.50$  on 6th day and  $43.12 \pm 2.95$  on 10th day after moulting. In case of the adult females the average  $R_s$  for those which were repeatedly used, was  $33.15 \pm 2.32$  on 2nd day,  $39.36 \pm 2.14$  on 6th day and  $42.50 \pm 2.45$  on 10th day after moulting. The corresponding values of average  $R_s$  of fore wings for the adult females, on which observations were

Table-3: Average  $R_s$  across pronotum for repeatedly measured (R) and fresh (F) adult S. gregaria ( $K_{OL} - cm^2$ )

| Age in days | Male            |                 | Female          |                 |
|-------------|-----------------|-----------------|-----------------|-----------------|
|             | R               | F               | R               | S               |
| 1           | 17.49<br>(1.73) | 17.49<br>(1.73) | 17.82<br>(1.30) | 17.82<br>(1.30) |
| 2           | 19.23<br>(1.68) | 18.74<br>(1.37) | 19.39<br>(1.48) | 19.51<br>(1.56) |
| 3           | 20.46<br>(1.79) | 19.85<br>(1.25) | 20.52<br>(1.50) | 20.68<br>(1.80) |
| 4           | 21.44<br>(1.68) | 20.86<br>(1.87) | 21.44<br>(1.57) | 21.60<br>(1.49) |
| 5           | 21.91<br>(1.69) | 21.35<br>(1.81) | 21.91<br>(1.55) | 22.12<br>(1.64) |
| 6           | 22.31<br>(1.83) | 21.93<br>(1.68) | 22.45<br>(1.65) | 22.56<br>(1.89) |
| 7           | 22.70<br>(2.02) | 22.42<br>(2.03) | 22.92<br>(1.71) | 22.97<br>(1.87) |
| 8           | 22.98<br>(1.90) | 22.99<br>(2.25) | 23.27<br>(1.59) | 23.32<br>(2.22) |
| 9           | 23.24<br>(1.98) | 23.29<br>(2.10) | 23.49<br>(1.46) | 23.58<br>(1.26) |
| 10          | 23.40<br>(1.89) | 23.51<br>(1.98) | 23.59<br>(1.67) | 23.80<br>(1.90) |

Each datum is an average of 12 observations - Appendix VII - X.

Figures in parentheses are standard deviations.

Table-4: Average  $R_s$  across fore wings for repeatedly measured (R) and Fresh (F) adult S.gregaria K $\Omega$ -cm<sup>2</sup>

| Age in days | Male            |                 | Female          |                 |
|-------------|-----------------|-----------------|-----------------|-----------------|
|             | R               | F               | R               | F               |
| 1           | 31.08<br>(2.24) | 31.08<br>(2.24) | 30.46<br>(2.12) | 30.46<br>(2.12) |
| 2           | 34.11<br>(2.15) | 33.41<br>(2.33) | 33.15<br>(2.32) | 33.35<br>(2.53) |
| 3           | 36.41<br>(1.71) | 35.79<br>(1.94) | 35.48<br>(1.76) | 35.74<br>(1.89) |
| 4           | 37.98<br>(2.03) | 37.34<br>(1.46) | 36.95<br>(1.90) | 37.25<br>(1.78) |
| 5           | 39.21<br>(2.15) | 38.73<br>(1.66) | 38.31<br>(1.94) | 38.82<br>(2.41) |
| 6           | 40.26<br>(2.53) | 40.03<br>(2.50) | 39.36<br>(2.14) | 39.98<br>(2.35) |
| 7           | 41.07<br>(3.04) | 41.09<br>(3.11) | 40.30<br>(2.50) | 40.95<br>(2.82) |
| 8           | 41.83<br>(2.94) | 42.08<br>(2.53) | 41.21<br>(3.22) | 42.03<br>(3.10) |
| 9           | 42.47<br>(2.52) | 42.75<br>(2.66) | 42.05<br>(2.64) | 42.69<br>(2.42) |
| 10          | 42.72<br>(2.29) | 43.12<br>(2.95) | 42.50<br>(2.45) | 43.06<br>(2.68) |

Each datum is an average of 12 observations - Appendix XI-XIV

Figures in parenthesis are the standard deviations.

Fig.4. Effect of repeated observations for the resistance of pronotum and fore wings from 1 to 10 days after moulting of adult S. gregaria

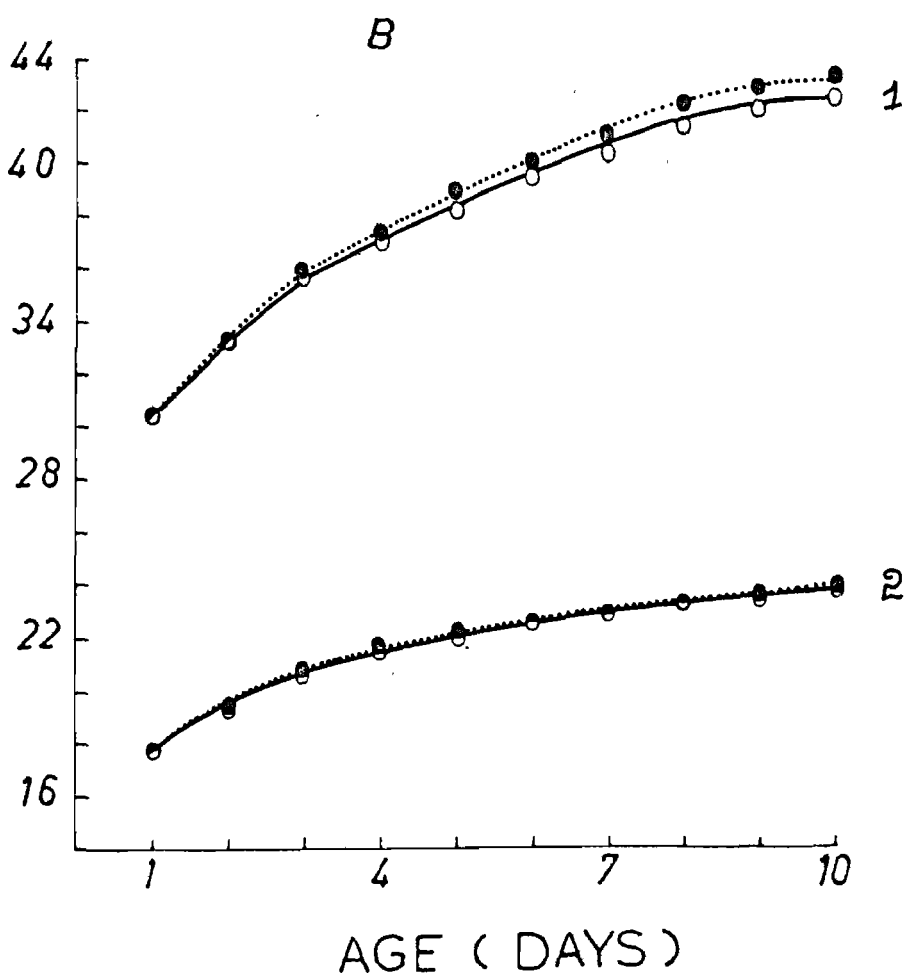
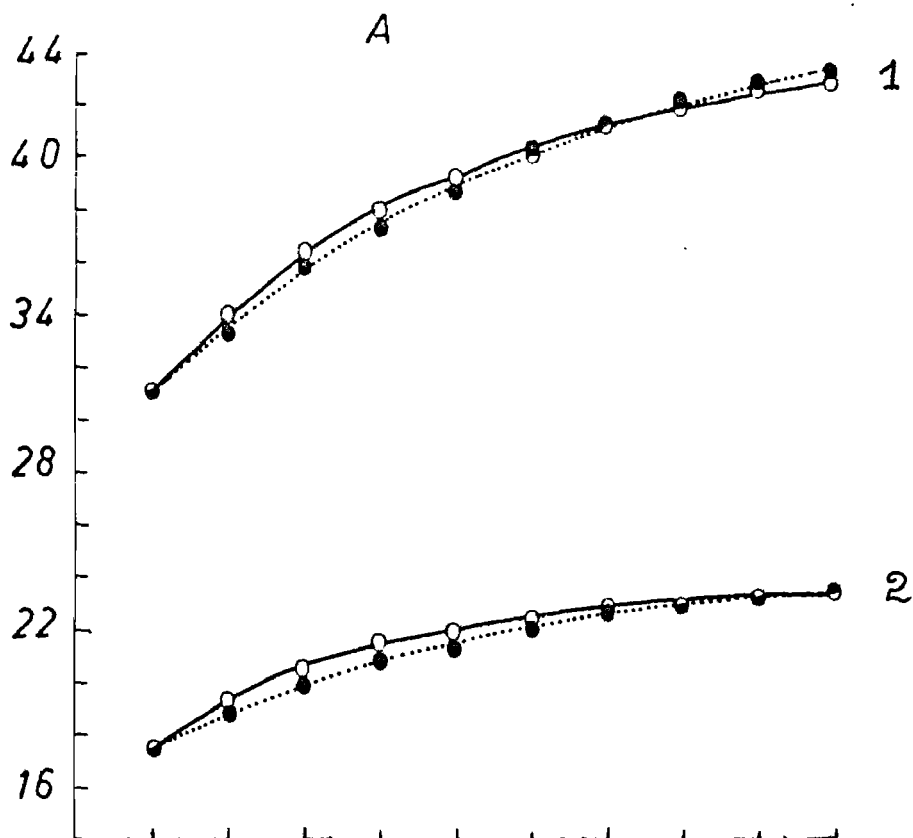
A. Male

B. Female

1. Fore wings
2. Pronotum

—○—○— - Repeatedly measured (R).  
...●...●... - Measured only once (F)

$R_s \text{ (K}\Omega\text{-cm}^2\text{)}$



taken only once, were  $33.35 \pm 2.53$  on 2nd day,  $39.98 \pm 2.35$  on 6th day and  $43.06 \pm 2.68$  on 10th day after moulting.

These results suggest that the average  $R_s$  values for the insects which were repeatedly measured from 1 to 10 days after moulting, did not differ significantly with the average  $R_s$  values for the insects of the same age, but used only once. This was true for both the sexes as well as for pronotum and fore wings. This fact suggest that the repeated observations on the same insect for measuring resistance, do not cause any damage to the cuticle. The results further suggest that there was a gradual increase in resistance on pronotum and fore wings from time after moult. This was also true in both the adult males and females. From the data (Figure-4A and 4B), it is apparent that the increase in resistance in both the pronotum and fore wings can be divided into 2 phases. First phase from immediately after moulting to 6 day old insects, was characterised by a fast rate of increase in resistance. The second phase, was between 7 to 10 day old insects, where the increase in resistance was slow. These observations suggest that the orientation and sclerotization takes place with in the first 6 days, after which the structure of the cuticle gets stabilized.

#### Toxicity of diflubenzuron to *Schistocerca gregaria*

Diflubenzuron not being a nerve poison, is not an acute poison in short period. The toxicity however,

PLATE -IV

- A. Diflubenzuron treated S.gregaris.
- B. Solvent treated S.gregaris.

A



B



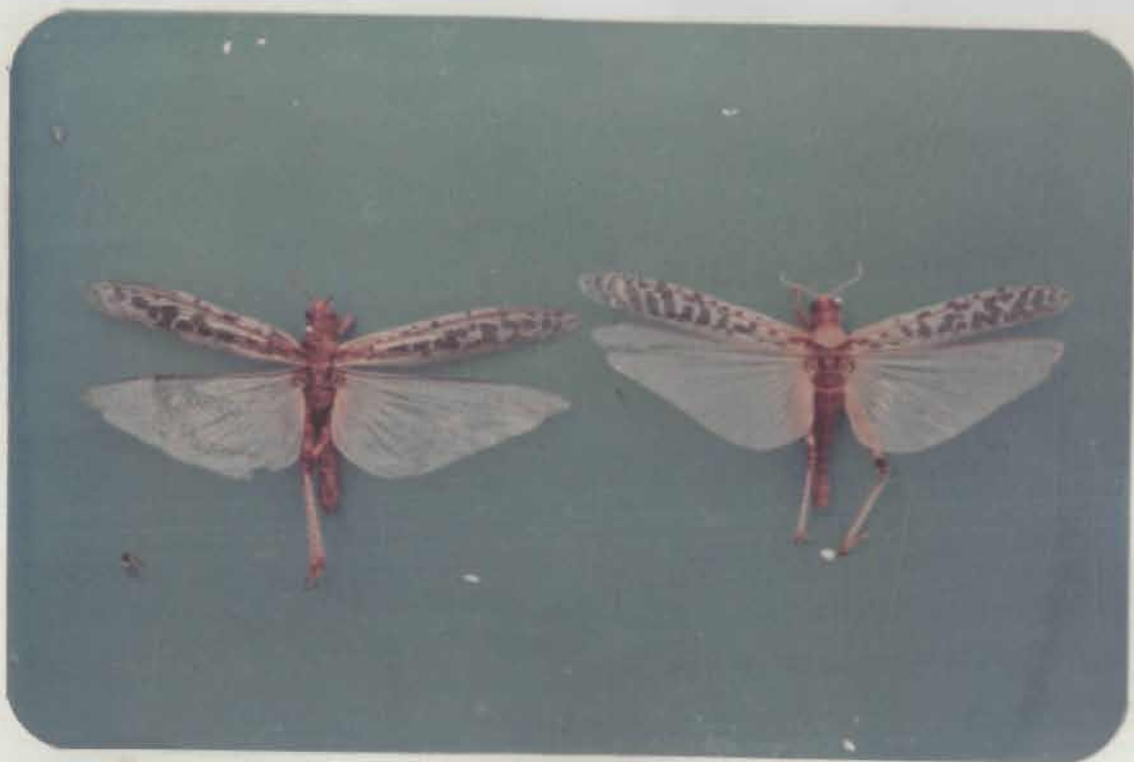
PLATE - V

- A. Diflubenzuron treated S.gregaria-wings expanded
- B. Solvent treated S.gregaria-wings expanded.

A



B



manifests itself at the time of moulting (Mulder and Gijswijt, 1973). In the present investigations toxicity of diflubenzuron to 5th instar hoppers of S. gregaria was determined by treating the hoppers and observing its effects on nymphal-adult transformation.

#### Effect of diflubenzuron treatment to S. gregaria

The 5th instar hoppers treated with various doses of diflubenzuron were found to be normal with no apparent adverse effects till the time of moulting. The adverse effects of diflubenzuron treatment manifested only during the nymphal-adult transformation. In general the morphological manifestations at the time of moulting due to diflubenzuron treatment can be classified into four categories (a) the first category comprised of insects which were unable to moult and died without completing moulting process (Plate 4A and 5A). In such individuals the initiation of splitting of the old cuticle was observed on the mid-dorsal line of the head and thorax. It was only partial and incomplete. A few drops of greenish yellow fluid was secreted out from the region of the split. Later the insects died without moulting. The dead insects were invariably very much darkened. (b) The second category comprised of insects in which the old cuticle completely splitted but the insects were unable to wriggle out of the exuviae (Plate-4A). About half or three-fourths of the body came out of the old cuticle, while the rest remained attached to the old cuticle. Such insects died in 2 to 3 days after this partial moulting. (c) The third category comprised

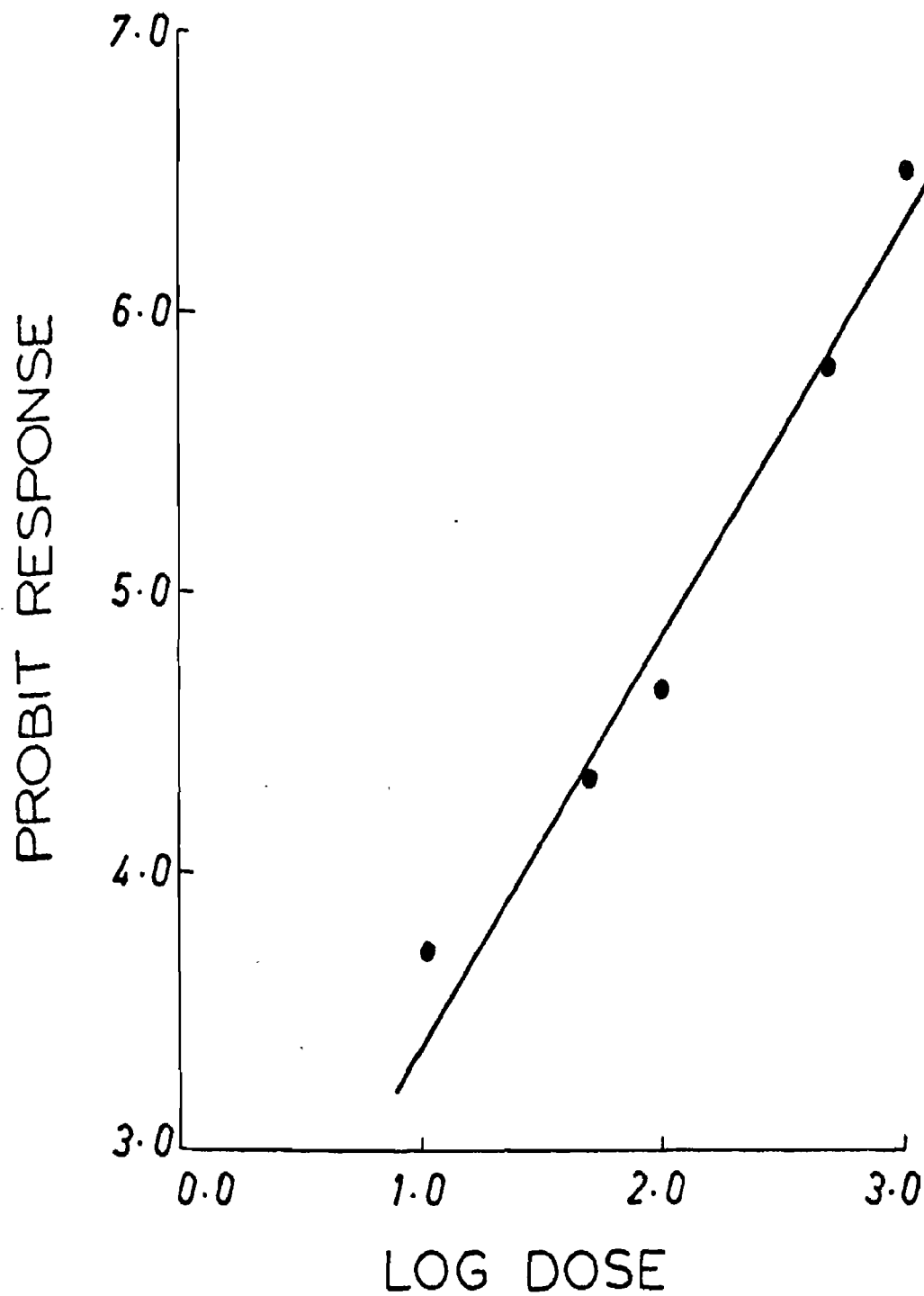
of insects which were able to moult but the adults were deformed to varying degrees (Plate-4A and 5A). In most of the such insects, the fore wings were found to be deformed. The insects were unable to expand their wings properly. The forewings were folded abnormally and looked crippled. In some cases the wings were also torn. Such deformities were also observed in hind wings but to a lesser degree. The other most common deformity associated with the action of diflubenzuron was the tibial deflection in hind legs. The tibia was found to be deflected and curved to various degrees. The legs were also found to break off very easily at the joints, especially between the tibia and the tarsus and between the trochanter and femur. Such insects were unable to walk properly. (d) The fourth category comprised of insects which were able to moult without any deformity in adults. Such individuals even though found normal, appeared to be less active than the adults obtained from solvent treated hoppers.

Table-5: Response of S. gregaria to diflubenzuron at various doses.

| Dose<br>µg/nymph | Number of<br>nymphs treated | Number<br>affected | Percentage<br>affected |
|------------------|-----------------------------|--------------------|------------------------|
| 10               | 80                          | 75                 | 93.75                  |
| 5                | 80                          | 63                 | 78.75                  |
| 1.0              | 80                          | 29                 | 36.25                  |
| 0.5              | 80                          | 20                 | 25.00                  |
| 0.1              | 80                          | 8                  | 10.00                  |
| Solvent          | 80                          | 0                  | -                      |

Fig.5. Log-dose probit mortality and moulting  
abnormality regression line

LOG DOSE  
PROBIT REGRESSION LINE



The data presented in Table-5 suggest that the response of the locusts to diflubenzuron was dose dependent. At 0.1  $\mu\text{g}/\text{nymph}$ , the lowest dose tested, only 10 per cent of the individuals were affected. At 0.5  $\mu\text{g}/\text{nymph}$ , 25 per cent of the population was affected. A response of 36.25 per cent was observed at 1.0  $\mu\text{g}/\text{nymph}$ . At 5.0  $\mu\text{g}/\text{nymph}$  78.75 per cent of the population was affected. At 10  $\mu\text{g}/\text{nymph}$ , the highest dose tested, 93.75 per cent of the population was affected.

The data on the response of the insects to diflubenzuron when subjected to probit analysis according to Finney (1947) (Appendix-XV), gave a straight log-dose probit line (Figure-5) from which  $\text{ED}_{50}$  was calculated to be 1.30  $\mu\text{g}/\text{nymph}$  (range 1.021 to 1.650  $\mu\text{g}/\text{nymph}$ ).

#### Effect of Diflubenzuron on the physical properties of the cuticle of *S. gregaria*

Since the action of diflubenzuron is associated with the cuticle formation (Ker, 1977), it was argued that it may have some effects on the physical properties of the cuticle as well. The present set of experiments report the effect of diflubenzuron on specific resistance, capacitance, potential difference and chitin content of the cuticle. For these studies a dose of 5.0  $\mu\text{g}$  of diflubenzuron/nymph, was used so that about 80 per cent of the affected insects could be obtained for the investigations.

#### I. Effect of diflubenzuron on the resistance of the cuticle of *S. gregaria*

The  $R_s$  of the cuticle of *S. gregaria* was measured at four sites on the cuticle, (1) on pronotum (2) on ventral

abdominal sternites, (3) on fore wings, and (4) on hind wings. The  $R_s$  was measured in both sexes, on both the deformed adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers, from '0' to '15' days after moulting.

(A) On pronotum

The data on average  $R_s$  of the pronotum of deformed adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers, at various ages after moulting are presented in Table-6 and Figure-6. The data suggest that the average  $R_s$  across the pronotum of the deformed adult males obtained from diflubenzuron treated hoppers was  $7.14 \pm 0.65$  immediately after moulting. It increased to  $20.98 \pm 1.79$  by 6th day and  $22.62 \pm 1.71$  by 15th day after moulting. The corresponding average  $R_s$  values for the normal adult males obtained from solvent treated nymphs were  $7.30 \pm 0.64$  immediately after moulting,  $22.69 \pm 1.66$  on 6th day and  $24.59 \pm 1.93$  on the 15th day after moulting. These results suggest that the  $R_s$  of pronotum of the deformed adult males obtained from diflubenzuron treated hoppers was consistently lower than that of normal males obtained from solvent treated hoppers. The  $R_s$  of pronotum of the deformed adult males was significantly lower than that of normal adults from 2nd day onwards after moulting.

The average  $R_s$  across the pronotum of the deformed adult females obtained from diflubenzuron treated hoppers (Table-6, Figure-6B) was  $7.19 \pm 0.65$  immediately after moulting. It increased to  $21.11 \pm 1.74$  by 6th day and  $23.07 \pm$

Table-6: Average  $R_s$  across the pronotum of deformed and normal adult S. gregaria ( $K\Omega$ -cm<sup>2</sup>)

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 7.14<br>(0.65)               | 0.702 | 7.30<br>(0.64)  | 7.19<br>(0.65)               | 0.711 | 7.35<br>(0.62)  |
| 1             | 16.72<br>(1.63)              | 1.588 | 17.63<br>(1.61) | 17.25<br>(1.58)              | 1.096 | 17.88<br>(1.67) |
| 2             | 18.07 <sup>b</sup><br>(1.75) | 2.614 | 19.67<br>(1.71) | 18.49 <sup>a</sup><br>(1.42) | 2.116 | 19.69<br>(1.77) |
| 3             | 19.24 <sup>a</sup><br>(1.48) | 2.382 | 20.60<br>(1.74) | 19.45 <sup>b</sup><br>(1.46) | 2.504 | 20.94<br>(1.88) |
| 4             | 19.91 <sup>b</sup><br>(1.56) | 2.504 | 21.42<br>(1.84) | 20.17 <sup>b</sup><br>(1.55) | 2.612 | 21.86<br>(2.07) |
| 5             | 20.53 <sup>b</sup><br>(1.77) | 2.704 | 22.19<br>(1.70) | 20.65 <sup>b</sup><br>(1.82) | 2.664 | 22.44<br>(1.98) |
| 6             | 20.98 <sup>c</sup><br>(1.79) | 2.803 | 22.69<br>(1.66) | 21.11 <sup>c</sup><br>(1.74) | 3.078 | 23.02<br>(1.77) |
| 7             | 21.44 <sup>c</sup><br>(1.56) | 3.080 | 23.14<br>(1.56) | 21.60 <sup>c</sup><br>(1.74) | 3.154 | 23.59<br>(1.83) |
| 8             | 21.87 <sup>c</sup><br>(1.83) | 2.827 | 23.62<br>(1.67) | 22.25 <sup>b</sup><br>(2.05) | 2.706 | 24.22<br>(2.07) |
| 9             | 22.21 <sup>c</sup><br>(1.76) | 2.868 | 24.02<br>(1.81) | 22.60 <sup>c</sup><br>(1.82) | 3.133 | 24.69<br>(1.95) |
| 10            | 22.49 <sup>b</sup><br>(1.67) | 2.588 | 24.18<br>(2.01) | 22.77 <sup>c</sup><br>(2.26) | 2.850 | 24.91<br>(1.98) |
| 15            | 22.62 <sup>c</sup><br>(1.71) | 3.054 | 24.59<br>(1.93) | 23.07 <sup>c</sup><br>(2.10) | 3.277 | 25.38<br>(1.88) |

Each datum is an average of 16 observations - Appendix XVI-XIX.

Figures in parentheses are the standard deviations.

Table 't' at 0.05 probability - 2.042    a - significant at 5%  
                   0.02            "        - 2.457    b -            "        2%  
                   0.01            "        - 2.750    c -            "        1%

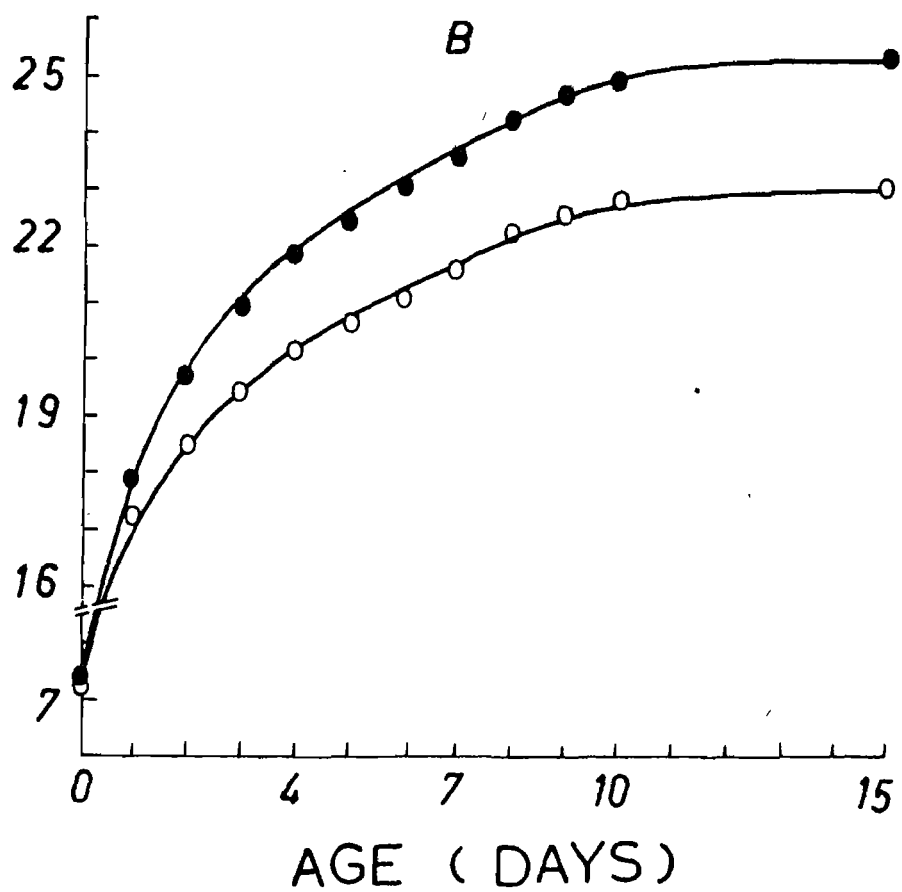
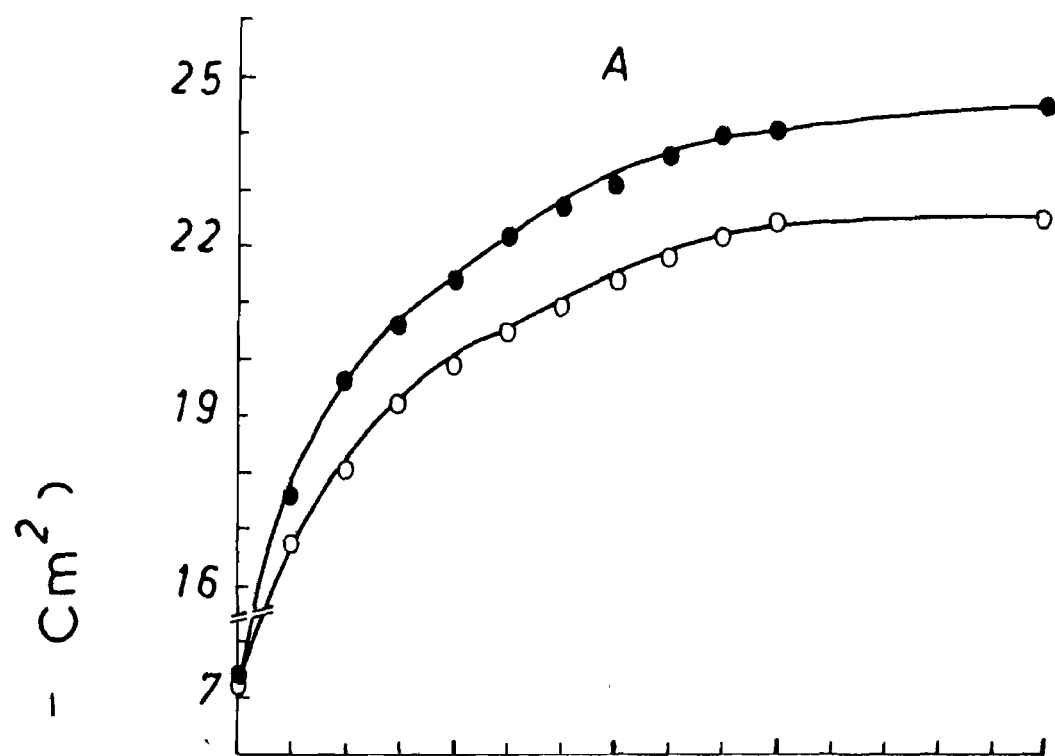
Fig.6. Effect of diflubenzuron on AC resistance of pronotum of adult S. gregaria

A. Male

B. Female

--○--○-- - Deformed

--●--○-- - Normal



2.10 by 15th day after moulting. The corresponding average  $R_s$  values for the normal adult females obtained from solvent treated hoppers were  $7.35 \pm 0.62$  immediately after moulting,  $23.02 \pm 1.77$  on 6th day and  $25.38 \pm 1.88$  on 15th day after moulting. The  $R_s$  across the pronotum of the deformed adult females was found to be significantly lower than that of normal adults from 2nd day onwards after moulting. At '0' and '1' days after moulting although the difference was not significant, the average  $R_s$  in deformed males was observed to be on lower side.

#### On Excised Pronotum:

Besides, the studies on the intact pronotum, measurements of the electrical AC resistance were also carried out on the excised pronotum.

The data on the average  $R_s$  across the excised pronotum of the deformed adult males obtained from the diflubenzuron treated hoppers and normal adult males obtained from solvent treated hoppers are presented in Table-7 and Figure-7A. The average  $R_s$  of excised pronotum of the deformed adult males was  $7.10 \pm 0.66$  immediately after moulting,  $20.64 \pm 1.49$  on 6th day and  $22.08 \pm 1.41$  on 15th day after moulting. The corresponding average  $R_s$  values of the excised pronotum of the normal adult males were  $7.23 \pm 0.67$  immediately after moulting,  $21.83 \pm 1.65$  on 6th day and  $23.31 \pm 1.95$  on 15th day after moulting. These results suggest that the  $R_s$  across the excised pronotum of the deformed adult males obtained from diflubenzuron treated hoppers was

Table-7: Average  $R_s$  across excised pronotum of deformed and normal adult S. gregaria ( $K\Omega$ -cm<sup>2</sup>)

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 7.10<br>(0.66)               | 0.553 | 7.23<br>(0.67)  | 7.11<br>(0.66)               | 0.511 | 7.23<br>(0.67)  |
| 1             | 16.24<br>(1.27)              | 1.267 | 16.90<br>(1.65) | 16.29<br>(1.45)              | 1.180 | 16.94<br>(1.66) |
| 2             | 17.50<br>(1.57)              | 1.734 | 18.45<br>(1.53) | 17.84<br>(1.74)              | 1.230 | 18.53<br>(1.42) |
| 3             | 18.58 <sup>a</sup><br>(1.64) | 2.166 | 19.86<br>(1.70) | 18.86<br>(1.61)              | 1.987 | 20.06<br>(1.80) |
| 4             | 19.48<br>(1.86)              | 1.897 | 20.66<br>(1.65) | 19.65<br>(1.87)              | 1.654 | 20.74<br>(1.86) |
| 5             | 19.99 <sup>a</sup><br>(1.61) | 2.047 | 21.21<br>(1.76) | 20.32<br>(1.59)              | 1.851 | 21.39<br>(1.68) |
| 6             | 20.64 <sup>a</sup><br>(1.49) | 2.140 | 21.83<br>(1.65) | 20.74 <sup>a</sup><br>(1.40) | 2.059 | 21.93<br>(1.84) |
| 7             | 20.98 <sup>a</sup><br>(1.76) | 2.081 | 22.22<br>(1.61) | 21.16 <sup>a</sup><br>(1.48) | 2.312 | 22.42<br>(1.60) |
| 8             | 21.39<br>(1.85)              | 1.928 | 22.52<br>(1.44) | 21.54 <sup>a</sup><br>(1.59) | 2.355 | 22.72<br>(1.22) |
| 9             | 21.69<br>(1.62)              | 1.945 | 22.75<br>(1.46) | 21.80 <sup>a</sup><br>(1.40) | 2.099 | 22.94<br>(1.66) |
| 10            | 21.73 <sup>a</sup><br>(1.69) | 2.232 | 23.04<br>(1.63) | 21.83 <sup>a</sup><br>(1.53) | 2.317 | 23.13<br>(1.64) |
| 15            | 22.08 <sup>a</sup><br>(1.41) | 2.043 | 23.31<br>(1.95) | 22.12 <sup>a</sup><br>(1.52) | 2.260 | 23.53<br>(1.98) |

Each datum is an average of 16 observations - Appendix XX-XXIII

Figures in parentheses are the standard deviations.

Table 't' at 0.05 probability - 2.042    a - significant at 5%  
                   0.02            ''        - 2.457    b -            ''        2%  
                   0.01            ''        - 2.750    c -            ''        1%

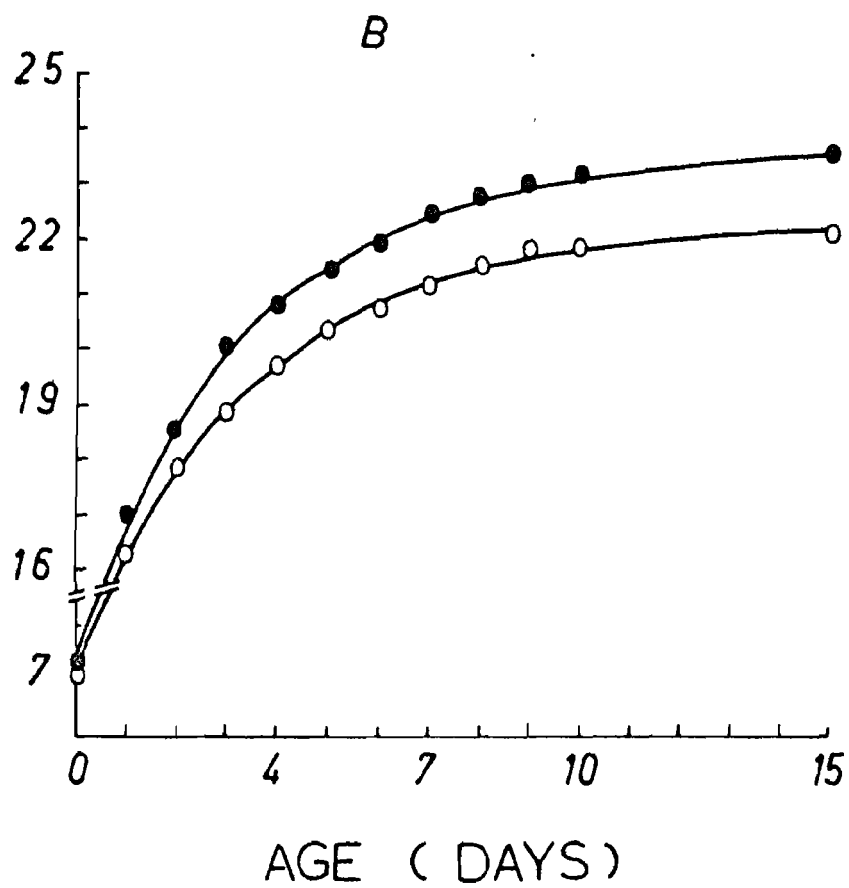
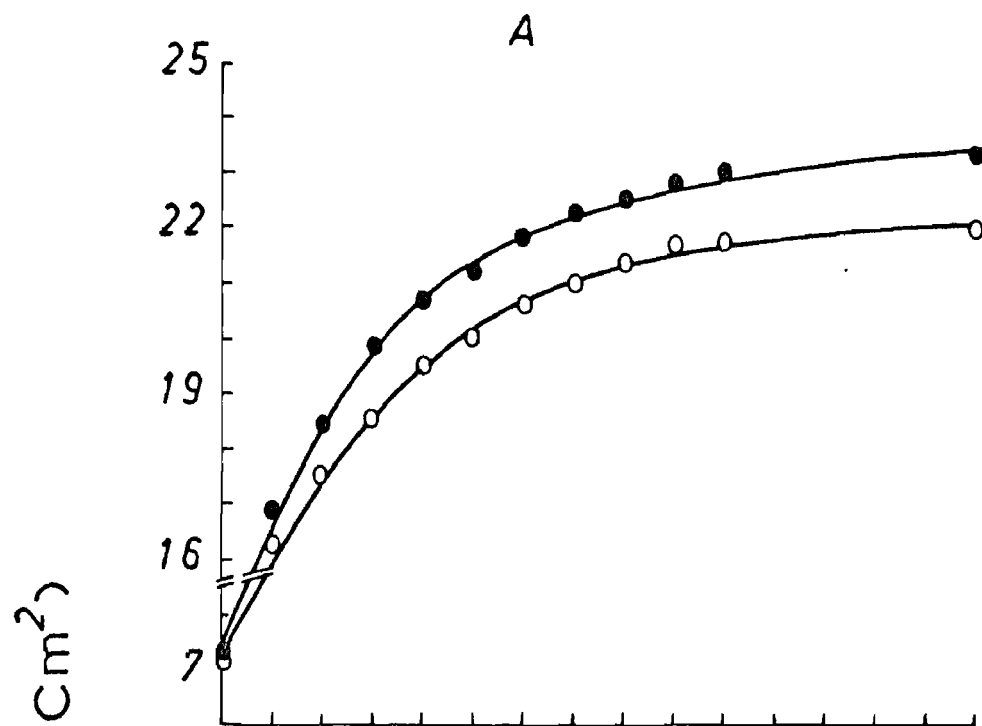
Fig.7. Effect of diflubenzuron on AC resistance of excised pronotum of adult S. gregaria

A. Male

B. Female

—o—o— Deformed

—o—o— Normal



consistently lower than that of normal insects obtained from solvent treated hoppers. At '0', 1, 2, 4, 8 and 9 days after moulting the difference in  $R_s$  of the excised pronotum of the deformed and normal adult males was not significantly different from one another. During the rest of the period of observations the  $R_s$  on excised pronotum of the deformed adult males was however, found to be significantly lower than that of normal insects.

It is apparent from the data presented in Table-7 and Figure-7B that the average  $R_s$  of the excised pronotum of the deformed adult females obtained from diflubenzuron treated hoppers was  $7.11 \pm 0.66$  immediately after moulting. It increased to  $20.74 \pm 1.40$  by 6th day and  $22.12 \pm 1.52$  by 15th day after moulting. The corresponding average  $R_s$  of excised pronotum of the normal adult females obtained from solvent treated hoppers was  $7.23 \pm 0.67$  immediately after moulting  $21.93 \pm 1.84$  on 6th day and  $23.53 \pm 1.98$  on 15th day after moulting. These observations suggest that the  $R_s$  of excised pronotum of the deformed adult females although not significantly different from '0' to 5 days after moulting, was found to be consistently on lower side than that of normal insects. The  $R_s$  of the excised pronotum of deformed adult females was, however, significantly lower than that of normal insects from 6th day onwards after moulting.

These results further suggest that the  $R_s$  of excised pronotum was invariably lower than that of the intact pronotum on live insects, in both the adult males and females. This was true for both, the deformed adults obtained from

diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers. This perhaps was due to the fact that the epidermal cells which also contribute some resistance to the total observed resistance of the integument (Scheie and Smyth, 1967, and 1968), gradually die after the pronotum has been excised.

(B)  $R_s$  across 2-3 abdominal sternites

Since, during the preliminary experiments, no significant difference in  $R_s$  was observed across 2-3 and 2-6 abdominal sternites,  $R_s$  in the present studies was measured across 2-3 abdominal sternites. From the data presented in Table-8 and Figure-8A, it would be seen that the average  $R_s$  across 2-3 abdominal sternites of the deformed adult males obtained from diflubenzuron treated hoppers was  $7.46 \pm 0.65$  immediately after moulting. It increased to  $20.86 \pm 1.70$  by 6th day and  $22.22 \pm 1.60$  by 15th day after moulting. The corresponding average  $R_s$  on the excised pronotum of the normal adult males obtained from solvent treated hoppers was  $7.79 \pm 0.63$  immediately after moulting  $22.03 \pm 1.81$  on 6th day and  $23.36 \pm 1.97$  on 15th day after moulting.

These results suggest that the  $R_s$  across 2-3 abdominal sternites of the deformed adult males was always on lower side. It was however, not significantly different from that of normal insects at 0, 2, 6, 7, 9, 10 and 15 days after moulting. The  $R_s$  across 2-3 abdominal sternites of the deformed adult males was significantly lower than that of normal insects at 1, 3, 4, 5, and 8 days after moulting.

Table-8: Average  $R_s$  across 2-3 abdominal sternites of deformed and normal adult S. gregaria ( $K \Omega - cm^2$ )

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 7.46<br>(0.65)               | 1.460 | 7.79<br>(0.63)  | 7.46<br>(0.65)               | 1.561 | 7.83<br>(0.69)  |
| 1             | 16.82 <sup>b</sup><br>(1.55) | 2.575 | 18.11<br>(1.27) | 17.15 <sup>a</sup><br>(1.18) | 2.369 | 18.28<br>(1.50) |
| 2             | 18.30<br>(1.56)              | 2.039 | 19.46<br>(1.66) | 18.45 <sup>a</sup><br>(1.26) | 2.357 | 19.60<br>(1.49) |
| 3             | 19.15 <sup>a</sup><br>(1.53) | 2.372 | 20.45<br>(1.57) | 19.40 <sup>a</sup><br>(1.26) | 2.421 | 20.70<br>(1.74) |
| 4             | 19.75 <sup>b</sup><br>(1.43) | 2.615 | 21.12<br>(1.53) | 19.99 <sup>c</sup><br>(1.49) | 2.921 | 21.57<br>(1.57) |
| 5             | 20.32 <sup>a</sup><br>(1.68) | 2.430 | 21.79<br>(1.74) | 20.51 <sup>a</sup><br>(1.53) | 2.304 | 21.92<br>(1.91) |
| 6             | 20.86<br>(1.70)              | 1.884 | 22.03<br>(1.81) | 20.93<br>(1.86)              | 1.820 | 22.12<br>(1.84) |
| 7             | 21.18<br>(1.30)              | 1.985 | 22.25<br>(1.72) | 21.37<br>(1.36)              | 1.877 | 22.38<br>(1.67) |
| 8             | 21.51 <sup>a</sup><br>(1.36) | 2.083 | 22.56<br>(1.49) | 21.70<br>(1.68)              | 1.712 | 22.71<br>(1.66) |
| 9             | 21.72<br>(2.01)              | 1.504 | 22.72<br>(1.74) | 21.98<br>(1.62)              | 1.629 | 23.05<br>(2.07) |
| 10            | 21.97<br>(1.71)              | 1.433 | 22.94<br>(2.10) | 22.17<br>(1.80)              | 1.468 | 23.18<br>(2.08) |
| 15            | 22.22<br>(1.60)              | 1.798 | 23.36<br>(1.97) | 22.23<br>(1.62)              | 1.944 | 23.48<br>(2.00) |

Each datum is an average of 16 observations - XXIV - XXVII

Figures in parentheses are standard deviations.

Table's t'at probability 0.05 - 2.042 a - significant at 5%  
0.02 - 2.457 b - " 2%  
0.01 - 2.750 c - " 1%

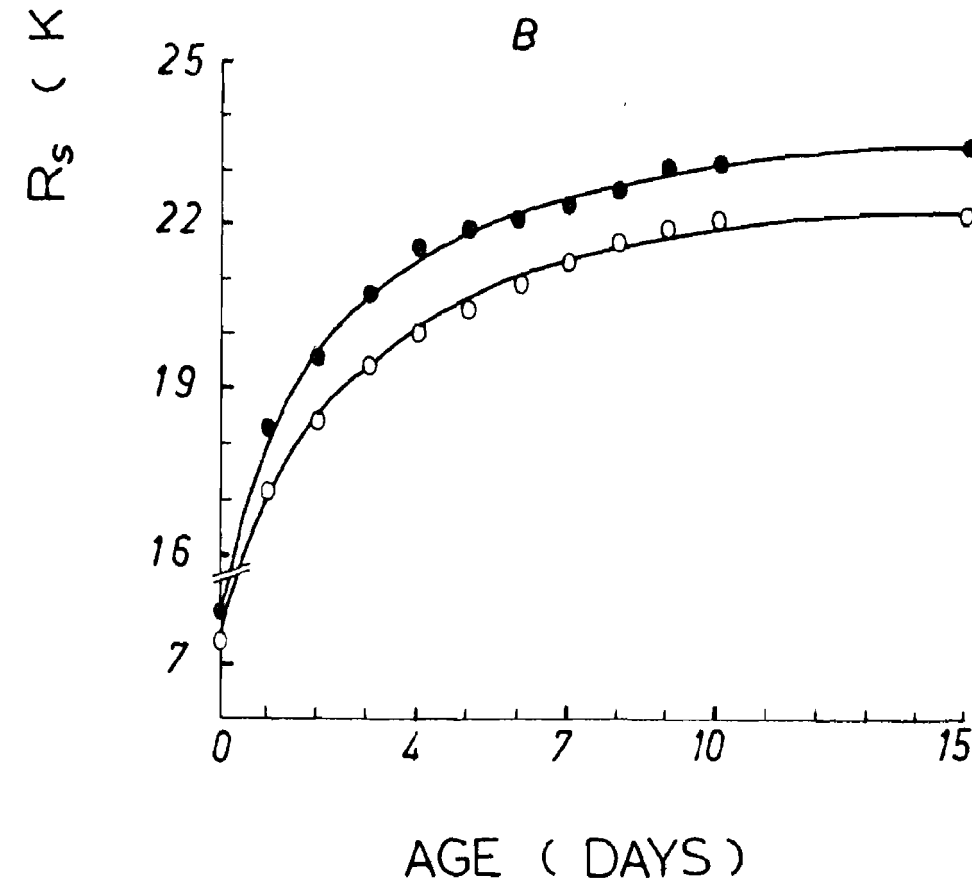
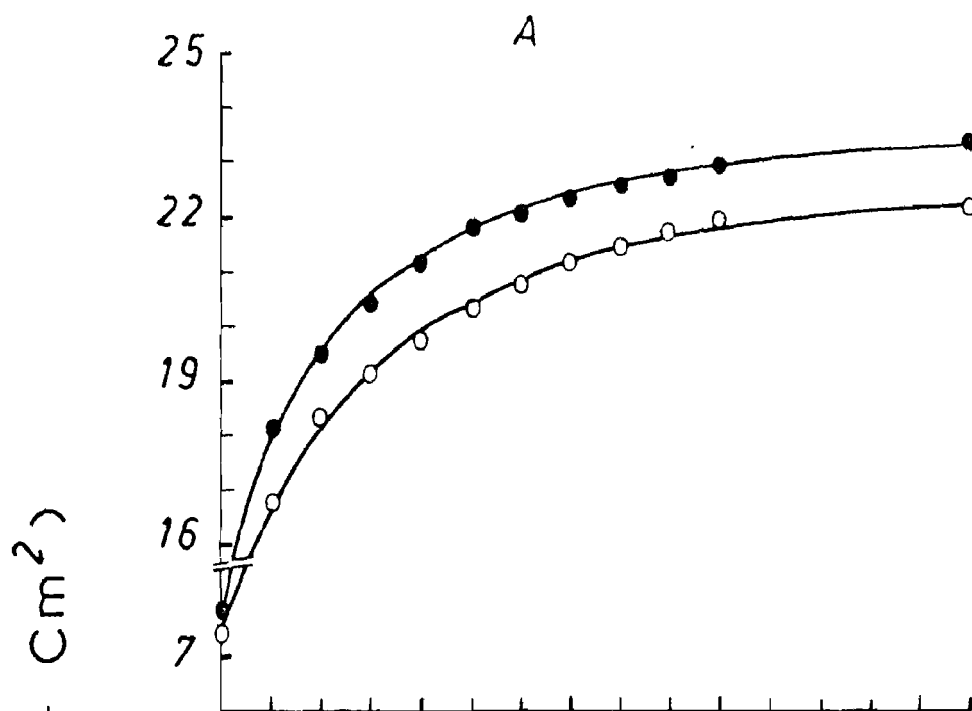
Fig.8. Effect of diflubenzuron on AC resistance of  
2-3 abdominal sternites of adult S. gregaria

A. Male

B. Female

—○—○— Deformed

—●—●— Normal



The data presented in Table-8 and Figure-8B show that the average  $R_s$  across 2-3 abdominal sternites of the deformed adult females obtained from diflubenzuron treated hoppers was  $7.46 \pm 0.65$  immediately after moulting,  $20.93 \pm 1.86$  on 6th day and  $22.23 \pm 1.62$  on 15th day, after moulting. The corresponding average  $R_s$  across 2-3 abdominal sternites of the normal adult females obtained from solvent treated hoppers was  $7.83 \pm 0.69$  immediately after moulting,  $22.12 \pm 1.84$  on 6th day and  $23.48 \pm 2.00$  on 15th day, after moulting. From these results, it is apparent that the  $R_s$  of 2-3 abdominal sternites of the deformed adult females was consistently on lower side than that of normal insects. The  $R_s$  of the abdominal sternites of the deformed adult females was not significantly different from that of normal insects at '0' days and from 6th day onwards after moulting. The  $R_s$  across 2-3 abdominal sternites of the deformed adult females was however, found to be significantly lower than that of normal insects from '1' to '5' days after moulting.

(C)  $R_s$  on fore wings

The data on average  $R_s$  of the fore wings of the deformed and normal adult males obtained from diflubenzuron and solvent treated hoppers are presented in Table-9 and Figure-9A. From the data it would be seen that the average  $R_s$  of fore wings of the deformed adult males was  $8.19 \pm 0.70$  immediately after moulting. It increased to  $38.28 \pm 2.21$  by 6th day and  $41.37 \pm 2.88$  by 15th day after moulting. The

Table-9: Average  $R_s$  across fore wings of deformed and normal adult S. gregaria ( $K \Omega - \text{cm}^2$ )

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 8.19<br>(0.70)               | 0.970 | 8.42<br>(0.64)  | 8.22<br>(0.69)               | 0.928 | 8.44<br>(0.65)  |
| 1             | 29.76<br>(2.32)              | 1.458 | 30.91<br>(2.14) | 29.66<br>(1.71)              | 1.363 | 30.61<br>(2.20) |
| 2             | 33.58<br>(2.92)              | 0.396 | 33.95<br>(2.34) | 33.20<br>(2.26)              | 0.856 | 33.87<br>(2.17) |
| 3             | 35.31<br>(2.05)              | 1.869 | 36.85<br>(2.58) | 34.97<br>(1.97)              | 0.746 | 35.46<br>(1.74) |
| 4             | 36.55<br>(2.25)              | 1.988 | 38.17<br>(2.36) | 36.00<br>(2.03)              | 1.894 | 37.46<br>(2.32) |
| 5             | 37.55 <sup>a</sup><br>(2.39) | 2.228 | 39.39<br>(2.28) | 36.84 <sup>b</sup><br>(2.27) | 2.724 | 39.18<br>(2.58) |
| 6             | 38.28 <sup>c</sup><br>(2.21) | 2.857 | 40.60<br>(2.38) | 37.64 <sup>c</sup><br>(2.16) | 3.640 | 40.49<br>(2.27) |
| 7             | 39.05 <sup>c</sup><br>(1.98) | 3.163 | 41.59<br>(2.53) | 38.26 <sup>c</sup><br>(1.92) | 3.777 | 41.41<br>(2.73) |
| 8             | 39.67 <sup>c</sup><br>(1.98) | 3.238 | 42.40<br>(2.73) | 38.92 <sup>c</sup><br>(3.16) | 3.327 | 42.35<br>(2.65) |
| 9             | 40.11 <sup>c</sup><br>(1.81) | 3.679 | 43.23<br>(2.87) | 39.58 <sup>c</sup><br>(3.00) | 3.867 | 43.35<br>(2.49) |
| 10            | 40.46 <sup>c</sup><br>(3.03) | 3.270 | 43.93<br>(2.97) | 40.00 <sup>c</sup><br>(3.09) | 3.141 | 43.76<br>(3.66) |
| 15            | 41.37 <sup>c</sup><br>(2.88) | 3.853 | 45.10<br>(2.59) | 41.16 <sup>c</sup><br>(3.08) | 3.608 | 45.10<br>(3.10) |

Each datum is an average of 16 observations - Appendix XXVIII-XXXI

Figures in parentheses are the standard deviations.

Table 't' at 0.05 probability - 2.042 a- significant at 5%  
0.02 " - 2.457 b - " 2%  
0.01 " - 2.750 c - " 1%

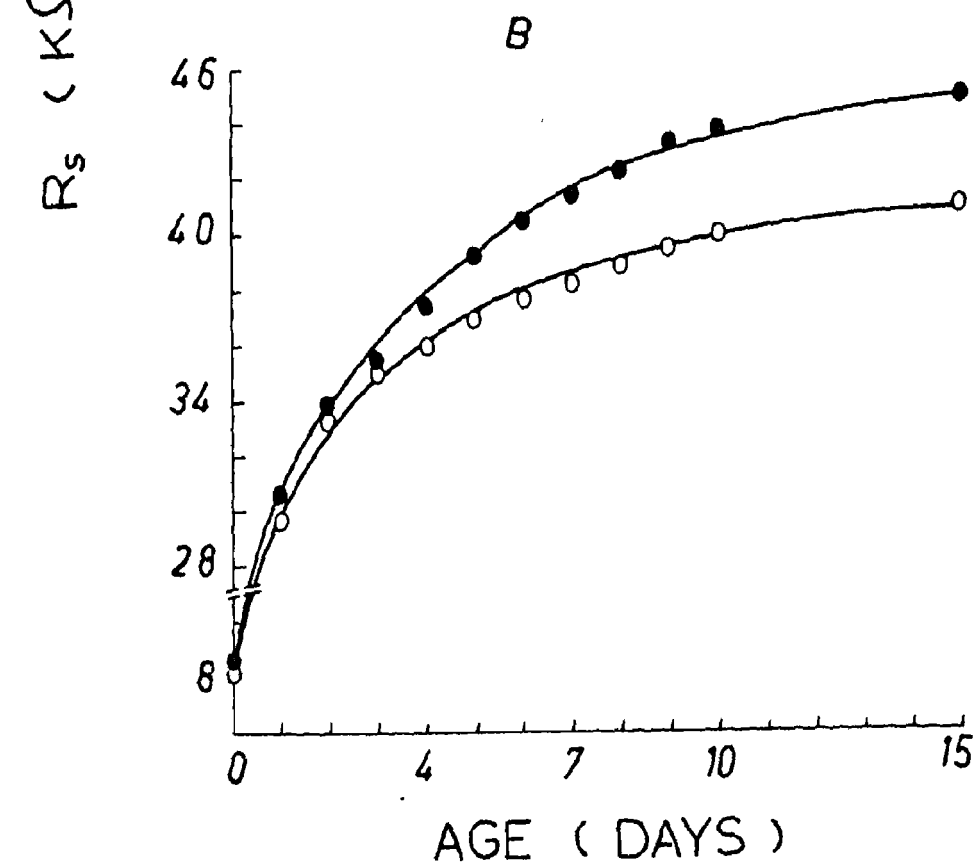
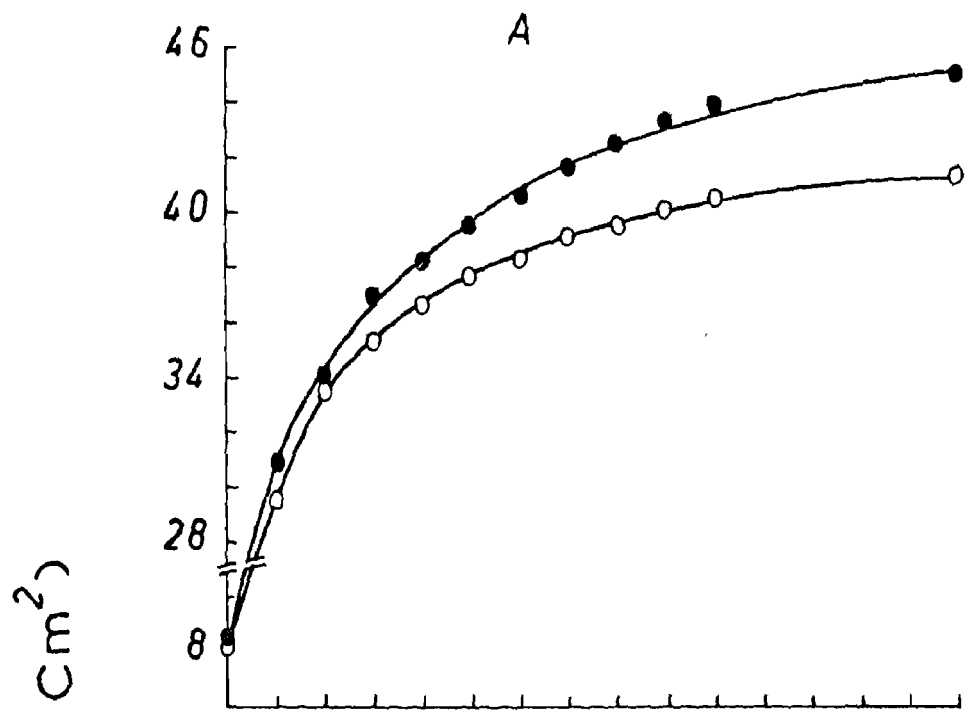
Fig. 9. Effect of diflubenzuron on AC resistance of  
fore wings of adult S. gregaria

A. Male

B. Female

—o—o— Deformed

—o—o— Normal



corresponding average  $R_s$  of the fore wings of the normal adult males was  $8.42 \pm 0.64$  immediately after moulting,  $40.60 \pm 2.38$  on 6th day and  $45.10 \pm 2.59$  on 15th day after moulting. These results suggest that the  $R_s$  of fore wings of the deformed adult males was consistently on lower side to that of normal adults. The  $R_s$  of fore wings of the deformed adult males was not significantly different from that of normal adult males, from '0' to '4' days after moulting; from 5th day onwards after moulting the  $R_s$  on fore wings of the deformed adult males was however, found to be significantly lower than that of normal adult males.

Similarly the average  $R_s$  of fore wings of the deformed adult females was consistently lower than that of normal adult females (Table-9 and Figure-9B). The differences in  $R_s$  between the two was not observed to be statistically significant from '0' to '4' days after moulting. From 5th day onwards after moulting the  $R_s$  on fore wings of the deformed adult females was significantly lower than that of normal adult females. The average  $R_s$  of the fore wings of the deformed adult females was observed to be  $8.22 \pm 0.69$  immediately after moulting,  $37.64 \pm 2.16$  on 6th day and  $41.16 \pm 3.08$  on 15th day, after moulting. The corresponding average  $R_s$  of the fore wings of the normal adult females was  $8.44 \pm 0.65$  immediately after moulting,  $40.49 \pm 2.27$  on 6th day and  $45.10 \pm 3.10$  on 15th day, after moulting.

#### (D) $R_s$ on hind wings

The data presented in Table-10 and Figure-10A

suggest that the average  $R_s$  across the hind wings of the deformed adult males obtained from diflubenzuron treated hoppers was  $8.04 \pm 0.73$  immediately after moulting. The  $R_s$  increased to  $41.36 \pm 2.40$  by 6th day and  $44.31 \pm 2.53$  by 15th day, after moulting. The corresponding average  $R_s$  values of hind wings of the normal adult males obtained from solvent treated hoppers were  $8.39 \pm 0.63$  immediately after moulting,  $44.49 \pm 2.43$  on 6th day and  $47.92 \pm 2.78$  on 15th day, after moulting. It is apparent from the results that the average  $R_s$  of the hind wings of the deformed adult males, was not significantly different from that of the normal adult males from '0' to '3' days after moulting, although it was consistently low. From 4th day onwards the  $R_s$  of the hind wings of the deformed adult males however, was found to be significantly lower than that of the normal insects.

The data on the average  $R_s$  of the hind wings of the deformed and normal adult females obtained from diflubenzuron and solvent treated hoppers respectively, are presented in Table-10 and Figure-10B. From the data it would be seen that the average  $R_s$  of the hind wings of the deformed adult females was  $8.03 \pm 0.73$  immediately after moulting. It increased to  $41.22 \pm 2.31$  by 6th day and  $44.39 \pm 2.70$  by 15th day after moulting. The corresponding average  $R_s$  values of the hind wings of the normal adult females were  $8.24 \pm 0.54$  immediately after moulting,  $44.43 \pm 2.51$  on 6th day and  $47.69 \pm 3.43$  on 15th day, after moulting. These results suggest that the  $R_s$  across the hind wings of the deformed adult females was consistently on lower side to

Table-10:  $R_s$  across hind wings of deformed and normal.  
adult *S. gregaria* ( $K\Omega$ -cm<sup>2</sup>)

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 8.04<br>(0.73)               | 1.452 | 8.39<br>(0.63)  | 8.03<br>(0.73)               | 0.925 | 8.24<br>(0.54)  |
| 1             | 28.55<br>(2.45)              | 0.428 | 28.95<br>(2.82) | 27.80<br>(2.42)              | 0.848 | 28.52<br>(2.38) |
| 2             | 32.04<br>(3.07)              | 1.181 | 33.31<br>(3.01) | 31.81<br>(2.77)              | 1.101 | 32.88<br>(2.73) |
| 3             | 36.47<br>(2.84)              | 0.879 | 37.39<br>(3.08) | 36.15<br>(2.94)              | 0.817 | 37.01<br>(3.01) |
| 4             | 39.31 <sup>a</sup><br>(2.12) | 2.110 | 40.88<br>(2.09) | 38.94<br>(2.89)              | 2.013 | 40.78<br>(2.24) |
| 5             | 40.27 <sup>c</sup><br>(2.14) | 2.947 | 42.86<br>(2.79) | 40.22 <sup>c</sup><br>(1.94) | 2.815 | 42.52<br>(2.63) |
| 6             | 41.36 <sup>c</sup><br>(2.40) | 3.665 | 44.49<br>(2.43) | 41.22 <sup>c</sup><br>(2.31) | 3.763 | 44.43<br>(2.51) |
| 7             | 43.00 <sup>c</sup><br>(2.50) | 3.074 | 45.88<br>(2.79) | 42.72 <sup>c</sup><br>(2.46) | 3.031 | 45.79<br>(3.22) |
| 8             | 43.70 <sup>c</sup><br>(1.78) | 3.353 | 46.61<br>(2.98) | 43.39 <sup>c</sup><br>(2.06) | 2.942 | 46.42<br>(3.57) |
| 9             | 44.07 <sup>c</sup><br>(2.08) | 3.272 | 47.09<br>(3.05) | 43.86 <sup>c</sup><br>(2.17) | 3.251 | 47.03<br>(3.24) |
| 10            | 44.28 <sup>c</sup><br>(2.49) | 3.616 | 47.56<br>(2.64) | 43.96 <sup>c</sup><br>(1.78) | 3.187 | 47.31<br>(3.81) |
| 15            | 44.31 <sup>c</sup><br>(2.53) | 3.840 | 47.92<br>(2.78) | 44.39 <sup>c</sup><br>(2.70) | 3.025 | 47.69<br>(3.43) |

Each datum is an average of 16 observations - Appendix  
XXXII - XXXV

Figures in parentheses are the standard deviations.

Table 't' at 0.05 probability - 2.042 a - significant at 5%  
0.02        ''        - 2.457 b -        ''        2%  
0.01        ''        - 2.750 c -        ''        1%

Fig.10. Effect of diflubenzuron on AC resistance of hind wings of adult S. gregaria

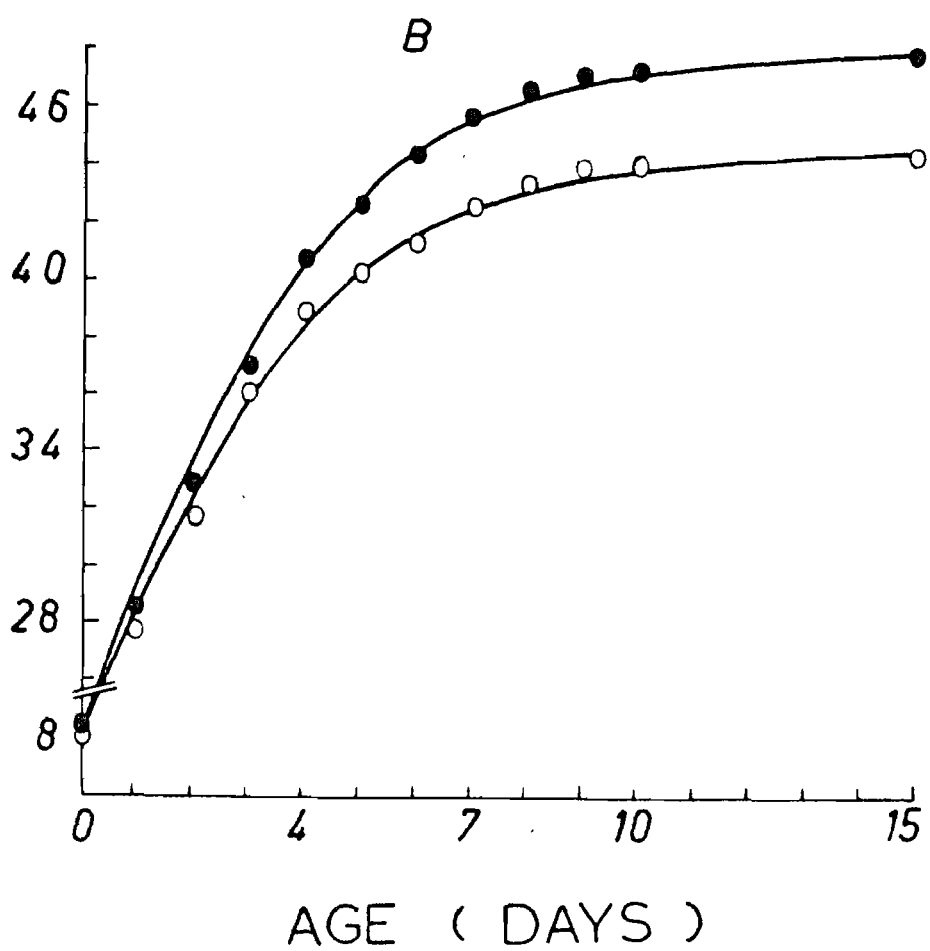
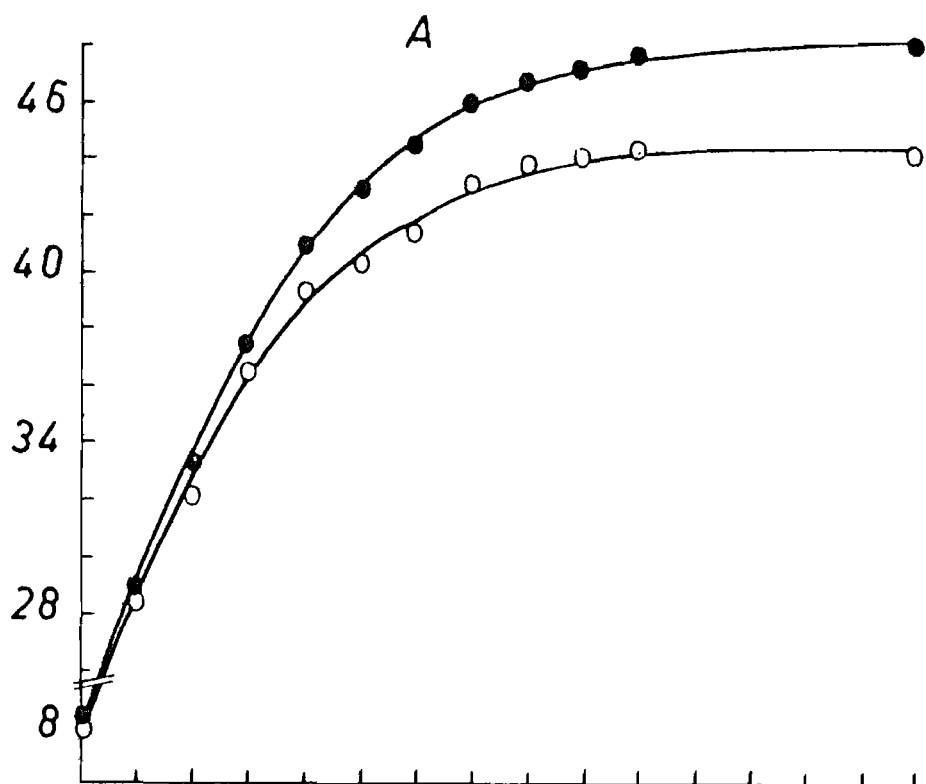
A. Male

B. Female

—○—○— Deformed

—○—○— Normal

$R_s \text{ (K}\Omega\text{-cm}^2\text{)}$



that of the normal adult females. The  $R_g$  of hind wings of the deformed adult females was not significantly different from that of the normal adult females from '0' to 4 days after moulting. However, it was found to be significantly lower in deformed adult females than that of the normal adult females from 5th day onwards after moulting.

The studies on the electrical AC resistance of the cuticle of S. gregaria at various sites evidently suggest that the  $R_g$  of the cuticle of the deformed adults obtained from diflubenzuron treated hoppers was always on lower side to that of the normal adults obtained from solvent treated hoppers. This was true in both the adult males and females. The  $R_g$  of intact pronotum of the deformed adults was significantly lower than that of normal adults from 2nd day onwards after moulting. Except in stray cases the  $R_g$  of excised pronotum of the deformed adults was found to be significantly lower than that of the normal adults from 5th day onwards after moulting. The  $R_g$  of abdominal sternites of the deformed adults was not significantly different from that of normal adults from 6th day afterwards after moulting except in one case. The  $R_g$  of both fore and hind wings of the deformed adults were significantly lower than that of normal insects from 5th day onwards after moulting.

## II. Effect of diflubenzuron on the potential difference between the two sides of the pronotum of adult S.gregaria

The data on potential difference between the outer and inner surfaces of the excised pronotum of the deformed

adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers are presented in Table-11. The following conclusions can be drawn from the data.

1. The potential difference across the two sides of the pronotum did not change significantly with the age of the adults.
2. The potential difference across the two sides of the pronotum did not change significantly with the sex of the adults.
3. Diflubenzuron treatment did not have any affect on the potential difference across the two sides of the pronotum.

It is evident that the potential difference between the outer and inner surfaces of the excised pronotum was always near 7 to 8 mV.

### III. Effect of diflubenzuron on the capacitance of the cuticle of *S. gregaria*

The capacitance of the cuticle of deformed adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers was measured on 2nd or 3rd abdominal sternites and the data are presented in Table-12 and Figure-11. The data suggest that the average capacitance of the cuticle of deformed adult males was  $31.70 \pm 2.18$  pF immediately after moulting,  $13.43 \pm 1.04$  pF on 6th day and  $10.40 \pm 0.93$  pF on 15th day after moulting. The corresponding average capacitance of the cuticle of normal adults was  $30.86 \pm 2.20$  pF immediately after moulting,  $12.25 \pm 1.01$  pF on

Table-11: Average potential difference between the two surfaces of excised pronotum of deformed and normal adult S. gregaria (mV)

| Age<br>(days) | Male         |              | Female       |              |
|---------------|--------------|--------------|--------------|--------------|
|               | Deformed     | Normal       | Deformed     | Normal       |
| 0             | 6.6<br>(6.0) | 7.1<br>(6.5) | 6.8<br>(6.0) | 7.2<br>(6.5) |
| 1             | 6.9<br>(6.5) | 8.1<br>(7.5) | 6.5<br>(6.5) | 7.8<br>(7.5) |
| 2             | 7.3<br>(7.0) | 7.8<br>(7.5) | 6.6<br>(6.0) | 8.1<br>(7.5) |
| 3             | 8.0<br>(6.0) | 8.6<br>(8.0) | 8.1<br>(8.0) | 8.4<br>(8.5) |
| 4             | 8.8<br>(8.5) | 8.7<br>(8.0) | 8.3<br>(8.0) | 8.7<br>(8.0) |
| 5             | 8.1<br>(8.0) | 8.3<br>(8.0) | 7.6<br>(6.0) | 8.2<br>(8.0) |
| 6             | 8.3<br>(8.0) | 8.3<br>(8.0) | 8.2<br>(8.0) | 8.3<br>(8.0) |
| 7             | 7.6<br>(6.0) | 8.3<br>(8.0) | 7.1<br>(7.0) | 7.6<br>(6.5) |
| 8             | 8.5<br>(8.0) | 8.6<br>(8.5) | 7.6<br>(8.0) | 7.8<br>(7.0) |
| 9             | 7.6<br>(8.0) | 7.8<br>(7.0) | 7.4<br>(8.0) | 7.9<br>(8.0) |
| 10            | 7.9<br>(7.5) | 7.9<br>(8.0) | 7.3<br>(8.0) | 8.0<br>(8.0) |
| 15            | 8.0<br>(8.0) | 8.2<br>(8.0) | 7.9<br>(7.5) | 8.6<br>(8.0) |

Each datum is an average of 16 observations - Appendix -  
XXXVI and  
XXXVII

Figures in parentheses are medians.

6th day and  $9.64 \pm 0.91$  pF on 15th day after moulting. In case of females the average capacitance of the cuticle of the deformed adults was  $32.32 \pm 1.96$  pF immediately after moulting,  $13.62 \pm 0.91$  pF on 6th day and  $11.12 \pm 1.00$  pF on 15th day after moulting. The corresponding average capacitance of the cuticle of the normal adult females was  $31.06 \pm 2.56$  pF immediately after moulting,  $13.07 \pm 0.87$  pF on 6th day and  $10.22 \pm 0.85$  pF on 15th day after moulting.

From the data presented it would be seen that the capacitance of the cuticle decreases with the age of the insect; that there was steep decline in the capacitance of the cuticle within 24 hours after moulting; that the capacitance of the cuticle of the adult male was always lower than that of the female; and that the capacitance of the cuticle of the deformed adults obtained from diflubenzuron treated hoppers was always higher than that of normal adults obtained from solvent treated hoppers. In case of deformed males the capacitance of the cuticle was found to be significantly higher than that of normal adults from 1st day onwards after moulting. While in deformed adult females the capacitance of the cuticle was significantly higher than that of normal adults from 4th day onwards, except on 6th day after moulting.

#### IV. Effect of diflubenzuron on dielectric constant of the cuticle of *S. gregaria*

The dielectric constant of the cuticle of *S. gregaria* was calculated from the capacitance measured during the

Table-12: Average capacitance of the cuticle of deformed and normal adult S. gregaria (pF)

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t     | Normal          | Deformed                     | t     | Normal          |
| 0             | 31.70<br>(2.18)              | 1.212 | 30.86<br>(2.20) | 32.32<br>(1.96)              | 1.748 | 31.06<br>(2.56) |
| 1             | 18.60 <sup>a</sup><br>(1.15) | 2.052 | 17.81<br>(1.28) | 18.90<br>(1.39)              | 1.596 | 18.22<br>(1.30) |
| 2             | 17.39 <sup>b</sup><br>(1.00) | 2.448 | 16.44<br>(1.42) | 17.46<br>(1.21)              | 1.190 | 16.99<br>(1.29) |
| 3             | 16.36 <sup>a</sup><br>(1.37) | 2.191 | 15.49<br>(1.13) | 16.53<br>(1.22)              | 1.898 | 15.86<br>(1.00) |
| 4             | 15.32 <sup>c</sup><br>(0.99) | 3.227 | 14.31<br>(0.99) | 15.60 <sup>a</sup><br>(1.17) | 2.135 | 14.84<br>(1.08) |
| 5             | 14.34 <sup>c</sup><br>(0.92) | 4.311 | 13.12<br>(0.87) | 14.53 <sup>b</sup><br>(1.06) | 2.517 | 13.80<br>(0.75) |
| 6             | 13.43 <sup>c</sup><br>(1.04) | 3.642 | 12.25<br>(1.01) | 13.62<br>(0.91)              | 1.950 | 13.07<br>(0.87) |
| 7             | 12.66 <sup>c</sup><br>(0.87) | 3.725 | 11.55<br>(1.01) | 12.97 <sup>c</sup><br>(0.78) | 2.868 | 12.23<br>(0.85) |
| 8             | 11.82 <sup>c</sup><br>(0.80) | 3.898 | 10.67<br>(1.05) | 12.39 <sup>c</sup><br>(0.82) | 2.817 | 11.68<br>(0.77) |
| 9             | 11.35 <sup>c</sup><br>(0.98) | 3.758 | 10.23<br>(0.90) | 12.03 <sup>c</sup><br>(0.88) | 3.091 | 11.18<br>(0.86) |
| 10            | 10.95 <sup>c</sup><br>(0.95) | 3.074 | 10.04<br>(0.92) | 11.77 <sup>c</sup><br>(0.84) | 3.285 | 10.86<br>(0.91) |
| 15            | 10.40 <sup>b</sup><br>(0.93) | 2.612 | 9.64<br>(0.91)  | 11.12 <sup>c</sup><br>(1.00) | 3.072 | 10.22<br>(0.85) |

Each datum is an average of 20 observations. — Appendix  
XXXVIII-XLI

Figures in parentheses are standard deviations.

Table 't' at 0.05 probability — 2.021 a — significant at 5%  
0.02        ''        — 2.423 b —        ''        2%  
0.01        ''        — 2.704 c —        ''        1%

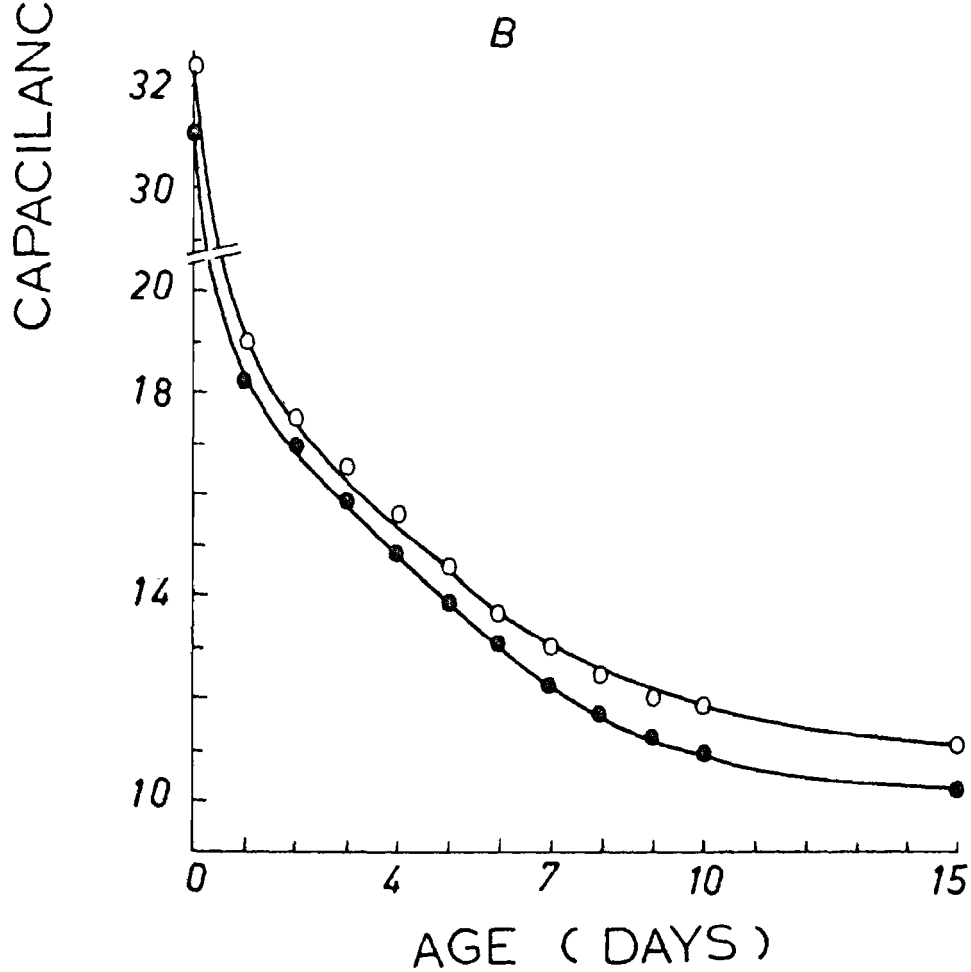
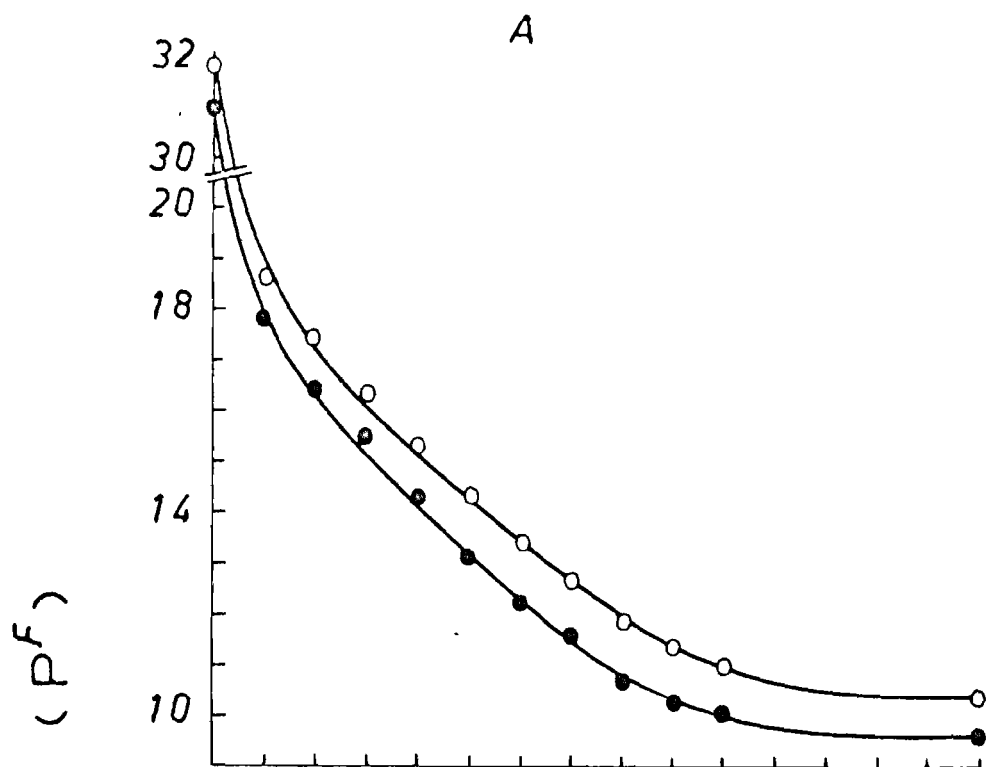
Fig.11. Effect of diflubenzuron on capacitance of  
the cuticle of adult S. gregaria

A. Male

B. Female

---o---o--- Deformed

---@---o--- Normal



investigations. Since the dielectric constant is a function of capacitance and is directly proportional to capacitance the trend of dielectric constant was similar to that of the capacitance.

The data (Table-13 and Figure-12A) suggest that the average dielectric constant of the cuticle of the deformed adult males obtained from diflubenzuron treated hoppers was  $9.12 \pm 0.63$  immediately after moulting,  $3.86 \pm 0.30$  on 6th day, and  $2.99 \pm 0.27$  on 15th day after moulting. The corresponding dielectric constant values of the cuticle of the normal adult males obtained from solvent treated hoppers were  $8.87 \pm 0.63$  immediately after moulting,  $3.52 \pm 0.29$  on 6th day and  $2.77 \pm 0.26$  on 15th day after moulting. These results show that the dielectric constant of the cuticle of the deformed adult males was consistently higher than that of the normal adult males. As in case of capacitance the dielectric constant of the cuticle of the deformed adult males was found to be significantly higher than that of normal adult males from 1st day onwards after moulting.

The data on the average dielectric constant of the cuticle of deformed and normal adult females obtained from diflubenzuron and solvent treated hoppers respectively are presented in Table-13 and Figure-12B. The data suggest that the average dielectric constant of the cuticle of the deformed adult females was  $9.29 \pm 0.56$  immediately after moulting,  $3.92 \pm 0.26$  on 6th day and  $3.20 \pm 0.29$  on 15th day

Table-13: Average dielectric constant of the cuticle of deformed and normal adult S. gregaria.

| Age<br>(days) | Male                        |       |                | Female                      |       |                |
|---------------|-----------------------------|-------|----------------|-----------------------------|-------|----------------|
|               | Deformed                    | t     | Normal         | Deformed                    | t     | Normal         |
| 0             | 9.12<br>(0.63)              | 1.256 | 8.87<br>(0.63) | 9.29<br>(0.56)              | 1.748 | 8.93<br>(0.73) |
| 1             | 5.25 <sup>a</sup><br>(0.33) | 2.072 | 5.12<br>(0.37) | 5.44<br>(0.40)              | 1.639 | 5.24<br>(0.37) |
| 2             | 5.00 <sup>a</sup><br>(0.29) | 2.411 | 4.73<br>(0.41) | 5.02<br>(0.35)              | 1.228 | 4.88<br>(0.37) |
| 3             | 4.71 <sup>a</sup><br>(0.39) | 2.193 | 4.46<br>(0.33) | 4.76<br>(0.35)              | 1.961 | 4.56<br>(0.29) |
| 4             | 4.40 <sup>c</sup><br>(0.28) | 3.111 | 4.12<br>(0.29) | 4.49 <sup>a</sup><br>(0.34) | 2.136 | 4.27<br>(0.31) |
| 5             | 4.12 <sup>c</sup><br>(0.27) | 4.268 | 3.77<br>(0.25) | 4.18 <sup>b</sup><br>(0.30) | 2.530 | 3.97<br>(0.22) |
| 6             | 3.86 <sup>c</sup><br>(0.30) | 3.656 | 3.52<br>(0.29) | 3.92<br>(0.26)              | 1.975 | 3.76<br>(0.25) |
| 7             | 3.64 <sup>c</sup><br>(0.25) | 3.721 | 3.32<br>(0.29) | 3.73 <sup>c</sup><br>(0.22) | 2.877 | 3.52<br>(0.24) |
| 8             | 3.40 <sup>c</sup><br>(0.23) | 3.529 | 3.10<br>(0.30) | 3.56 <sup>c</sup><br>(0.24) | 2.740 | 3.36<br>(0.22) |
| 9             | 3.27 <sup>c</sup><br>(0.28) | 3.882 | 2.94<br>(0.26) | 3.46 <sup>c</sup><br>(0.25) | 3.039 | 3.22<br>(0.25) |
| 10            | 3.15 <sup>c</sup><br>(0.27) | 3.095 | 2.89<br>(0.26) | 3.38 <sup>c</sup><br>(0.24) | 3.291 | 3.12<br>(0.26) |
| 15            | 2.99 <sup>b</sup><br>(0.27) | 2.619 | 2.77<br>(0.26) | 3.20 <sup>c</sup><br>(0.29) | 3.095 | 2.94<br>(0.24) |

Each datum is an average of 20 observations - Appendix - XLII-XLV

Figures in parentheses are standard deviations.

Table 't' value at 0.05 probability 2.021 a -significat at 5%  
0.02 " 2.423 b - " 2%  
0.01 " 2.704 c - " 1%

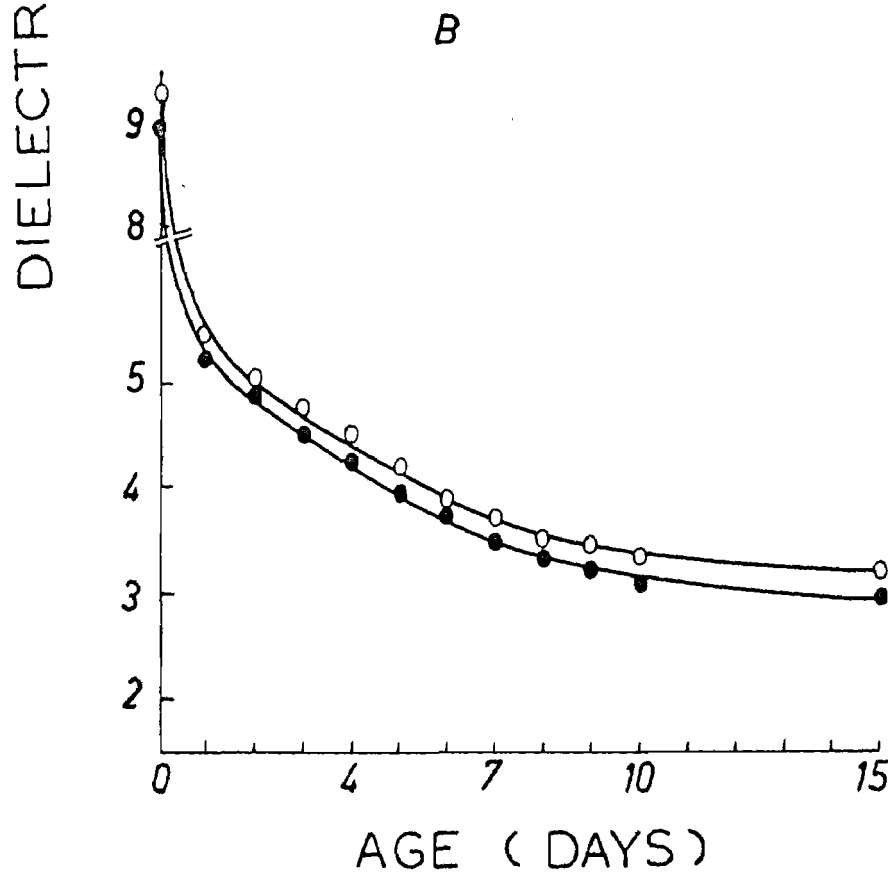
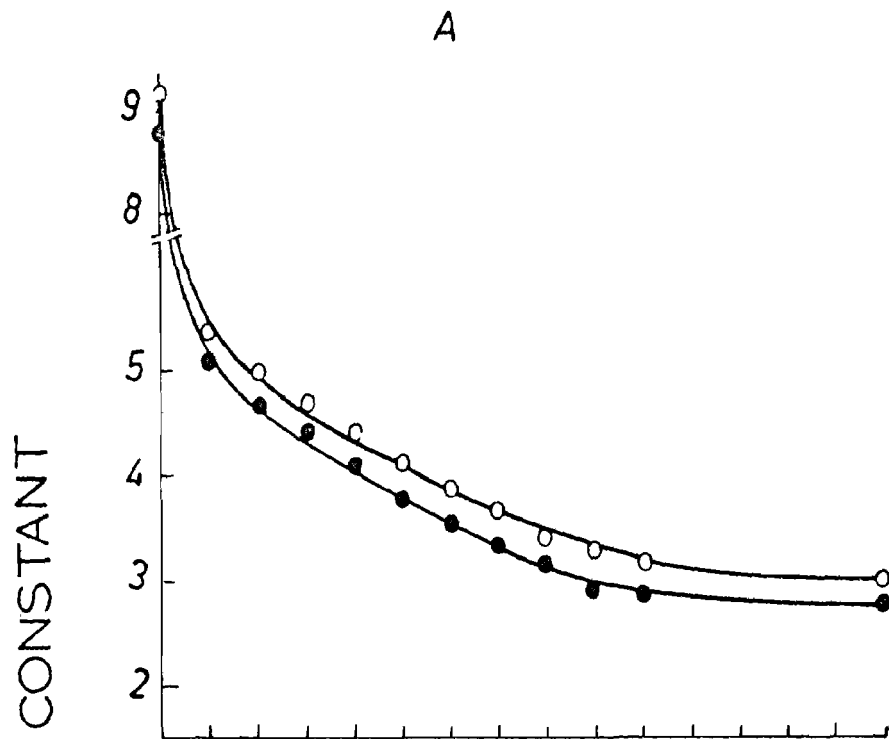
Fig. 12. Effect of diflubenzuron on dielectric constant  
of the cuticle of adult S. gregaria

A. Male

B. Female

—o—o— Deformed

—o—o— Normal



after moulting. The corresponding dielectric constant values of the cuticle of the normal adult females were  $8.93 \pm 0.73$  immediately after moulting,  $3.76 \pm 0.25$  on 6th day and  $2.94 \pm 0.24$  on 15th day after moulting. These results suggest that the dielectric constant of the cuticle of the deformed adult females although consistently higher, was not significantly different from that of the normal adult females from '0' to 3 days and on 6th day after moulting. It was however, found to be significantly higher in deformed adult females than that of normal adult females from 4th day onwards after moulting, except on 6th day.

V. Effect of diflubenzuron on chitin content in the wings of *S. gregaria*

The chitin content in the wings of the deformed and normal adult locusts obtained from diflubenzuron and solvent treated hoppers respectively, was determined by taking all the four wings of an insect as an unit. The absolute amount of chitin and also as percentage of the fresh weight of the wings was estimated. In addition chitin content was also determined in both the fore and hind wings individually.

Absolute weight of chitin in wings

The data on chitin content of the wings of the deformed adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers are presented in Table-14 and Figure-13. The data suggest that in normal adults the chitin content of the wings continued to increase from '0' to 15 days after moulting. The increase

Table-14: Average chitin content in the wings (a set of four) of deformed and normal adult S. gregaria (mg)

| Age<br>(days) | Male                        |       |                 | Female                       |        |                 |
|---------------|-----------------------------|-------|-----------------|------------------------------|--------|-----------------|
|               | Deformed                    |       | Normal          | Deformed                     |        | Normal          |
| 0             | 2.88<br>(0.25)              | 1.412 | 3.13<br>(0.25)  | 3.00<br>(0.41)               | 1.583  | 3.38<br>(0.25)  |
| 1             | 4.38<br>(0.25)              | 1.937 | 4.75<br>(0.29)  | 4.75<br>(0.50)               | 1.730  | 5.25<br>(0.29)  |
| 2             | 5.50 <sup>a</sup><br>(0.41) | 2.817 | 6.50<br>(0.58)  | 6.25<br>(0.87)               | 1.992  | 7.25<br>(0.50)  |
| 3             | 6.50 <sup>a</sup><br>(0.58) | 3.005 | 7.63<br>(0.48)  | 7.50 <sup>b</sup><br>(0.41)  | 3.232  | 8.88<br>(0.75)  |
| 4             | 7.38<br>(0.75)              | 2.263 | 9.00<br>(1.22)  | 8.75 <sup>b</sup><br>(0.65)  | 3.514  | 10.63<br>(0.85) |
| 5             | 8.38 <sup>c</sup><br>(0.48) | 3.776 | 10.00<br>(0.71) | 9.75 <sup>b</sup><br>(0.29)  | 3.704  | 11.75<br>(1.04) |
| 6             | 8.63 <sup>b</sup><br>(0.48) | 3.306 | 10.63<br>(1.11) | 10.13 <sup>c</sup><br>(0.48) | 6.944  | 12.88<br>(0.63) |
| 7             | 8.75 <sup>c</sup><br>(0.87) | 5.717 | 11.50<br>(0.41) | 10.38 <sup>c</sup><br>(0.63) | 6.633  | 13.63<br>(0.75) |
| 8             | 9.00 <sup>c</sup><br>(0.41) | 6.102 | 11.88<br>(0.85) | 10.63<br>(0.85)              | 4.611  | 14.25<br>(1.32) |
| 9             | 9.00 <sup>c</sup><br>(0.41) | 5.650 | 12.13<br>(1.03) | 11.00 <sup>c</sup><br>(0.91) | 4.676  | 14.75<br>(1.32) |
| 10            | 9.00 <sup>c</sup><br>(1.00) | 4.190 | 12.13<br>(1.11) | 11.00 <sup>c</sup><br>(1.08) | 7.004  | 14.88<br>(0.25) |
| 15            | 9.00 <sup>c</sup><br>(0.41) | 8.324 | 12.13<br>(0.63) | 11.13 <sup>c</sup><br>(0.25) | 13.838 | 14.88<br>(0.48) |

Each datum is an average of 4 observations - Appendix  
XLVI and XLVII

Figures in parentheses are standard deviations.

Table 't' value at 0.05 probability - 2.447 a - significant at 5%  
0.02 " - 3.143 b - " 2%  
0.01 " - 3.707 c - " 1%

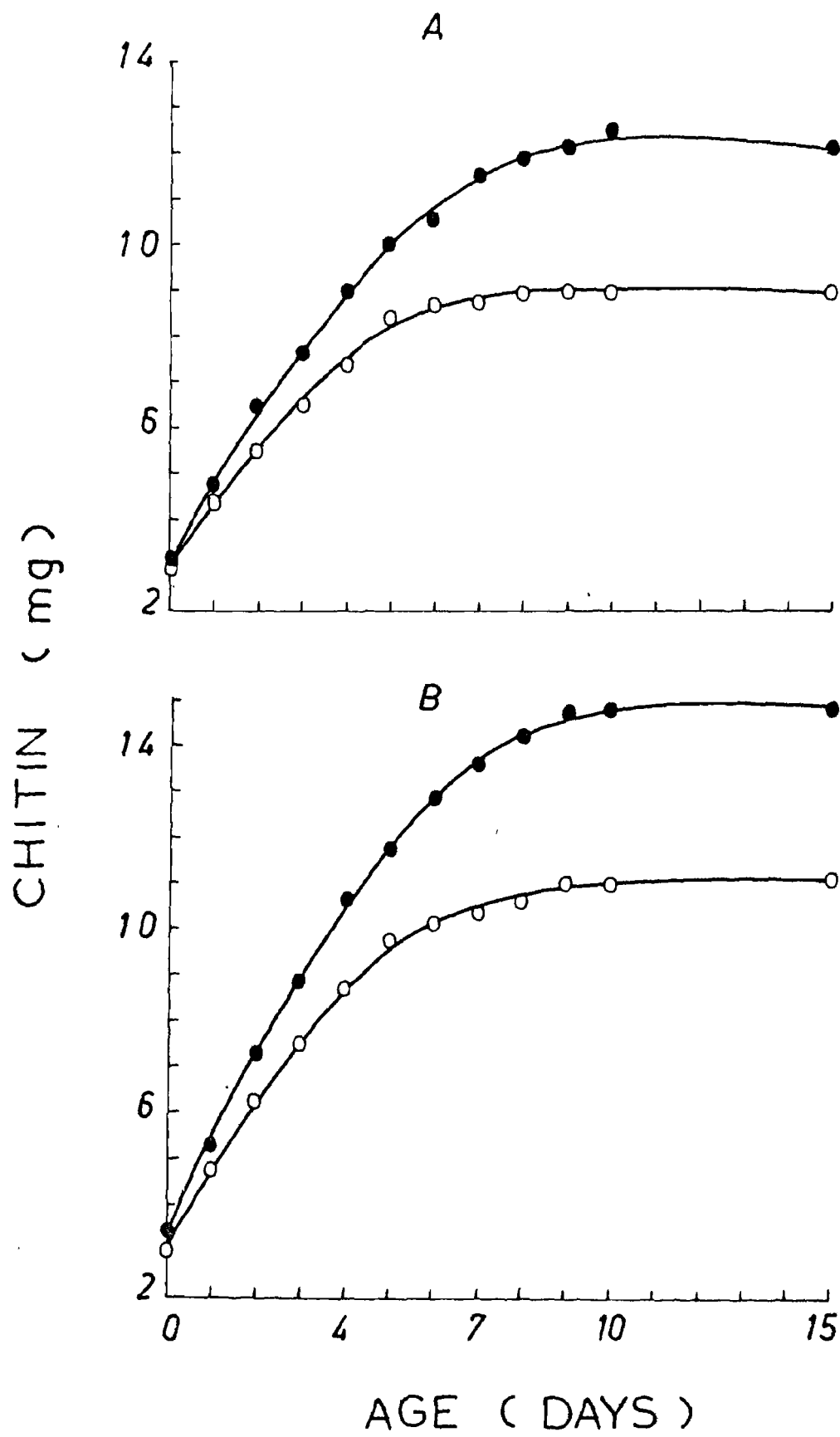
Fig.13. Effect of diflubenzuron on the chitin  
content in the wings of adult S. gregaria

A. Male

B. Female

—o—o— Deformed

—o—o— Normal



in chitin content of the wings was observed to be biphasic; a fast phase of increase from '0' to 6 days after moulting and a slow phase from 7th day onwards after moulting. The chitin content in the wings of the deformed adults although consistently lower, followed similar pattern of increase during the period of observation as in case of normal adults. The chitin content in the wings of adult males was consistently lower than that of females.

The average chitin content in the wings of the deformed adult males obtained from diflubenzuron treated hoppers was  $2.88 \pm 0.25$  mg immediately after moulting. It increased to  $8.63 \pm 0.48$  mg by 6th day and  $9.00 \pm 0.41$  mg by 15th day after moulting. The corresponding average chitin content in the wings of the normal adult males obtained from solvent treated hoppers was  $3.13 \pm 0.25$  mg immediately after moulting,  $10.63 \pm 1.11$  mg on 6th day and  $12.13 \pm 0.63$  mg on 15th day after moulting. From these results, it would be seen that the chitin content in the wings of deformed adult males was consistently lower than that of the wings of the normal adult males. The chitin content in the wings of the deformed adult males was however, not significantly different from that of normal adult males at 0, 1, and 4 days after moulting. The chitin content was observed to be significantly lower in the wings of the deformed adult males than that of the wings of the normal adult males during the rest of the period of experimentation.

The average chitin content (Table-14 and Figure-13B) in the wings of deformed adult females obtained from

diflubenzuron treated hoppers was  $3.00 \pm 0.41$  mg immediately after moulting. It increased to  $10.13 \pm 0.48$  mg by 6th day and  $11.13 \pm 0.25$  mg by 15th day after moulting. The corresponding average chitin content in the wings of the normal adult females obtained from solvent treated hoppers was  $3.38 \pm 0.25$  mg immediately after moulting,  $12.88 \pm 0.63$  mg on 6th day and  $14.88 \pm 0.48$  mg on 15th day after moulting. These results thus suggested that although the chitin content in the wings of the deformed adult females was consistently lower, it was not significantly different from that of normal adult females from '0' to 2 days after moulting. However, the chitin content in the wings of the deformed adult females was observed to be significantly lower than that of the normal adult females from 3rd day onwards after moulting.

#### Percentage of chitin in wings:

In addition to the determination of chitin content of the wings, the percentage of chitin in the wings of deformed adults obtained from diflubenzuron treated hoppers and normal adults obtained from solvent treated hoppers was calculated based on fresh weight of the wings. As in case of absolute chitin content, there was continuous increase in the percentage of chitin in the wings of normal adults from '0' to 15 days after moulting. The increase in percentage of chitin in the wings was biphasic; a fast phase of increase from '0' to 6th day after moulting and a slow phase of increase from 7th day onwards after moulting. Despite the fact that the

percentage of chitin in the wings of deformed adults was consistently low, the trend of increase from '0' to 15 days after moulting remained the same as that seen in the normal adults. Percentage wise there was no difference in chitin content between the wings of male and female adults. The average percentage of chitin in the wings of deformed adult males was  $4.85 \pm 0.30$  immediately after moulting. It increased to  $15.43 \pm 1.15$  by 6th day and  $16.48 \pm 1.12$  by 15th day after moulting (Table-15 and Figure-14A). The corresponding values for the average percentage of chitin in the wings of normal adult males were  $5.06 \pm 0.31$  immediately after moulting,  $18.44 \pm 0.77$  on 6th day and  $20.82 \pm 1.19$  on 15th day after moulting. It is apparent from the data, that the percentage of chitin in the wings of the deformed adult males although consistently lower, was not significantly different from that of the normal adult males during '0' and 1 day after moulting. It was however, found significantly lower in the wings of the deformed adult males than that of the normal adult males from 2nd day onwards after moulting.

The average percentage of chitin in the wings of the deformed adult females obtained from diflubenzuron treated hoppers (Table-15 and Figure-14B) was  $4.65 \pm 0.38$  immediately after moulting. It increased to  $15.20 \pm 1.13$  by 6th day and  $16.45 \pm 0.79$  by 15th day after moulting. The corresponding average percentage of chitin in the wings of the normal adult females obtained from solvent treated hoppers was  $4.91 \pm 0.28$  immediately after moulting,  $18.61 \pm 0.73$  on 6th day and  $20.85 \pm 0.98$  on 15th day after moulting. From these results, it is

Table-15: Average percentage of chitin in the wings(a set of four) of deformed and normal adult S. gregaria.

| Age<br>(days) | Male                         |        |                 | Female                       |       |                 |
|---------------|------------------------------|--------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     | t      | Normal          | Deformed                     | t     | Normal          |
| 0             | 4.85<br>(0.30)               | 0.972  | 5.06<br>(0.31)  | 4.65<br>(0.38)               | 1.102 | 4.91<br>(0.28)  |
| 1             | 7.68<br>(0.32)               | 1.806  | 8.20<br>(0.48)  | 7.49<br>(0.57)               | 1.142 | 8.01<br>(0.71)  |
| 2             | 9.70 <sup>a</sup><br>(0.69)  | 2.648  | 10.91<br>(0.60) | 9.62<br>(0.90)               | 2.382 | 10.83<br>(0.47) |
| 3             | 11.36 <sup>a</sup><br>(0.83) | 2.784  | 12.88<br>(0.71) | 11.32 <sup>c</sup><br>(0.48) | 4.300 | 13.04<br>(0.64) |
| 4             | 13.03 <sup>b</sup><br>(0.80) | 3.394  | 15.27<br>(1.05) | 13.02 <sup>c</sup><br>(0.58) | 4.393 | 15.30<br>(0.73) |
| 5             | 14.78 <sup>c</sup><br>(0.62) | 5.000  | 17.01<br>(0.64) | 14.57 <sup>c</sup><br>(0.81) | 4.033 | 17.01<br>(0.90) |
| 6             | 15.43 <sup>c</sup><br>(1.15) | 4.350  | 18.44<br>(0.77) | 15.20 <sup>c</sup><br>(1.13) | 5.067 | 18.61<br>(0.73) |
| 7             | 15.60 <sup>c</sup><br>(0.99) | 7.055  | 19.84<br>(0.68) | 15.62 <sup>c</sup><br>(0.80) | 7.435 | 19.62<br>(0.72) |
| 8             | 16.03 <sup>c</sup><br>(0.40) | 12.827 | 20.39<br>(0.54) | 16.03 <sup>c</sup><br>(1.00) | 5.156 | 20.34<br>(1.34) |
| 9             | 16.38 <sup>c</sup><br>(0.79) | 6.111  | 20.67<br>(1.16) | 16.25<br>(0.63)              | 9.486 | 20.68<br>(0.69) |
| 10            | 16.43 <sup>c</sup><br>(0.52) | 7.504  | 20.79<br>(1.04) | 16.40 <sup>c</sup><br>(0.77) | 6.590 | 20.69<br>(1.05) |
| 15            | 16.48 <sup>c</sup><br>(1.12) | 5.312  | 20.82<br>(1.19) | 16.45 <sup>c</sup><br>(0.79) | 6.995 | 20.85<br>(0.98) |

Each datum is an average of 4 observations - Appendix -  
XLVI and XLVII

Figures in parentheses are standard deviations.

Table 't' at 0.05 probability - 2.447    a - significant at 5%  
                   0.02            "        - 3.143    b -            "        at 2%  
                   0.01            "        - 3.707    c -            "        at 1%

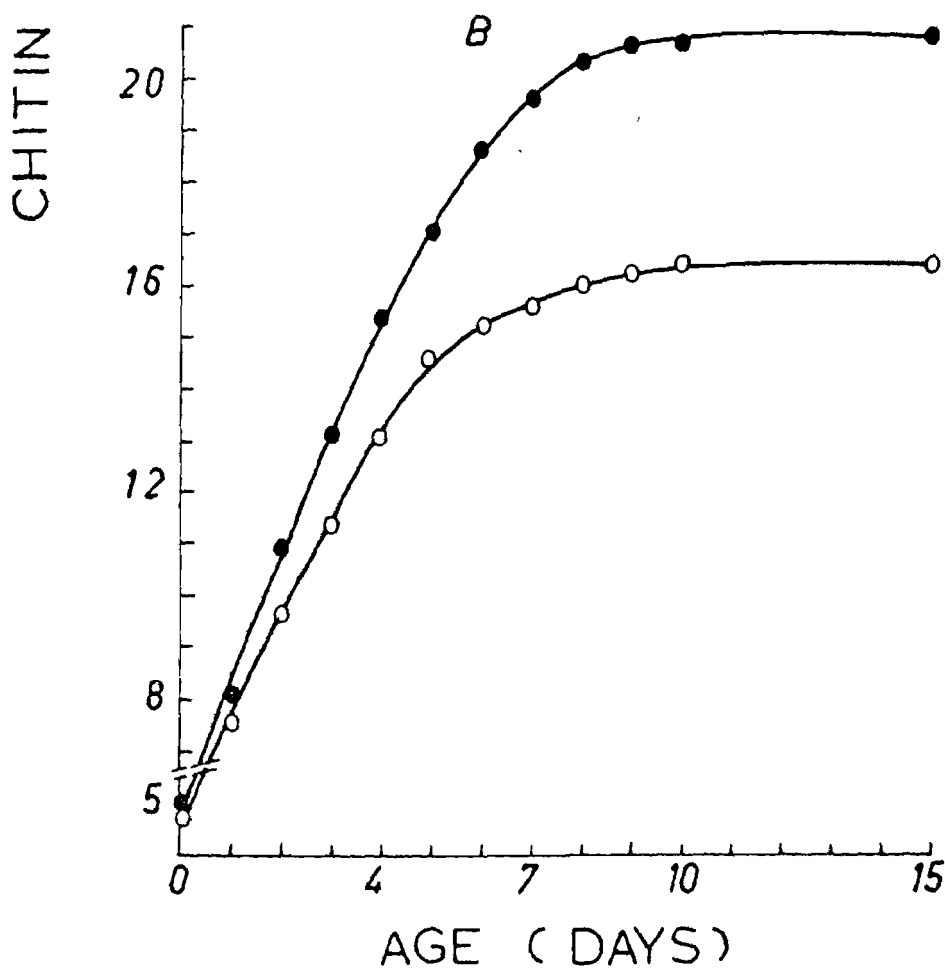
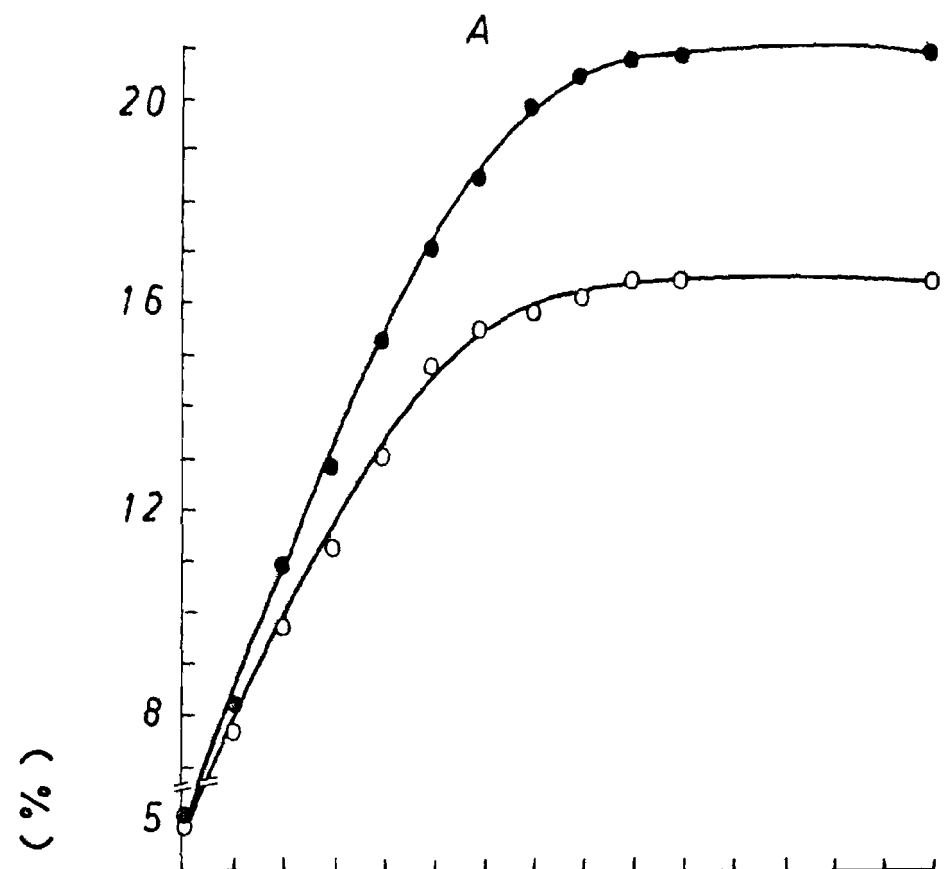
Fig.14. Effect of diflubenzuron on percentage of chitin in the wings of adult S. gregaria

A. Male

B. Female

—○—○— Deformed

—○—○— Normal



apparent that the percentage of chitin in the wings of the deformed adult females was always lower than that of the normal adult females. The percentage of chitin in the wings of the deformed adult females was not significantly different from that of the normal adult females from '0' to 2 days after moulting. However, the percentage of chitin was found to be significantly lower in the wings of the deformed adult females when compared to that of the normal adult females from 3rd day onwards after moulting.

#### Chitin content in forewings

From the previous results, it would be seen that diflubenzuron treatment to the hoppers invariably resulted in decreased chitin synthesis or incorporation in the cuticle of the wings of adult desert locusts. The present set of experiments were carried out to observe whether there was any differential response to diflubenzuron treatment in the fore and hind wings of the locusts.

The data on absolute weight of chitin/pair of fore wings of the deformed and normal adult males obtained from diflubenzuron and solvent treated hoppers are presented in Table-16 and Figure-15A. From the data it would be seen that the average chitin content in the forewings of deformed adult males was  $2.25 \pm 0.20$  mg on 1st day,  $4.69 \pm 0.43$  mg on 7th day and  $5.19 \pm 0.38$  mg on 15th day after moulting. The corresponding average chitin content in the fore wings of the normal adult males was  $2.56 \pm 0.13$  mg on 1st day,  $6.13 \pm 0.32$  mg on 7th day

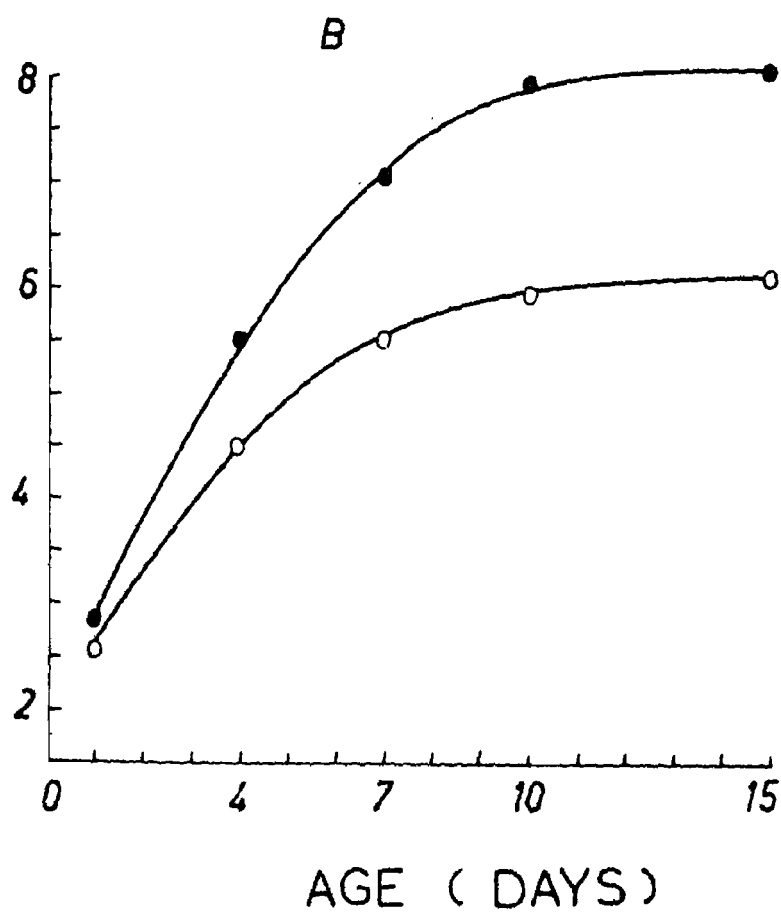
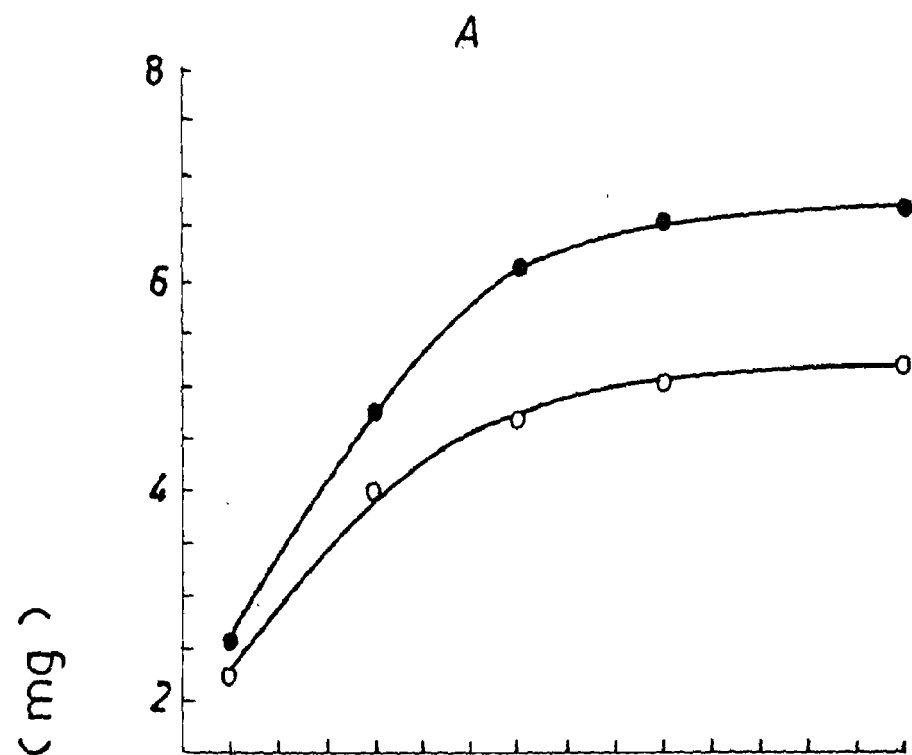
Fig.15. Effect of diflubenzuron on the chitin content  
of the fore wings of adult S. gregaria

A. Male

B. Female

—○—○— Deformed

—○—○— Normal



and  $6.69 \pm 0.24$  mg on 15th day after moulting. These results suggest that the chitin content in the fore wings of the deformed adult males was found to be significantly lower than that of the fore wings of normal adults throughout the period of observation.

The average chitin content in the forewings of the deformed adult females obtained from diflubenzuron treated hoppers (Table-16 and Figure-15B) was  $2.56 \pm 0.24$  mg on 1st day. It increased to  $5.30 \pm 0.35$  mg by 7th day and  $6.13 \pm 0.43$  mg by 15th day after moulting. The corresponding average chitin content in the fore wings of the normal adult females obtained from solvent treated hoppers was  $2.88 \pm 0.32$  mg on 1st day,  $7.06 \pm 0.31$  mg on 7th day and  $8.06 \pm 0.52$  mg on 15th day after moulting. From the data, it is apparent that the chitin content in the fore wings of the deformed adult females was significantly lower than that of the fore wings of normal adult females during the entire period of observation except on 1st day.

#### Percentage of chitin in Fore wings:

The data on average percentage of chitin in the fore wings of the deformed and normal adult males obtained from diflubenzuron and solvent treated hoppers are presented in Table-17 and Figure-16A. These results suggest that the average percentage of chitin in the fore wings of the deformed adult males was  $7.53 \pm 0.41$  on 1st day,  $15.61 \pm 0.55$  on 7th day, and  $16.47 \pm 0.84$  on 15th day after moulting.

Table-16: Average chitin content in the fore wings (per pair) of deformed and normal adult S. gregaria (mg).

| Age<br>(days) | Male                        |        | Female         |                             |
|---------------|-----------------------------|--------|----------------|-----------------------------|
|               | Deformed                    | Normal | Deformed       | Normal                      |
| 1             | 2.25 <sup>a</sup><br>(0.20) | 2.605  | 2.56<br>(0.24) | 1.600                       |
| 4             | 4.00 <sup>c</sup><br>(0.20) | 5.319  | 4.75<br>(0.20) | 4.50 <sup>c</sup><br>(0.20) |
| 7             | 4.69 <sup>c</sup><br>(0.43) | 5.373  | 6.13<br>(0.32) | 5.50 <sup>c</sup><br>(0.35) |
| 10            | 5.06 <sup>c</sup><br>(0.13) | 11.029 | 6.56<br>(0.24) | 5.94 <sup>c</sup><br>(0.39) |
| 15            | 5.19 <sup>c</sup><br>(0.38) | 6.667  | 6.69<br>(0.24) | 6.13 <sup>c</sup><br>(0.43) |

Table-17: Average percentage of chitin in fore wings of deformed and normal adult S. gregaria.

| Age<br>(days) | Male                         |        | Female          |                              |
|---------------|------------------------------|--------|-----------------|------------------------------|
|               | Deformed                     | Normal | Deformed        | Normal                       |
| 1             | 7.53<br>(0.41)               | 1.818  | 8.11<br>(0.49)  | 7.34<br>(0.55)               |
| 4             | 12.87 <sup>c</sup><br>(0.59) | 4.932  | 15.42<br>(0.85) | 12.95 <sup>c</sup><br>(0.56) |
| 7             | 15.61 <sup>c</sup><br>(0.55) | 7.938  | 19.46<br>(0.80) | 15.62 <sup>c</sup><br>(0.71) |
| 10            | 16.31 <sup>c</sup><br>(0.92) | 5.912  | 20.62<br>(1.13) | 16.52 <sup>c</sup><br>(0.78) |
| 15            | 16.47 <sup>c</sup><br>(0.84) | 7.469  | 20.75<br>(0.78) | 16.50 <sup>c</sup><br>(0.75) |

Each datum is an average of four observations - Appendix -  
XLVIII and  
XLIX

Figures in parentheses are standard deviations.

Table 't' at 0.05 probability - 2.447 a - significant at 5%  
0.02 " - 3.143 b - significant at 2%  
0.01 " - 3.707 c - significant at 1%

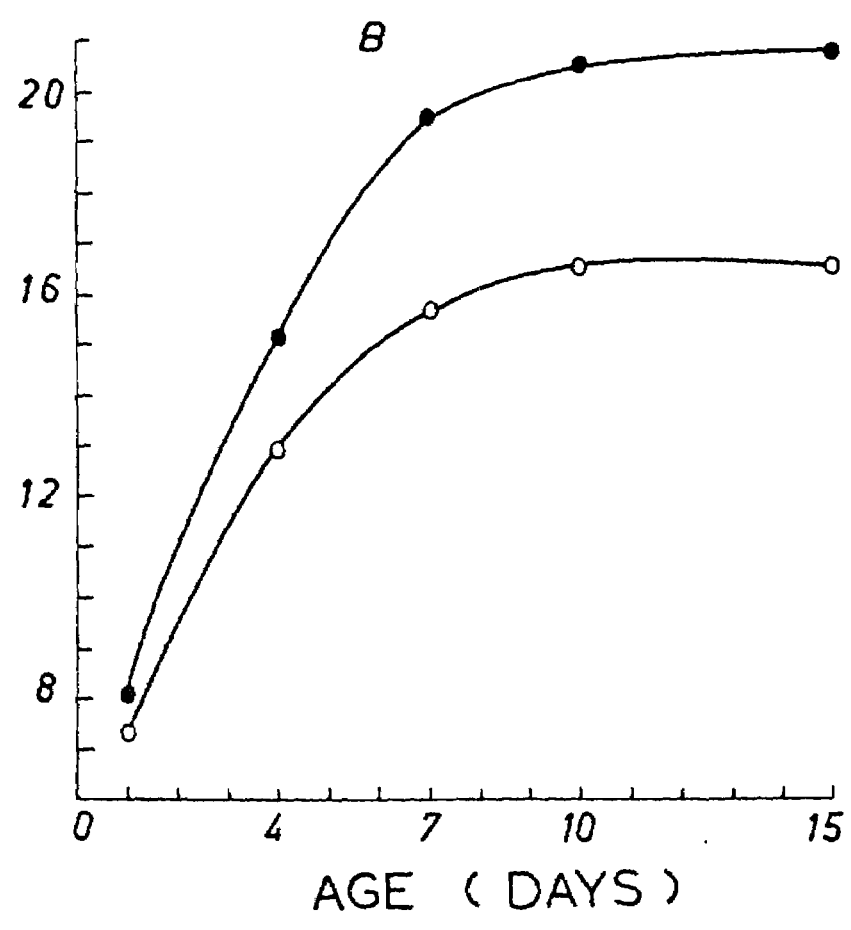
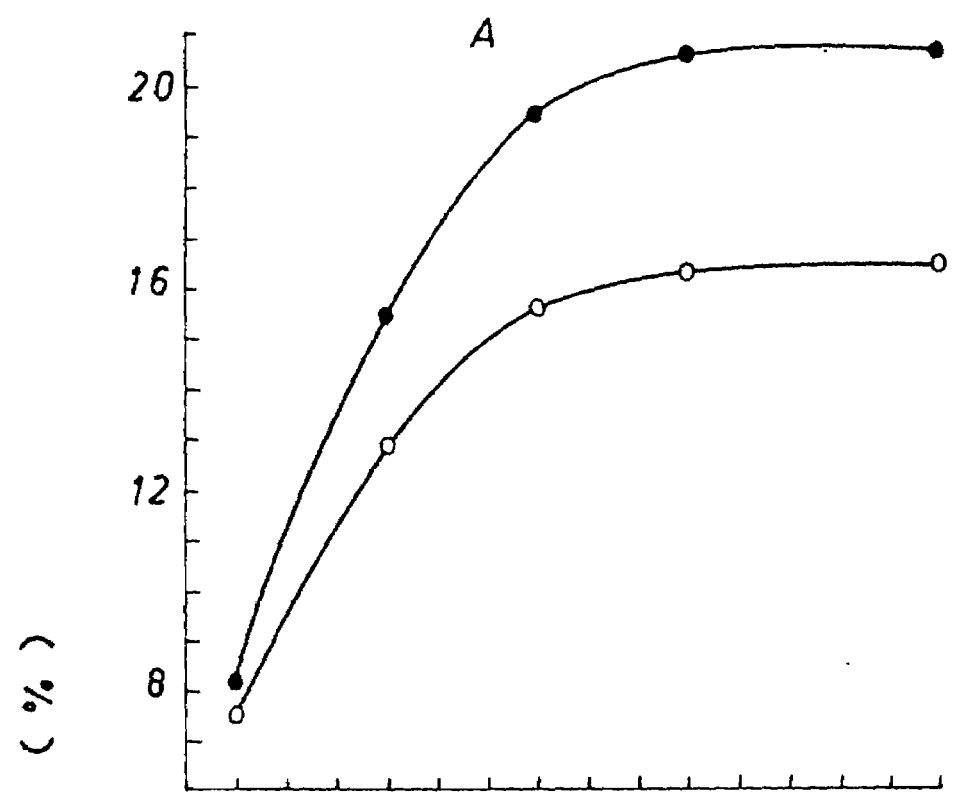
Fig.16. Effect of diflubenzuron on percentage of chitin  
in the fore wings of adult S. gregaria

A. Male

B. Female

--o--o-- Deformed

--o--o-- Normal



The corresponding average percentage of chitin in the fore wings of the normal adult males was  $8.11 \pm 0.49$  on 1st day,  $19.46 \pm 0.80$  on 7th day, and  $20.75 \pm 0.78$  on 15th day after moulting. From the data, it would be seen that the percentage of chitin in the fore wings of the deformed adult males was always on lower side than that of the normal insects. Except on 1st day the percentage of chitin in fore wings of the deformed adult males was found to be significantly lower than that of the normal adult males.

The data (Table-17 and Figure-16B) also suggest that the average percentage of chitin in the forewings of the deformed adult females obtained from diflubenzuron treated hoppers was  $7.34 \pm 0.55$  on 1st day,  $15.62 \pm 0.71$  on 7th day, and  $16.50 \pm 0.75$  on 15th day after moulting. The corresponding average percentage of chitin in the fore wings of the normal adult females obtained from solvent treated hoppers was  $8.06 \pm 0.63$  on 1st day,  $19.50 \pm 0.78$  on 7th day, and  $20.78 \pm 0.85$  on 15th day after moulting. As in case of males, the average percentage of chitin was found to be significantly lower in the fore wings of the deformed females during the entire period of observation except on 1st day, when compared to that of the normal adult females.

#### Chitin content in hind wings

The data on the amount of chitin per pair of hind wings and the effect of diflubenzuron treatment on the chitin content of the hind wings are presented in Table-18 and Figure-17. The average chitin content in the hind wings

Fig.17. Effect of diflubenzuron on chitin content  
of the hind wings of adult S. gregaria

A. Male

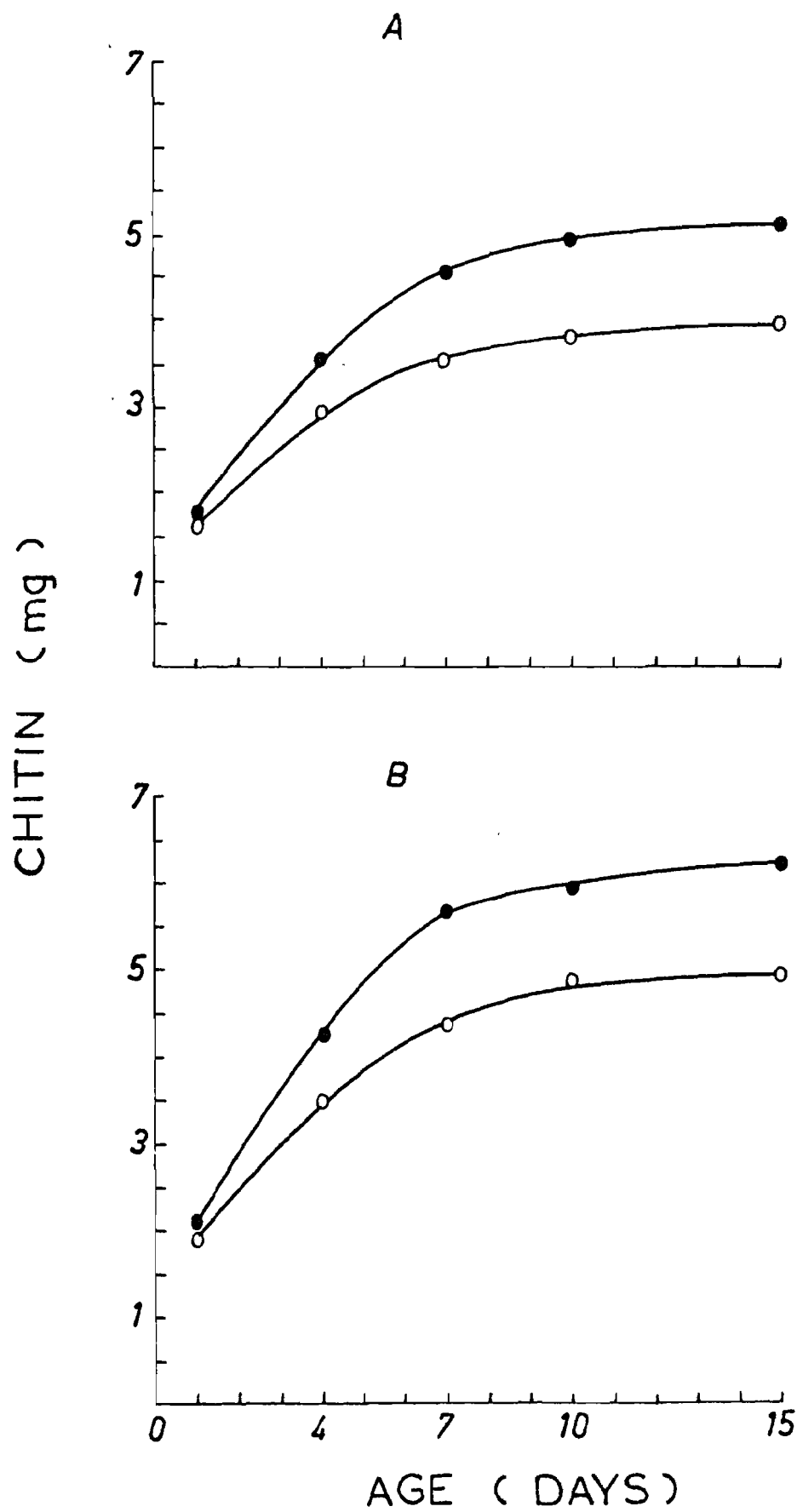
B. Female

--o--o--

Deformed

--o--o--

Normal



of the deformed adult males obtained from diflubenzuron treated hoppers was  $1.63 \pm 0.14$  mg on 1st day,  $3.56 \pm 0.13$  mg on 7th day, and  $4.00 \pm 0.20$  mg on 15th day after moulting. The corresponding average chitin content in the hind wings of the normal adult males obtained from solvent treated hoppers was  $1.75 \pm 0.20$  mg on 1st day,  $4.56 \pm 0.24$  mg on 7th day, and  $5.13 \pm 0.43$  mg on 15th day after moulting. These results suggest that except on 1st day the chitin content in hind wings of the deformed adult males was significantly lower than that of normal adult males.

The data (Table-18 and Figure-17B) also suggest that the average chitin content in the hind wings of the deformed adult females obtained from diflubenzuron treated hoppers was  $1.94 \pm 0.24$  mg on 1st day,  $4.38 \pm 0.32$  mg on 7th day, and  $4.94 \pm 0.13$  mg on 15th day after moulting. The corresponding average chitin content in the hind wings of the normal adult females obtained from solvent treated hoppers was  $2.13 \pm 0.25$  mg on 1st day,  $5.69 \pm 0.24$  mg on 7th day, and  $6.25 \pm 0.54$  mg on 15th day after moulting. These results also suggest that although the chitin content in the hind wings of the deformed adult males was consistently on lower side than that of the normal adult males, it however, was not significantly different from one another upto 4th day after moulting. The difference was however, statistically significant from 7th day onwards after moulting between the deformed and normal adult females.

Percentage of chitin in hind wings:

The data on the percentage of chitin in the hind wings of the deformed and normal adult males obtained from

Table-18: Average chitin content in hind wings(per pair)  
of deformed and normal adult S. gregaria(mg).

| Age<br>(days) | Male                        |       |                | Female                      |       |                |
|---------------|-----------------------------|-------|----------------|-----------------------------|-------|----------------|
|               | Deformed                    |       | Normal         | Deformed                    |       | Normal         |
| 1             | 1.63<br>(0.14)              | 0.984 | 1.75<br>(0.20) | 1.94<br>(0.24)              | 1.098 | 2.13<br>(0.25) |
| 4             | 2.94 <sup>b</sup><br>(0.13) | 3.690 | 3.56<br>(0.31) | 3.50<br>(0.35)              | 2.131 | 4.25<br>(0.61) |
| 7             | 3.56 <sup>c</sup><br>(0.13) | 7.353 | 4.56<br>(0.24) | 4.38 <sup>c</sup><br>(0.32) | 6.550 | 5.69<br>(0.24) |
| 10            | 3.81 <sup>b</sup><br>(0.38) | 3.383 | 4.94<br>(0.55) | 4.88 <sup>c</sup><br>(0.25) | 7.518 | 5.94<br>(0.13) |
| 15            | 4.00 <sup>c</sup><br>(0.20) | 4.768 | 5.13<br>(0.43) | 4.94 <sup>c</sup><br>(0.13) | 4.712 | 6.25<br>(0.54) |

Table-19: Average percentage of chitin in the hind wings  
of deformed and normal adult S. gregaria.

| Age<br>(days) | Male                         |       |                 | Female                       |       |                 |
|---------------|------------------------------|-------|-----------------|------------------------------|-------|-----------------|
|               | Deformed                     |       | Normal          | Deformed                     |       | Normal          |
| 1             | 7.34<br>(0.32)               | 0.695 | 7.62<br>(0.74)  | 7.20<br>(0.33)               | 1.348 | 7.68<br>(0.63)  |
| 4             | 12.78 <sup>c</sup><br>(0.50) | 5.126 | 15.22<br>(0.81) | 12.63 <sup>c</sup><br>(0.60) | 3.882 | 15.13<br>(1.14) |
| 7             | 15.60 <sup>c</sup><br>(0.77) | 5.761 | 19.12<br>(0.95) | 15.41 <sup>c</sup><br>(0.78) | 9.258 | 19.53<br>(0.43) |
| 10            | 16.13 <sup>c</sup><br>(0.89) | 6.291 | 20.32<br>(0.99) | 16.06 <sup>c</sup><br>(0.65) | 9.771 | 20.32<br>(0.58) |
| 15            | 16.41 <sup>c</sup><br>(0.51) | 6.530 | 20.70<br>(1.21) | 16.16 <sup>c</sup><br>(1.01) | 5.983 | 20.39<br>(0.99) |

Each datum is an average of 4 observations - Appendix L and LI

Figures in parentheses are standard deviations.

Table 't' at 0.05 probability - 2.447    a - significant at 5%  
                   0.02            ''        - 3.143    b -            ''        at 2%  
                   0.01            ''        - 3.707    c -            ''        at 1%

Fig. 18. Effect of diflubenzuron on percentage of  
chitin in the hind wings of adult J. gregaria

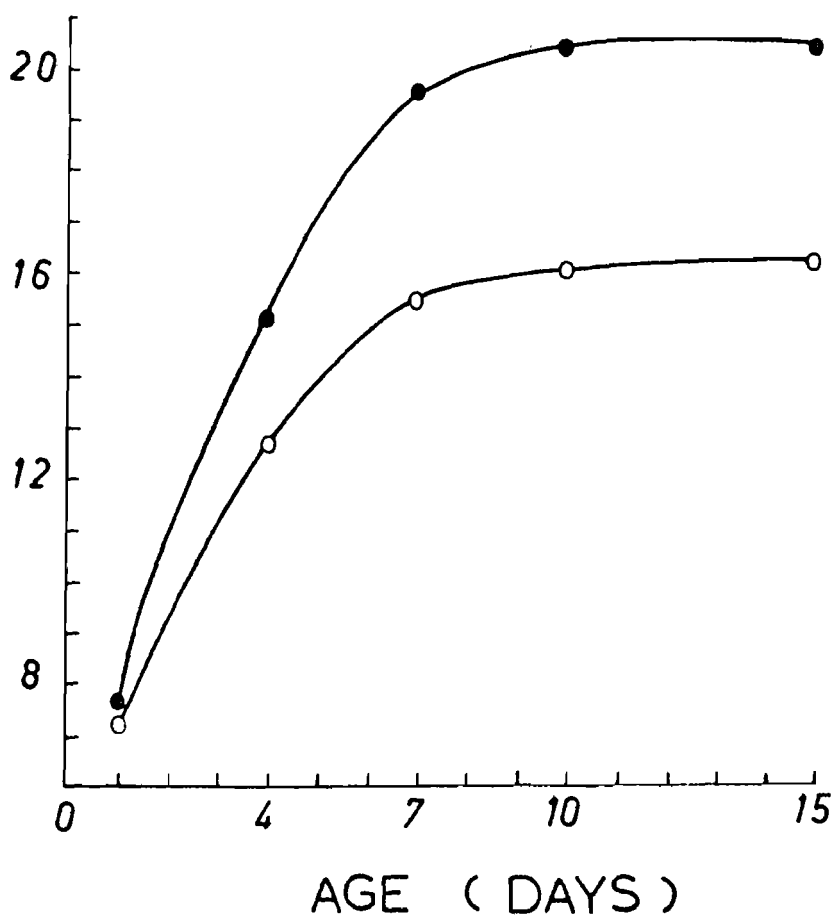
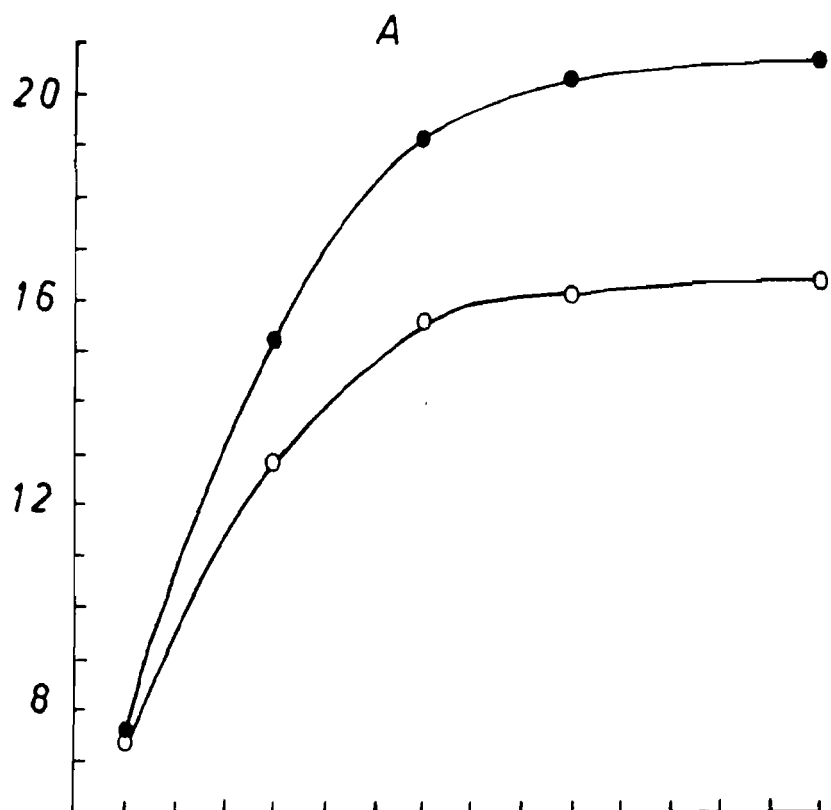
A. Male

B. Female

—○—○— Deformed

—●—●— Normal

CHITIN (%)



diflubenzuron and solvent treated hoppers are presented in Table-19 and Figure-18A. From the data it would be seen that the average percentage of chitin in the hind wings of the deformed adult males was  $7.34 \pm 0.32$  on 1st day,  $15.60 \pm 0.77$  on 7th day, and  $16.41 \pm 0.51$  on 15th day after moulting. The corresponding average percentage of chitin in the hind wings of the normal adult males was  $7.62 \pm 0.60$  on 1st day,  $19.12 \pm 0.95$  on 7th day and  $20.70 \pm 1.2$  on 15th day after moulting. From these results, it is apparent that the average percentage of chitin in the hind wings of the deformed adult males was significantly lower than that of the normal adults during the entire period of observation except on 1st day.

The data presented in Table-19 and Figure-18B, suggest that the average percentage of chitin in the hind wings of the deformed adult females obtained from diflubenzuron treated hoppers was  $7.20 \pm 0.33$  on 1st day. It increased to  $15.41 \pm 0.78$  by 7th day and  $16.16 \pm 1.01$  by 15th day after moulting. The corresponding average percentage of chitin in the hind wings of the normal adult females obtained from solvent treated hoppers was  $7.68 \pm 0.63$  on 1st day,  $19.53 \pm 0.43$  on 7th day and  $20.39 \pm 0.99$  on 15th day after moulting. These results also show that as in case of males, the percentage of chitin in the hind wings of the deformed adult females was significantly lower than that of normal insects during the entire period of observation except on 1st day.

Fig. 19. Chitin content in the fore and hind wings of deformed and normal adult S. gregaria

A. Male

B. Female

—○—○— Fore wings deformed

—●—●— Fore wings normal

..△..△.. Hind wings deformed

..△..△.. Hind wings normal

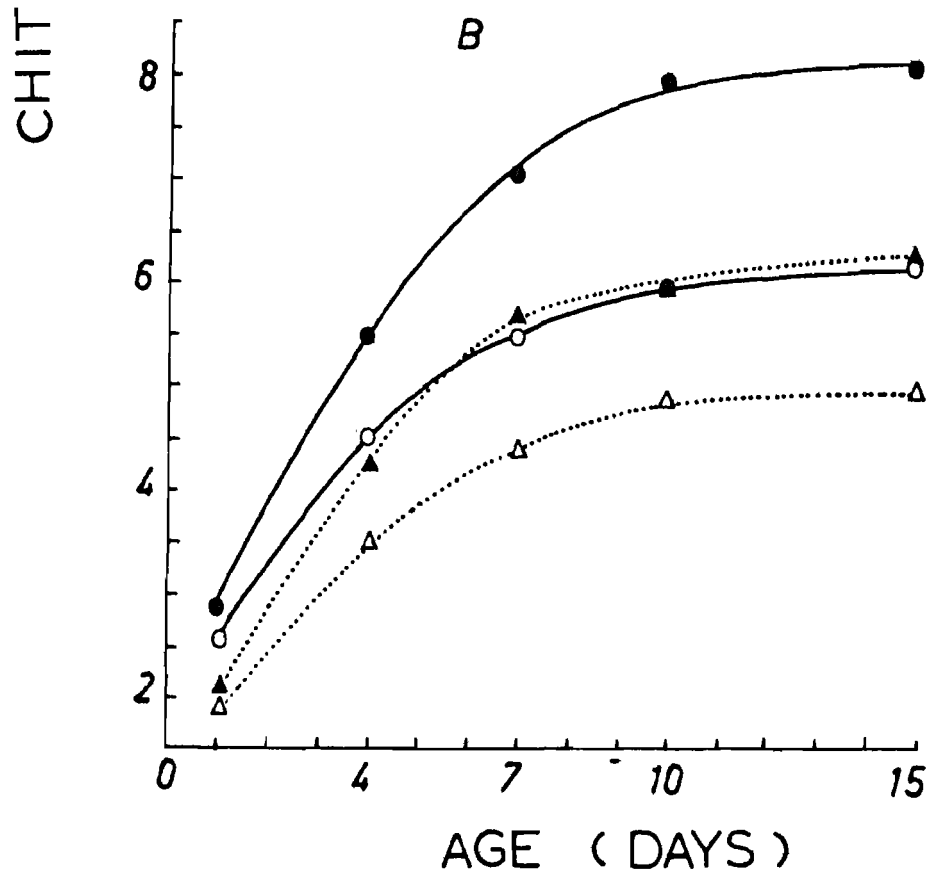
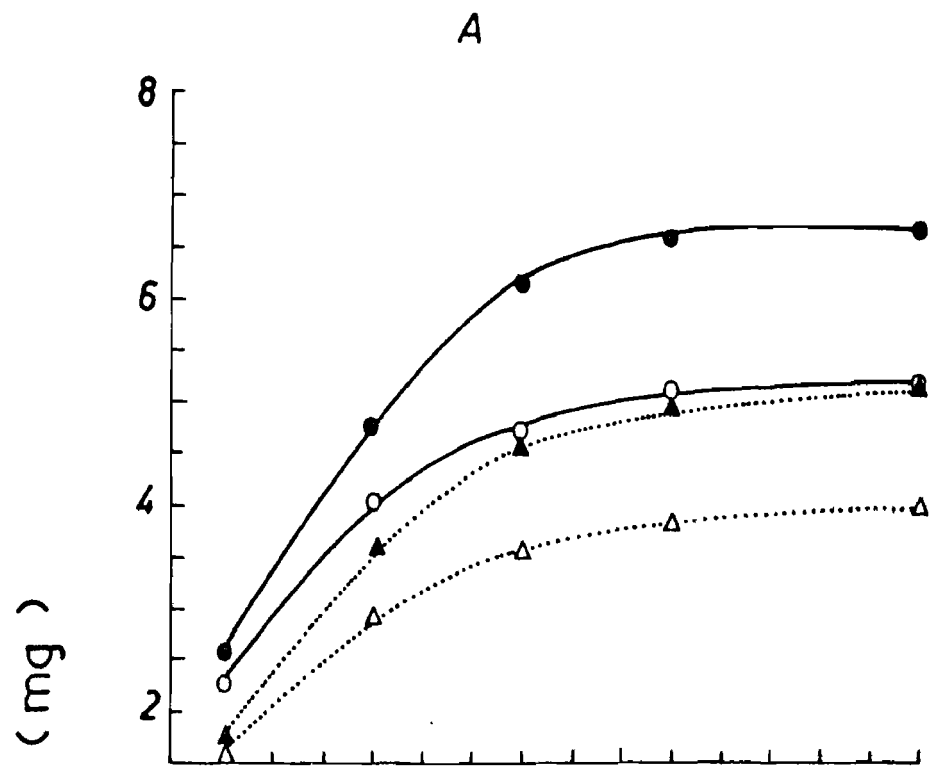


Fig.20. Percentage of chitin in the fore and hind wings of deformed and normal adult S. gregaria

A. Male

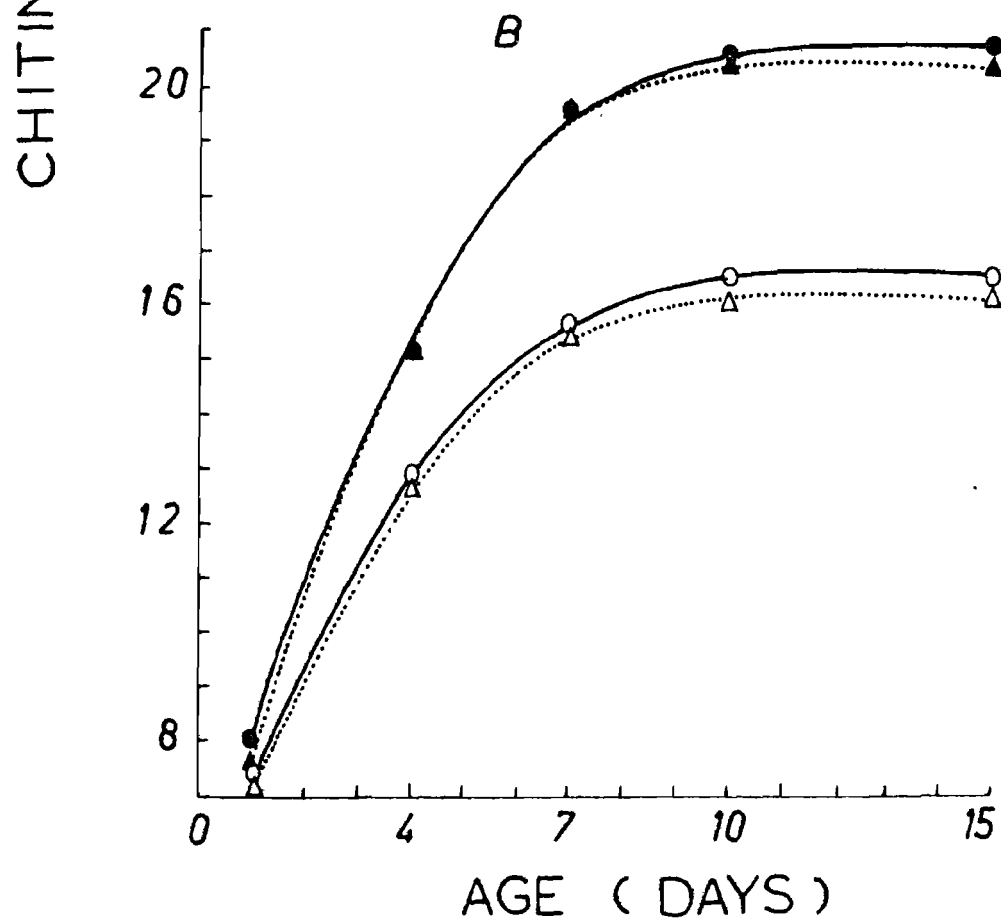
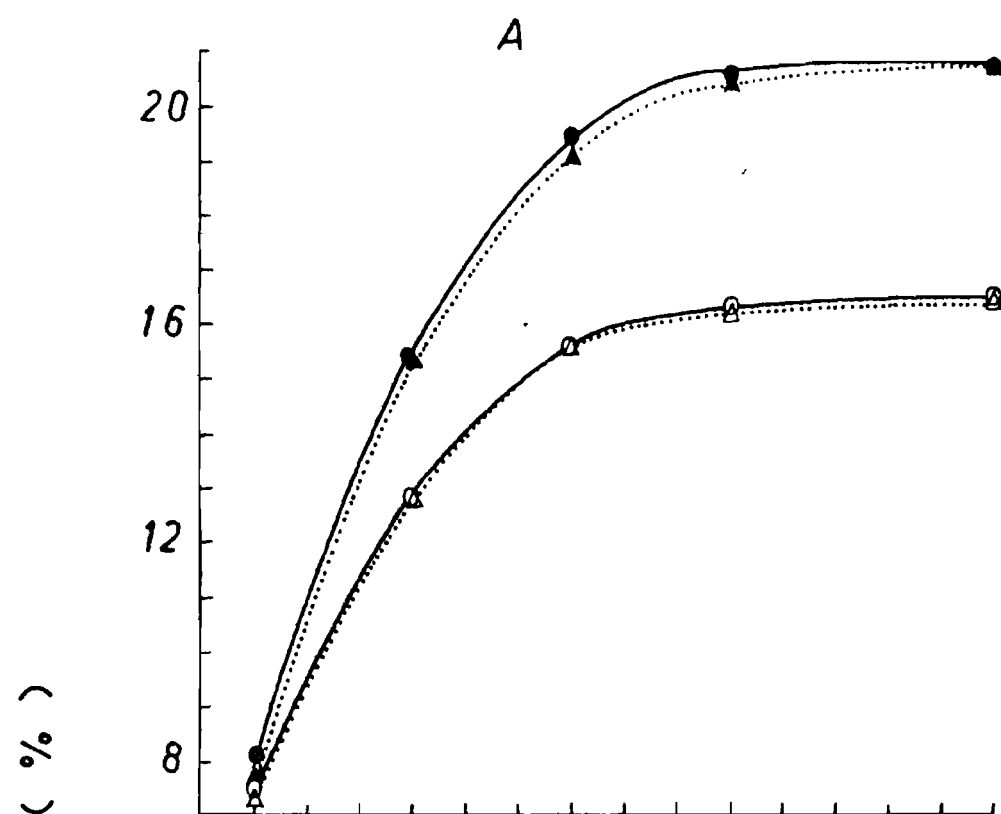
B. Female

—○—○— Fore wings deformed

—○—○— Fore wings normal

..△..△.. Hind wings deformed

..△..△.. Hind wings normal



The data presented on chitin content in the fore and hind wings individually, suggest that the fore wings contained higher chitin content than hind wings in both the deformed and normal adults (Figure-19). This was also true for both the sexes. It may however, be mentioned that percentage wise there was no difference in chitin in fore and hind wings, whether normal or deformed, and male or female (Figure-20). The pattern of chitin deposition based on the amount of chitin from the time after moult suggest that in both fore and hind wings the increase in chitin content is biphasic. A fast phase of increase from 1 to 7 days after moulting, during which the chitin content was more than doubled and a slow phase of increase, during which the increase was quite insignificant. Further percentagewise also the increase in chitin was found to be biphasic both in fore and hind wings.

## DISCUSSION

The present investigation mainly concerns with (a) the electrical properties of the insect cuticle and (b) the effect of diflubenzuron on the electrical properties. For the sake of brevity the discussion will deal first the electrical properties of the cuticle and then the effect of diflubenzuron on these properties.

### Electrical properties of the cuticle of *S. gregaria*

The basic electrical properties of any material are resistance, capacitance and dielectric constant. The biological systems are known to have another property known as potential difference, which is due to the difference in ionic concentrations between the two surfaces of the membranes.

### AC resistance of the cuticle of *S. gregaria*

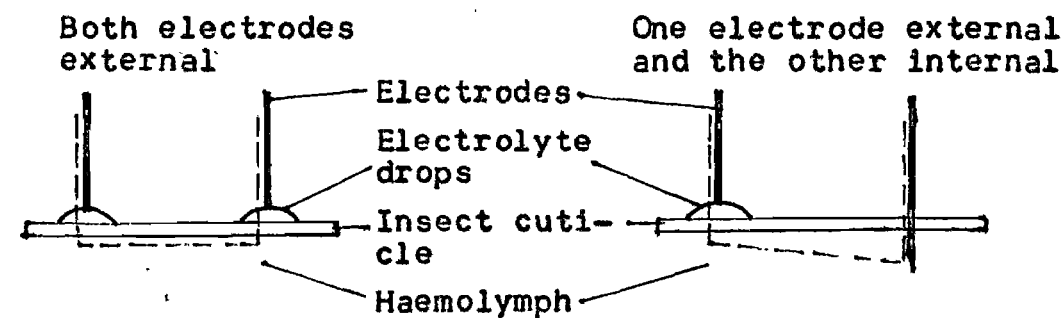
During the course of present investigations, it was observed that different areas of the cuticle of adult *S. gregaria* have different electrical resistances. This perhaps, was due to the differences in organisation of cuticle in different areas, particularly the exocuticle and endocuticle (Locke, 1974; and Neville, 1975).

Among the different areas of cuticle studied for electrical resistance, wings were found to have the

highest resistance; the resistance of wings was nearly 2-fold higher than that of pronotum or abdominal sternites. There was little difference between the electrical resistance of the pronotum and abdominal sternites. Indeed the difference in resistance at various areas of cuticle has been observed by Scheie and Smyth (1968). In the pronotum of P. americana The ratio of resistance of dark area/resistance of light area has been reported to be  $0.7 \pm 0.2$ . Since, no such light and dark areas are present on S. gregaria, such differences on pronotum were not seen. It may be interesting to note that the  $R_s$  of pronotum of adult S. gregaria was around  $25.5 \text{ K}\Omega\text{-cm}^2$ . Compared to this, Scheie and Smyth (1968) and Richards (1957) obtained higher values of resistance on pronotum of P. americana and isolated cuticle of Sarcophaga larvae respectively. Since the resistance of cuticle differs at various areas for the same sclerite (Scheie and Smyth, 1968), it is still more likely that the electrical resistance of cuticle can vary from one insect species to another. Scheie and Smyth (1967) however, reported a lower resistance on the excised cuticle of adult P. americana. The difference in resistance of the pronotum of P. americana was due to the different methods of preparation of the cuticle. These differences also suggest that one or the other layer of the cuticle was damaged during preparation. Since it is known that ionic permeability of the cuticle is closely related to the

electrical resistance (Scheie and Smyth, 1968), these differences must have been due to the abrasion of cuticle. Indeed it has been shown that the abrasion of the cuticle of S. gregaria increases its permeability to various electrolyte and non-electrolytes (Treherne, 1957; and Tuli and Mehrotra, 1980). Scheie and Smyth (1968) have also reported that external abrasion resulted in a reduction of cuticle resistance by a factor of 2, and internal abrasion by a factor of 3 in P. americana.

The fact that the electrical resistance of the cuticle is directly related to the permeability of the cuticle to ions can further be seen from the observation that, unlike in other conductors and semiconductors, there are no transverse paths of current in the plane of the cuticle. In other words, when the resistance is measured between two external electrolyte drops on the cuticle, the current has to pass all the way from one electrolyte drop to the haemolymph and from haemolymph to the other electrolyte drop. This fact was also amply proved during the present investigations, wherein it was shown that the resistance when measured between one of the external electrolyte drop and haemolymph was exactly half of that when measured between the two external electrolyte drops.



Path of the current in the cuticle.

Since the  $R_s \left( \frac{V}{I} \times \frac{A}{2} \right)$  between two external electrolyte drops and the  $R_s \left( \frac{V}{I} \times A \right)$  between one of the external electrolyte drop and haemolymph did not differ from one another, the area of the electrolyte being common in both the cases, the factor of '2' which is used as a denominator suggests that the resistance between one of the external electrolyte drop and haemolymph (single thickness of cuticle) was half of the resistance between the two electrolyte drops (two thicknesses of the cuticle). Had there been any transverse paths of current in the plane of the cuticle, the ratio would certainly change. In addition, this fact also provides justification for using only external contacts for determining integument resistance on live insects over a period of time. Besides, the experiments on the effect of distance between the two points of measurement on the cuticle resistance, also show, that the distance has no effect on the resistance of the cuticle. The  $R_s$  across 2-3 and 2-6 abdominal sternites was nearly the same, despite the fact that the distance between the two electrolyte drops was more than 3 times, when the resistance was measured between 2-6 sternites than that of between 2-3 sternites. This also points out the absence of any detectable low resistance paths in the plane of the cuticle external to haemolymph. Further, since haemolymph is rich in ions it offers negligible resistance to current and hence the distance between the two electrodes have a little effect on the overall resistance of the cuticle, in the absence

of transverse paths of current in the plane of the cuticle. All the above facts lead to the conclusion that permeability of insect integument to ions in solution could be associated in a direct manner with the electric conduction through the integument as suggested by Scheie and Smyth (1968).

The observations on the  $R_s$  of pronotum and fore wings of adult S. gregaria from time of moult suggest that the resistance of the cuticle was at its minimum immediately after moulting. It gradually increases and gets stabilised around 8-10 days after moulting. The resistance just after moulting was  $7 \text{ K}\Omega\text{-cm}^2$  on pronotum and  $8 \text{ K}\Omega\text{-cm}^2$  on fore wings. The resistance on pronotum was the same as observed by Scheie and Smyth (1968) on the pronotum of P. americana just after moulting. It is also interesting to note that the resistance on the pronotum of P. americana was found to increase continuously even after 20 days after moulting (Scheie and Smyth, 1968), while in S. gregaria it gets stabilized around 8-10 days after moulting. This fact also leads to the suggestion that besides having direct relation with the ion permeability of the cuticle, the resistance of the cuticle also changes during various phases of formation of new cuticle after moulting, and hardening process.

Another fact, is that repeated observations on the same insect over a period of time had no effect on the resistance of the cuticle. In other words repeated measurements for electrical resistance do not cause any injury

or damage to the cuticle. In fact, Scheie and Smyth (1968) have earlier observed that repeated measurements of resistance on the pronotum of P. americana over a period of time do not cause any damage to the cuticle. The increase in resistance of cuticle on pronotum or on forewings, was found to be biphasic. A fast phase of increase in resistance upto 6th day from immediately after moulting and a very slow phase of increase from 6th day onwards after moulting. If this is correlated with the chitin content of the wings at various times after moulting a very good correlation between these two is seen. The chitin content in the wings increased from the time after moulting to around 8-10 days, at which it gets stabilized. The increase in chitin content after moulting is also a biphasic one. A fast phase of increase upto 6th day from the time after moulting and a very slow phase of increase from 6th day onwards after moulting.

Potential difference between the two surfaces of the pronotum of *S. gregaria*

Biological membranes are known to maintain potential difference between the two surfaces of membranes due to the difference in ionic concentrations (Enyikwola and Burton, 1983). Since the permeability of the cuticle of insects is said to be asymmetric (Hurst, 1941, and 1948; and Beament, 1945; and 1948), it was argued that there is every possibility of having some potential difference between the two surfaces of insect cuticle leading to the selective permeability of the cuticle. During the present

investigation a potential difference of about 7-8 mV between the two sides of pronotum was consistently recorded irrespective of the age of S. gregaria, the outside being positive. This was true for both the sexes. Although the potential difference recorded was insignificant due to the very low values, nevertheless, it exists. The findings of Scheie and Smyth (1967) suggest no detectable potential difference between the outer and inner surfaces of the excised pronotum of P. americana when both sides are perfused with the same strength of the same electrolyte. However, Beament (1961b) earlier reported a potential difference of the magnitude of 200 mV between the outer and inner surfaces of the pronotum of P. americana. Scheie and Smyth (1967) questioned the findings of Beament (1961) but suggested that a potential difference however, exists between the two sides of the pronotum of P. americana when two different concentrations of the same electrolyte was placed in contact with the two surfaces.

#### Capacitance and dielectric constant of the cuticle of S. gregaria

Capacitance is another property which is the function of dielectric constant of the material. Insect cuticle with chitin, and proteins as major constituents (Neville, 1975), is a dielectric material. During the present investigations it was observed that unlike resistance, the capacitance of the cuticle of S. gregaria gradually decreased from time after moult. The decrease in capacitance of the abdominal

sternites of S. gregaria was found to be biphasic, despite the fact that it gradually increased from time after moult to 15th day. A fast phase of decrease from immediately after moulting to 6th day after moulting and a slow phase of decrease from 6th day onwards after moulting. In fact the decrease in capacitance from time after moult was observed earlier by Schiele and Smyth (1967), who had shown a change in capacitance from  $0.045 \pm 0.001 \mu\text{F}/\text{cm}^2$  for freshly moulted cuticle to  $0.005 \pm 0.003 \mu\text{F}/\text{cm}^2$  for cuticle excised two weeks later in P. americana. If the chitin deposition in wings as reflected by the amount of chitin, which might be similar in abdominal sternites, is compared with the capacitance of the cuticle from time after moulting, it amply brings out the fact that with the increase in chitin contents in the cuticle, there was a decrease in capacitance of the cuticle. This suggest that the capacitance of the cuticle is inversely correlated with the chitin contents of the cuticle. Since dielectric constant is a function of capacitance and is directly proportional to the capacitance, it is also inversely related to the chitin content of the cuticle.

Effect of diflubenzuron on the electrical properties of the cuticle of S. gregaria

Diflubenzuron and other benzophenyl urea compounds are characterised by the fact that these compounds are selective to phylum arthropoda. This selectivity is supposed to be due to the presence of chitin in their

cuticle or exoskeleton (Richards, 1951). Diflubenzuron is also characterised by the fact that in the treated insects, the toxicity is manifested quite late. In the present study when diflubenzuron was injected into 2-3 day old 5th instar hoppers, no apparent adverse affects were seen immediately after treatment. The toxicity to hoppers was observed only at the time of moulting i.e., 6 to 7 days after treatment. The abnormalities seen during moulting resembled as if the hormonal system has been disturbed-especially the treatment gave a characteristic hyper juvenile hormonal condition. Indeed this type of juveno-mimetic affects have also been observed in other insects (Retnakaran and Smith, 1975; Sundarmurthy, 1977; Retnakaran et al., 1980; and Lim and Lee, 1982). Further support to the contention that diflubenzuron might be affecting hormonal system can be seen from the work of Mariy et al. (1981), who showed that the 5th instar hoppers of S. gregaria were susceptible to the action of diflubenzuron as seen at the time of moulting, only when the insects were treated during the early stages of development i.e., upto the age of 5 days after moulting, older insects when treated did not show any affect. The findings of Mariy et al. (1981) are reminiscent of the age dependance effect of both juvenile hormone as well as ecdysone (Wigglesworth, 1972). The  $ED_{50}$  value of diflubenzuron obtained during the present investigations by injection was higher than that observed by Mariy et al. (1981) by topical application to the 5th instar hoppers of S. gregaria.

It perhaps was due to the different modes of application. Indeed Lim and Lee (1982) observed that diflubenzuron was more effective to the 5th instar hoppers of Oxya japonica when applied topically than when injected.

The diflubenzuron treatment to 5th instar S. gregaria showed the following effects. (a) The chitin content in the wings, both fore and hind wings was reduced significantly, from 2 or 3 days after moulting. Besides reduction in chitin the insects also showed deformity in the wings. Although it must be stated that the pattern of the increase in chitin concentration in a wing was nearly similar in abnormal and normal insects, the amount of chitin was considerably reduced in the abnormal insects. The fact that diflubenzuron treatment results in the reduction of chitin content in cuticle has been reported by various workers (Ker, 1977; Grosscurt, 1978b; Saxena and Kumar, 1981a, Mitsui et al., 1984). Another important fact was that the reduction in chitin content in the wings of deformed adults gradually increased as the age of the adults advanced after moulting. Indeed Saxena and Kumar (1981a) observed that the reduction in chitin content increased as the age of adults advanced due to diflubenzuron treatment in Chrotogonus. (b) Diflubenzuron was found to have no effect on the potential difference between the outer and inner surfaces of the excised pronotum. Since potential difference across membranes is related to relative ionic concentrations and diflubenzuron is not known to effect the ion concentration of haemolymph, it may not have any

effect on the potential difference across the cuticle.

(c) Besides its effect on chitin, diflubenzuron treatment decreased the resistance in the wings, pronotum and abdominal sternites of the treated insects. The decrease in resistance was highest in wings and also was significant in pronotum. In both the cases the reduction in the electrical resistance of the cuticle due to the diflubenzuron treatment increased as the age of adults advanced after moulting. In case of abdominal sternites the resistance was not significantly different but was certainly reduced. It can be stated that it is likely that diflubenzuron specifically effects both wings and thoracic region but in abdominal sternites the affects are not so marked, so as to manifest a distinct effect on them. Since there appears to be a very good correlation between the amount of chitin present in the wings and the resistance of wings it is likely that the reduction in the resistance of wings as well as pronotum was because of the reduction in chitin contents. It is also likely that besides chitin, proteins might also be contributing significantly towards imparting resistance in the abdominal sternites. As diflubenzuron does not affect protein contents of cuticle (Hunter and Vincent, 1974; and Ker, 1977), the resistance of the abdominal sternites was thus not significantly affected.

Besides affecting resistance diflubenzuron treatment also led to increased capacitance in the abdominal sternites of adult S. gregaria. The significant increase in capacitance of the abdominal sternites again suggest that

diflubenzuron, besides affecting chitin deposition, also effects some other component which is principally responsible for the capacitance of the abdominal sternites. This may be due to the ratio of chitin/protein or the protein itself. Since dielectric constant is a function of capacitance and is calculated from the observed capacitance similar effects of diflubenzuron were obtained on dielectric constant of the cuticle. Further work is needed to elucidate the reason for increase in capacitance and dielectric constant of the abdominal sternites in the diflubenzuron treated insects.

There are no reports available on the affects of diflubenzuron on the electrical properties of insect cuticle

The decrease in chitin contents of the cuticle of wings may be due to the reported inhibition of chitin synthesis in insects treated with diflubenzuron (Sowa and Marks, 1973; Deul et al., 1978; Mitsui et al., 1981, and 1984). However, it may also be mentioned that the exact cause of inhibition of chitin synthesis is as yet not known. Biochemically the evidences have been presented to show on one hand that the enzyme chitin synthetase was inhibited as a result of diflubenzuron treatment (Leighton and Marks, 1981) and on the other hand it has also been claimed that chitin synthetase is not inhibited (Cohen and Cassida, 1980, and 1982; and Mayer et al., 1980 and 1981). The delayed action certainly suggest that diflubenzuron must be affecting some basic mechanisms which regulate the growth and

development in insects including moulting. Whether the effects of diflubenzuron are at the neuroendocrine system or at a primary genetic mechanism is as yet not known and must await further research.

In conclusion it may be stated that the main aim of the present investigations was to study the electrical properties of the cuticle of S. gregaria and to see the effects of diflubenzuron on these properties of the cuticle. Our results very clearly show that the insect cuticle offers significant resistance to electrical current and that the resistance increases with age after moulting. The results could be interpreted to suggest that the biophysical organisation of the cuticle is completed only after 6th day after moulting in adult desert locust. Capacitance on the abdominal sternites also confirm these findings. Diflubenzuron not only effect resistance, but also the capacitance, as well as the chitin contents of the cuticle. Exact cause of the electrical as well as biochemical changes as seen in chitin contents are not known. Further work is needed to elucidate the primary mode of action of diflubenzuron and the exact cause for the electrical and biochemical changes in the cuticle associated with its treatment.

## SUMMARY

Investigations were undertaken to study the electrical properties of the cuticle of Schistocerca gregaria Forskal and the effect of diflubenzuron on the electrical properties of the cuticle. The results obtained can be summarised as follows:-

1. The electrical resistance of the cuticle of S.gregaria was found to vary at different areas of the cuticle. The resistance of the cuticle was found to be slightly higher in mature adult females than that of mature adult males. The wings offered the highest resistance followed by pronotum. The resistance of the cuticle was lowest across abdominal sternites.
2. The resistance between one of the external electrolyte drop and haemolymph was half of the resistance between the two external electrolyte drops, due to the absence of transverse paths of current in the plane of the cuticle.
3. The distance between two electrolyte drops on the surface of cuticle had no affect on the overall resistance of abdominal sternites. This supports the contention that when the resistance was measured between two external electrolyte drops, the current has to pass from one electrolyte drop to the haemolymph and from haemolymph to the other electrolyte drop and under such situation two thicknesses of cuticle offering resistance come in the way of current.

4. The resistance of the cuticle gradually increased in adult S. gregaria from time after moulting. The increase in resistance was biphasic; a fast phase of increase upto 6th day after moulting and a slow phase of increase from 6th day after moulting. The increase in resistance of the cuticle after moulting got stabilised around 8-10 days.

5. Repeated measurements for the resistance of the cuticle with the same insect did not cause any damage to the cuticle.

6. Diflubenzuron was not acutely toxic to the 5th instar hoppers of S. gregaria. The affects manifested during moulting, i.e. 6 to 7 days after treatment suggesting a delayed action by diflubenzuron. Treatment of diflubenzuron to 2-3 day old 5th instar hoppers resulted in death of the treated insects during moulting or development of deformed adults.

7. The  $ED_{50}$  of diflubenzuron to 5th instar hoppers of S. gregaria was 1.30  $\mu\text{g}/\text{nymph}$  (range 1.021 to 1.60  $\mu\text{g}/\text{nymph}$ ).

8. Diflubenzuron treatment resulted in a significant reduction of cuticle resistance on pronotum, excised pronotum, fore wings and hind wings. The electrical resistance of abdominal sternites of the deformed adults obtained from diflubenzuron treated hoppers was not significantly different from that of normal adults.

9. Diflubenzuron treatment did not influence the potential difference between the outer and inner surfaces of the excised pronotum. Potential difference across the excised pronotum of the normal adults did not change with the age of adult after moulting.

10.     Diflubenzuron treatment significantly increased the capacitance and dielectric constant of the cuticle in the treated insects: Capacitance and dielectric constants of the cuticle of abdominal sternites was found to decrease with the advance in the age of the adult after moulting. The cuticle of the adult females was found to have higher capacitance and dielectric constant than that of adult males.

11     Diflubenzuron treatment resulted in significant reduction in the chitin content of both the fore and hind wings of the treated adults. Although in terms of absolute chitin content females had higher chitin in the wings than that of males, and fore wings had higher chitin than that of hind wings, percentage-wise it was same in both the sexes as well as in fore wings and hind wings.

12.     The electrical resistance of the wings and chitin content of the wings were found to have direct correlation with one another due to the fact that the trend in increase of chitin content and electrical resistance of the wings was same from time after moulting.

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\* Original not seen.

# Appendix-I

AC Resistance on pronotum of mature adult male S. gregaria

| S. No. | Both electrodes on outer surface           |                                |                                            |                                | One electrode on outer surface and the other in haemolymph |
|--------|--------------------------------------------|--------------------------------|--------------------------------------------|--------------------------------|------------------------------------------------------------|
|        | With smaller electrolyte drops (5 $\mu$ l) | Specific Resistance            | With larger electrolyte drops (10 $\mu$ l) | Specific Resistance            |                                                            |
|        | Resistance (K $\Omega$ )                   | (K $\Omega$ -cm <sup>2</sup> ) | Resistance (K $\Omega$ )                   | (K $\Omega$ -cm <sup>2</sup> ) | Specific Resistance (K $\Omega$ -cm <sup>2</sup> )         |
| 1      | 687.7                                      | 28.78                          | 473.9                                      | 28.56                          | 27.92                                                      |
| 2      | 520.2                                      | 24.01                          | 416.9                                      | 25.13                          | 24.48                                                      |
| 3      | 481.0                                      | 23.27                          | 352.7                                      | 22.15                          | 23.27                                                      |
| 4      | 634.2                                      | 26.54                          | 481.0                                      | 26.63                          | 25.64                                                      |
| 5      | 737.6                                      | 27.86                          | 513.1                                      | 28.40                          | 27.61                                                      |
| 6      | 644.9                                      | 25.66                          | 481.0                                      | 27.80                          | 26.77                                                      |
| 7      | 680.5                                      | 28.49                          | 481.0                                      | 27.80                          | 26.77                                                      |
| 8      | 584.4                                      | 24.46                          | 416.9                                      | 25.13                          | 25.13                                                      |
| 9      | 641.4                                      | 26.84                          | 481.0                                      | 27.80                          | 26.77                                                      |
| 10     | 602.2                                      | 26.48                          | 411.5                                      | 25.85                          | 25.51                                                      |
| 11     | 584.4                                      | 24.46                          | 416.9                                      | 24.09                          | 23.47                                                      |
| 12     | 680.5                                      | 28.49                          | 481.0                                      | 28.99                          | 27.92                                                      |
| 13     | 595.1                                      | 24.90                          | 416.9                                      | 26.18                          | 26.18                                                      |
| 14     | 559.4                                      | 25.82                          | 427.6                                      | 25.77                          | 25.13                                                      |
| 15     | 520.2                                      | 21.78                          | 416.9                                      | 22.08                          | 22.08                                                      |
| 16     | 513.1                                      | 21.48                          | 352.7                                      | 21.26                          | 22.33                                                      |
| Av.    | 604.2                                      | 25.58                          | 438.8                                      | 25.85                          | 25.44                                                      |
| SD     | 73.4                                       | 2.28                           | 47.4                                       | 2.44                           | 1.89                                                       |

Contact area of smaller electrolyte drop (5  $\mu$ l) =  $4.25 \pm 0.25$  mm<sup>2</sup>

Contact area of larger electrolyte drop (10  $\mu$ l) =  $5.91 \pm 0.29$  mm<sup>2</sup>

Appendix-II

AC Resistance on pronotum of mature adult female S. gregaria

| S. No. | Both electrodes on outer surface           |                                                       |                                            |                                                       | One electrode on outer surface and the other in haemolymph-Specific resistance<br>(K $\Omega$ -cm <sup>2</sup> ) |
|--------|--------------------------------------------|-------------------------------------------------------|--------------------------------------------|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
|        | With smaller electrolyte drops (5 $\mu$ l) |                                                       | With larger electrolyte drops (10 $\mu$ l) |                                                       |                                                                                                                  |
|        | Resistance<br>(K $\Omega$ )                | Specific Resistance<br>(K $\Omega$ -cm <sup>2</sup> ) | Resistance<br>(K $\Omega$ )                | Specific Resistance<br>(K $\Omega$ -cm <sup>2</sup> ) |                                                                                                                  |
| 1      | 680.5                                      | 25.71                                                 | 481.0                                      | 25.48                                                 | 24.44                                                                                                            |
| 2      | 520.2                                      | 21.78                                                 | 352.7                                      | 21.26                                                 | 22.33                                                                                                            |
| 3      | 680.5                                      | 27.08                                                 | 481.0                                      | 27.80                                                 | 26.77                                                                                                            |
| 4      | 559.4                                      | 24.60                                                 | 416.9                                      | 25.13                                                 | 24.48                                                                                                            |
| 5      | 584.4                                      | 25.69                                                 | 456.1                                      | 27.49                                                 | 27.92                                                                                                            |
| 6      | 801.7                                      | 28.71                                                 | 520.2                                      | 28.79                                                 | 27.61                                                                                                            |
| 7      | 577.2                                      | 24.16                                                 | 448.9                                      | 24.85                                                 | 25.64                                                                                                            |
| 8      | 602.2                                      | 27.79                                                 | 448.9                                      | 28.20                                                 | 29.09                                                                                                            |
| 9      | 584.4                                      | 24.46                                                 | 456.1                                      | 26.35                                                 | 26.77                                                                                                            |
| 10     | 680.5                                      | 25.71                                                 | 481.0                                      | 25.48                                                 | 24.44                                                                                                            |
| 11     | 509.5                                      | 23.51                                                 | 334.9                                      | 21.90                                                 | 21.90                                                                                                            |
| 12     | 648.5                                      | 28.51                                                 | 481.0                                      | 28.99                                                 | 27.92                                                                                                            |
| 13     | 673.4                                      | 26.79                                                 | 513.1                                      | 27.18                                                 | 26.42                                                                                                            |
| 14     | 673.4                                      | 28.19                                                 | 538.0                                      | 28.50                                                 | 28.31                                                                                                            |
| 15     | 680.5                                      | 28.49                                                 | 513.1                                      | 28.40                                                 | 27.61                                                                                                            |
| 16     | 513.1                                      | 21.48                                                 | 409.7                                      | 23.68                                                 | 23.47                                                                                                            |
| Av.    | 623.1                                      | 25.79                                                 | 458.3                                      | 26.22                                                 | 25.95                                                                                                            |
| SD     | 80.0                                       | 2.33                                                  | 57.1                                       | 2.41                                                  | 2.20                                                                                                             |

Contact area of smaller electrolyte drop (5  $\mu$ l) =  $4.16 \pm 0.29$  mm<sup>2</sup>

Contact area of larger electrolyte drop (10  $\mu$ l) =  $5.75 \pm 0.33$  mm<sup>2</sup>

# Appendix-III

AC Resistance on forewings of mature adult male S. gregaria

| S.<br>No. | Both electrodes on outer surface                                               |                                                          |                                                                                |                                                          | One electrode<br>on outer sur-<br>face and the<br>other in hae-<br>molymp-Spe-<br>cific resis-<br>tance<br>(K $\Omega$ -cm <sup>2</sup> ) |
|-----------|--------------------------------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
|           | With smaller electro-<br>lyte drops (5 $\mu$ l)<br>Resistance<br>(K $\Omega$ ) | Specific<br>Resistance<br>(K $\Omega$ -cm <sup>2</sup> ) | With larger electro-<br>lyte drops (10 $\mu$ l)<br>Resistance<br>(K $\Omega$ ) | Specific<br>Resistance<br>(K $\Omega$ -cm <sup>2</sup> ) |                                                                                                                                           |
| 1         | 1122.00                                                                        | 46.97                                                    | 780.00                                                                         | 46.98                                                    | 47.25                                                                                                                                     |
| 2         | 1032.00                                                                        | 45.30                                                    | 860.00                                                                         | 45.53                                                    | 46.91                                                                                                                                     |
| 3         | 980.00                                                                         | 45.21                                                    | 802.00                                                                         | 46.33                                                    | 45.30                                                                                                                                     |
| 4         | 993.00                                                                         | 45.83                                                    | 681.00                                                                         | 44.56                                                    | 43.69                                                                                                                                     |
| 5         | 1073.00                                                                        | 44.93                                                    | 851.00                                                                         | 47.09                                                    | 44.87                                                                                                                                     |
| 6         | 931.00                                                                         | 42.95                                                    | 722.00                                                                         | 43.49                                                    | 43.49                                                                                                                                     |
| 7         | 1243.00                                                                        | 49.44                                                    | 953.00                                                                         | 50.49                                                    | 50.02                                                                                                                                     |
| 8         | 882.00                                                                         | 40.69                                                    | 722.00                                                                         | 43.49                                                    | 43.49                                                                                                                                     |
| 9         | 922.00                                                                         | 42.54                                                    | 722.00                                                                         | 43.49                                                    | 44.87                                                                                                                                     |
| 10        | 1122.00                                                                        | 42.39                                                    | 851.00                                                                         | 45.06                                                    | 46.71                                                                                                                                     |
| 11        | 1105.00                                                                        | 48.57                                                    | 802.00                                                                         | 48.32                                                    | 47.25                                                                                                                                     |
| 12        | 1060.00                                                                        | 44.37                                                    | 802.00                                                                         | 46.33                                                    | 45.30                                                                                                                                     |
| 13        | 1122.00                                                                        | 49.35                                                    | 851.00                                                                         | 47.09                                                    | 44.87                                                                                                                                     |
| 14        | 1122.00                                                                        | 46.97                                                    | 793.00                                                                         | 43.88                                                    | 43.39                                                                                                                                     |
| 15        | 1113.00                                                                        | 46.60                                                    | 793.00                                                                         | 45.81                                                    | 45.30                                                                                                                                     |
| 16        | 980.00                                                                         | 41.01                                                    | 771.00                                                                         | 42.65                                                    | 40.92                                                                                                                                     |
| Av.       | 1053.00                                                                        | 45.20                                                    | 797.00                                                                         | 45.66                                                    | 45.23                                                                                                                                     |
| SD        | 96.00                                                                          | 2.76                                                     | 68.00                                                                          | 2.08                                                     | 2.11                                                                                                                                      |

Contact area of smaller electrolyte drop (5  $\mu$ l) =  $4.31 \pm 0.26$  mm<sup>2</sup>

Contact area of larger electrolyte drop (10  $\mu$ l) =  $5.75 \pm 0.35$  mm<sup>2</sup>

# Appendix-IV

AC Resistance on forewings of mature adult female S.gregaria

| S. No. | Both electrodes on the outer surface       |                                |                                            |                                                    | One electrode on outer surface and the other in haemolymph-Specific resistance |
|--------|--------------------------------------------|--------------------------------|--------------------------------------------|----------------------------------------------------|--------------------------------------------------------------------------------|
|        | With smaller electrolyte drops (5 $\mu$ l) | Specific Resistance            | With larger electrolyte drops (10 $\mu$ l) | Specific Resistance                                |                                                                                |
|        | Resistance (K $\Omega$ )                   | (K $\Omega$ -cm <sup>2</sup> ) | Resistance (K $\Omega$ )                   | Specific Resistance (K $\Omega$ -cm <sup>2</sup> ) | (K $\Omega$ -cm <sup>2</sup> )                                                 |
| 1      | 1122.00                                    | 46.97                          | 882.00                                     | 48.81                                              | 48.81                                                                          |
| 2      | 1073.00                                    | 47.20                          | 793.00                                     | 47.78                                              | 47.25                                                                          |
| 3      | 1212.00                                    | 45.76                          | 851.00                                     | 43.08                                              | 43.75                                                                          |
| 4      | 1131.00                                    | 47.35                          | 802.00                                     | 48.32                                              | 47.25                                                                          |
| 5      | 1042.00                                    | 48.09                          | 851.00                                     | 49.16                                              | 48.64                                                                          |
| 6      | 1212.00                                    | 43.38                          | 860.00                                     | 41.58                                              | 42.65                                                                          |
| 7      | 1011.00                                    | 46.65                          | 802.00                                     | 48.32                                              | 47.25                                                                          |
| 8      | 953.00                                     | 43.98                          | 731.00                                     | 44.03                                              | 44.56                                                                          |
| 9      | 1122.00                                    | 46.97                          | 753.00                                     | 47.27                                              | 46.44                                                                          |
| 10     | 1002.00                                    | 41.94                          | 722.00                                     | 43.49                                              | 43.49                                                                          |
| 11     | 1042.00                                    | 43.62                          | 753.00                                     | 45.37                                              | 44.56                                                                          |
| 12     | 1011.00                                    | 46.65                          | 780.00                                     | 46.98                                              | 44.56                                                                          |
| 13     | 1265.00                                    | 47.78                          | 882.00                                     | 46.71                                              | 46.71                                                                          |
| 14     | 1033.00                                    | 47.68                          | 802.00                                     | 46.33                                              | 45.30                                                                          |
| 15     | 1131.00                                    | 49.74                          | 802.00                                     | 46.33                                              | 45.30                                                                          |
| 16     | 922.00                                     | 38.59                          | 771.00                                     | 40.81                                              | 41.20                                                                          |
| Av.    | 1080.00                                    | 45.77                          | 802.00                                     | 45.90                                              | 45.48                                                                          |
| SD     | 96.00                                      | 2.80                           | 51.0                                       | 2.59                                               | 2.14                                                                           |

Contact area of smaller electrolyte drop (5  $\mu$ l)=4.26 $\pm$ 0.33 mm<sup>2</sup>

Contact area of larger electrolyte drop (10  $\mu$ l)=5.74 $\pm$ 0.41 mm<sup>2</sup>

# Appendix-V

Specific resistance ( $R_s$ ) across abdominal sternites of  
mature adult male S. gregaria  
( $K \Omega\text{-cm}^2$ )

| S.<br>No. | AC resistance across the sternites |       |       |       |
|-----------|------------------------------------|-------|-------|-------|
|           | 2-3                                | 2-4   | 2-5   | 2-6   |
| 1         | 20.13                              | 21.48 | 21.78 | 21.78 |
| 2         | 24.16                              | 24.16 | 25.50 | 25.20 |
| 3         | 21.15                              | 21.15 | 20.84 | 20.05 |
| 4         | 21.69                              | 21.69 | 21.69 | 20.70 |
| 5         | 21.78                              | 24.16 | 22.07 | 22.52 |
| 6         | 21.80                              | 22.07 | 21.80 | 21.80 |
| 7         | 22.07                              | 21.80 | 22.07 | 21.80 |
| 8         | 20.05                              | 22.56 | 20.84 | 22.87 |
| 9         | 23.31                              | 23.92 | 23.31 | 23.07 |
| 10        | 21.78                              | 21.48 | 21.78 | 22.52 |
| 11        | 24.23                              | 24.23 | 24.50 | 24.50 |
| 12        | 21.69                              | 21.69 | 20.70 | 21.41 |
| 13        | 24.50                              | 22.75 | 24.50 | 24.23 |
| 14        | 23.96                              | 24.23 | 23.29 | 23.96 |
| 15        | 24.46                              | 24.16 | 24.46 | 24.90 |
| 16        | 24.16                              | 23.86 | 23.71 | 24.16 |
| Av.       | 22.56                              | 22.84 | 22.68 | 22.84 |
| SD        | 1.54                               | 1.22  | 1.51  | 1.54  |

# Appendix-VI

R<sub>s</sub> across abdominal sternites of mature adult female

S. gregaria

(K  $\Omega$ -cm<sup>2</sup>)

| S.<br>No. | AC resistance across the sternites |       |       |       |
|-----------|------------------------------------|-------|-------|-------|
|           | 2-3                                | 2-4   | 2-5   | 2-6   |
| 1         | 22.52                              | 22.82 | 22.82 | 22.52 |
| 2         | 26.33                              | 25.85 | 25.85 | 25.85 |
| 3         | 21.78                              | 21.78 | 21.48 | 21.78 |
| 4         | 24.46                              | 24.16 | 24.16 | 24.46 |
| 5         | 20.70                              | 20.98 | 21.41 | 21.41 |
| 6         | 24.23                              | 24.23 | 24.50 | 24.50 |
| 7         | 22.82                              | 22.82 | 22.52 | 22.82 |
| 8         | 20.05                              | 20.05 | 20.84 | 21.15 |
| 9         | 21.05                              | 21.05 | 21.05 | 21.05 |
| 10        | 22.07                              | 21.40 | 22.07 | 21.80 |
| 11        | 20.13                              | 21.78 | 20.13 | 21.48 |
| 12        | 21.48                              | 21.78 | 21.78 | 21.78 |
| 13        | 20.84                              | 20.84 | 21.15 | 21.15 |
| 14        | 25.98                              | 25.71 | 25.71 | 26.65 |
| 15        | 26.84                              | 26.84 | 26.54 | 27.88 |
| 16        | 24.16                              | 24.16 | 23.71 | 24.46 |
| Av.       | 22.84                              | 22.89 | 22.86 | 23.17 |
| SD        | 2.23                               | 2.04  | 1.99  | 2.18  |

# Appendix-VII

$R_s$  on pronotum of adult male S. gregaria at various ages, repeatedly used for measurement.  
( $K \Omega\text{-cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 19.84                      | 16.41 | 19.09 | 19.09 | 24.16 | 24.16 | 26.54 | 21.48 | 21.48 | 21.78 |
| 2         | 15.06                      | 19.09 | 17.45 | 21.78 | 21.48 | 19.84 | 23.86 | 24.16 | 21.78 | 20.13 |
| 3         | 19.09                      | 19.09 | 17.45 | 19.09 | 20.13 | 21.48 | 19.84 | 24.46 | 23.86 | 22.52 |
| 4         | 16.41                      | 21.48 | 19.09 | 21.48 | 24.46 | 21.78 | 21.78 | 21.48 | 23.86 | 21.78 |
| 5         | 19.09                      | 21.48 | 21.48 | 21.78 | 21.78 | 23.86 | 24.16 | 24.16 | 19.84 | 24.16 |
| 6         | 19.09                      | 19.84 | 21.48 | 22.52 | 21.78 | 24.16 | 21.48 | 24.16 | 26.84 | 23.86 |
| 7         | 17.15                      | 19.09 | 21.78 | 21.48 | 19.09 | 24.46 | 23.86 | 23.86 | 24.16 | 24.16 |
| 8         | 14.76                      | 21.48 | 21.78 | 23.86 | 24.16 | 19.84 | 21.48 | 21.78 | 21.78 | 25.80 |
| 9         | 16.41                      | 19.09 | 21.48 | 19.09 | 20.13 | 21.78 | 21.48 | 20.13 | 25.80 | 21.78 |
| 10        | 17.45                      | 17.15 | 22.82 | 21.48 | 22.22 | 24.46 | 23.86 | 21.48 | 23.86 | 24.16 |
| 11        | 16.41                      | 17.45 | 21.48 | 24.16 | 21.78 | 20.13 | 24.16 | 21.78 | 23.86 | 23.86 |
| 12        | 19.09                      | 19.09 | 20.13 | 21.48 | 21.78 | 21.78 | 19.84 | 26.84 | 21.78 | 26.84 |
| AV.       | 17.49                      | 19.23 | 20.46 | 21.44 | 21.91 | 22.31 | 22.70 | 22.98 | 23.24 | 23.40 |
| SD        | 1.73                       | 1.68  | 1.79  | 1.68  | 1.69  | 1.83  | 2.02  | 1.90  | 1.98  | 1.89  |

# Appendix-VIII

$R_s$  on pronotum of adult male S. gregaria at various ages, used only for one measurement,  
( $K \Omega - \text{cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 19.84                      | 21.48 | 19.09 | 19.84 | 19.09 | 24.16 | 22.82 | 24.46 | 21.48 | 23.86 |
| 2         | 15.06                      | 19.09 | 21.48 | 19.09 | 21.48 | 19.84 | 21.48 | 26.54 | 24.46 | 26.84 |
| 3         | 19.09                      | 20.13 | 19.09 | 24.16 | 22.82 | 19.84 | 24.16 | 24.16 | 21.78 | 21.78 |
| 4         | 16.41                      | 17.45 | 19.84 | 19.09 | 21.48 | 21.48 | 19.09 | 21.78 | 23.86 | 24.16 |
| 5         | 19.09                      | 17.45 | 19.09 | 21.48 | 21.78 | 24.16 | 19.84 | 21.78 | 21.78 | 21.78 |
| 6         | 19.09                      | 17.45 | 20.13 | 19.09 | 24.16 | 24.46 | 26.54 | 23.86 | 26.84 | 20.13 |
| 7         | 17.15                      | 19.09 | 19.84 | 20.13 | 19.84 | 21.48 | 21.78 | 21.48 | 24.16 | 22.82 |
| 8         | 14.76                      | 19.09 | 19.09 | 19.09 | 19.09 | 21.48 | 21.78 | 19.84 | 19.84 | 24.16 |
| 9         | 16.41                      | 16.41 | 19.84 | 22.52 | 21.48 | 19.84 | 24.16 | 26.54 | 24.16 | 23.86 |
| 10        | 17.45                      | 19.09 | 21.48 | 20.13 | 19.09 | 21.78 | 21.78 | 21.48 | 26.54 | 26.54 |
| 11        | 16.41                      | 19.09 | 17.45 | 23.86 | 21.78 | 21.78 | 21.78 | 20.13 | 21.78 | 21.78 |
| 12        | 19.09                      | 19.09 | 21.78 | 21.78 | 24.16 | 22.82 | 23.86 | 23.86 | 22.82 | 24.46 |
| Av.       | 17.49                      | 18.74 | 19.85 | 20.86 | 21.35 | 21.93 | 22.42 | 22.99 | 23.29 | 23.51 |
| SD        | 1.73                       | 1.37  | 1.25  | 1.87  | 1.81  | 1.68  | 2.03  | 2.25  | 2.10  | 1.98  |

# Appendix-X

$R_s$  on pronotum of adult female S. gregaria at various ages, used for only one measurement,  
( $K\Omega\text{-cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 19.09                      | 17.45 | 19.84 | 21.78 | 21.78 | 21.78 | 22.52 | 24.16 | 23.86 | 24.16 |
| 2         | 17.15                      | 19.84 | 21.78 | 21.48 | 23.86 | 21.48 | 21.48 | 26.84 | 21.78 | 25.80 |
| 3         | 17.45                      | 20.13 | 19.09 | 21.78 | 23.86 | 24.16 | 24.46 | 24.16 | 24.16 | 23.86 |
| 4         | 19.09                      | 21.78 | 21.48 | 21.48 | 19.84 | 21.48 | 25.80 | 21.78 | 23.86 | 21.78 |
| 5         | 16.41                      | 19.09 | 21.48 | 21.78 | 22.82 | 19.09 | 19.09 | 23.86 | 21.78 | 19.84 |
| 6         | 19.09                      | 21.48 | 23.86 | 19.09 | 21.78 | 24.16 | 21.78 | 24.16 | 24.16 | 25.54 |
| 7         | 17.45                      | 19.09 | 18.35 | 23.86 | 19.09 | 24.16 | 24.46 | 21.48 | 24.16 | 24.16 |
| 8         | 15.06                      | 17.45 | 17.45 | 21.48 | 21.48 | 19.84 | 24.16 | 24.16 | 23.86 | 23.86 |
| 9         | 19.09                      | 21.48 | 21.78 | 21.78 | 21.48 | 21.78 | 24.16 | 25.54 | 23.86 | 24.16 |
| 10        | 17.45                      | 19.09 | 21.48 | 24.16 | 24.16 | 24.16 | 21.78 | 21.78 | 24.16 | 21.78 |
| 11        | 17.45                      | 19.84 | 19.84 | 19.09 | 23.86 | 24.16 | 24.16 | 19.09 | 25.80 | 25.80 |
| 12        | 19.09                      | 17.45 | 21.78 | 21.48 | 21.48 | 24.46 | 21.78 | 21.78 | 21.48 | 23.86 |
| Av.       | 17.82                      | 19.51 | 20.63 | 21.60 | 22.12 | 22.56 | 22.97 | 23.32 | 23.58 | 23.80 |
| SD        | 1.30                       | 1.56  | 1.80  | 1.49  | 1.64  | 1.89  | 1.87  | 2.22  | 1.26  | 1.90  |

# Appendix-XI

'R<sub>s</sub> on forewings of adult male S. gregaria at various ages, repeatedly used for measurement.  
(KΩ-cm<sup>2</sup>)

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 32.25                      | 32.25 | 37.28 | 35.60 | 40.63 | 43.99 | 40.63 | 43.99 | 40.63 | 40.63 |
| 2         | 30.20                      | 37.66 | 35.23 | 40.63 | 39.70 | 41.01 | 35.60 | 43.62 | 40.63 | 43.62 |
| 3         | 28.15                      | 31.88 | 37.66 | 37.66 | 38.59 | 43.62 | 43.62 | 38.59 | 43.62 | 38.96 |
| 4         | 35.23                      | 32.25 | 35.60 | 35.23 | 43.62 | 37.66 | 39.70 | 43.62 | 43.99 | 41.94 |
| 5         | 32.62                      | 35.60 | 37.66 | 39.33 | 35.60 | 42.69 | 38.59 | 40.63 | 43.99 | 40.63 |
| 6         | 30.57                      | 35.23 | 32.25 | 37.28 | 37.66 | 40.63 | 46.97 | 41.01 | 41.01 | 46.97 |
| 7         | 33.55                      | 30.57 | 35.60 | 37.28 | 41.57 | 38.59 | 40.63 | 46.97 | 38.59 | 41.94 |
| 8         | 29.83                      | 35.23 | 37.28 | 40.26 | 37.66 | 41.57 | 43.99 | 40.63 | 46.97 | 45.67 |
| 9         | 30.57                      | 35.60 | 37.28 | 35.23 | 38.59 | 38.59 | 40.26 | 41.01 | 40.26 | 41.01 |
| 10        | 32.25                      | 35.23 | 38.59 | 37.28 | 37.66 | 35.60 | 38.59 | 37.66 | 43.62 | 43.99 |
| 11        | 27.22                      | 35.60 | 37.28 | 40.63 | 38.59 | 40.63 | 40.63 | 38.59 | 40.63 | 43.62 |
| 12        | 30.57                      | 32.25 | 35.23 | 39.33 | 40.63 | 38.59 | 43.62 | 45.67 | 45.67 | 43.62 |
| Av.       | 31.08                      | 34.11 | 36.41 | 37.98 | 39.21 | 40.26 | 41.07 | 41.83 | 42.47 | 42.72 |
| SD        | 2.24                       | 2.15  | 1.71  | 2.03  | 2.15  | 2.53  | 3.04  | 2.94  | 2.52  | 2.29  |

# Appendix-XII

$R_s$  on forewings of adult male S. gregaria at various ages, used for only one measurement.

( $K\Omega$  - $cm^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1      | 32.25                      | 35.23 | 35.60 | 37.28 | 38.22 | 43.62 | 40.63 | 41.94 | 46.05 | 45.67 |
| 2      | 30.20                      | 33.92 | 35.23 | 37.28 | 38.96 | 41.94 | 43.62 | 43.62 | 38.59 | 43.62 |
| 3      | 28.15                      | 30.20 | 37.28 | 37.28 | 40.63 | 38.59 | 41.94 | 41.94 | 40.63 | 40.63 |
| 4      | 35.23                      | 32.62 | 37.28 | 35.23 | 38.59 | 37.28 | 40.63 | 41.01 | 43.99 | 49.02 |
| 5      | 32.62                      | 30.57 | 37.66 | 37.66 | 39.33 | 43.99 | 35.60 | 43.99 | 46.97 | 46.05 |
| 6      | 30.57                      | 30.57 | 32.25 | 35.60 | 40.63 | 40.63 | 38.59 | 39.70 | 43.99 | 38.59 |
| 7      | 33.55                      | 35.23 | 35.23 | 40.26 | 36.91 | 41.57 | 43.99 | 38.59 | 42.69 | 43.99 |
| 8      | 29.83                      | 35.60 | 37.28 | 39.33 | 37.28 | 38.96 | 43.62 | 46.97 | 43.62 | 41.01 |
| 9      | 30.57                      | 37.28 | 37.28 | 37.28 | 40.63 | 40.63 | 38.59 | 40.63 | 40.63 | 43.99 |
| 10     | 32.25                      | 35.23 | 37.28 | 35.60 | 40.26 | 35.60 | 40.26 | 43.99 | 43.62 | 40.63 |
| 11     | 27.22                      | 32.25 | 34.86 | 37.66 | 35.60 | 38.96 | 38.59 | 38.59 | 43.62 | 43.62 |
| 12     | 30.57                      | 32.25 | 32.25 | 37.66 | 37.66 | 38.59 | 46.97 | 43.99 | 38.59 | 40.63 |
| Av.    | 31.08                      | 33.41 | 35.79 | 37.34 | 38.73 | 40.03 | 41.09 | 42.08 | 42.75 | 43.12 |
| SD     | 2.24                       | 2.33  | 1.93  | 1.46  | 1.66  | 2.50  | 3.11  | 2.53  | 2.66  | 2.95  |

# Appendix-XIII

$R_s$  on forewings of adult female S. gregaria at various ages, repeatedly used for measurement,  
( $K \Omega - \text{cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 32.25                      | 30.57 | 37.28 | 37.28 | 40.26 | 37.66 | 40.63 | 40.26 | 43.62 | 45.67 |
| 2         | 30.20                      | 32.25 | 35.23 | 35.23 | 40.26 | 38.59 | 43.06 | 38.59 | 45.67 | 43.62 |
| 3         | 29.83                      | 31.88 | 35.60 | 40.63 | 35.60 | 40.63 | 38.59 | 40.63 | 40.63 | 40.63 |
| 4         | 33.55                      | 35.23 | 37.28 | 37.28 | 37.66 | 38.59 | 40.63 | 46.97 | 41.01 | 41.01 |
| 5         | 30.20                      | 35.23 | 35.60 | 40.26 | 38.59 | 37.66 | 35.60 | 43.62 | 43.62 | 43.62 |
| 6         | 27.22                      | 30.57 | 32.25 | 35.23 | 38.59 | 41.57 | 38.59 | 46.05 | 40.63 | 40.63 |
| 7         | 32.25                      | 32.25 | 35.23 | 35.23 | 35.60 | 40.63 | 41.01 | 40.26 | 40.63 | 46.97 |
| 8         | 32.25                      | 34.86 | 35.23 | 37.28 | 40.63 | 43.62 | 38.59 | 38.59 | 38.59 | 41.01 |
| 9         | 27.22                      | 37.28 | 37.28 | 37.28 | 37.66 | 38.59 | 38.22 | 43.99 | 43.62 | 43.62 |
| 10        | 28.15                      | 35.23 | 37.28 | 35.23 | 38.59 | 35.60 | 43.99 | 37.28 | 38.59 | 40.63 |
| 11        | 30.20                      | 32.25 | 35.23 | 37.28 | 35.60 | 40.63 | 41.01 | 40.63 | 41.01 | 38.59 |
| 12        | 32.25                      | 30.20 | 32.25 | 35.23 | 40.63 | 38.59 | 43.62 | 37.66 | 46.97 | 43.99 |
| Av.       | 30.46                      | 33.15 | 35.48 | 36.95 | 38.31 | 39.36 | 40.30 | 41.21 | 42.05 | 42.50 |
| SD        | 2.12                       | 2.32  | 1.76  | 1.90  | 1.94  | 2.14  | 2.50  | 3.22  | 2.64  | 2.45  |

$R_s$  on forewings of adult female S. gregaria at various ages, used for only one measurement.  
( $K\Omega\text{-cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    |
| 1         | 32.25                      | 35.23 | 37.28 | 36.91 | 35.60 | 38.59 | 43.62 | 46.97 | 43.99 | 40.63 |
| 2         | 30.20                      | 32.25 | 37.66 | 35.23 | 43.62 | 38.96 | 43.62 | 41.01 | 41.57 | 45.67 |
| 3         | 29.83                      | 30.57 | 37.28 | 40.26 | 40.63 | 43.62 | 40.63 | 38.96 | 40.63 | 45.67 |
| 4         | 33.55                      | 35.60 | 35.60 | 37.28 | 39.70 | 40.63 | 38.59 | 43.62 | 46.97 | 43.62 |
| 5         | 30.20                      | 30.20 | 35.23 | 37.28 | 37.66 | 37.66 | 45.30 | 43.62 | 43.99 | 40.63 |
| 6         | 27.22                      | 30.57 | 35.23 | 35.23 | 40.26 | 40.63 | 35.60 | 41.94 | 41.94 | 43.99 |
| 7         | 32.25                      | 35.23 | 32.25 | 37.66 | 35.60 | 35.60 | 38.59 | 43.62 | 40.63 | 45.67 |
| 8         | 32.25                      | 30.57 | 35.60 | 37.66 | 37.28 | 41.57 | 40.26 | 43.99 | 43.62 | 41.01 |
| 9         | 27.22                      | 32.25 | 37.66 | 37.66 | 37.28 | 38.96 | 38.59 | 38.59 | 45.67 | 43.62 |
| 10        | 28.15                      | 35.23 | 35.60 | 40.63 | 40.63 | 38.96 | 43.62 | 44.55 | 40.63 | 40.63 |
| 11        | 30.20                      | 35.23 | 32.25 | 35.60 | 37.28 | 41.01 | 41.94 | 41.94 | 43.99 | 46.97 |
| 12        | 32.25                      | 37.28 | 37.28 | 35.60 | 40.26 | 43.62 | 41.01 | 35.60 | 38.59 | 38.59 |
| Av.       | 30.46                      | 33.35 | 35.74 | 37.25 | 38.82 | 39.98 | 40.95 | 42.03 | 42.69 | 43.06 |
| SD        | 2.12                       | 2.53  | 1.89  | 1.78  | 2.41  | 2.35  | 2.82  | 3.10  | 2.42  | 2.68  |

# Appendix-XV

## Response of S. gregaria to Diflubenzuron treatment - Probit analysis

| Dose<br>µg/<br>nymph | log<br>dose<br>(x 100) | No.<br>trea-<br>ted | Res-<br>ponse | Perce-<br>tage<br>response | Emperi-<br>cal<br>Probit | Expec-<br>ted<br>Probit | Weighting<br>coefficient | nw      | Working<br>Probit | nwx     | nwy     |
|----------------------|------------------------|---------------------|---------------|----------------------------|--------------------------|-------------------------|--------------------------|---------|-------------------|---------|---------|
|                      |                        | n                   | r             | p                          |                          | y                       | w                        |         | y                 |         |         |
| 10.0                 | 3.0                    | 80                  | 75            | 93.75                      | 6.53                     | 6.24                    | 0.37031                  | 29.625  | 6.484             | 88.875  | 192.089 |
| 5.0                  | 2.7                    | 80                  | 63            | 78.75                      | 5.80                     | 5.80                    | 0.50260                  | 40.208  | 5.806             | 108.562 | 233.448 |
| 1.0                  | 2.0                    | 80                  | 29            | 36.25                      | 4.65                     | 4.76                    | 0.62742                  | 50.194  | 4.645             | 100.388 | 233.151 |
| 0.5                  | 1.7                    | 80                  | 20            | 25.00                      | 4.33                     | 4.33                    | 0.53159                  | 42.527  | 4.326             | 72.296  | 183.972 |
| 0.1                  | 1.0                    | 80                  | 8             | 10.00                      | 3.72                     | 3.30                    | 0.20774                  | 16.619  | 3.889             | 16.619  | 64.631  |
|                      |                        |                     |               |                            |                          |                         |                          | 179.173 |                   | 386.740 | 907.291 |

$$S_{nwx}^2 = 900.04$$

$$S_{nwy} = 2050.263$$

$$S_{nwy}^2 = 4731.103$$

$$\bar{x} = \frac{S_{nwx}}{S_{nw}} = \frac{386.74}{179.173} = 2.1585$$

$$\bar{y} = \frac{S_{nwy}}{S_{nw}} = \frac{907.291}{179.173} = 5.0638$$

$$\frac{(S_{nwx})^2}{S_{nw}} = 834.768$$

$$\frac{S_{nwx} \times S_{nwy}}{S_{nw}} = 1958.363$$

$$\frac{(S_{nwy})^2}{S_{nw}} = 4594.314$$

$$S_{xx} = 65.272$$

$$S_{xy} = 91.900$$

$$S_{yy} = 136.789$$

$$b = \frac{S_{xy}}{S_{xx}} = \frac{91.9}{65.272} = 1.408$$

$$Y = \bar{y} + b (x - \bar{x})$$

$$5.0 = 5.0638 + 1.408 (x - 2.1585)$$

$$ED_{50} = 2.1132 = 1.298 \text{ µg/nymph}$$

$$V_{(m)} = 0.0028311$$

$$SE_{(m)} = \sqrt{V_{(m)}} = 0.0532$$

$$\text{Fiducial limits to } ED_{50} = SE_{(m)} \times 1.96 \pm x$$

$$= 0.0532 \times 1.96 \pm 2.1132$$

$$= 0.1043 \pm 2.1132$$

$$ED_{50} \text{ (range)} = 1.021 \text{ to } 1.65 \text{ µg/nymph}$$

# Appendix-XVI

R<sub>s</sub> on pronotum of deformed adult male S. gregaria at various ages, obtained from \*diflubenzuron treated hoppers.

(K.Ω -cm<sup>2</sup>)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 7.90                       | 14.76 | 19.09 | 21.48 | 21.78 | 21.48 | 19.09 | 21.48 | 19.09 | 19.09 | 21.48 | 22.52 |  |  |  |
| 2      | 7.90                       | 16.41 | 19.84 | 19.09 | 19.09 | 19.09 | 19.84 | 19.09 | 21.48 | 19.84 | 23.86 | 24.16 |  |  |  |
| 3      | 6.56                       | 14.76 | 19.09 | 17.45 | 19.09 | 19.09 | 21.48 | 19.84 | 21.48 | 21.48 | 21.48 | 22.82 |  |  |  |
| 4      | 6.71                       | 17.45 | 16.41 | 19.09 | 19.84 | 17.45 | 18.79 | 24.16 | 19.09 | 24.16 | 19.09 | 20.13 |  |  |  |
| 5      | 8.05                       | 17.45 | 19.09 | 17.45 | 19.09 | 21.48 | 21.48 | 21.48 | 22.52 | 22.22 | 23.86 | 24.46 |  |  |  |
| 6      | 6.71                       | 14.02 | 17.45 | 19.84 | 19.84 | 21.78 | 21.48 | 21.48 | 23.86 | 23.41 | 22.52 | 20.13 |  |  |  |
| 7      | 6.56                       | 17.15 | 16.41 | 19.09 | 21.48 | 19.09 | 19.09 | 19.84 | 21.78 | 22.82 | 25.50 | 21.78 |  |  |  |
| 8      | 6.71                       | 14.76 | 17.45 | 19.09 | 17.45 | 17.45 | 17.45 | 24.16 | 20.73 | 22.22 | 22.22 | 25.80 |  |  |  |
| 9      | 7.90                       | 16.41 | 19.09 | 17.45 | 19.09 | 19.84 | 21.48 | 22.52 | 23.41 | 23.86 | 21.78 | 21.78 |  |  |  |
| 10     | 8.05                       | 18.79 | 16.41 | 21.78 | 19.09 | 22.22 | 23.86 | 21.78 | 21.78 | 22.52 | 23.86 | 24.16 |  |  |  |
| 11     | 6.71                       | 17.45 | 19.84 | 19.09 | 17.45 | 21.48 | 22.52 | 19.84 | 22.52 | 21.78 | 21.48 | 22.82 |  |  |  |
| 12     | 6.56                       | 19.09 | 17.45 | 19.09 | 21.48 | 22.82 | 22.22 | 20.13 | 20.43 | 21.78 | 22.52 | 22.52 |  |  |  |
| 13     | 7.90                       | 18.05 | 18.79 | 19.84 | 19.09 | 19.09 | 19.84 | 23.12 | 23.86 | 22.22 | 24.46 | 19.84 |  |  |  |
| 14     | 6.71                       | 15.51 | 16.41 | 21.78 | 21.78 | 21.78 | 23.41 | 20.13 | 25.80 | 25.50 | 23.41 | 21.78 |  |  |  |
| 15     | 6.56                       | 16.41 | 14.76 | 17.15 | 22.82 | 21.78 | 22.22 | 22.52 | 22.22 | 19.09 | 19.84 | 24.46 |  |  |  |
| 16     | 6.71                       | 19.09 | 21.48 | 19.09 | 20.13 | 22.52 | 21.48 | 21.48 | 19.84 | 23.41 | 22.52 | 22.82 |  |  |  |
| Av.    | 7.14                       | 16.72 | 18.07 | 19.24 | 19.91 | 20.53 | 20.98 | 21.44 | 21.87 | 22.21 | 22.49 | 22.62 |  |  |  |
| SD     | 0.65                       | 1.63  | 1.75  | 1.48  | 1.56  | 1.77  | 1.79  | 1.56  | 1.83  | 1.76  | 1.67  | 1.71  |  |  |  |

\* Dose - 5.0 µg of diflubenzuron/nymph

# Appendix-XVII

R<sub>s</sub> on pronotum of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

(K Ω-cm<sup>2</sup>)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 7.90                       | 19.84 | 19.09 | 21.48 | 21.78 | 24.46 | 25.50 | 24.16 | 24.16 | 24.46 | 24.16 | 26.84 |  |  |  |
| 2      | 6.56                       | 15.06 | 19.84 | 22.52 | 23.86 | 20.13 | 22.82 | 22.52 | 23.41 | 22.52 | 22.52 | 24.46 |  |  |  |
| 3      | 6.56                       | 19.09 | 19.09 | 22.22 | 22.22 | 22.82 | 21.48 | 23.41 | 22.82 | 26.54 | 24.16 | 28.48 |  |  |  |
| 4      | 7.90                       | 16.41 | 21.78 | 19.09 | 22.52 | 21.78 | 21.78 | 21.78 | 22.22 | 22.82 | 23.86 | 22.52 |  |  |  |
| 5      | 7.38                       | 17.15 | 21.48 | 21.78 | 21.78 | 19.84 | 22.52 | 24.16 | 21.78 | 24.16 | 22.82 | 24.16 |  |  |  |
| 6      | 7.90                       | 19.09 | 17.45 | 20.13 | 22.52 | 24.16 | 23.41 | 20.13 | 24.46 | 24.16 | 27.44 | 26.10 |  |  |  |
| 7      | 6.56                       | 16.41 | 20.13 | 22.22 | 19.09 | 23.41 | 24.46 | 23.86 | 23.86 | 22.52 | 24.16 | 24.46 |  |  |  |
| 8      | 6.56                       | 18.79 | 21.78 | 17.45 | 17.45 | 21.48 | 24.16 | 22.52 | 22.52 | 22.22 | 26.84 | 22.82 |  |  |  |
| 9      | 6.71                       | 17.15 | 17.15 | 19.84 | 21.48 | 19.39 | 20.13 | 24.16 | 26.54 | 24.46 | 24.46 | 24.46 |  |  |  |
| 10     | 7.38                       | 14.76 | 21.48 | 22.52 | 19.84 | 23.71 | 24.16 | 23.86 | 26.84 | 20.13 | 21.48 | 26.84 |  |  |  |
| 11     | 7.90                       | 18.05 | 17.45 | 21.48 | 19.09 | 21.78 | 21.48 | 26.84 | 24.16 | 25.50 | 26.84 | 22.82 |  |  |  |
| 12     | 8.05                       | 17.45 | 20.13 | 19.09 | 23.86 | 22.52 | 22.52 | 24.46 | 24.46 | 26.54 | 25.50 | 24.16 |  |  |  |
| 13     | 6.71                       | 17.15 | 19.84 | 21.48 | 22.82 | 20.13 | 22.82 | 22.52 | 24.16 | 22.82 | 24.16 | 21.78 |  |  |  |
| 14     | 7.90                       | 19.09 | 17.15 | 17.45 | 21.78 | 23.86 | 24.16 | 21.78 | 20.13 | 24.16 | 25.80 | 26.84 |  |  |  |
| 15     | 8.05                       | 20.13 | 19.09 | 21.78 | 22.82 | 24.16 | 22.52 | 21.48 | 23.86 | 24.46 | 20.13 | 24.16 |  |  |  |
| 16     | 6.71                       | 16.41 | 21.78 | 19.09 | 19.84 | 21.48 | 19.09 | 22.52 | 22.52 | 26.84 | 22.52 | 22.52 |  |  |  |
| Av.    | 7.30                       | 17.63 | 19.67 | 20.60 | 21.42 | 22.19 | 22.69 | 23.14 | 23.62 | 24.02 | 24.18 | 24.59 |  |  |  |
| SD     | 0.64                       | 1.61  | 1.71  | 1.74  | 1.84  | 1.70  | 1.66  | 1.56  | 1.67  | 1.81  | 2.01  | 1.93  |  |  |  |

Appendix-XVIII

$R_s$  on pronotum of deformed adult female S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

( $K\Omega\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |
| 1      | 6.71                       | 17.15 | 19.09 | 19.09 | 19.09 | 21.48 | 21.48 | 21.78 | 21.48 | 20.13 | 21.78 | 22.82 |
| 2      | 6.56                       | 16.41 | 17.45 | 21.48 | 21.78 | 19.09 | 19.84 | 24.46 | 20.13 | 21.48 | 21.78 | 26.84 |
| 3      | 6.71                       | 17.45 | 20.13 | 19.09 | 19.09 | 19.84 | 19.84 | 19.84 | 21.78 | 22.82 | 23.86 | 20.13 |
| 4      | 7.90                       | 14.76 | 19.09 | 17.45 | 21.48 | 21.78 | 19.09 | 21.78 | 19.09 | 21.78 | 19.09 | 24.46 |
| 5      | 7.90                       | 14.76 | 16.41 | 19.09 | 19.09 | 19.09 | 21.48 | 24.16 | 23.86 | 24.46 | 22.82 | 22.52 |
| 6      | 7.90                       | 19.84 | 19.09 | 19.09 | 21.48 | 21.48 | 24.16 | 19.09 | 22.22 | 22.82 | 20.13 | 24.16 |
| 7      | 7.90                       | 18.05 | 17.45 | 19.84 | 17.45 | 20.13 | 19.09 | 21.78 | 18.79 | 20.13 | 22.52 | 24.46 |
| 8      | 6.71                       | 17.45 | 19.09 | 18.35 | 21.48 | 17.45 | 21.48 | 21.48 | 23.12 | 22.22 | 23.86 | 22.52 |
| 9      | 6.56                       | 16.41 | 17.45 | 19.09 | 20.13 | 22.52 | 17.45 | 20.73 | 25.50 | 21.78 | 23.41 | 26.54 |
| 10     | 6.71                       | 19.09 | 21.48 | 19.84 | 21.78 | 22.22 | 22.22 | 18.35 | 22.22 | 25.80 | 20.13 | 21.78 |
| 11     | 7.90                       | 17.15 | 19.09 | 21.48 | 19.09 | 21.78 | 21.48 | 21.78 | 21.78 | 22.52 | 22.52 | 24.16 |
| 12     | 7.90                       | 14.76 | 17.45 | 17.45 | 19.84 | 20.13 | 23.12 | 23.41 | 24.46 | 23.41 | 25.80 | 19.84 |
| 13     | 6.71                       | 17.45 | 17.15 | 17.45 | 22.22 | 22.22 | 22.52 | 21.48 | 23.41 | 24.16 | 25.80 | 24.46 |
| 14     | 6.56                       | 19.09 | 19.09 | 21.48 | 21.48 | 23.86 | 22.52 | 19.84 | 25.50 | 22.52 | 19.84 | 20.13 |
| 15     | 7.90                       | 19.09 | 16.41 | 19.09 | 17.45 | 17.45 | 21.78 | 23.41 | 22.52 | 25.80 | 24.46 | 22.52 |
| 16     | 6.56                       | 17.15 | 19.84 | 21.78 | 19.84 | 19.84 | 20.13 | 22.22 | 20.13 | 19.84 | 26.54 | 21.78 |
| Av.    | 7.19                       | 17.25 | 18.49 | 19.45 | 20.17 | 20.65 | 21.11 | 21.60 | 22.25 | 22.60 | 22.77 | 23.07 |
| SD     | 0.65                       | 1.58  | 1.42  | 1.46  | 1.55  | 1.82  | 1.74  | 1.74  | 2.05  | 1.82  | 2.26  | 2.10  |

Appendix-XIX

$R_s$  on pronotum of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers

( $K \Omega\text{-cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
|           | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |
| 1         | 6.71                       | 19.09 | 17.45 | 20.13 | 21.48 | 22.22 | 24.46 | 22.82 | 26.54 | 24.90 | 25.50 | 24.46 |  |
| 2         | 6.71                       | 17.15 | 21.48 | 22.22 | 19.84 | 24.16 | 20.43 | 25.80 | 22.22 | 23.86 | 24.16 | 28.48 |  |
| 3         | 7.90                       | 16.41 | 19.84 | 21.78 | 19.09 | 19.09 | 22.52 | 21.78 | 24.46 | 28.49 | 28.19 | 26.84 |  |
| 4         | 7.90                       | 19.09 | 20.13 | 19.09 | 23.86 | 21.48 | 21.78 | 24.16 | 26.84 | 22.82 | 26.84 | 25.80 |  |
| 5         | 7.90                       | 19.84 | 21.48 | 21.78 | 21.78 | 22.82 | 21.48 | 23.12 | 23.71 | 26.84 | 27.44 | 22.82 |  |
| 6         | 6.71                       | 19.84 | 20.13 | 17.45 | 24.16 | 24.46 | 25.50 | 25.50 | 21.78 | 22.82 | 24.46 | 26.84 |  |
| 7         | 7.90                       | 15.06 | 19.09 | 22.22 | 20.13 | 19.09 | 22.22 | 20.13 | 25.50 | 26.84 | 26.10 | 24.16 |  |
| 8         | 7.90                       | 17.45 | 17.45 | 20.13 | 22.52 | 23.86 | 24.46 | 22.82 | 26.84 | 24.46 | 21.48 | 28.19 |  |
| 9         | 7.90                       | 18.05 | 20.13 | 22.22 | 22.82 | 21.48 | 24.46 | 21.78 | 20.13 | 24.16 | 25.80 | 24.46 |  |
| 10        | 7.38                       | 19.09 | 21.78 | 21.48 | 20.13 | 24.46 | 22.82 | 25.80 | 25.80 | 24.46 | 22.82 | 26.10 |  |
| 11        | 6.56                       | 14.76 | 17.15 | 23.41 | 21.48 | 22.52 | 24.16 | 24.46 | 24.16 | 21.48 | 24.16 | 22.52 |  |
| 12        | 6.71                       | 17.45 | 19.09 | 19.84 | 24.16 | 20.13 | 19.84 | 22.22 | 24.16 | 26.54 | 22.22 | 24.46 |  |
| 13        | 6.71                       | 19.09 | 21.78 | 21.78 | 22.52 | 24.16 | 22.82 | 26.84 | 24.46 | 26.84 | 25.80 | 22.82 |  |
| 14        | 7.90                       | 17.15 | 16.41 | 23.86 | 24.16 | 21.78 | 25.80 | 24.90 | 26.54 | 22.22 | 24.16 | 26.84 |  |
| 15        | 6.71                       | 20.13 | 21.48 | 17.45 | 24.16 | 25.80 | 21.48 | 22.52 | 21.78 | 24.16 | 26.84 | 24.46 |  |
| 16        | 8.03                       | 16.41 | 20.13 | 20.13 | 17.45 | 21.48 | 24.16 | 22.82 | 22.52 | 24.16 | 22.52 | 26.84 |  |
| AV.       | 7.35                       | 17.88 | 19.69 | 20.94 | 21.86 | 22.44 | 23.02 | 23.59 | 24.22 | 24.69 | 24.91 | 25.38 |  |
| SD        | 0.62                       | 1.67  | 1.77  | 1.88  | 2.07  | 1.98  | 1.77  | 1.83  | 2.07  | 1.95  | 1.93  | 1.88  |  |

# Appendix-XX

$R_s$  on excised pronotum of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

(  $K\Omega$ - $cm^2$  )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 6.56                       | 17.15 | 19.09 | 19.09 | 17.45 | 21.48 | 19.09 | 21.48 | 21.48 | 21.78 | 21.48 | 22.52 |  |  |  |
| 2      | 6.71                       | 17.15 | 15.06 | 17.45 | 17.45 | 21.48 | 21.78 | 22.22 | 22.52 | 22.52 | 19.09 | 22.82 |  |  |  |
| 3      | 6.56                       | 14.76 | 17.15 | 21.48 | 17.45 | 19.09 | 20.13 | 19.09 | 21.78 | 23.86 | 24.16 | 19.84 |  |  |  |
| 4      | 7.90                       | 17.45 | 17.45 | 21.48 | 21.78 | 20.13 | 21.48 | 24.16 | 20.13 | 24.16 | 21.48 | 21.78 |  |  |  |
| 5      | 6.56                       | 14.76 | 17.15 | 20.13 | 19.84 | 17.45 | 21.78 | 17.45 | 19.09 | 21.48 | 22.52 | 22.82 |  |  |  |
| 6      | 7.90                       | 14.76 | 15.06 | 16.41 | 20.13 | 17.45 | 19.09 | 20.13 | 17.45 | 21.78 | 19.84 | 24.46 |  |  |  |
| 7      | 6.71                       | 17.45 | 19.09 | 17.45 | 17.45 | 20.13 | 21.48 | 19.09 | 24.16 | 19.84 | 23.86 | 20.13 |  |  |  |
| 8      | 6.56                       | 17.15 | 19.09 | 17.45 | 21.78 | 19.84 | 17.45 | 22.52 | 21.78 | 19.09 | 21.78 | 22.82 |  |  |  |
| 9      | 8.05                       | 15.06 | 17.45 | 17.15 | 21.48 | 21.78 | 22.52 | 21.48 | 21.48 | 22.52 | 19.09 | 20.13 |  |  |  |
| 10     | 7.90                       | 17.45 | 19.09 | 19.09 | 19.09 | 21.48 | 19.84 | 19.84 | 22.52 | 19.09 | 24.16 | 21.78 |  |  |  |
| 11     | 6.56                       | 14.76 | 20.13 | 17.45 | 22.82 | 20.13 | 20.13 | 22.82 | 24.46 | 22.82 | 22.82 | 24.16 |  |  |  |
| 12     | 6.71                       | 17.45 | 17.45 | 17.45 | 17.45 | 17.45 | 20.13 | 20.13 | 22.82 | 20.13 | 22.52 | 20.13 |  |  |  |
| 13     | 7.90                       | 17.15 | 17.45 | 20.13 | 20.13 | 20.13 | 22.52 | 22.52 | 22.52 | 22.82 | 22.82 | 22.82 |  |  |  |
| 14     | 6.56                       | 15.06 | 14.76 | 17.45 | 20.13 | 19.84 | 20.13 | 20.13 | 20.13 | 19.84 | 20.13 | 22.52 |  |  |  |
| 15     | 6.56                       | 14.76 | 17.45 | 20.13 | 17.45 | 22.82 | 22.82 | 22.52 | 20.13 | 22.52 | 21.78 | 22.82 |  |  |  |
| 16     | 7.90                       | 17.45 | 17.15 | 17.45 | 19.84 | 19.09 | 19.84 | 20.13 | 19.84 | 22.82 | 20.13 | 21.78 |  |  |  |
| Av.    | 7.10                       | 16.24 | 17.50 | 18.58 | 19.48 | 19.99 | 20.64 | 20.98 | 21.39 | 21.69 | 21.73 | 22.08 |  |  |  |
| SD     | 0.66                       | 1.27  | 1.57  | 1.64  | 1.86  | 1.61  | 1.49  | 1.76  | 1.85  | 1.62  | 1.69  | 1.41  |  |  |  |

$R_s$  on excised pronotum of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 6.71                       | 14.76 | 19.09 | 19.09 | 21.48 | 19.09 | 20.13 | 21.78 | 23.86 | 21.78 | 24.16 | 24.16 |  |  |  |
| 2      | 7.90                       | 15.06 | 21.48 | 19.09 | 19.09 | 17.45 | 21.78 | 19.09 | 21.48 | 24.16 | 21.78 | 26.84 |  |  |  |
| 3      | 8.05                       | 17.15 | 17.15 | 21.78 | 21.78 | 19.09 | 22.52 | 21.48 | 21.78 | 22.52 | 24.46 | 22.82 |  |  |  |
| 4      | 6.71                       | 17.15 | 17.45 | 17.45 | 17.45 | 21.78 | 21.48 | 24.16 | 19.84 | 24.16 | 22.52 | 22.82 |  |  |  |
| 5      | 6.56                       | 17.45 | 16.41 | 20.13 | 19.09 | 21.48 | 21.78 | 23.86 | 24.16 | 23.86 | 21.78 | 21.78 |  |  |  |
| 6      | 8.05                       | 19.09 | 19.09 | 21.78 | 19.84 | 20.13 | 19.09 | 21.78 | 20.13 | 21.48 | 24.16 | 24.46 |  |  |  |
| 7      | 6.71                       | 19.09 | 19.09 | 19.09 | 19.84 | 22.52 | 20.13 | 21.78 | 22.52 | 21.78 | 25.80 | 20.13 |  |  |  |
| 8      | 6.56                       | 16.41 | 16.41 | 19.84 | 21.78 | 24.16 | 19.84 | 21.48 | 24.16 | 19.84 | 24.16 | 22.52 |  |  |  |
| 9      | 6.71                       | 15.06 | 19.09 | 17.45 | 20.13 | 22.52 | 21.48 | 22.22 | 21.78 | 22.82 | 19.84 | 22.82 |  |  |  |
| 10     | 7.90                       | 17.45 | 17.15 | 19.09 | 23.86 | 21.48 | 24.16 | 19.09 | 21.78 | 24.16 | 22.82 | 24.16 |  |  |  |
| 11     | 7.90                       | 14.76 | 17.45 | 20.13 | 20.13 | 22.82 | 22.82 | 22.82 | 22.52 | 20.13 | 22.52 | 21.78 |  |  |  |
| 12     | 6.71                       | 17.45 | 17.45 | 20.13 | 20.13 | 22.52 | 24.46 | 24.46 | 22.82 | 24.46 | 20.13 | 22.82 |  |  |  |
| 13     | 8.05                       | 14.76 | 20.13 | 17.45 | 22.82 | 19.84 | 20.13 | 22.82 | 21.78 | 22.82 | 24.46 | 24.46 |  |  |  |
| 14     | 6.56                       | 17.45 | 20.13 | 22.82 | 20.13 | 21.78 | 22.52 | 21.78 | 24.46 | 22.82 | 22.82 | 20.13 |  |  |  |
| 15     | 7.90                       | 19.84 | 17.45 | 22.52 | 22.82 | 22.52 | 22.82 | 24.46 | 22.82 | 24.46 | 22.82 | 24.46 |  |  |  |
| 16     | 6.71                       | 17.45 | 20.13 | 19.84 | 20.13 | 20.13 | 24.16 | 22.52 | 24.46 | 22.82 | 24.46 | 26.84 |  |  |  |
| Av.    | 7.23                       | 16.90 | 18.45 | 19.86 | 20.66 | 21.21 | 21.83 | 22.22 | 22.52 | 22.75 | 23.04 | 23.31 |  |  |  |
| SD     | 0.67                       | 1.65  | 1.53  | 1.70  | 1.65  | 1.76  | 1.65  | 1.61  | 1.44  | 1.46  | 1.63  | 1.95  |  |  |  |

# Appendix-XXII

R<sub>s</sub> on excised pronotum of deformed adult female S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

(K Ω -cm<sup>2</sup>)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |
| 1      | 6.56                       | 17.45 | 17.15 | 19.09 | 19.09 | 21.78 | 21.78 | 21.78 | 21.78 | 24.16 | 21.48 | 22.82 |
| 2      | 7.90                       | 14.76 | 19.84 | 17.45 | 19.84 | 22.52 | 21.78 | 21.48 | 22.52 | 22.52 | 21.78 | 22.52 |
| 3      | 7.90                       | 17.45 | 15.06 | 16.41 | 19.09 | 19.84 | 22.52 | 21.78 | 19.09 | 21.78 | 24.16 | 21.78 |
| 4      | 6.71                       | 19.09 | 19.09 | 19.84 | 17.45 | 21.48 | 19.84 | 19.09 | 24.16 | 21.78 | 21.48 | 21.78 |
| 5      | 6.56                       | 14.76 | 19.09 | 21.48 | 17.45 | 21.48 | 20.13 | 21.48 | 24.16 | 19.84 | 21.78 | 24.46 |
| 6      | 6.56                       | 17.15 | 17.45 | 21.48 | 21.78 | 19.09 | 17.45 | 19.09 | 19.84 | 20.13 | 23.86 | 20.13 |
| 7      | 7.90                       | 16.41 | 17.45 | 19.09 | 21.78 | 17.45 | 19.09 | 22.52 | 21.48 | 22.52 | 22.52 | 22.82 |
| 8      | 6.56                       | 14.76 | 15.06 | 17.45 | 21.48 | 21.78 | 21.78 | 24.16 | 19.84 | 23.86 | 24.16 | 21.78 |
| 9      | 6.71                       | 14.76 | 19.09 | 19.84 | 21.48 | 19.84 | 21.48 | 21.48 | 21.78 | 21.78 | 19.09 | 24.16 |
| 10     | 7.90                       | 15.06 | 19.09 | 17.45 | 17.15 | 19.09 | 21.78 | 19.84 | 22.52 | 22.52 | 21.48 | 20.13 |
| 11     | 6.56                       | 17.45 | 17.45 | 20.13 | 22.82 | 22.82 | 19.84 | 20.13 | 22.82 | 20.13 | 22.82 | 21.78 |
| 12     | 6.71                       | 14.76 | 20.13 | 20.13 | 20.13 | 20.13 | 20.13 | 22.82 | 20.13 | 22.82 | 20.13 | 19.84 |
| 13     | 8.05                       | 17.45 | 14.76 | 17.45 | 19.84 | 20.13 | 22.52 | 20.13 | 22.82 | 22.52 | 19.84 | 22.82 |
| 14     | 7.90                       | 17.15 | 17.45 | 17.45 | 17.45 | 17.45 | 21.78 | 19.84 | 20.13 | 20.13 | 21.78 | 20.13 |
| 15     | 6.56                       | 14.76 | 17.45 | 19.84 | 20.13 | 20.13 | 20.13 | 22.82 | 21.78 | 19.84 | 22.82 | 24.46 |
| 16     | 6.71                       | 17.45 | 19.84 | 17.15 | 17.45 | 20.13 | 19.84 | 20.13 | 19.84 | 22.52 | 20.13 | 22.52 |
| Av.    | 7.11                       | 16.29 | 17.84 | 18.86 | 19.65 | 20.32 | 20.74 | 21.16 | 21.54 | 21.80 | 21.83 | 22.12 |
| SD     | 0.66                       | 1.45  | 1.74  | 1.61  | 1.87  | 1.59  | 1.40  | 1.48  | 1.59  | 1.40  | 1.53  | 1.52  |

# Appendix-XXIII

$R_s$  on excised pronotum of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers.

( $K \Omega\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 7.90                       | 17.15 | 17.45 | 21.78 | 21.78 | 21.78 | 21.48 | 21.78 | 22.52 | 24.16 | 24.16 | 24.46 |  |  |  |
| 2      | 8.05                       | 15.06 | 21.48 | 19.09 | 17.45 | 19.09 | 22.52 | 22.52 | 21.78 | 25.80 | 25.80 | 22.82 |  |  |  |
| 3      | 6.71                       | 16.41 | 18.79 | 17.45 | 19.09 | 21.78 | 24.16 | 24.16 | 24.16 | 21.48 | 24.16 | 22.52 |  |  |  |
| 4      | 6.71                       | 17.45 | 19.09 | 19.84 | 18.79 | 21.48 | 19.09 | 21.78 | 23.86 | 24.16 | 24.16 | 20.13 |  |  |  |
| 5      | 6.56                       | 14.76 | 17.45 | 21.48 | 19.84 | 17.45 | 21.48 | 19.09 | 21.48 | 24.16 | 21.78 | 24.16 |  |  |  |
| 6      | 7.90                       | 19.09 | 16.41 | 17.45 | 21.48 | 21.78 | 20.13 | 20.13 | 22.82 | 22.82 | 24.46 | 24.46 |  |  |  |
| 7      | 6.71                       | 15.06 | 17.45 | 21.78 | 21.78 | 22.52 | 22.52 | 21.78 | 20.13 | 23.86 | 22.52 | 22.52 |  |  |  |
| 8      | 7.90                       | 17.45 | 19.09 | 19.09 | 24.16 | 20.13 | 21.78 | 23.86 | 24.16 | 21.48 | 21.78 | 26.84 |  |  |  |
| 9      | 6.56                       | 19.09 | 19.09 | 21.78 | 21.78 | 24.16 | 19.09 | 24.16 | 21.48 | 21.78 | 24.16 | 21.78 |  |  |  |
| 10     | 6.71                       | 17.45 | 17.45 | 19.09 | 19.09 | 21.48 | 24.16 | 24.16 | 24.16 | 19.84 | 19.84 | 24.46 |  |  |  |
| 11     | 7.90                       | 17.15 | 20.13 | 20.13 | 20.13 | 22.82 | 20.13 | 22.52 | 22.52 | 24.46 | 24.46 | 24.46 |  |  |  |
| 12     | 8.05                       | 14.76 | 17.45 | 22.82 | 22.52 | 20.13 | 22.82 | 22.82 | 22.82 | 22.82 | 22.82 | 19.84 |  |  |  |
| 13     | 6.56                       | 17.45 | 20.13 | 19.09 | 22.82 | 22.82 | 24.46 | 24.46 | 24.46 | 22.82 | 22.82 | 22.52 |  |  |  |
| 14     | 8.05                       | 17.45 | 20.13 | 22.52 | 19.84 | 22.52 | 20.13 | 22.52 | 22.52 | 24.46 | 20.13 | 24.16 |  |  |  |
| 15     | 6.71                       | 20.13 | 17.45 | 17.45 | 18.79 | 19.84 | 24.46 | 20.13 | 22.82 | 20.13 | 24.16 | 24.46 |  |  |  |
| 16     | 6.71                       | 15.06 | 17.45 | 20.13 | 22.52 | 22.52 | 22.52 | 22.82 | 21.78 | 22.82 | 22.82 | 26.84 |  |  |  |
| AV     | 7.23                       | 16.94 | 18.53 | 20.06 | 20.74 | 21.39 | 21.93 | 22.42 | 22.72 | 22.94 | 23.13 | 23.53 |  |  |  |
| SD     | 0.67                       | 1.66  | 1.42  | 1.80  | 1.86  | 1.68  | 1.84  | 1.60  | 1.22  | 1.66  | 1.64  | 1.98  |  |  |  |

# Appendix-XXIV

R<sub>s</sub> on 2-3 abdominal sternites of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

(K $\Omega$ -cm<sup>2</sup>)

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|           | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1         | 7.90                       | 16.41 | 19.84 | 19.84 | 19.09 | 21.48 | 24.16 | 21.48 | 19.09 | 19.09 | 21.48 | 22.82 |  |  |  |
| 2         | 6.71                       | 14.76 | 17.15 | 17.45 | 19.84 | 19.09 | 19.09 | 21.48 | 19.84 | 19.09 | 23.86 | 24.46 |  |  |  |
| 3         | 7.90                       | 14.76 | 19.09 | 17.15 | 21.48 | 19.09 | 21.48 | 19.09 | 21.78 | 21.78 | 21.48 | 20.13 |  |  |  |
| 4         | 7.90                       | 16.41 | 19.09 | 19.09 | 19.09 | 20.13 | 18.05 | 20.13 | 21.48 | 21.48 | 19.09 | 22.82 |  |  |  |
| 5         | 8.05                       | 17.15 | 17.15 | 17.45 | 19.09 | 19.09 | 19.84 | 21.48 | 21.78 | 23.12 | 23.86 | 19.84 |  |  |  |
| 6         | 7.90                       | 16.41 | 19.09 | 19.09 | 21.48 | 21.78 | 19.84 | 20.13 | 23.12 | 23.86 | 23.41 | 24.16 |  |  |  |
| 7         | 6.71                       | 19.09 | 16.41 | 19.09 | 18.35 | 22.52 | 21.78 | 19.09 | 20.73 | 22.52 | 22.52 | 21.78 |  |  |  |
| 8         | 7.90                       | 14.76 | 18.79 | 21.48 | 17.45 | 20.13 | 19.09 | 21.78 | 22.22 | 21.48 | 21.78 | 21.78 |  |  |  |
| 9         | 6.56                       | 17.15 | 19.09 | 18.79 | 21.48 | 22.52 | 20.13 | 21.48 | 19.09 | 24.16 | 19.09 | 24.46 |  |  |  |
| 10        | 8.05                       | 18.79 | 16.41 | 21.78 | 19.84 | 19.09 | 23.12 | 22.22 | 22.52 | 23.41 | 23.41 | 20.13 |  |  |  |
| 11        | 7.90                       | 19.09 | 18.05 | 19.84 | 17.15 | 17.45 | 22.22 | 19.09 | 22.82 | 19.09 | 22.52 | 22.52 |  |  |  |
| 12        | 6.71                       | 14.76 | 17.15 | 17.45 | 21.48 | 21.48 | 21.78 | 21.78 | 20.13 | 21.48 | 20.13 | 20.13 |  |  |  |
| 13        | 7.90                       | 18.79 | 20.13 | 19.84 | 19.84 | 20.13 | 20.13 | 23.41 | 22.22 | 20.13 | 23.41 | 21.78 |  |  |  |
| 14        | 8.05                       | 17.15 | 17.15 | 21.48 | 19.09 | 17.45 | 22.52 | 21.48 | 23.41 | 25.50 | 19.84 | 22.82 |  |  |  |
| 15        | 6.56                       | 16.41 | 16.41 | 17.45 | 21.48 | 21.48 | 21.48 | 22.22 | 21.78 | 19.09 | 24.16 | 24.16 |  |  |  |
| 16        | 6.71                       | 17.15 | 21.78 | 19.09 | 19.84 | 22.22 | 19.09 | 22.52 | 22.22 | 22.22 | 21.48 | 21.78 |  |  |  |
| Av.       | 7.46                       | 16.82 | 18.30 | 19.15 | 19.75 | 20.32 | 20.86 | 21.18 | 21.51 | 21.72 | 21.97 | 22.22 |  |  |  |
| SD        | 0.65                       | 1.55  | 1.56  | 1.53  | 1.43  | 1.63  | 1.70  | 1.30  | 1.36  | 2.01  | 1.71  | 1.60  |  |  |  |

Appendix-XXV

$R_s$  on 2-3 abdominal sternites of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

( $K\Omega - \text{cm}^2$ )

| S.<br>No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-----------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|           | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |       |       |       |
| 1         | 7.90                       | 19.09 | 19.84 | 22.22 | 21.48 | 24.16 | 25.80 | 23.86 | 24.16 | 22.82 | 23.41 | 22.82 | 22.82 | 23.41 | 22.82 |
| 2         | 6.71                       | 17.15 | 19.09 | 21.78 | 22.82 | 19.09 | 21.48 | 21.78 | 22.52 | 20.13 | 22.22 | 24.46 | 24.46 | 22.22 | 24.46 |
| 3         | 7.90                       | 19.09 | 21.48 | 21.78 | 21.78 | 22.22 | 19.84 | 23.12 | 21.78 | 24.46 | 24.46 | 22.52 | 22.52 | 24.46 | 22.52 |
| 4         | 8.05                       | 19.84 | 21.48 | 19.84 | 19.09 | 21.48 | 21.78 | 21.48 | 23.41 | 24.16 | 24.16 | 24.46 | 24.46 | 24.16 | 24.46 |
| 5         | 6.71                       | 16.41 | 17.45 | 21.48 | 21.48 | 20.13 | 22.52 | 24.16 | 21.48 | 22.82 | 24.16 | 24.16 | 24.16 | 24.16 | 24.16 |
| 6         | 7.90                       | 19.09 | 17.45 | 19.09 | 22.22 | 24.46 | 23.86 | 20.13 | 24.16 | 24.16 | 24.46 | 20.13 | 20.13 | 24.46 | 20.13 |
| 7         | 7.90                       | 17.15 | 19.09 | 22.52 | 19.84 | 22.52 | 24.16 | 24.16 | 22.82 | 22.22 | 22.52 | 26.54 | 26.54 | 22.52 | 26.54 |
| 8         | 6.71                       | 19.84 | 21.48 | 19.84 | 19.09 | 21.48 | 19.84 | 22.52 | 20.13 | 21.48 | 20.13 | 21.78 | 21.78 | 20.13 | 21.78 |
| 9         | 9.25                       | 17.45 | 19.09 | 19.09 | 20.13 | 19.09 | 19.84 | 21.48 | 24.16 | 23.86 | 24.16 | 24.46 | 24.46 | 24.16 | 24.46 |
| 10        | 7.90                       | 19.09 | 19.09 | 22.22 | 22.52 | 23.41 | 22.52 | 22.82 | 19.09 | 21.48 | 22.22 | 22.82 | 22.82 | 22.22 | 22.82 |
| 11        | 8.05                       | 19.09 | 17.15 | 21.48 | 22.22 | 21.48 | 21.48 | 24.16 | 24.16 | 25.50 | 19.09 | 22.52 | 22.52 | 19.09 | 22.52 |
| 12        | 7.90                       | 19.09 | 21.48 | 17.45 | 21.78 | 22.22 | 23.41 | 19.09 | 23.41 | 21.78 | 25.80 | 24.16 | 24.16 | 25.80 | 24.16 |
| 13        | 7.90                       | 17.15 | 19.09 | 19.09 | 21.48 | 23.86 | 21.78 | 24.16 | 22.52 | 21.48 | 24.16 | 26.84 | 26.84 | 24.16 | 26.84 |
| 14        | 7.90                       | 16.41 | 21.78 | 21.48 | 19.09 | 22.22 | 22.82 | 21.78 | 21.48 | 23.86 | 25.50 | 21.78 | 21.78 | 25.50 | 21.78 |
| 15        | 7.90                       | 17.45 | 19.09 | 18.79 | 19.09 | 21.78 | 22.22 | 19.09 | 23.41 | 24.16 | 19.09 | 24.46 | 24.46 | 19.09 | 24.46 |
| 16        | 8.05                       | 16.41 | 17.15 | 19.09 | 23.86 | 19.09 | 19.09 | 22.22 | 22.22 | 19.09 | 21.48 | 19.84 | 19.84 | 21.48 | 19.84 |
| Av.       | 7.79                       | 18.11 | 19.46 | 20.45 | 21.12 | 21.79 | 22.03 | 22.25 | 22.56 | 22.72 | 22.94 | 23.36 | 23.36 | 22.94 | 23.36 |
| SD        | 0.63                       | 1.27  | 1.66  | 1.57  | 1.53  | 1.74  | 1.81  | 1.72  | 1.49  | 1.74  | 2.10  | 1.97  | 1.97  | 2.10  | 1.97  |

# Appendix-XXVI

$R_s$  on 2-3 abdominal sternites of deformed adult female S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

( $K\Omega\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 7.90                       | 17.45 | 19.09 | 19.09 | 19.09 | 21.78 | 24.16 | 21.48 | 21.78 | 19.09 | 21.48 | 22.52 |  |  |  |
| 2      | 7.90                       | 17.15 | 19.09 | 19.84 | 20.13 | 18.79 | 19.84 | 19.09 | 21.78 | 21.78 | 21.48 | 20.13 |  |  |  |
| 3      | 6.71                       | 14.76 | 17.45 | 19.09 | 19.84 | 19.09 | 21.78 | 21.78 | 21.48 | 19.84 | 21.78 | 22.82 |  |  |  |
| 4      | 7.90                       | 16.41 | 17.45 | 21.48 | 21.48 | 21.48 | 19.09 | 19.84 | 19.09 | 21.78 | 20.13 | 22.52 |  |  |  |
| 5      | 6.71                       | 16.41 | 17.15 | 19.09 | 17.45 | 21.78 | 21.48 | 21.78 | 22.22 | 22.82 | 23.12 | 19.84 |  |  |  |
| 6      | 6.56                       | 18.79 | 18.79 | 19.84 | 19.84 | 19.84 | 21.48 | 22.82 | 19.09 | 22.22 | 21.78 | 24.16 |  |  |  |
| 7      | 7.90                       | 17.15 | 17.15 | 21.48 | 21.78 | 21.48 | 19.09 | 21.48 | 19.09 | 19.84 | 22.22 | 21.78 |  |  |  |
| 8      | 8.05                       | 16.41 | 19.09 | 19.09 | 21.78 | 17.45 | 20.13 | 21.78 | 22.52 | 23.41 | 24.16 | 24.46 |  |  |  |
| 9      | 7.90                       | 16.41 | 18.79 | 20.13 | 19.09 | 19.09 | 18.35 | 19.39 | 23.71 | 22.52 | 19.09 | 22.52 |  |  |  |
| 10     | 6.71                       | 19.09 | 19.09 | 17.45 | 21.48 | 19.84 | 22.52 | 20.13 | 22.52 | 21.48 | 24.46 | 24.46 |  |  |  |
| 11     | 7.90                       | 18.05 | 17.45 | 19.84 | 19.09 | 21.48 | 22.22 | 22.22 | 21.48 | 24.46 | 22.22 | 20.13 |  |  |  |
| 12     | 6.71                       | 17.15 | 17.45 | 17.45 | 19.84 | 22.82 | 23.41 | 23.86 | 24.16 | 21.78 | 21.78 | 21.78 |  |  |  |
| 13     | 8.05                       | 17.45 | 17.15 | 17.15 | 22.52 | 20.13 | 17.45 | 20.73 | 21.78 | 22.52 | 23.86 | 19.84 |  |  |  |
| 14     | 7.90                       | 18.79 | 18.35 | 20.13 | 19.84 | 22.22 | 22.22 | 20.13 | 24.16 | 23.86 | 22.52 | 24.16 |  |  |  |
| 15     | 6.56                       | 17.45 | 21.78 | 19.09 | 17.45 | 19.09 | 21.48 | 22.82 | 22.52 | 24.16 | 25.50 | 22.82 |  |  |  |
| 16     | 8.05                       | 15.51 | 19.84 | 20.13 | 19.09 | 21.78 | 20.13 | 22.52 | 19.84 | 20.13 | 19.09 | 21.78 |  |  |  |
| Av.    | 7.46                       | 17.15 | 18.45 | 19.40 | 19.99 | 20.51 | 20.93 | 21.37 | 21.70 | 21.98 | 22.17 | 22.23 |  |  |  |
| SD     | 0.65                       | 1.18  | 1.26  | 1.26  | 1.49  | 1.53  | 1.86  | 1.36  | 1.68  | 1.62  | 1.80  | 1.62  |  |  |  |

# Appendix-XXVII

$R_s$  on 2-3 abdominal sternites of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers.

( $K_L$ - $cm^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 8.05                       | 18.05 | 18.05 | 19.09 | 21.78 | 22.52 | 22.52 | 21.78 | 22.82 | 24.16 | 24.46 | 24.46 |  |  |  |
| 2      | 7.90                       | 16.41 | 17.45 | 21.78 | 19.84 | 21.78 | 19.09 | 24.16 | 21.78 | 25.50 | 23.86 | 20.13 |  |  |  |
| 3      | 7.90                       | 17.15 | 19.09 | 21.48 | 21.48 | 19.09 | 23.86 | 19.84 | 23.86 | 19.09 | 26.54 | 22.82 |  |  |  |
| 4      | 7.90                       | 19.09 | 20.13 | 19.84 | 22.52 | 24.16 | 21.48 | 22.52 | 20.13 | 21.78 | 21.48 | 22.52 |  |  |  |
| 5      | 6.71                       | 19.09 | 21.48 | 21.48 | 19.84 | 22.22 | 21.48 | 21.78 | 22.52 | 25.20 | 21.78 | 26.84 |  |  |  |
| 6      | 6.56                       | 21.48 | 19.84 | 17.15 | 22.82 | 24.16 | 24.16 | 23.86 | 21.48 | 22.22 | 23.86 | 22.82 |  |  |  |
| 7      | 7.90                       | 17.15 | 19.84 | 22.52 | 23.86 | 19.09 | 22.82 | 20.13 | 24.46 | 25.80 | 24.16 | 24.16 |  |  |  |
| 8      | 8.05                       | 17.45 | 17.45 | 19.09 | 21.78 | 23.71 | 19.09 | 22.52 | 19.09 | 21.48 | 19.09 | 19.84 |  |  |  |
| 9      | 9.72                       | 18.79 | 21.78 | 21.78 | 19.09 | 20.73 | 24.46 | 21.48 | 22.82 | 24.46 | 24.46 | 24.46 |  |  |  |
| 10     | 6.71                       | 17.15 | 19.09 | 21.48 | 22.52 | 24.16 | 21.78 | 25.50 | 25.50 | 21.48 | 22.22 | 24.46 |  |  |  |
| 11     | 7.90                       | 16.41 | 21.48 | 24.16 | 23.86 | 21.48 | 24.16 | 24.16 | 22.22 | 23.86 | 26.54 | 21.78 |  |  |  |
| 12     | 7.90                       | 19.09 | 17.45 | 19.09 | 19.09 | 19.09 | 19.09 | 20.13 | 23.41 | 19.09 | 21.48 | 24.16 |  |  |  |
| 13     | 7.90                       | 19.84 | 21.48 | 21.48 | 21.78 | 22.52 | 22.52 | 21.48 | 24.16 | 24.16 | 24.46 | 26.84 |  |  |  |
| 14     | 9.25                       | 18.79 | 19.09 | 19.84 | 22.52 | 21.48 | 24.16 | 24.46 | 24.16 | 22.52 | 23.86 | 21.78 |  |  |  |
| 15     | 8.05                       | 20.13 | 20.13 | 21.78 | 22.52 | 24.46 | 21.48 | 21.78 | 23.41 | 23.86 | 20.13 | 24.16 |  |  |  |
| 16     | 7.90                       | 16.41 | 19.84 | 19.09 | 19.84 | 20.13 | 21.78 | 22.52 | 21.48 | 24.16 | 22.52 | 24.46 |  |  |  |
| Av.    | 7.83                       | 18.28 | 19.60 | 20.70 | 21.57 | 21.92 | 22.12 | 22.38 | 22.71 | 23.05 | 23.18 | 23.48 |  |  |  |
| SD     | 0.69                       | 1.50  | 1.49  | 1.74  | 1.57  | 1.91  | 1.84  | 1.67  | 1.66  | 2.07  | 2.08  | 2.00  |  |  |  |

# Appendix-XXVIII

$R_s$  on forewings of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers,  
( $K\angle\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 7.90                       | 30.20 | 36.60 | 37.28 | 37.66 | 37.28 | 37.66 | 38.59 | 43.62 | 40.63 | 40.63 | 40.26 |  |  |  |
| 2      | 7.90                       | 32.25 | 35.60 | 34.86 | 37.28 | 35.60 | 40.63 | 37.66 | 37.66 | 43.99 | 38.59 | 45.30 |  |  |  |
| 3      | 6.71                       | 27.22 | 33.18 | 32.25 | 35.60 | 37.66 | 35.60 | 40.63 | 37.66 | 40.26 | 38.59 | 38.96 |  |  |  |
| 4      | 7.90                       | 32.25 | 37.28 | 37.28 | 38.59 | 39.33 | 43.62 | 37.28 | 40.63 | 40.63 | 35.60 | 36.91 |  |  |  |
| 5      | 9.25                       | 30.57 | 37.66 | 37.66 | 35.23 | 38.59 | 37.66 | 37.66 | 40.63 | 36.91 | 41.01 | 41.94 |  |  |  |
| 6      | 7.90                       | 30.20 | 37.28 | 32.25 | 32.25 | 40.63 | 37.28 | 40.63 | 36.91 | 41.01 | 42.31 | 38.96 |  |  |  |
| 7      | 7.90                       | 33.18 | 32.25 | 32.25 | 37.66 | 38.59 | 40.26 | 35.60 | 40.26 | 39.70 | 38.96 | 47.35 |  |  |  |
| 8      | 8.05                       | 30.20 | 35.23 | 35.60 | 32.25 | 35.60 | 35.23 | 40.63 | 38.59 | 38.96 | 44.93 | 42.31 |  |  |  |
| 9      | 9.25                       | 32.25 | 30.20 | 37.66 | 35.60 | 38.96 | 39.33 | 40.26 | 41.01 | 38.96 | 43.62 | 45.30 |  |  |  |
| 10     | 7.90                       | 27.22 | 32.25 | 35.60 | 37.66 | 32.25 | 38.96 | 38.22 | 36.91 | 36.91 | 38.96 | 40.26 |  |  |  |
| 11     | 7.90                       | 32.25 | 30.20 | 35.23 | 35.23 | 35.60 | 37.66 | 38.96 | 38.96 | 38.96 | 40.63 | 41.94 |  |  |  |
| 12     | 8.05                       | 27.22 | 30.57 | 36.91 | 35.23 | 35.23 | 36.91 | 43.62 | 37.66 | 39.89 | 41.01 | 41.01 |  |  |  |
| 13     | 8.05                       | 27.22 | 34.30 | 37.66 | 37.66 | 40.63 | 38.96 | 41.01 | 41.01 | 42.69 | 46.97 | 40.26 |  |  |  |
| 14     | 7.90                       | 26.84 | 28.15 | 32.62 | 37.66 | 35.60 | 36.91 | 36.91 | 40.26 | 40.63 | 38.96 | 42.31 |  |  |  |
| 15     | 9.25                       | 26.84 | 32.25 | 34.67 | 38.59 | 40.63 | 40.26 | 38.96 | 42.31 | 41.01 | 35.60 | 36.91 |  |  |  |
| 16     | 9.25                       | 30.20 | 34.30 | 35.23 | 40.63 | 38.59 | 35.60 | 38.22 | 40.63 | 40.63 | 41.01 | 41.94 |  |  |  |
| Av.    | 8.19                       | 29.76 | 33.58 | 35.31 | 36.55 | 37.55 | 38.28 | 39.05 | 39.67 | 40.11 | 40.46 | 41.37 |  |  |  |
| SD     | 0.70                       | 2.32  | 2.92  | 2.05  | 2.25  | 2.39  | 2.21  | 1.98  | 1.98  | 1.81  | 3.03  | 2.88  |  |  |  |

# Appendix-XXIX

$R_s$  on forewings of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

( $K \Omega - cm^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |
| 1      | 7.90                       | 30.57 | 37.66 | 37.66 | 40.63 | 41.01 | 43.06 | 40.63 | 43.62 | 46.60 | 45.67 | 45.30 |  |
| 2      | 7.90                       | 28.15 | 35.60 | 32.62 | 40.26 | 36.91 | 38.59 | 41.01 | 40.63 | 38.96 | 46.97 | 42.31 |  |
| 3      | 9.25                       | 30.20 | 35.23 | 37.28 | 37.66 | 38.59 | 39.70 | 46.97 | 44.93 | 41.01 | 44.55 | 46.97 |  |
| 4      | 9.25                       | 28.52 | 38.59 | 35.60 | 37.28 | 37.66 | 43.62 | 38.59 | 37.66 | 40.63 | 43.62 | 41.94 |  |
| 5      | 7.90                       | 32.62 | 32.62 | 35.60 | 35.60 | 37.28 | 40.63 | 43.62 | 40.63 | 43.62 | 43.62 | 47.35 |  |
| 6      | 7.90                       | 32.25 | 34.67 | 40.63 | 40.63 | 40.63 | 36.91 | 41.94 | 42.69 | 41.01 | 45.67 | 44.93 |  |
| 7      | 7.90                       | 28.52 | 34.30 | 37.66 | 37.66 | 38.96 | 38.59 | 40.63 | 38.96 | 42.69 | 41.01 | 45.30 |  |
| 8      | 8.72                       | 30.57 | 30.57 | 38.59 | 38.59 | 43.62 | 37.66 | 38.59 | 46.05 | 43.62 | 43.06 | 50.70 |  |
| 9      | 9.25                       | 32.25 | 32.25 | 40.63 | 37.66 | 40.26 | 38.96 | 46.05 | 40.26 | 41.01 | 40.63 | 43.99 |  |
| 10     | 7.90                       | 28.15 | 35.23 | 32.62 | 40.63 | 38.59 | 43.99 | 41.01 | 43.99 | 45.67 | 46.60 | 42.31 |  |
| 11     | 8.72                       | 30.57 | 32.62 | 38.96 | 40.26 | 40.63 | 39.70 | 40.63 | 41.01 | 49.02 | 51.08 | 45.30 |  |
| 12     | 9.25                       | 34.30 | 30.57 | 38.59 | 37.28 | 35.60 | 40.63 | 43.99 | 46.97 | 46.97 | 41.01 | 48.65 |  |
| 13     | 7.90                       | 34.30 | 32.25 | 37.28 | 41.01 | 40.63 | 38.96 | 39.89 | 40.26 | 43.62 | 44.93 | 41.94 |  |
| 14     | 7.90                       | 33.18 | 31.50 | 35.60 | 32.62 | 43.62 | 43.99 | 43.06 | 45.67 | 45.67 | 41.94 | 46.97 |  |
| 15     | 7.90                       | 31.88 | 34.30 | 37.66 | 37.66 | 38.96 | 41.01 | 40.26 | 43.99 | 41.38 | 43.62 | 42.31 |  |
| 16     | 9.25                       | 28.52 | 35.23 | 32.62 | 35.23 | 37.28 | 43.62 | 38.59 | 41.01 | 40.26 | 38.96 | 45.30 |  |
| AV.    | 8.42                       | 30.91 | 33.95 | 36.85 | 38.17 | 39.39 | 40.60 | 41.59 | 42.40 | 43.23 | 43.93 | 45.10 |  |
| SD     | 0.64                       | 2.14  | 2.34  | 2.58  | 2.36  | 2.28  | 2.38  | 2.53  | 2.73  | 2.87  | 2.97  | 2.59  |  |

# Appendix-XXXI

R<sub>g</sub> on forewings of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers,

(KΩ-cm<sup>2</sup>)

| S. No. | O.   | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |
|--------|------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        |      | 1                          | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |
| 1      | 8.05 | 32.25                      | 35.23 | 36.91 | 38.59 | 42.69 | 41.01 | 41.57 | 46.05 | 41.01 | 45.67 | 46.97 |
| 2      | 8.05 | 28.15                      | 30.57 | 37.28 | 35.60 | 43.62 | 40.26 | 36.96 | 39.89 | 46.97 | 52.38 | 45.30 |
| 3      | 7.90 | 35.23                      | 30.57 | 35.60 | 40.63 | 35.60 | 37.66 | 40.63 | 40.63 | 43.62 | 45.67 | 41.94 |
| 4      | 9.25 | 31.50                      | 32.62 | 35.23 | 38.22 | 38.59 | 38.96 | 46.97 | 46.97 | 42.69 | 40.26 | 42.31 |
| 5      | 7.90 | 27.78                      | 32.62 | 37.28 | 41.94 | 39.89 | 43.99 | 37.66 | 41.01 | 43.62 | 43.62 | 50.70 |
| 6      | 9.25 | 32.62                      | 31.13 | 32.25 | 34.67 | 36.91 | 43.62 | 43.99 | 38.96 | 46.97 | 41.01 | 43.99 |
| 7      | 7.90 | 30.20                      | 34.30 | 34.67 | 38.22 | 37.66 | 40.26 | 45.67 | 43.99 | 43.99 | 45.67 | 41.01 |
| 8      | 9.25 | 30.57                      | 35.23 | 34.30 | 35.23 | 38.59 | 38.59 | 41.01 | 43.62 | 41.38 | 49.02 | 46.60 |
| 9      | 7.90 | 31.50                      | 32.25 | 35.60 | 37.66 | 35.60 | 37.66 | 38.96 | 43.62 | 41.01 | 41.01 | 41.94 |
| 10     | 9.25 | 28.15                      | 34.67 | 32.62 | 37.28 | 40.63 | 43.99 | 41.01 | 40.63 | 45.67 | 43.62 | 48.65 |
| 11     | 8.05 | 30.57                      | 35.60 | 37.28 | 33.18 | 43.62 | 43.62 | 38.59 | 40.63 | 38.96 | 40.63 | 45.30 |
| 12     | 8.05 | 32.62                      | 32.62 | 37.66 | 36.91 | 37.66 | 40.26 | 40.63 | 45.30 | 40.63 | 43.99 | 50.33 |
| 13     | 9.25 | 32.25                      | 37.28 | 35.60 | 37.28 | 37.66 | 41.01 | 43.62 | 45.67 | 44.93 | 41.01 | 45.30 |
| 14     | 9.25 | 27.22                      | 34.30 | 34.30 | 40.63 | 40.63 | 38.96 | 38.59 | 41.01 | 41.57 | 46.97 | 46.97 |
| 15     | 7.90 | 30.57                      | 37.28 | 37.28 | 37.66 | 37.28 | 40.26 | 40.63 | 40.63 | 43.62 | 38.96 | 41.94 |
| 16     | 7.90 | 28.52                      | 35.60 | 33.55 | 35.60 | 40.26 | 37.66 | 43.99 | 38.96 | 46.97 | 40.63 | 42.31 |
| Av.    | 8.44 | 30.61                      | 33.87 | 35.46 | 37.46 | 39.18 | 40.49 | 41.41 | 42.35 | 43.35 | 43.76 | 45.10 |
| SD     | 0.65 | 2.20                       | 2.17  | 1.74  | 2.32  | 2.58  | 2.27  | 2.73  | 2.65  | 2.49  | 3.66  | 3.10  |

# Appendix-XXXII

$R_s$  on hindwings of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

( $K\Omega\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |
| 1      | 9.25                       | 28.15 | 36.91 | 31.88 | 40.26 | 38.21 | 40.26 | 42.31 | 45.67 | 43.62 | 43.62 | 41.57 |  |
| 2      | 8.65                       | 31.50 | 31.88 | 35.23 | 40.64 | 43.62 | 38.21 | 46.60 | 41.57 | 45.67 | 43.25 | 46.60 |  |
| 3      | 7.90                       | 30.57 | 28.52 | 38.59 | 38.21 | 40.26 | 38.59 | 41.57 | 42.31 | 41.57 | 45.67 | 43.62 |  |
| 4      | 7.90                       | 28.52 | 31.50 | 38.21 | 38.21 | 40.64 | 41.57 | 46.97 | 43.25 | 43.25 | 41.94 | 43.62 |  |
| 5      | 6.71                       | 25.16 | 31.88 | 40.26 | 34.86 | 43.25 | 43.62 | 43.25 | 43.25 | 41.57 | 43.62 | 49.02 |  |
| 6      | 9.25                       | 25.16 | 33.93 | 37.28 | 40.26 | 42.31 | 40.26 | 38.59 | 46.97 | 42.31 | 41.57 | 46.97 |  |
| 7      | 7.90                       | 25.16 | 34.86 | 31.88 | 38.59 | 38.21 | 41.94 | 45.67 | 43.62 | 46.97 | 45.67 | 42.31 |  |
| 8      | 7.90                       | 28.52 | 31.50 | 38.21 | 36.91 | 38.59 | 41.57 | 41.57 | 46.04 | 45.67 | 43.62 | 40.26 |  |
| 9      | 6.71                       | 28.52 | 28.52 | 36.91 | 36.91 | 40.26 | 41.57 | 42.31 | 43.62 | 41.94 | 41.57 | 45.67 |  |
| 10     | 8.05                       | 28.15 | 28.52 | 40.26 | 41.94 | 41.57 | 38.21 | 43.62 | 43.62 | 46.97 | 46.60 | 46.97 |  |
| 11     | 7.90                       | 31.50 | 30.57 | 31.88 | 42.31 | 38.21 | 38.21 | 41.57 | 41.57 | 43.62 | 49.96 | 43.62 |  |
| 12     | 7.90                       | 31.88 | 28.52 | 38.59 | 38.21 | 40.26 | 43.25 | 43.25 | 41.94 | 46.60 | 43.25 | 41.57 |  |
| 13     | 7.90                       | 28.52 | 35.23 | 36.91 | 40.26 | 40.26 | 43.62 | 45.67 | 42.31 | 41.57 | 40.64 | 43.25 |  |
| 14     | 8.05                       | 31.88 | 34.86 | 38.21 | 41.57 | 36.91 | 41.57 | 43.62 | 43.25 | 43.62 | 43.62 | 46.60 |  |
| 15     | 8.05                       | 25.16 | 36.91 | 35.23 | 38.21 | 38.21 | 46.97 | 38.21 | 43.25 | 43.25 | 46.97 | 45.67 |  |
| 16     | 9.25                       | 28.52 | 28.52 | 33.93 | 41.57 | 43.62 | 42.31 | 43.25 | 46.97 | 46.97 | 46.97 | 41.57 |  |
| Av.    | 8.04                       | 28.55 | 32.04 | 36.47 | 39.31 | 40.27 | 41.36 | 43.00 | 43.70 | 44.07 | 44.28 | 44.31 |  |
| SD     | 0.73                       | 2.45  | 3.07  | 2.84  | 2.12  | 2.14  | 2.40  | 2.50  | 1.78  | 2.08  | 2.49  | 2.53  |  |

# Appendix-XXIII

$R_s$  on hind wings of normal adult male S. gregaria at various ages, obtained from solvent treated hopper.

( $K \Omega$ -cm<sup>2</sup>)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |
| 1      | 7.90                       | 31.88 | 35.23 | 33.93 | 42.31 | 43.62 | 41.57 | 50.33 | 46.97 | 46.60 | 46.97 | 43.62 |
| 2      | 7.90                       | 28.52 | 28.52 | 38.59 | 43.25 | 46.60 | 46.97 | 46.97 | 43.99 | 43.62 | 46.60 | 50.33 |
| 3      | 9.25                       | 33.55 | 31.88 | 35.23 | 41.94 | 36.91 | 43.25 | 50.33 | 46.60 | 49.96 | 50.33 | 43.25 |
| 4      | 7.90                       | 28.15 | 38.21 | 40.64 | 41.57 | 46.97 | 41.94 | 43.99 | 41.94 | 43.62 | 43.62 | 45.67 |
| 5      | 7.90                       | 25.16 | 34.86 | 35.23 | 43.62 | 41.94 | 46.97 | 43.62 | 43.62 | 50.33 | 46.60 | 46.97 |
| 6      | 9.23                       | 25.16 | 31.88 | 38.21 | 42.31 | 42.31 | 41.94 | 46.97 | 50.33 | 50.33 | 50.33 | 50.33 |
| 7      | 7.90                       | 28.52 | 28.52 | 33.55 | 40.26 | 40.26 | 45.67 | 43.62 | 46.97 | 46.97 | 46.60 | 52.38 |
| 8      | 8.05                       | 31.50 | 38.21 | 35.23 | 41.57 | 46.60 | 43.62 | 41.94 | 49.96 | 53.68 | 49.96 | 46.97 |
| 9      | 7.90                       | 31.88 | 31.88 | 41.57 | 43.62 | 40.64 | 49.02 | 46.97 | 50.33 | 43.62 | 52.01 | 50.33 |
| 10     | 7.90                       | 25.16 | 35.23 | 35.23 | 40.26 | 40.26 | 46.60 | 46.60 | 46.60 | 46.97 | 46.04 | 49.96 |
| 11     | 8.72                       | 28.52 | 31.50 | 40.26 | 36.91 | 40.26 | 43.62 | 43.62 | 43.62 | 46.60 | 50.33 | 46.60 |
| 12     | 9.25                       | 31.50 | 36.91 | 41.57 | 38.21 | 43.62 | 46.97 | 46.97 | 46.97 | 43.99 | 46.97 | 46.97 |
| 13     | 9.25                       | 28.15 | 31.50 | 38.59 | 40.26 | 43.25 | 43.25 | 41.94 | 49.96 | 46.60 | 43.62 | 49.02 |
| 14     | 8.05                       | 25.16 | 31.88 | 38.21 | 38.21 | 43.25 | 41.57 | 43.62 | 41.94 | 46.97 | 49.96 | 45.67 |
| 15     | 7.90                       | 31.88 | 34.86 | 31.88 | 38.21 | 45.67 | 46.60 | 46.60 | 50.33 | 43.62 | 46.97 | 46.60 |
| 16     | 9.25                       | 28.52 | 31.88 | 40.26 | 41.57 | 43.62 | 42.31 | 49.96 | 45.67 | 49.96 | 43.99 | 52.01 |
| Av.    | 8.39                       | 28.95 | 33.31 | 37.39 | 40.88 | 42.86 | 44.49 | 45.88 | 46.61 | 47.09 | 47.56 | 47.92 |
| SD     | 0.63                       | 2.82  | 3.01  | 3.08  | 2.09  | 2.79  | 2.43  | 2.79  | 2.98  | 3.05  | 2.64  | 2.78  |

# Appendix-XXXIV

$R_s$  on hind wings of deformed adult female S.gregaria at various ages, obtained from diflubenzuron treated hoppers.

( $K \Omega\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |       |       |       |
| 1      | 7.90                       | 28.52 | 31.88 | 38.21 | 36.91 | 40.26 | 38.21 | 41.57 | 43.62 | 46.97 | 45.67 | 45.67 | 45.67 | 45.67 | 45.67 |
| 2      | 8.05                       | 31.88 | 31.50 | 38.59 | 38.59 | 41.57 | 38.21 | 46.60 | 46.97 | 42.31 | 41.57 | 41.57 | 41.57 | 41.57 | 41.57 |
| 3      | 9.25                       | 25.16 | 31.88 | 35.23 | 41.94 | 38.21 | 42.31 | 43.62 | 46.04 | 43.25 | 43.62 | 43.62 | 43.62 | 43.62 | 43.25 |
| 4      | 7.90                       | 25.16 | 31.88 | 31.88 | 38.21 | 38.59 | 40.26 | 40.26 | 43.25 | 41.57 | 45.30 | 46.97 | 46.97 | 46.97 | 46.97 |
| 5      | 6.71                       | 28.15 | 35.23 | 38.59 | 33.55 | 40.26 | 42.31 | 41.94 | 41.57 | 43.25 | 46.60 | 43.62 | 43.62 | 43.62 | 43.62 |
| 6      | 7.90                       | 26.47 | 34.86 | 35.23 | 40.26 | 38.21 | 43.25 | 43.62 | 43.62 | 41.94 | 43.25 | 41.57 | 41.57 | 41.57 | 41.57 |
| 7      | 7.90                       | 28.52 | 28.52 | 31.88 | 41.57 | 42.31 | 40.26 | 43.25 | 41.57 | 45.67 | 43.62 | 40.62 | 40.62 | 40.62 | 40.62 |
| 8      | 8.05                       | 28.52 | 28.52 | 38.59 | 36.91 | 38.59 | 40.64 | 38.21 | 42.31 | 40.26 | 41.57 | 43.62 | 43.62 | 43.62 | 43.62 |
| 9      | 6.71                       | 25.16 | 28.52 | 33.93 | 33.93 | 40.26 | 38.21 | 46.60 | 45.67 | 46.60 | 43.25 | 46.97 | 46.97 | 46.97 | 46.97 |
| 10     | 9.25                       | 31.88 | 33.93 | 38.21 | 41.94 | 42.31 | 43.25 | 41.57 | 41.57 | 43.62 | 46.97 | 43.62 | 43.62 | 43.62 | 43.62 |
| 11     | 7.90                       | 25.16 | 34.86 | 35.23 | 38.21 | 38.21 | 45.67 | 41.57 | 46.97 | 43.62 | 46.60 | 50.33 | 50.33 | 50.33 | 50.33 |
| 12     | 8.05                       | 26.47 | 31.50 | 41.57 | 36.91 | 43.62 | 41.57 | 43.62 | 43.25 | 46.97 | 43.62 | 41.57 | 41.57 | 41.57 | 41.57 |
| 13     | 7.90                       | 25.16 | 28.52 | 38.59 | 40.26 | 42.31 | 38.21 | 43.25 | 40.26 | 41.57 | 43.25 | 43.25 | 43.25 | 43.25 | 43.25 |
| 14     | 7.90                       | 28.52 | 36.91 | 36.91 | 41.57 | 41.57 | 40.26 | 45.67 | 42.31 | 43.62 | 41.57 | 46.97 | 46.97 | 46.97 | 46.97 |
| 15     | 9.25                       | 28.52 | 28.52 | 31.88 | 43.62 | 40.26 | 43.25 | 38.59 | 41.57 | 43.62 | 43.62 | 43.99 | 43.99 | 43.99 | 43.99 |
| 16     | 7.90                       | 31.50 | 31.88 | 33.93 | 38.59 | 36.91 | 43.62 | 43.62 | 43.62 | 46.97 | 43.25 | 46.97 | 46.97 | 46.97 | 46.97 |
| Av.    | 8.03                       | 27.80 | 31.81 | 36.15 | 38.94 | 40.22 | 41.22 | 42.72 | 43.39 | 43.86 | 43.96 | 44.39 | 44.39 | 44.39 | 44.39 |
| SD     | 0.73                       | 2.42  | 2.77  | 2.94  | 2.89  | 1.94  | 2.31  | 2.46  | 2.06  | 2.17  | 1.78  | 2.70  | 2.70  | 2.70  | 2.70  |

Appendix-XXXV

$R_s$  on hind wings of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers.

( $K\lambda\text{-cm}^2$ )

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 9.25                       | 25.16 | 28.52 | 35.23 | 36.91 | 40.26 | 43.62 | 50.33 | 43.62 | 50.33 | 46.04 | 46.97 |  |  |  |
| 2      | 7.90                       | 28.52 | 31.88 | 38.59 | 43.62 | 38.59 | 41.94 | 40.64 | 53.31 | 41.57 | 43.62 | 50.33 |  |  |  |
| 3      | 7.90                       | 28.15 | 37.28 | 41.57 | 38.21 | 40.64 | 50.33 | 50.33 | 49.96 | 53.31 | 46.60 | 46.97 |  |  |  |
| 4      | 8.05                       | 25.16 | 33.93 | 35.23 | 40.26 | 45.67 | 42.31 | 46.97 | 43.62 | 43.62 | 43.25 | 43.62 |  |  |  |
| 5      | 9.25                       | 25.16 | 31.50 | 31.88 | 43.62 | 41.94 | 41.57 | 43.62 | 41.94 | 47.35 | 43.62 | 50.33 |  |  |  |
| 6      | 7.90                       | 28.52 | 38.21 | 40.26 | 41.94 | 43.62 | 45.67 | 46.97 | 46.60 | 46.97 | 46.97 | 45.67 |  |  |  |
| 7      | 8.05                       | 30.57 | 31.88 | 35.23 | 38.59 | 43.62 | 43.62 | 43.62 | 46.97 | 43.62 | 46.97 | 52.38 |  |  |  |
| 8      | 8.72                       | 28.52 | 34.86 | 37.28 | 43.62 | 46.97 | 43.62 | 45.67 | 50.33 | 49.96 | 53.31 | 45.67 |  |  |  |
| 9      | 7.90                       | 30.57 | 35.23 | 40.26 | 43.25 | 43.62 | 46.97 | 42.31 | 41.57 | 47.35 | 50.33 | 43.25 |  |  |  |
| 10     | 8.05                       | 28.52 | 31.88 | 38.59 | 41.94 | 40.26 | 46.60 | 43.62 | 50.33 | 43.62 | 43.62 | 49.96 |  |  |  |
| 11     | 9.25                       | 31.88 | 31.88 | 33.93 | 38.21 | 43.25 | 42.31 | 41.94 | 45.97 | 46.97 | 42.31 | 55.36 |  |  |  |
| 12     | 7.90                       | 25.16 | 35.23 | 35.23 | 40.26 | 43.25 | 46.97 | 50.33 | 43.62 | 50.33 | 46.97 | 45.67 |  |  |  |
| 13     | 7.90                       | 31.50 | 31.88 | 41.94 | 38.21 | 41.94 | 41.94 | 46.97 | 50.33 | 46.60 | 54.99 | 46.60 |  |  |  |
| 14     | 7.90                       | 31.88 | 31.88 | 38.21 | 41.57 | 46.97 | 46.97 | 45.67 | 43.25 | 50.33 | 49.02 | 49.96 |  |  |  |
| 15     | 8.05                       | 28.52 | 28.52 | 35.23 | 40.26 | 38.21 | 43.25 | 49.96 | 43.62 | 43.62 | 46.97 | 43.25 |  |  |  |
| 16     | 7.90                       | 28.52 | 31.50 | 33.55 | 41.94 | 41.57 | 43.25 | 43.62 | 46.60 | 46.97 | 52.38 | 46.97 |  |  |  |
| Av.    | 8.24                       | 28.52 | 32.88 | 37.01 | 40.78 | 42.52 | 44.43 | 45.79 | 46.42 | 47.03 | 47.31 | 47.69 |  |  |  |
| SD     | 0.54                       | 2.38  | 2.73  | 3.01  | 2.24  | 2.63  | 2.51  | 3.22  | 3.57  | 3.24  | 3.81  | 3.43  |  |  |  |

# Appendix-XXVI

Potential difference between outer and inner surfaces of excised pronotum of deformed and normal adult male S. gregaria at various ages.

(mV)

| S. No.      | Age in days after moulting |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|-------------|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|             | 0                          |     | 1   |     | 2   |     | 3   |     | 4   |     | 5   |     | 6   |     | 7   |     | 8   |     | 9   |     | 10  |     | 15  |     |
|             | D                          | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   |
| 1           | 0                          | 0   | 2   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 2   | 4   | 4   | 4   | 4   | 2   | 4   | 4   | 0   | 2   | 0   | 0   | 0   | 0   |
| 2           | 3                          | 3   | 2   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 2   | 4   | 4   | 2   | 3   | 4   | 2   | 2   | 2   |
| 3           | 4                          | 4   | 3   | 4   | 4   | 6   | 4   | 6   | 4   | 4   | 4   | 4   | 6   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 2   | 4   | 5   |
| 4           | 4                          | 4   | 4   | 4   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 4   | 5   | 6   | 5   | 4   | 5   | 6   | 5   | 4   | 4   | 4   | 4   | 6   |
| 5           | 5                          | 4   | 4   | 6   | 5   | 7   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 4   | 6   | 6   | 6   | 4   | 6   | 6   | 5   | 6   |
| 6           | 5                          | 6   | 6   | 6   | 5   | 7   | 6   | 8   | 7   | 6   | 6   | 7   | 6   | 6   | 7   | 5   | 6   | 6   | 6   | 6   | 6   | 6   | 6   | 6   |
| 7           | 5                          | 6   | 6   | 6   | 6   | 8   | 8   | 8   | 8   | 8   | 7   | 8   | 7   | 7   | 6   | 8   | 8   | 8   | 7   | 6   | 7   | 8   | 7   | 7   |
| 8           | 6                          | 6   | 6   | 7   | 7   | 6   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 6   | 8   | 8   | 8   | 8   | 6   | 7   | 8   | 8   | 8   |
| 9           | 6                          | 7   | 7   | 8   | 7   | 8   | 6   | 8   | 9   | 8   | 8   | 8   | 8   | 8   | 6   | 8   | 9   | 8   | 8   | 8   | 8   | 8   | 8   | 8   |
| 10          | 6                          | 7   | 8   | 8   | 8   | 8   | 8   | 9   | 10  | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 9   | 8   | 8   | 8   | 8   | 8   | 9   | 8   |
| 11          | 8                          | 8   | 8   | 9   | 8   | 10  | 10  | 10  | 10  | 9   | 8   | 9   | 10  | 9   | 9   | 10  | 9   | 10  | 9   | 9   | 8   | 9   | 10  | 9   |
| 12          | 8                          | 8   | 8   | 10  | 9   | 10  | 10  | 10  | 11  | 10  | 9   | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 9   | 10  | 10  | 10  |
| 13          | 10                         | 10  | 10  | 11  | 9   | 10  | 12  | 10  | 12  | 12  | 12  | 10  | 11  | 12  | 11  | 12  | 12  | 12  | 10  | 12  | 12  | 11  | 12  | 12  |
| 14          | 11                         | 12  | 12  | 12  | 10  | 12  | 12  | 10  | 12  | 12  | 12  | 12  | 12  | 12  | 12  | 14  | 12  | 12  | 12  | 12  | 14  | 13  | 12  | 14  |
| 15          | 12                         | 13  | 13  | 15  | 12  | 14  | 12  | 14  | 14  | 14  | 15  | 14  | 12  | 14  | 14  | 14  | 14  | 14  | 12  | 14  | 14  | 14  | 13  | 14  |
| 16          | 12                         | 15  | 14  | 18  | 14  | 16  | 18  | 18  | 16  | 16  | 16  | 16  | 14  | 16  | 14  | 16  | 15  | 14  | 14  | 16  | 16  | 18  | 18  | 16  |
| Av.         | 6.6                        | 7.1 | 6.9 | 8.1 | 7.3 | 7.8 | 8.0 | 8.6 | 8.8 | 8.7 | 8.1 | 8.3 | 8.3 | 8.3 | 7.6 | 8.3 | 8.4 | 8.6 | 7.6 | 7.8 | 7.9 | 7.9 | 8.0 | 8.2 |
| Me-<br>dian | 6.0                        | 6.5 | 6.5 | 7.5 | 7.0 | 7.5 | 6.0 | 8.0 | 8.5 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 6.0 | 8.0 | 8.0 | 8.5 | 8.0 | 7.0 | 7.5 | 8.0 | 8.0 | 8.0 |

D - deformed adults; N - normal adults

# Appendix--XXVII

Potential difference between outer and inner surfaces of excised pronotum of deformed and normal adult female S. gregaria at various ages.

(mV)

| S.<br>No. | 0   |     | 1   |     | 2   |     | 3   |     | 4   |     | 5   |     | 6   |     | 7   |     | 8   |     | 9   |     | 10  |     | 15  |     |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
|           |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
|           | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   | D   | N   |
| 1         | 0   | 0   | 2   | 2   | 0   | 2   | 4   | 4   | 2   | 4   | 2   | 3   | 2   | 2   | 2   | 0   | 2   | 0   | 0   | 0   | 0   | 2   | 2   | 4   |
| 2         | 2   | 2   | 2   | 3   | 2   | 4   | 4   | 4   | 4   | 4   | 2   | 4   | 4   | 4   | 3   | 2   | 2   | 2   | 2   | 2   | 0   | 4   | 4   | 4   |
| 3         | 3   | 3   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 2   | 2   | 4   | 4   | 5   |
| 4         | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 4   | 5   | 5   | 4   | 4   | 4   | 5   | 4   | 4   | 4   | 4   | 4   | 4   | 6   |
| 5         | 4   | 5   | 4   | 6   | 4   | 4   | 5   | 6   | 5   | 6   | 5   | 6   | 5   | 5   | 4   | 5   | 6   | 4   | 4   | 4   | 6   | 6   | 6   | 6   |
| 6         | 5   | 6   | 5   | 6   | 5   | 6   | 8   | 6   | 6   | 6   | 5   | 6   | 6   | 6   | 5   | 6   | 6   | 4   | 6   | 6   | 6   | 6   | 6   | 6   |
| 7         | 6   | 6   | 6   | 7   | 6   | 6   | 8   | 8   | 6   | 6   | 6   | 7   | 6   | 6   | 6   | 7   | 6   | 7   | 8   | 7   | 6   | 7   | 7   | 7   |
| 8         | 6   | 6   | 6   | 7   | 6   | 7   | 8   | 8   | 8   | 8   | 6   | 8   | 8   | 8   | 6   | 6   | 8   | 8   | 8   | 8   | 8   | 7   | 8   | 8   |
| 9         | 6   | 7   | 7   | 8   | 6   | 8   | 8   | 9   | 8   | 8   | 6   | 8   | 8   | 8   | 8   | 7   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 8   |
| 10        | 7   | 8   | 7   | 8   | 8   | 8   | 8   | 9   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 8   | 9   | 8   | 8   | 8   | 8   | 8   |
| 11        | 8   | 8   | 8   | 8   | 8   | 8   | 9   | 10  | 9   | 10  | 8   | 8   | 9   | 9   | 8   | 8   | 8   | 8   | 9   | 10  | 9   | 9   | 8   | 10  |
| 12        | 8   | 9   | 8   | 10  | 9   | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 10  | 8   | 8   | 10  | 9   | 10  | 11  | 10  | 10  | 9   | 10  |
| 13        | 10  | 12  | 9   | 10  | 10  | 12  | 12  | 10  | 12  | 12  | 11  | 12  | 12  | 12  | 10  | 10  | 11  | 12  | 12  | 12  | 10  | 12  | 10  | 12  |
| 14        | 12  | 12  | 10  | 12  | 10  | 12  | 12  | 12  | 14  | 15  | 12  | 12  | 14  | 12  | 10  | 12  | 12  | 13  | 12  | 12  | 12  | 12  | 11  | 14  |
| 15        | 14  | 13  | 10  | 14  | 11  | 14  | 12  | 14  | 16  | 16  | 14  | 14  | 14  | 13  | 12  | 14  | 13  | 14  | 13  | 14  | 12  | 14  | 14  | 14  |
| 16        | 14  | 14  | 12  | 15  | 12  | 19  | 14  | 16  | 16  | 16  | 18  | 16  | 16  | 16  | 16  | 18  | 16  | 15  | 14  | 16  | 14  | 15  | 18  | 15  |
| Av.       | 6.8 | 7.2 | 6.5 | 7.8 | 6.6 | 8.1 | 8.1 | 8.4 | 8.3 | 8.7 | 7.6 | 8.2 | 8.2 | 8.3 | 7.1 | 7.6 | 7.6 | 7.8 | 7.4 | 7.9 | 7.3 | 8.0 | 7.9 | 8.6 |
| Me        | 6.0 | 6.5 | 6.5 | 7.5 | 6.0 | 7.5 | 8.0 | 8.5 | 8.0 | 8.0 | 6.0 | 8.0 | 8.0 | 8.0 | 7.0 | 6.5 | 8.0 | 7.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.5 | 8.0 |
| dian      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

D - deformed adults; N - normal adults

Appendix-XXXVIII

Capacitance of the cuticle of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

(pF)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |  |  |
| 1      | 32.4                       | 20.8  | 19.1  | 18.8  | 15.1  | 15.6  | 11.6  | 10.8  | 12.2  | 10.7  | 10.6  | 10.1  |  |  |  |
| 2      | 28.9                       | 18.2  | 17.6  | 15.9  | 16.0  | 13.5  | 13.5  | 12.2  | 10.7  | 9.8   | 10.8  | 10.4  |  |  |  |
| 3      | 34.2                       | 15.8  | 18.4  | 16.9  | 15.8  | 15.2  | 12.2  | 11.6  | 12.4  | 12.4  | 11.4  | 11.0  |  |  |  |
| 4      | 29.6                       | 18.1  | 18.6  | 18.6  | 15.1  | 12.9  | 14.9  | 12.8  | 10.8  | 10.7  | 12.5  | 12.1  |  |  |  |
| 5      | 28.7                       | 18.5  | 17.3  | 14.7  | 13.9  | 14.4  | 12.4  | 12.4  | 12.6  | 11.5  | 11.6  | 11.2  |  |  |  |
| 6      | 33.4                       | 20.6  | 15.7  | 17.4  | 15.4  | 14.6  | 14.6  | 12.1  | 12.8  | 9.7   | 9.8   | 9.2   |  |  |  |
| 7      | 30.7                       | 17.8  | 16.2  | 14.7  | 16.8  | 13.8  | 1.29  | 14.6  | 11.6  | 12.4  | 12.1  | 11.6  |  |  |  |
| 8      | 31.6                       | 18.9  | 15.8  | 15.6  | 15.9  | 14.9  | 13.5  | 12.7  | 10.7  | 12.1  | 10.7  | 10.4  |  |  |  |
| 9      | 31.2                       | 19.5  | 16.6  | 15.8  | 12.9  | 13.4  | 14.6  | 13.4  | 11.6  | 10.2  | 12.4  | 10.0  |  |  |  |
| 10     | 33.4                       | 18.9  | 17.1  | 16.2  | 13.6  | 15.5  | 12.9  | 12.2  | 13.2  | 11.9  | 11.3  | 10.8  |  |  |  |
| 11     | 28.6                       | 18.4  | 18.8  | 15.7  | 14.8  | 14.8  | 14.2  | 12.8  | 12.5  | 12.5  | 9.6   | 9.1   |  |  |  |
| 12     | 27.9                       | 19.4  | 18.3  | 16.3  | 15.6  | 13.2  | 12.4  | 11.6  | 11.1  | 13.1  | 11.2  | 10.7  |  |  |  |
| 13     | 34.5                       | 19.6  | 16.6  | 18.4  | 14.9  | 12.7  | 15.3  | 12.5  | 10.8  | 12.7  | 12.7  | 12.4  |  |  |  |
| 14     | 30.6                       | 18.2  | 17.3  | 13.9  | 16.3  | 14.2  | 12.6  | 13.9  | 12.6  | 10.6  | 10.5  | 9.9   |  |  |  |
| 15     | 35.8                       | 16.9  | 17.5  | 14.5  | 15.9  | 15.7  | 12.8  | 13.1  | 11.9  | 11.4  | 9.7   | 9.2   |  |  |  |
| 16     | 32.9                       | 17.5  | 16.2  | 17.5  | 16.7  | 14.9  | 12.8  | 13.6  | 11.4  | 10.9  | 10.4  | 9.8   |  |  |  |
| 17     | 31.7                       | 18.2  | 16.9  | 16.2  | 15.2  | 14.2  | 13.3  | 12.5  | 11.8  | 11.4  | 11.1  | 10.6  |  |  |  |
| 18     | 33.5                       | 18.9  | 17.9  | 16.7  | 16.1  | 14.1  | 14.4  | 13.4  | 12.9  | 10.8  | 10.2  | 9.7   |  |  |  |
| 19     | 32.6                       | 18.6  | 17.7  | 16.0  | 15.1  | 15.4  | 13.1  | 12.2  | 11.2  | 11.6  | 9.8   | 9.4   |  |  |  |
| 20     | 31.8                       | 19.2  | 18.1  | 17.4  | 15.2  | 13.7  | 14.6  | 12.8  | 11.6  | 10.6  | 10.6  | 10.3  |  |  |  |
| Av.    | 31.70                      | 18.60 | 17.39 | 16.36 | 15.32 | 14.34 | 13.43 | 12.66 | 11.82 | 11.35 | 10.95 | 10.40 |  |  |  |
| SD     | 2.18                       | 1.15  | 1.00  | 1.37  | 0.99  | 0.92  | 1.04  | 0.87  | 0.80  | 0.98  | 0.95  | 0.93  |  |  |  |

# Appendix-XXXIX

Capacitance of the cuticle of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

(pF)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |      |  |  |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|--|--|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15   |  |  |  |
| 1      | 29.6                       | 15.6  | 15.8  | 16.6  | 15.1  | 14.4  | 12.8  | 12.1  | 9.9   | 9.8   | 10.5  | 10.4 |  |  |  |
| 2      | 32.5                       | 15.5  | 15.4  | 17.6  | 14.6  | 13.4  | 11.9  | 12.7  | 10.4  | 11.5  | 10.8  | 9.0  |  |  |  |
| 3      | 34.6                       | 19.1  | 15.0  | 14.2  | 13.6  | 11.4  | 10.7  | 10.2  | 11.1  | 12.1  | 11.1  | 8.6  |  |  |  |
| 4      | 33.7                       | 18.5  | 16.4  | 15.8  | 16.4  | 13.3  | 12.9  | 12.1  | 11.5  | 11.2  | 10.6  | 10.1 |  |  |  |
| 5      | 32.4                       | 16.2  | 18.8  | 13.6  | 13.1  | 12.4  | 13.1  | 12.4  | 10.8  | 10.4  | 10.4  | 9.8  |  |  |  |
| 6      | 29.7                       | 19.6  | 15.7  | 14.8  | 13.8  | 12.8  | 10.8  | 9.9   | 12.1  | 10.6  | 9.6   | 9.3  |  |  |  |
| 7      | 32.6                       | 19.8  | 15.6  | 16.7  | 12.7  | 13.6  | 12.5  | 12.2  | 9.4   | 9.2   | 9.8   | 9.1  |  |  |  |
| 8      | 29.4                       | 17.7  | 15.4  | 16.8  | 13.8  | 12.8  | 12.8  | 11.6  | 10.4  | 8.6   | 8.8   | 8.4  |  |  |  |
| 9      | 30.6                       | 17.2  | 18.2  | 15.8  | 14.4  | 12.6  | 14.2  | 10.6  | 11.3  | 9.8   | 8.9   | 8.6  |  |  |  |
| 10     | 31.8                       | 16.8  | 14.7  | 14.6  | 14.8  | 13.8  | 12.6  | 10.9  | 9.8   | 11.4  | 10.8  | 9.4  |  |  |  |
| 11     | 28.8                       | 18.6  | 18.9  | 14.9  | 15.2  | 12.2  | 11.4  | 13.2  | 10.2  | 10.2  | 8.9   | 11.7 |  |  |  |
| 12     | 30.8                       | 18.7  | 16.6  | 15.9  | 13.8  | 12.6  | 9.9   | 10.9  | 10.6  | 9.6   | 12.1  | 10.3 |  |  |  |
| 13     | 27.6                       | 16.4  | 17.8  | 15.6  | 15.4  | 14.8  | 12.4  | 9.4   | 11.4  | 10.1  | 8.6   | 8.2  |  |  |  |
| 14     | 28.3                       | 18.2  | 13.7  | 14.4  | 14.1  | 13.2  | 12.6  | 10.8  | 10.8  | 10.8  | 8.7   | 10.9 |  |  |  |
| 15     | 28.1                       | 16.7  | 16.1  | 13.8  | 12.9  | 12.9  | 13.2  | 12.4  | 13.6  | 8.8   | 9.9   | 10.1 |  |  |  |
| 16     | 31.7                       | 18.1  | 15.6  | 16.5  | 15.4  | 11.6  | 11.4  | 12.1  | 9.4   | 10.2  | 10.6  | 10.6 |  |  |  |
| 17     | 33.6                       | 17.6  | 16.4  | 15.5  | 14.4  | 13.3  | 12.4  | 11.8  | 9.2   | 9.5   | 10.3  | 9.8  |  |  |  |
| 18     | 27.2                       | 17.9  | 17.4  | 16.4  | 12.9  | 13.4  | 11.8  | 11.9  | 9.6   | 10.4  | 9.8   | 8.9  |  |  |  |
| 19     | 33.2                       | 18.7  | 17.1  | 14.1  | 15.2  | 13.8  | 12.4  | 12.4  | 10.8  | 9.8   | 10.4  | 9.4  |  |  |  |
| 20     | 30.9                       | 19.2  | 18.2  | 16.2  | 14.6  | 14.1  | 13.1  | 11.4  | 11.1  | 10.6  | 10.2  | 10.1 |  |  |  |
| Av.    | 30.86                      | 17.81 | 16.44 | 15.49 | 14.31 | 13.12 | 12.25 | 11.55 | 10.67 | 10.23 | 10.04 | 9.64 |  |  |  |
| SD     | 2.20                       | 1.28  | 1.42  | 1.13  | 0.99  | 0.87  | 1.01  | 1.01  | 1.05  | 0.90  | 0.92  | 0.91 |  |  |  |

Appendix-XL  
Capacitance of the cuticle of deformed adult female S. gregaria at various ages, obtained from diflubenzuron treated hoppers.  
(pF)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |
| 1      | 31.4                       | 19.7  | 18.0  | 15.6  | 14.9  | 14.5  | 14.7  | 14.7  | 12.5  | 11.9  | 11.8  | 12.0  |
| 2      | 30.6                       | 18.6  | 20.1  | 16.8  | 16.8  | 14.7  | 13.7  | 12.8  | 11.9  | 12.3  | 11.9  | 11.4  |
| 3      | 32.2                       | 18.9  | 17.8  | 17.8  | 13.6  | 14.1  | 13.9  | 12.9  | 12.6  | 10.9  | 12.4  | 11.5  |
| 4      | 29.8                       | 19.4  | 17.4  | 14.9  | 16.2  | 14.0  | 12.7  | 12.6  | 12.8  | 12.7  | 11.9  | 11.2  |
| 5      | 31.7                       | 17.8  | 18.6  | 18.0  | 16.1  | 16.6  | 11.8  | 13.9  | 11.2  | 13.7  | 13.6  | 8.8   |
| 6      | 34.6                       | 20.6  | 17.7  | 15.7  | 18.7  | 12.8  | 12.7  | 13.4  | 11.7  | 11.4  | 9.8   | 13.1  |
| 7      | 33.8                       | 16.9  | 17.6  | 14.8  | 16.4  | 13.9  | 12.4  | 12.8  | 10.8  | 12.9  | 12.3  | 10.8  |
| 8      | 34.9                       | 18.8  | 15.7  | 18.7  | 14.6  | 15.8  | 14.8  | 13.6  | 14.1  | 12.3  | 10.9  | 12.4  |
| 9      | 35.6                       | 18.1  | 16.3  | 18.3  | 15.7  | 14.4  | 13.5  | 11.8  | 12.2  | 12.1  | 11.7  | 11.2  |
| 10     | 32.5                       | 18.3  | 18.1  | 16.4  | 15.2  | 13.1  | 13.7  | 12.7  | 12.8  | 13.5  | 12.3  | 10.9  |
| 11     | 30.7                       | 16.8  | 16.4  | 14.9  | 15.7  | 16.6  | 14.6  | 12.6  | 11.9  | 10.5  | 11.8  | 9.8   |
| 12     | 32.9                       | 21.5  | 17.9  | 16.9  | 15.4  | 15.8  | 15.2  | 12.4  | 13.6  | 12.6  | 11.9  | 11.4  |
| 13     | 33.7                       | 17.4  | 16.8  | 16.6  | 14.9  | 13.5  | 13.8  | 11.9  | 11.4  | 11.9  | 11.8  | 10.6  |
| 14     | 31.8                       | 22.4  | 14.2  | 14.5  | 14.1  | 13.4  | 13.4  | 13.6  | 12.3  | 10.8  | 10.7  | 10.2  |
| 15     | 30.9                       | 18.2  | 17.3  | 15.9  | 13.7  | 14.6  | 12.9  | 12.8  | 11.7  | 11.9  | 12.9  | 12.5  |
| 16     | 29.5                       | 18.9  | 18.4  | 17.5  | 16.4  | 15.2  | 13.6  | 14.2  | 13.2  | 12.6  | 12.4  | 12.0  |
| 17     | 32.6                       | 18.5  | 17.3  | 16.3  | 15.4  | 14.5  | 13.8  | 13.2  | 12.6  | 10.6  | 11.9  | 10.6  |
| 18     | 28.7                       | 19.4  | 17.3  | 17.3  | 15.8  | 14.8  | 14.5  | 11.6  | 12.9  | 12.2  | 11.6  | 11.1  |
| 19     | 33.2                       | 18.6  | 18.2  | 16.5  | 16.5  | 13.7  | 12.4  | 13.1  | 13.1  | 11.9  | 10.9  | 10.5  |
| 20     | 35.2                       | 19.2  | 18.0  | 17.2  | 15.9  | 14.6  | 14.2  | 12.8  | 12.4  | 11.8  | 10.8  | 10.3  |
| Av.    | 32.32                      | 18.90 | 17.46 | 16.53 | 15.60 | 14.53 | 13.62 | 12.97 | 12.39 | 12.03 | 11.77 | 11.12 |
| SD     | 1.96                       | 1.39  | 1.21  | 1.22  | 1.17  | 1.06  | 0.91  | 0.78  | 0.82  | 0.88  | 0.84  | 1.00  |

# Appendix-XLI

Capacitance of the cuticle of normal adult female S. gregaria at various ages, obtained from solvent treated hoppers.

(pF)

| S. No. | Age in days after moulting |       |       |       |       |       |       |       |       |       |       |       |  |
|--------|----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
|        | 0                          | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 15    |  |
| 1      | 34.1                       | 18.8  | 16.2  | 15.4  | 17.4  | 14.2  | 11.4  | 10.6  | 12.8  | 13.1  | 12.6  | 10.3  |  |
| 2      | 28.5                       | 15.8  | 18.4  | 14.6  | 16.5  | 12.7  | 14.2  | 12.4  | 10.8  | 12.2  | 10.8  | 12.1  |  |
| 3      | 32.8                       | 19.4  | 16.9  | 15.9  | 15.2  | 14.8  | 13.8  | 13.4  | 11.8  | 10.5  | 12.1  | 10.4  |  |
| 4      | 33.5                       | 18.6  | 15.3  | 17.2  | 14.1  | 13.9  | 12.9  | 12.1  | 11.2  | 10.2  | 10.8  | 10.6  |  |
| 5      | 32.2                       | 16.7  | 18.9  | 14.8  | 15.4  | 14.6  | 14.4  | 13.2  | 12.2  | 12.1  | 11.6  | 10.1  |  |
| 6      | 34.6                       | 20.4  | 17.6  | 16.2  | 13.7  | 13.2  | 13.6  | 12.8  | 10.8  | 10.5  | 10.8  | 11.3  |  |
| 7      | 27.8                       | 18.0  | 17.7  | 17.9  | 14.3  | 13.4  | 12.7  | 11.8  | 13.1  | 11.8  | 12.1  | 11.7  |  |
| 8      | 28.5                       | 16.6  | 15.8  | 16.2  | 16.3  | 12.6  | 12.6  | 14.1  | 12.2  | 10.2  | 10.4  | 10.7  |  |
| 9      | 27.3                       | 18.2  | 15.6  | 14.9  | 13.2  | 13.6  | 11.9  | 12.4  | 10.8  | 11.1  | 11.2  | 9.9   |  |
| 10     | 33.8                       | 18.4  | 14.6  | 16.8  | 13.6  | 14.4  | 11.9  | 11.8  | 12.6  | 10.9  | 12.4  | 10.8  |  |
| 11     | 32.8                       | 19.6  | 18.8  | 15.6  | 13.4  | 12.8  | 12.9  | 12.1  | 10.9  | 12.4  | 10.2  | 9.6   |  |
| 12     | 31.2                       | 17.8  | 15.1  | 16.8  | 14.8  | 15.6  | 12.6  | 10.9  | 11.8  | 11.6  | 10.6  | 10.1  |  |
| 13     | 28.4                       | 18.1  | 16.7  | 13.9  | 15.6  | 13.8  | 13.3  | 11.6  | 10.6  | 10.8  | 10.5  | 9.8   |  |
| 14     | 26.9                       | 15.2  | 18.1  | 14.4  | 13.4  | 13.4  | 14.6  | 12.2  | 10.5  | 10.4  | 9.8   | 9.2   |  |
| 15     | 28.6                       | 18.5  | 15.4  | 15.6  | 13.8  | 13.2  | 12.4  | 11.1  | 12.4  | 10.8  | 9.4   | 10.6  |  |
| 16     | 32.8                       | 18.0  | 16.7  | 15.7  | 14.7  | 13.7  | 13.0  | 12.4  | 11.9  | 11.5  | 11.2  | 8.8   |  |
| 17     | 33.7                       | 18.9  | 18.2  | 16.7  | 15.4  | 14.4  | 14.1  | 13.0  | 12.1  | 11.8  | 10.4  | 9.8   |  |
| 18     | 31.3                       | 19.4  | 17.4  | 16.4  | 14.9  | 13.8  | 13.2  | 11.8  | 11.4  | 9.9   | 9.8   | 9.3   |  |
| 19     | 29.9                       | 18.7  | 17.7  | 15.9  | 15.2  | 14.2  | 13.4  | 12.6  | 11.6  | 10.6  | 10.6  | 10.1  |  |
| 20     | 32.5                       | 19.2  | 18.1  | 16.2  | 14.9  | 13.6  | 12.4  | 12.2  | 12.0  | 11.2  | 9.9   | 9.2   |  |
| Av.    | 31.06                      | 18.22 | 16.99 | 15.86 | 14.84 | 13.80 | 13.07 | 12.23 | 11.68 | 11.18 | 10.86 | 10.22 |  |
| SD     | 2.56                       | 1.30  | 1.29  | 1.00  | 1.08  | 0.75  | 0.87  | 0.85  | 0.77  | 0.86  | 0.91  | 0.85  |  |

Appendix-XLII

Dielectric constant of the cuticle of deformed adult male S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

| S. No. | Age in days after moulting |      |      |      |      |      |      |      |      |      |      |      |
|--------|----------------------------|------|------|------|------|------|------|------|------|------|------|------|
| No.    | 0                          | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 15   |
| 1      | 9.32                       | 5.98 | 5.49 | 5.41 | 4.34 | 4.49 | 3.34 | 3.11 | 3.51 | 3.08 | 3.05 | 2.90 |
| 2      | 8.31                       | 5.23 | 5.06 | 4.57 | 4.60 | 3.88 | 3.88 | 3.51 | 3.08 | 2.82 | 3.11 | 2.99 |
| 3      | 9.84                       | 4.54 | 5.29 | 4.86 | 4.54 | 4.37 | 3.51 | 3.34 | 3.57 | 3.57 | 3.28 | 3.16 |
| 4      | 8.51                       | 5.21 | 5.35 | 5.35 | 4.34 | 3.71 | 4.29 | 3.68 | 3.11 | 3.08 | 3.60 | 3.48 |
| 5      | 8.25                       | 5.32 | 4.98 | 4.23 | 4.00 | 4.14 | 3.57 | 3.57 | 3.62 | 3.31 | 3.34 | 3.22 |
| 6      | 9.61                       | 5.92 | 4.52 | 5.00 | 4.43 | 4.20 | 4.20 | 3.48 | 3.68 | 2.79 | 2.82 | 2.65 |
| 7      | 8.83                       | 5.12 | 4.66 | 4.23 | 4.83 | 3.97 | 3.71 | 4.20 | 3.34 | 3.57 | 3.48 | 3.34 |
| 8      | 9.09                       | 5.44 | 4.54 | 4.49 | 4.57 | 4.29 | 3.88 | 3.65 | 3.08 | 3.48 | 3.08 | 2.99 |
| 9      | 8.97                       | 5.61 | 4.77 | 4.54 | 3.71 | 3.85 | 4.20 | 3.85 | 3.34 | 2.93 | 3.57 | 2.88 |
| 10     | 9.61                       | 5.44 | 4.92 | 4.66 | 3.91 | 4.46 | 3.71 | 3.51 | 3.80 | 3.42 | 3.25 | 3.11 |
| 11     | 8.23                       | 5.29 | 5.41 | 4.52 | 4.26 | 4.26 | 4.08 | 3.68 | 3.60 | 3.60 | 2.76 | 2.62 |
| 12     | 8.02                       | 5.58 | 5.26 | 4.69 | 4.49 | 3.80 | 3.57 | 3.34 | 3.19 | 3.77 | 3.22 | 3.08 |
| 13     | 9.92                       | 5.64 | 4.77 | 5.29 | 4.29 | 3.65 | 4.40 | 3.60 | 3.11 | 3.65 | 3.65 | 3.57 |
| 14     | 8.80                       | 5.23 | 4.98 | 4.00 | 4.69 | 4.08 | 3.62 | 4.00 | 3.62 | 3.05 | 3.02 | 2.85 |
| 15     | 10.30                      | 4.86 | 5.03 | 4.17 | 4.57 | 4.52 | 3.68 | 3.77 | 3.42 | 3.28 | 2.79 | 2.65 |
| 16     | 9.46                       | 5.03 | 4.66 | 5.03 | 4.80 | 4.29 | 3.68 | 3.68 | 3.28 | 3.13 | 2.99 | 2.82 |
| 17     | 9.12                       | 5.23 | 4.86 | 4.66 | 4.37 | 4.08 | 3.83 | 3.60 | 3.39 | 3.28 | 3.20 | 3.05 |
| 18     | 9.63                       | 5.44 | 5.15 | 4.80 | 4.63 | 4.06 | 4.14 | 3.85 | 3.71 | 3.11 | 2.93 | 2.79 |
| 19     | 9.38                       | 5.35 | 5.09 | 4.60 | 4.34 | 4.43 | 3.77 | 3.51 | 3.22 | 3.34 | 2.82 | 2.70 |
| 20     | 9.15                       | 5.52 | 5.21 | 5.00 | 4.37 | 3.94 | 4.20 | 3.68 | 3.34 | 3.05 | 3.05 | 2.96 |
| Av.    | 9.12                       | 5.35 | 5.00 | 4.71 | 4.40 | 4.12 | 3.86 | 3.64 | 3.40 | 3.27 | 3.15 | 2.99 |
| SD     | 0.63                       | 0.33 | 0.29 | 0.39 | 0.28 | 0.27 | 0.30 | 0.25 | 0.23 | 0.28 | 0.27 | 0.27 |

# Appendix-XLIII

Dielectric constant of the cuticle of normal adult male S. gregaria at various ages, obtained from solvent treated hoppers.

| S. No. | Age in days after moulting |      |      |      |      |      |      |      |      |      |      |      |  |  |  |
|--------|----------------------------|------|------|------|------|------|------|------|------|------|------|------|--|--|--|
|        | 0                          | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 15   |  |  |  |
| 1      | 8.51                       | 4.49 | 4.54 | 4.77 | 4.34 | 4.14 | 3.68 | 3.48 | 2.85 | 2.82 | 3.02 | 2.99 |  |  |  |
| 2      | 9.35                       | 4.46 | 4.43 | 5.06 | 4.20 | 3.85 | 3.42 | 3.65 | 3.99 | 3.31 | 3.11 | 2.59 |  |  |  |
| 3      | 9.95                       | 5.49 | 4.31 | 4.08 | 3.91 | 3.28 | 3.03 | 2.93 | 3.19 | 3.48 | 3.19 | 2.47 |  |  |  |
| 4      | 9.69                       | 5.32 | 4.72 | 4.54 | 4.72 | 3.83 | 3.71 | 3.48 | 3.31 | 3.22 | 3.05 | 2.90 |  |  |  |
| 5      | 9.32                       | 4.66 | 5.41 | 3.91 | 3.77 | 3.57 | 3.77 | 3.57 | 3.11 | 2.99 | 2.99 | 2.82 |  |  |  |
| 6      | 8.54                       | 5.64 | 4.52 | 4.26 | 3.97 | 3.68 | 3.11 | 2.85 | 3.48 | 3.05 | 2.76 | 2.67 |  |  |  |
| 7      | 9.38                       | 5.69 | 4.49 | 4.80 | 3.65 | 3.91 | 3.60 | 3.51 | 2.70 | 2.65 | 2.82 | 2.62 |  |  |  |
| 8      | 8.46                       | 5.09 | 4.43 | 4.83 | 3.97 | 3.68 | 3.68 | 3.34 | 2.99 | 2.47 | 2.53 | 2.42 |  |  |  |
| 9      | 8.80                       | 4.95 | 5.23 | 4.54 | 4.14 | 3.62 | 4.08 | 3.05 | 3.25 | 2.82 | 2.56 | 2.47 |  |  |  |
| 10     | 9.15                       | 4.83 | 4.23 | 4.20 | 4.26 | 3.97 | 3.62 | 3.13 | 2.82 | 3.28 | 3.11 | 2.70 |  |  |  |
| 11     | 8.28                       | 5.35 | 5.44 | 4.29 | 4.37 | 3.51 | 3.28 | 3.80 | 2.93 | 2.93 | 2.56 | 3.36 |  |  |  |
| 12     | 8.86                       | 5.38 | 4.77 | 4.57 | 3.97 | 3.62 | 2.85 | 3.13 | 3.05 | 2.76 | 3.48 | 2.96 |  |  |  |
| 13     | 7.94                       | 4.72 | 5.12 | 4.49 | 4.43 | 4.26 | 3.57 | 2.70 | 3.28 | 2.90 | 2.47 | 2.36 |  |  |  |
| 14     | 8.14                       | 5.23 | 3.94 | 4.14 | 4.06 | 3.80 | 3.62 | 3.11 | 3.11 | 3.11 | 2.50 | 3.13 |  |  |  |
| 15     | 8.08                       | 4.80 | 4.63 | 3.97 | 3.71 | 3.71 | 3.80 | 3.57 | 3.91 | 2.53 | 2.85 | 2.90 |  |  |  |
| 16     | 9.12                       | 5.21 | 4.49 | 4.75 | 4.43 | 3.34 | 3.28 | 3.48 | 2.70 | 2.93 | 3.05 | 3.05 |  |  |  |
| 17     | 9.66                       | 5.06 | 4.72 | 4.46 | 4.14 | 3.83 | 3.57 | 3.39 | 2.65 | 2.73 | 2.96 | 2.82 |  |  |  |
| 18     | 7.82                       | 5.15 | 5.00 | 4.72 | 3.71 | 3.85 | 3.39 | 3.42 | 3.34 | 2.99 | 2.82 | 2.56 |  |  |  |
| 19     | 9.55                       | 5.38 | 4.92 | 4.06 | 4.37 | 3.97 | 3.57 | 3.57 | 3.11 | 2.82 | 2.99 | 2.70 |  |  |  |
| 20     | 8.89                       | 5.52 | 5.23 | 4.66 | 4.20 | 4.06 | 3.77 | 3.28 | 3.19 | 3.05 | 2.93 | 2.90 |  |  |  |
| Av.    | 8.87                       | 5.12 | 4.73 | 4.46 | 4.12 | 3.77 | 3.52 | 3.32 | 3.10 | 2.94 | 2.89 | 2.77 |  |  |  |
| SD     | 0.63                       | 0.37 | 0.41 | 0.33 | 0.29 | 0.25 | 0.29 | 0.29 | 0.30 | 0.26 | 0.26 | 0.26 |  |  |  |

## Appendix-XLIV

Dielectric constant of the cuticle of deformed adult female S. gregaria at various ages, obtained from diflubenzuron treated hoppers.

| S. No. | Age in days after moulting |      |      |      |      |      |      |      |      |      |      |      |  |  |  |
|--------|----------------------------|------|------|------|------|------|------|------|------|------|------|------|--|--|--|
|        | 0                          | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 15   |  |  |  |
| 1      | 9.03                       | 5.67 | 5.18 | 4.49 | 4.29 | 4.17 | 4.23 | 4.23 | 3.60 | 3.42 | 3.39 | 3.45 |  |  |  |
| 2      | 8.80                       | 5.35 | 5.78 | 4.83 | 4.83 | 4.23 | 3.94 | 3.68 | 3.42 | 3.54 | 3.42 | 3.28 |  |  |  |
| 3      | 9.26                       | 5.44 | 5.12 | 5.12 | 3.91 | 4.06 | 4.00 | 3.71 | 3.62 | 3.13 | 3.57 | 3.31 |  |  |  |
| 4      | 8.57                       | 5.58 | 5.00 | 4.29 | 4.66 | 4.03 | 3.65 | 3.62 | 3.68 | 3.65 | 3.42 | 3.22 |  |  |  |
| 5      | 9.12                       | 5.12 | 5.35 | 5.18 | 4.63 | 4.77 | 3.39 | 4.00 | 3.22 | 3.94 | 3.91 | 2.53 |  |  |  |
| 6      | 9.95                       | 5.92 | 5.09 | 4.52 | 5.38 | 3.68 | 3.65 | 3.85 | 3.36 | 3.28 | 2.82 | 3.77 |  |  |  |
| 7      | 9.72                       | 4.86 | 5.06 | 4.26 | 4.72 | 4.00 | 3.57 | 3.68 | 3.11 | 3.71 | 3.54 | 3.11 |  |  |  |
| 8      | 10.04                      | 5.41 | 4.52 | 5.38 | 4.20 | 4.54 | 4.26 | 3.91 | 4.06 | 3.54 | 3.13 | 3.57 |  |  |  |
| 9      | 10.24                      | 5.21 | 4.69 | 5.26 | 4.52 | 4.14 | 3.88 | 3.39 | 3.51 | 3.48 | 3.36 | 3.22 |  |  |  |
| 10     | 9.35                       | 5.26 | 5.21 | 4.72 | 4.37 | 3.77 | 3.94 | 3.65 | 3.68 | 3.88 | 3.54 | 3.13 |  |  |  |
| 11     | 8.83                       | 4.83 | 4.72 | 4.29 | 4.52 | 4.77 | 4.20 | 3.62 | 3.42 | 3.02 | 3.39 | 2.82 |  |  |  |
| 12     | 9.46                       | 6.18 | 5.15 | 4.86 | 4.43 | 4.54 | 4.37 | 3.57 | 3.91 | 3.62 | 3.42 | 3.28 |  |  |  |
| 13     | 9.69                       | 5.00 | 4.83 | 4.77 | 4.29 | 3.88 | 3.97 | 3.42 | 3.28 | 3.42 | 3.39 | 3.05 |  |  |  |
| 14     | 9.15                       | 6.44 | 4.08 | 4.17 | 4.06 | 3.85 | 3.85 | 3.91 | 3.54 | 3.11 | 3.08 | 2.93 |  |  |  |
| 15     | 8.89                       | 5.23 | 4.98 | 4.57 | 3.94 | 4.20 | 3.71 | 3.68 | 3.36 | 3.42 | 3.71 | 3.60 |  |  |  |
| 16     | 8.48                       | 5.44 | 5.29 | 5.03 | 4.72 | 4.37 | 3.91 | 4.08 | 3.80 | 3.62 | 3.57 | 3.45 |  |  |  |
| 17     | 9.38                       | 5.32 | 4.98 | 4.69 | 4.43 | 4.17 | 3.97 | 3.80 | 3.62 | 3.05 | 3.42 | 3.05 |  |  |  |
| 18     | 8.25                       | 5.58 | 4.98 | 4.98 | 4.54 | 4.26 | 4.17 | 3.34 | 3.71 | 3.51 | 3.34 | 3.19 |  |  |  |
| 19     | 9.55                       | 5.35 | 5.23 | 4.75 | 4.75 | 3.94 | 3.57 | 3.77 | 3.77 | 3.42 | 3.13 | 3.02 |  |  |  |
| 20     | 10.12                      | 5.52 | 5.18 | 4.95 | 4.57 | 4.20 | 4.08 | 3.68 | 3.57 | 3.39 | 3.11 | 2.96 |  |  |  |
| Av.    | 9.29                       | 5.44 | 5.02 | 4.76 | 4.49 | 4.18 | 3.92 | 3.73 | 3.56 | 3.46 | 3.38 | 3.20 |  |  |  |
| SD     | 0.56                       | 0.40 | 0.35 | 0.35 | 0.34 | 0.30 | 0.26 | 0.22 | 0.24 | 0.25 | 0.24 | 0.29 |  |  |  |

Appendix-XLV

Dielectric constant of the cuticle of normal adult female S.gregaria at various ages, obtained from solvent treated hoppers.

| S. No. | Age in days after moulting |      |      |      |      |      |      |      |      |      |      |      |  |  |  |
|--------|----------------------------|------|------|------|------|------|------|------|------|------|------|------|--|--|--|
|        | 0                          | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 8    | 10   | 15   |  |  |  |
| 1      | 9.81                       | 5.41 | 4.66 | 4.43 | 5.00 | 4.08 | 3.28 | 3.05 | 3.68 | 3.77 | 3.62 | 2.96 |  |  |  |
| 2      | 8.20                       | 4.54 | 5.29 | 4.20 | 4.75 | 3.65 | 4.08 | 3.57 | 3.11 | 3.51 | 3.11 | 3.48 |  |  |  |
| 3      | 9.43                       | 5.58 | 4.86 | 4.57 | 4.37 | 4.26 | 3.97 | 3.85 | 3.39 | 3.02 | 3.48 | 2.99 |  |  |  |
| 4      | 9.63                       | 5.35 | 4.54 | 4.95 | 4.06 | 4.00 | 3.71 | 3.48 | 3.22 | 2.93 | 3.11 | 3.05 |  |  |  |
| 5      | 9.26                       | 4.80 | 5.44 | 4.26 | 4.43 | 4.20 | 4.14 | 3.80 | 3.51 | 3.48 | 3.34 | 2.90 |  |  |  |
| 6      | 9.95                       | 5.87 | 5.06 | 4.66 | 3.94 | 3.80 | 3.91 | 3.68 | 3.11 | 3.02 | 3.11 | 3.25 |  |  |  |
| 7      | 8.00                       | 5.18 | 5.09 | 5.15 | 4.11 | 3.85 | 3.65 | 3.39 | 3.77 | 3.39 | 3.48 | 3.36 |  |  |  |
| 8      | 8.20                       | 4.77 | 4.54 | 4.66 | 4.69 | 3.62 | 3.62 | 4.06 | 3.51 | 2.93 | 2.99 | 3.08 |  |  |  |
| 9      | 7.85                       | 5.23 | 4.49 | 4.29 | 4.08 | 3.91 | 3.42 | 3.57 | 3.11 | 3.19 | 3.22 | 2.85 |  |  |  |
| 10     | 9.72                       | 5.29 | 4.20 | 4.83 | 3.91 | 4.14 | 3.42 | 3.39 | 3.62 | 3.13 | 3.57 | 3.11 |  |  |  |
| 11     | 9.43                       | 5.64 | 5.41 | 4.49 | 3.85 | 3.68 | 3.71 | 3.48 | 3.13 | 3.57 | 2.93 | 2.76 |  |  |  |
| 12     | 8.97                       | 5.12 | 4.34 | 4.83 | 4.26 | 4.49 | 3.62 | 3.13 | 3.39 | 3.34 | 3.05 | 2.90 |  |  |  |
| 13     | 8.17                       | 5.21 | 4.80 | 4.00 | 4.49 | 3.97 | 3.83 | 3.34 | 3.05 | 3.11 | 3.02 | 2.82 |  |  |  |
| 14     | 7.74                       | 4.37 | 5.21 | 4.14 | 3.85 | 3.85 | 4.20 | 3.51 | 3.02 | 2.99 | 2.82 | 2.65 |  |  |  |
| 15     | 8.23                       | 5.32 | 4.43 | 4.49 | 3.97 | 3.80 | 3.57 | 3.19 | 3.57 | 3.11 | 2.70 | 3.05 |  |  |  |
| 16     | 9.43                       | 5.18 | 4.80 | 4.52 | 4.23 | 3.94 | 3.74 | 3.57 | 3.42 | 3.31 | 3.22 | 2.53 |  |  |  |
| 17     | 9.69                       | 5.44 | 5.23 | 4.80 | 4.43 | 4.14 | 4.06 | 3.74 | 3.48 | 3.39 | 2.99 | 2.82 |  |  |  |
| 18     | 9.00                       | 5.58 | 5.00 | 4.72 | 4.29 | 3.97 | 3.80 | 3.39 | 3.28 | 2.85 | 2.82 | 2.67 |  |  |  |
| 19     | 8.60                       | 5.38 | 5.09 | 4.57 | 4.37 | 4.08 | 3.85 | 3.62 | 3.34 | 3.05 | 3.05 | 2.90 |  |  |  |
| 20     | 9.35                       | 5.52 | 5.21 | 4.66 | 4.29 | 3.91 | 3.57 | 3.51 | 3.45 | 3.22 | 2.85 | 2.65 |  |  |  |
| AV.    | 8.93                       | 5.24 | 4.88 | 4.56 | 4.27 | 3.97 | 3.76 | 3.52 | 3.36 | 3.22 | 3.12 | 2.94 |  |  |  |
| SD     | 0.73                       | 0.37 | 0.37 | 0.29 | 0.31 | 0.22 | 0.25 | 0.24 | 0.22 | 0.25 | 0.26 | 0.24 |  |  |  |

## Appendix-XLVI

Chitin content in the wings (set of four) of deformed and normal adult male S. gregaria at various ages.

| Age in days<br>after moulting | Deformed |       |       |       |       |       | Normal |       |       |       |       |       |      |
|-------------------------------|----------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | Av.   | SD    | 1      | 2     | 3     | 4     | Av.   | SD    |      |
| 0                             | a        | 52.00 | 57.00 | 66.00 | 63.00 | 59.50 | -      | 58.00 | 65.00 | 56.00 | 69.00 | 62.00 | -    |
|                               | b        | 2.50  | 3.00  | 3.00  | 3.00  | 2.88  | 0.25   | 3.00  | 3.00  | 3.00  | 3.50  | 3.13  | 0.25 |
|                               | c        | 4.81  | 5.26  | 4.55  | 4.76  | 4.85  | 0.30   | 5.17  | 4.62  | 5.36  | 5.07  | 5.06  | 0.31 |
| 1                             | a        | 56.00 | 59.00 | 58.00 | 55.00 | 57.00 | -      | 62.00 | 59.00 | 57.00 | 54.00 | 58.00 | -    |
|                               | b        | 4.50  | 4.50  | 4.50  | 4.00  | 4.38  | 0.25   | 5.00  | 4.50  | 5.00  | 4.50  | 4.75  | 0.29 |
|                               | c        | 8.04  | 7.63  | 7.76  | 7.27  | 7.68  | 0.32   | 8.06  | 7.63  | 8.77  | 8.33  | 8.20  | 0.48 |
| 2                             | a        | 57.00 | 53.00 | 57.00 | 60.00 | 56.75 | -      | 57.00 | 60.00 | 58.00 | 63.00 | 59.50 | -    |
|                               | b        | 5.00  | 5.50  | 5.50  | 6.00  | 5.50  | 0.41   | 6.00  | 7.00  | 6.00  | 7.00  | 6.50  | 0.58 |
|                               | c        | 8.77  | 10.38 | 9.65  | 10.00 | 9.70  | 0.69   | 10.53 | 11.67 | 10.34 | 11.11 | 10.91 | 0.60 |
| 3                             | a        | 52.00 | 59.00 | 58.00 | 60.00 | 57.25 | -      | 59.00 | 64.00 | 58.00 | 56.00 | 59.25 | -    |
|                               | b        | 6.00  | 6.00  | 7.00  | 7.00  | 6.50  | 0.58   | 8.00  | 8.00  | 7.00  | 7.50  | 7.63  | 0.48 |
|                               | c        | 11.54 | 10.17 | 12.07 | 11.67 | 11.36 | 0.83   | 13.56 | 12.50 | 12.07 | 13.39 | 12.88 | 0.71 |
| 4                             | a        | 55.00 | 59.00 | 54.00 | 58.00 | 56.50 | -      | 54.00 | 64.00 | 60.00 | 57.00 | 58.75 | -    |
|                               | b        | 7.00  | 8.00  | 6.50  | 8.00  | 7.38  | 0.75   | 8.00  | 10.50 | 9.50  | 8.00  | 9.00  | 1.22 |
|                               | c        | 12.73 | 13.56 | 12.04 | 13.79 | 13.03 | 0.80   | 14.81 | 16.41 | 15.83 | 14.04 | 15.27 | 1.05 |
| 5                             | a        | 57.00 | 62.00 | 56.00 | 52.00 | 56.75 | -      | 58.00 | 60.00 | 61.00 | 56.00 | 58.75 | -    |
|                               | b        | 8.00  | 9.00  | 8.50  | 8.00  | 8.38  | 0.48   | 10.00 | 10.50 | 10.50 | 9.00  | 10.00 | 0.71 |
|                               | c        | 14.04 | 14.52 | 15.18 | 15.38 | 14.78 | 0.62   | 17.24 | 17.50 | 17.21 | 16.07 | 17.01 | 0.64 |
| 6                             | a        | 52.00 | 58.00 | 56.00 | 58.00 | 56.00 | -      | 58.00 | 52.00 | 61.00 | 59.00 | 57.50 | -    |
|                               | b        | 8.50  | 9.00  | 9.00  | 8.00  | 8.63  | 0.48   | 11.00 | 9.00  | 11.50 | 11.00 | 10.63 | 1.11 |
|                               | c        | 16.35 | 15.52 | 16.07 | 13.79 | 15.43 | 1.15   | 18.97 | 17.31 | 18.85 | 18.64 | 18.44 | 0.77 |

| Age in days<br>after moulting |   | Deformed |       |       |       | Normal |      |       |       |       |       |       |      |
|-------------------------------|---|----------|-------|-------|-------|--------|------|-------|-------|-------|-------|-------|------|
|                               |   | 1        | 2     | 3     | 4     | Av.    | SD   | 1     | 2     | 3     | 4     | Av.   | SD   |
| 7                             | a | 57.00    | 54.00 | 54.00 | 59.00 | 56.00  | -    | 57.00 | 61.00 | 58.00 | 56.00 | 58.00 | -    |
|                               | b | 8.50     | 8.00  | 8.50  | 10.00 | 8.75   | 0.87 | 11.50 | 12.00 | 11.00 | 11.50 | 11.50 | 0.41 |
|                               | c | 14.91    | 14.81 | 15.74 | 16.95 | 15.60  | 0.99 | 20.18 | 19.67 | 18.97 | 20.54 | 19.84 | 0.68 |
| 8                             | a | 58.00    | 56.00 | 52.00 | 58.00 | 56.00  | -    | 56.00 | 54.00 | 62.00 | 61.00 | 58.25 | -    |
|                               | b | 9.50     | 9.00  | 8.50  | 9.00  | 9.00   | 0.41 | 11.50 | 11.00 | 13.00 | 12.00 | 11.88 | 0.85 |
|                               | c | 16.38    | 16.07 | 16.35 | 15.52 | 16.08  | 0.40 | 20.54 | 20.37 | 20.97 | 19.67 | 20.39 | 0.54 |
| 9                             | a | 55.00    | 52.00 | 54.00 | 59.00 | 55.00  | -    | 58.00 | 52.00 | 62.00 | 63.00 | 58.75 | -    |
|                               | b | 8.50     | 9.00  | 9.00  | 9.50  | 9.00   | 0.41 | 12.00 | 11.00 | 13.50 | 12.00 | 12.13 | 1.03 |
|                               | c | 15.45    | 17.31 | 16.67 | 16.10 | 16.38  | 0.79 | 20.69 | 21.15 | 21.77 | 19.05 | 20.67 | 1.16 |
| 10                            | a | 52.00    | 62.00 | 54.00 | 51.00 | 54.75  | -    | 54.00 | 61.00 | 58.00 | 60.00 | 58.25 | -    |
|                               | b | 8.50     | 10.50 | 8.50  | 8.50  | 9.00   | 1.00 | 10.50 | 12.50 | 12.50 | 13.00 | 12.13 | 1.11 |
|                               | c | 16.35    | 16.94 | 15.74 | 16.67 | 16.43  | 0.52 | 19.44 | 20.49 | 21.55 | 21.67 | 20.79 | 1.04 |
| 15                            | a | 53.00    | 51.00 | 56.00 | 59.00 | 54.75  | -    | 57.00 | 58.00 | 58.00 | 60.00 | 58.25 | -    |
|                               | b | 9.50     | 8.50  | 9.00  | 9.00  | 9.00   | 0.41 | 12.00 | 11.50 | 13.00 | 12.00 | 12.13 | 0.63 |
|                               | c | 17.92    | 16.67 | 16.07 | 15.25 | 16.48  | 1.12 | 21.05 | 19.83 | 22.41 | 20.00 | 20.82 | 1.19 |

a - Weight of wings (mg);

b - Weight of chitin(mg);

c - Percentage of chitin

Appendix-XLVII  
Chitin content in the wings (set of four) of deformed and normal adult female S. gregaria  
at various ages.

| Age in days<br>after moulting | Deformed |       |       |       |       |       | Normal |       |       |       |       |       |      |
|-------------------------------|----------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | Av.   | SD    | 1      | 2     | 3     | 4     | Av.   | SD    |      |
| 0                             | a        | 71.00 | 68.00 | 59.00 | 60.00 | 64.50 | -      | 64.00 | 71.00 | 74.00 | 66.00 | 68.75 | -    |
|                               | b        | 3.50  | 3.00  | 2.50  | 3.00  | 3.00  | 0.41   | 3.00  | 3.50  | 3.50  | 3.50  | 3.38  | 0.25 |
|                               | c        | 4.93  | 4.41  | 4.24  | 5.00  | 4.65  | 0.38   | 4.69  | 4.93  | 4.73  | 5.30  | 4.91  | 0.28 |
| 1                             | a        | 60.00 | 67.00 | 68.00 | 59.00 | 63.50 | -      | 68.00 | 61.00 | 64.00 | 70.00 | 65.75 | -    |
|                               | b        | 4.50  | 4.50  | 5.50  | 4.50  | 4.75  | 0.50   | 5.00  | 5.50  | 5.00  | 5.50  | 5.25  | 0.29 |
|                               | c        | 7.50  | 6.72  | 8.09  | 7.63  | 7.49  | 0.57   | 7.35  | 9.02  | 7.81  | 7.86  | 8.01  | 0.71 |
| 2                             | a        | 63.00 | 67.00 | 69.00 | 60.00 | 64.75 | -      | 68.00 | 73.00 | 66.00 | 61.00 | 67.00 | -    |
|                               | b        | 6.50  | 6.50  | 7.00  | 5.00  | 6.25  | 0.87   | 7.50  | 7.50  | 6.50  | 7.50  | 7.25  | 0.50 |
|                               | c        | 10.32 | 9.70  | 10.14 | 8.33  | 9.62  | 0.90   | 11.03 | 10.27 | 10.66 | 11.36 | 10.83 | 0.47 |
| 3                             | a        | 64.00 | 68.00 | 64.00 | 69.00 | 66.25 | -      | 69.00 | 71.00 | 64.00 | 68.00 | 68.00 | -    |
|                               | b        | 7.00  | 8.00  | 7.50  | 7.50  | 7.50  | 0.41   | 9.50  | 9.50  | 8.00  | 8.50  | 8.88  | 0.75 |
|                               | c        | 10.94 | 11.76 | 11.72 | 10.87 | 11.32 | 0.48   | 13.77 | 13.38 | 12.50 | 12.50 | 13.04 | 0.64 |
| 4                             | a        | 65.00 | 74.00 | 62.00 | 68.00 | 67.25 | -      | 74.00 | 71.00 | 72.00 | 61.00 | 69.50 | -    |
|                               | b        | 9.00  | 9.50  | 8.00  | 8.50  | 8.75  | 0.65   | 11.00 | 11.50 | 10.50 | 9.50  | 10.63 | 0.85 |
|                               | c        | 13.85 | 12.84 | 12.90 | 12.50 | 13.02 | 0.58   | 14.80 | 16.20 | 14.58 | 15.57 | 15.30 | 0.73 |
| 5                             | a        | 66.00 | 65.00 | 68.00 | 69.00 | 67.00 | -      | 67.00 | 66.00 | 69.00 | 74.00 | 69.00 | -    |
|                               | b        | 10.00 | 10.00 | 9.50  | 9.50  | 9.75  | 0.29   | 10.50 | 11.50 | 12.00 | 13.00 | 11.75 | 1.04 |
|                               | c        | 15.15 | 15.38 | 13.97 | 13.77 | 14.57 | 0.81   | 15.67 | 17.42 | 17.39 | 17.57 | 17.01 | 0.90 |
| 6                             | a        | 71.00 | 65.00 | 68.00 | 63.00 | 66.75 | -      | 74.00 | 64.00 | 70.00 | 69.00 | 69.25 | -    |
|                               | b        | 10.00 | 9.50  | 10.50 | 10.50 | 10.13 | 0.48   | 13.00 | 12.00 | 13.50 | 13.00 | 12.88 | 0.63 |
|                               | c        | 14.08 | 14.62 | 15.44 | 16.67 | 15.20 | 1.13   | 17.57 | 18.75 | 19.29 | 18.84 | 18.61 | 0.73 |

| Age in days<br>after moulting |   | Deformed |       |       |       | Normal |      |       |       |       |       |       |      |
|-------------------------------|---|----------|-------|-------|-------|--------|------|-------|-------|-------|-------|-------|------|
|                               |   | 1        | 2     | 3     | 4     | AV.    | SD   | 1     | 2     | 3     | 4     | Av.   | SD   |
| 7                             | a | 63.00    | 68.00 | 71.00 | 64.00 | 66.50  | -    | 64.00 | 73.00 | 69.00 | 72.00 | 69.50 | -    |
|                               | b | 9.50     | 11.00 | 10.50 | 10.50 | 10.38  | 0.63 | 13.00 | 14.00 | 13.00 | 14.50 | 13.63 | 0.75 |
|                               | c | 15.08    | 16.18 | 14.79 | 16.41 | 15.62  | 0.80 | 20.31 | 19.18 | 18.84 | 20.14 | 19.62 | 0.72 |
| 8                             | a | 63.00    | 67.00 | 66.00 | 69.00 | 66.25  | -    | 65.00 | 71.00 | 73.00 | 71.00 | 70.00 | -    |
|                               | b | 9.50     | 10.50 | 11.50 | 11.00 | 10.63  | 0.85 | 12.50 | 15.50 | 14.00 | 15.00 | 14.25 | 1.32 |
|                               | c | 15.08    | 15.67 | 17.42 | 15.94 | 16.03  | 1.00 | 19.23 | 21.83 | 21.13 | 19.18 | 20.34 | 1.34 |
| 9                             | a | 67.00    | 73.00 | 71.00 | 60.00 | 67.75  | -    | 65.00 | 71.00 | 75.00 | 74.00 | 71.25 | -    |
|                               | b | 10.50    | 11.50 | 12.00 | 10.00 | 11.00  | 0.91 | 13.00 | 14.50 | 15.50 | 16.00 | 14.75 | 1.32 |
|                               | c | 15.67    | 15.75 | 16.90 | 16.67 | 16.25  | 0.63 | 20.00 | 20.42 | 20.67 | 21.62 | 20.68 | 0.69 |
| 10                            | a | 73.00    | 68.00 | 66.00 | 61.00 | 67.00  | -    | 75.00 | 69.00 | 74.00 | 70.00 | 72.00 | -    |
|                               | b | 12.00    | 11.00 | 11.50 | 9.50  | 11.00  | 1.08 | 15.00 | 15.00 | 14.50 | 15.00 | 14.88 | 0.25 |
|                               | c | 16.44    | 16.18 | 17.42 | 15.57 | 16.40  | 0.77 | 20.00 | 21.74 | 19.59 | 21.43 | 20.69 | 1.05 |
| 15                            | a | 66.00    | 65.00 | 72.00 | 68.00 | 67.75  | -    | 74.00 | 65.00 | 71.00 | 76.00 | 71.50 | -    |
|                               | b | 11.00    | 11.00 | 11.00 | 11.50 | 11.13  | 0.25 | 15.00 | 14.50 | 14.50 | 15.50 | 14.88 | 0.48 |
|                               | c | 16.67    | 16.92 | 15.28 | 16.91 | 16.45  | 0.79 | 20.27 | 22.31 | 20.42 | 20.39 | 20.85 | 0.98 |

a - Weight of wings (mg);

b - Weight of chitin(mg);

c - Percentage of chitin

Appendix-XLVIII

Chitin content in the forewings (per pair) of deformed and normal adult male S. gregaria at various ages.

| Age in days<br>after moulting | Deformed |       |       |       |       | Normal |      |       |       |       |       |       |      |
|-------------------------------|----------|-------|-------|-------|-------|--------|------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | Av.   | SD     | 1    | 2     | 3     | 4     | Av.   | SD    |      |
| 1                             | a        | 29.00 | 31.50 | 30.50 | 28.50 | 29.88  | -    | 32.50 | 32.50 | 29.50 | 32.00 | 31.63 | -    |
|                               | b        | 2.25  | 2.50  | 2.00  | 2.25  | 2.25   | 0.20 | 2.50  | 2.50  | 2.50  | 2.75  | 2.56  | 0.13 |
|                               | c        | 7.76  | 7.94  | 7.02  | 7.38  | 7.53   | 0.41 | 7.69  | 7.69  | 8.47  | 8.59  | 8.11  | 0.49 |
| 4                             | a        | 28.00 | 31.50 | 33.00 | 32.00 | 31.13  | -    | 28.50 | 33.00 | 32.00 | 30.00 | 30.88 | -    |
|                               | b        | 3.75  | 4.00  | 4.00  | 4.25  | 4.00   | 0.20 | 4.75  | 5.00  | 4.75  | 4.50  | 4.75  | 0.20 |
|                               | c        | 13.39 | 12.70 | 12.12 | 13.28 | 12.87  | 0.59 | 16.67 | 15.15 | 14.84 | 15.00 | 15.42 | 0.85 |
| 7                             | a        | 31.00 | 29.00 | 32.00 | 28.00 | 30.00  | -    | 29.50 | 34.00 | 32.00 | 30.50 | 31.50 | -    |
|                               | b        | 4.75  | 4.50  | 5.25  | 4.25  | 4.69   | 0.43 | 5.75  | 6.25  | 6.50  | 6.00  | 6.13  | 0.32 |
|                               | c        | 15.32 | 15.52 | 16.41 | 15.18 | 15.61  | 0.55 | 19.49 | 18.38 | 20.31 | 19.67 | 19.46 | 0.80 |
| 10                            | a        | 33.50 | 29.50 | 32.50 | 29.00 | 31.13  | -    | 32.00 | 30.50 | 34.00 | 31.00 | 31.88 | -    |
|                               | b        | 5.25  | 5.00  | 5.00  | 5.00  | 5.06   | 0.13 | 6.75  | 6.25  | 6.50  | 6.75  | 6.56  | 0.24 |
|                               | c        | 15.67 | 16.95 | 15.38 | 17.24 | 16.31  | 0.92 | 21.09 | 20.49 | 19.12 | 21.77 | 20.62 | 1.13 |
| 15                            | a        | 30.50 | 33.00 | 30.00 | 32.50 | 31.50  | -    | 32.50 | 33.50 | 32.00 | 31.00 | 32.25 | -    |
|                               | b        | 5.00  | 5.75  | 5.00  | 5.00  | 5.19   | 0.38 | 6.50  | 7.00  | 6.50  | 6.75  | 6.69  | 0.24 |
|                               | c        | 16.39 | 17.42 | 16.67 | 15.38 | 16.47  | 0.84 | 20.00 | 20.90 | 20.31 | 21.77 | 20.75 | 0.78 |

a - Weight of wings (mg);

b - Weight of chitin(mg);

c - Percentage of chitin

# Appendix--XLIX

Chitin content in the forewings (per pair) of deformed and normal adult female S. gregaria at various ages.

| Age in days<br>after moulting | Deformed |       |       |       | Normal |       |      |       |       |       |       |       |      |
|-------------------------------|----------|-------|-------|-------|--------|-------|------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | Av.    | SD    | 1    | 2     | 3     | 4     | Av.   | SD    |      |
| 1                             | a        | 34.00 | 34.00 | 37.00 | 34.50  | 34.88 | -    | 34.00 | 37.00 | 34.50 | 37.00 | 35.63 | -    |
|                               | b        | 2.25  | 2.50  | 2.75  | 2.75   | 2.56  | 0.24 | 2.75  | 3.00  | 2.50  | 3.25  | 2.88  | 0.32 |
|                               | c        | 6.62  | 7.35  | 7.43  | 7.97   | 7.34  | 0.55 | 8.09  | 8.11  | 7.25  | 8.78  | 8.06  | 0.63 |
| 4                             | a        | 34.50 | 33.50 | 36.00 | 35.00  | 34.75 | -    | 36.50 | 38.50 | 35.50 | 35.00 | 36.38 | -    |
|                               | b        | 4.50  | 4.50  | 4.75  | 4.25   | 4.50  | 0.20 | 5.50  | 5.50  | 5.75  | 5.25  | 5.50  | 0.20 |
|                               | c        | 13.04 | 13.43 | 13.19 | 12.14  | 12.95 | 0.56 | 15.07 | 14.29 | 16.20 | 15.00 | 15.14 | 0.79 |
| 7                             | a        | 38.00 | 34.00 | 36.00 | 33.00  | 35.25 | -    | 38.00 | 37.00 | 34.50 | 35.50 | 36.25 | -    |
|                               | b        | 6.00  | 5.50  | 5.25  | 5.25   | 5.50  | 0.35 | 7.00  | 7.50  | 6.75  | 7.00  | 7.06  | 0.31 |
|                               | c        | 15.79 | 16.18 | 14.58 | 15.91  | 15.62 | 0.71 | 18.42 | 20.77 | 19.57 | 19.72 | 19.50 | 0.78 |
| 10                            | a        | 36.00 | 34.00 | 38.50 | 35.00  | 35.88 | -    | 38.00 | 36.00 | 42.00 | 38.50 | 38.63 | -    |
|                               | b        | 6.00  | 5.50  | 6.75  | 5.50   | 5.94  | 0.59 | 7.75  | 7.25  | 8.50  | 8.25  | 7.94  | 0.55 |
|                               | c        | 16.67 | 16.18 | 17.53 | 15.71  | 16.52 | 0.78 | 20.39 | 20.14 | 20.24 | 21.43 | 20.55 | 0.60 |
| 15                            | a        | 35.50 | 38.50 | 35.00 | 39.50  | 37.13 | -    | 35.00 | 38.00 | 43.00 | 39.50 | 38.88 | -    |
|                               | b        | 5.75  | 6.00  | 6.75  | 6.00   | 6.13  | 0.43 | 7.50  | 7.75  | 8.50  | 8.50  | 8.06  | 0.52 |
|                               | c        | 16.20 | 15.58 | 17.14 | 17.09  | 16.50 | 0.75 | 21.43 | 20.39 | 19.77 | 21.52 | 20.78 | 0.85 |

a - Weight of wings (mg);

b - Weight of chitin(mg);

c - Percentage of chitin

# Appendix-L

Chitin content in the hind wings (per pair) of deformed and normal adult male S. gregaria at various ages.

| Age in days<br>after moulting | Deformed |       |       |       | Normal |       |      |       |       |       |       |       |      |
|-------------------------------|----------|-------|-------|-------|--------|-------|------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | AV.    | SD    | 1    | 2     | 3     | 4     | AV.   | SD    |      |
| 1                             | a        | 23.00 | 21.00 | 23.00 | 21.50  | 22.13 | -    | 25.50 | 22.00 | 24.00 | 20.50 | 23.00 | -    |
|                               | b        | 1.75  | 1.50  | 1.75  | 1.50   | 1.63  | 0.14 | 2.00  | 1.50  | 1.75  | 1.75  | 1.75  | 0.20 |
|                               | c        | 7.61  | 7.14  | 7.61  | 6.98   | 7.34  | 0.32 | 7.84  | 6.62  | 7.29  | 8.54  | 7.62  | 0.74 |
| 4                             | a        | 23.00 | 22.50 | 22.00 | 24.50  | 23.00 | -    | 23.50 | 22.50 | 24.50 | 23.00 | 23.38 | -    |
|                               | b        | 3.00  | 3.00  | 2.75  | 3.00   | 2.94  | 0.13 | 3.50  | 3.25  | 4.00  | 3.50  | 3.56  | 0.31 |
|                               | c        | 13.04 | 13.33 | 12.50 | 12.24  | 12.78 | 0.50 | 14.89 | 14.44 | 16.33 | 15.22 | 15.22 | 0.81 |
| 7                             | a        | 23.00 | 24.00 | 21.00 | 23.50  | 22.88 | -    | 23.00 | 24.50 | 24.00 | 24.00 | 23.88 | -    |
|                               | b        | 3.50  | 3.75  | 3.50  | 3.50   | 3.56  | 0.13 | 4.50  | 4.75  | 4.75  | 4.25  | 4.56  | 0.24 |
|                               | c        | 15.22 | 15.63 | 16.67 | 14.89  | 15.60 | 0.77 | 19.57 | 19.39 | 19.79 | 17.71 | 19.12 | 0.95 |
| 10                            | a        | 25.00 | 23.50 | 21.50 | 24.50  | 23.63 | -    | 25.50 | 22.00 | 25.50 | 24.00 | 24.25 | -    |
|                               | b        | 4.25  | 3.50  | 3.50  | 4.00   | 3.81  | 0.38 | 5.25  | 4.25  | 5.50  | 4.75  | 4.94  | 0.55 |
|                               | c        | 17.00 | 14.89 | 16.28 | 16.33  | 16.13 | 0.89 | 20.59 | 19.32 | 21.57 | 19.79 | 20.32 | 0.99 |
| 15                            | a        | 23.50 | 25.00 | 24.00 | 25.00  | 24.38 | -    | 24.00 | 26.00 | 23.50 | 25.50 | 24.75 | -    |
|                               | b        | 3.75  | 4.25  | 4.00  | 4.00   | 4.00  | 0.20 | 4.75  | 5.75  | 5.00  | 5.00  | 5.13  | 0.43 |
|                               | c        | 15.96 | 17.00 | 16.67 | 16.00  | 16.41 | 0.51 | 19.79 | 22.12 | 21.28 | 19.61 | 20.70 | 1.21 |

a - Weight of wings (mg);  
b - Weight of chitin(mg);  
c - Percentage of chitin

# Appendix-LI

Chitin content in the hind wings (per pair) of deformed and normal adult female S. gregaria at various ages.

| Age in days<br>after moulting | Deformed |       |       |       | Normal |       |      |       | AV.   | SD    |       |       |      |
|-------------------------------|----------|-------|-------|-------|--------|-------|------|-------|-------|-------|-------|-------|------|
|                               | 1        | 2     | 3     | 4     | 1      | 2     | 3    | 4     |       |       |       |       |      |
| 1                             | a        | 27.50 | 26.00 | 30.00 | 24.00  | 26.88 | -    | 28.00 | 26.00 | 28.50 | 28.00 | 27.63 | -    |
|                               | b        | 2.00  | 1.75  | 2.25  | 1.75   | 1.94  | 0.24 | 2.25  | 1.75  | 2.25  | 2.25  | 2.13  | 0.25 |
|                               | c        | 7.27  | 6.73  | 7.50  | 7.29   | 7.20  | 0.33 | 8.04  | 6.73  | 7.89  | 8.04  | 7.68  | 0.63 |
| 4                             | a        | 29.50 | 31.00 | 26.00 | 24.50  | 27.75 | -    | 29.00 | 30.00 | 28.00 | 25.00 | 28.00 | -    |
|                               | b        | 3.50  | 4.00  | 3.25  | 3.25   | 3.50  | 0.35 | 4.25  | 5.00  | 4.25  | 3.50  | 4.25  | 0.61 |
|                               | c        | 11.36 | 12.90 | 12.50 | 13.27  | 12.63 | 0.60 | 14.66 | 16.67 | 15.18 | 14.00 | 14.13 | 1.14 |
| 7                             | a        | 29.00 | 29.50 | 27.00 | 28.00  | 28.38 | -    | 30.00 | 29.50 | 28.00 | 29.00 | 29.13 | -    |
|                               | b        | 4.25  | 4.75  | 4.00  | 4.50   | 4.38  | 0.32 | 6.00  | 5.75  | 5.50  | 5.50  | 5.69  | 0.24 |
|                               | c        | 14.66 | 16.10 | 14.81 | 16.07  | 15.41 | 0.78 | 20.00 | 19.49 | 19.64 | 18.97 | 19.53 | 0.43 |
| 10                            | a        | 32.00 | 29.00 | 31.00 | 29.50  | 30.38 | -    | 30.00 | 29.00 | 30.50 | 27.50 | 29.25 | -    |
|                               | b        | 5.00  | 4.50  | 5.00  | 5.00   | 4.88  | 0.25 | 6.00  | 6.00  | 6.00  | 5.75  | 5.94  | 0.13 |
|                               | c        | 15.63 | 15.52 | 16.13 | 16.95  | 16.06 | 0.65 | 20.00 | 20.69 | 19.67 | 20.91 | 20.32 | 0.58 |
| 15                            | a        | 33.00 | 30.00 | 31.00 | 28.50  | 30.63 | -    | 32.50 | 31.00 | 30.00 | 29.00 | 30.63 | -    |
|                               | b        | 5.00  | 4.75  | 5.00  | 5.00   | 4.94  | 0.13 | 7.00  | 6.00  | 6.25  | 5.75  | 6.25  | 0.54 |
|                               | c        | 15.15 | 15.83 | 16.13 | 17.54  | 16.16 | 1.01 | 21.54 | 19.35 | 20.83 | 19.83 | 20.39 | 0.99 |

a - Weight of wings (mg);  
b - Weight of chitin(mg);  
c - Percentage of chitin

