UNIVERSITY OF IFE NIGERIA

Inaugural Lecture Series 35

INSECTS AND HUMAN WELFARE WITH SPECIAL REFERENCE TO THEIR ROLE IN AGRICULTURAL PRODUCTION

by A. O. Adenuga

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This I believe is the second inaugural lecture to be delivered by a Professor of Plant Science in this University but the first by a Nigerian Professor of Plant Science. My predecessor, Professor Duncan, who first inaugurated the chair of Plant Science showed in his treatise quite clearly the importance of weather in agricultural production in a discipline known as agroclimatology. My own lecture today on "Insects and Human Welfare," is in the area of insect science known technically as entomology. You can see, therefore, that Plant Science has a broad scope, some of its disciplines seemingly unrelated to an uninitiated observer. Indeed, I have often been asked: 'If you study insects, which are in any case animals, why are you not in the Department of Animal Science?'. As an agricultural entomologist the ultimate aim of my study of insects is to be able to reduce the damages insect pests do to crop plants, livestock and agricultural produce, and quite recently, that function has been extended to the improvement of environmental factors under which beneficial insects like parasites or predators of insect pests and insects that pollinate flowers can multiply and thrive well. But principally because insect pests of crops are several times more numerous than pests of livestock, entomologists are based in the Department of Plant Science rather than the Department of Animal Science.

Mr Vice-Chancellor Sir, the Department of Plant Science, as structurally organised at Ife consists principally of Crop Production, and Crop Protection. Crop Production includes such disciplines as Plant Breding, Agronomy, Crop Physiology and Horticulture, whilst Crop Protection accommodates Entomology, Nematology, Weed Science and Plant Pathology, which again can be sub-divided into Bacteriology, Mycology and Virology. Given such a multi-disciplinary nature of the Department, it is obvious that a Professor of Plant Science can only claim to truly profess one of the disciplines I have enumerated earlier.

Entomology as a science has its genesis in both art and theology. Curiously enough it gives satisfaction either as a hobby or as a profession and for some it can be both without diminishing their intellectual experience. The duality in the origin of entomology is reflected in its definition by several dictionaries. While the British dictionaries define it as "that part of natural history that treats insects", French and American ones generally define it as "a branch of zoology". The enduring affinity of synanthropic flies for man and domestic animals presupposes an ancient and intense association. The impact of these insects as annoyers and despoilers of food is well felt in many regions of the world where primitive system of sanitation and waste disposal prevail. All of you listeners whose exposures to flies is happily limited to the occasional attacks on your morning sleeps can hardly appreciate the ubiquity of these insects nor their potential for explosive multiplication during war, famine and or other disasters. Hopefully in time, flies will join cockroaches, bed-bug and lice as vanquished symbols of poverty, apathy and disease. At present, however, a pathetical small part of humanity is reasonably free from these pests.

A few historical passages have been selected to underscore the timelessness of the insect problem and its global aspect. Probably the best known passage is from Exodus, 8: 21 and 24 "Else if thou will not let my people go, behold I will send swarms of fly upon thee and upon thy servants and upon thy people and into thy houses: and the houses of the Egyptians shall be full of swarms of flies and also the ground weapon they are. And the Lord did so and there came a grevious swarm of flies into the house of Pharaoh and to his servants' houses and into all the land of Egypt. The land was corrupted by the reason of flies." Ecologically, it is reasonable that a plague of frogs preceded the flies "and they gathered them (the dead frogs) together upon heaps and the land stank". It is easy to see that flies would have bred enormous numbers in these heaps more so than from a single frog which would have quickly dried in the heat.

Middle East, the Bible land which cradles civilization is still a fly haven. The mild climate has provided warmth, humidity, and human beings have unintentionally added food and shelter for the flies. Production of potential fly breeding materials mounted as human and domestic animal populations increased. It is therefore not surprising that the ubiquitous fly was already present in art and writings at the beginning of written history about 3,000 B.C. (Peck 1965). The 14th tablet of the series 'Har-ra-Hubulla', is a systematic list of names of wild terrestrial animals that dates from the time of Hammurabi, some 3,600 years ago and is based on even more ancient Sumerian lists. This compilation is written in an Akkadian cuneiform on clay tablets and is the oldest known book in zoology (Greenberb 1973). There are 396 animals listed of which 111 are insects and 10 are flies.

There are many passages in the ancient folk-lores where the gods are compared with the pestilential insects or where the gods are reported to have changed to flies buzzling around the streets like flies (Van Buren, 1939). Fly amulets skillfully calved from stone shells and frit have been unearthed from various levels in the ancient Babilonian sites (Busvine, 1976). Flies often occur in

cylinder seals associated with gods and this led to the 19th Century notion perpetuated by contemporary medical historians that the fly was the symbol of Nergal, the Mesopotamian god of disease and death. Some modern scholars have argued that there is no evidence of a fly god in Mesopotamia nor a link between Nergal, flies and disease. Instead they suggest that the fly symbol in this early period served as a purely decorative function as did lizards, mammals and flowers. It is reasonable to infer that such common and intrusive insect like the flies which swarmed on wound and faeces, got into one's eyes, food and mouth, attacked carcasses and corpses and avariciously attended at sacrificial altar undoubtedly made impact beyond the decorative.

Again the Bible alludes several times to maggots infesting human flesh for this was common affliction in those days. Intense competitors among flies for breeding site would have encouraged carrion feeders to turn opportunistically to the wounds of living hosts. Strictly speaking those maggots that confine their appetites to tissue debris and secretions abjuring living tissues are not parasites; but the victims can hardly be expected to appreciate this fine distinction. Job, the prototype of the endless sufferer, is not spared this affliction for in Job 7:5 he said thus "my flesh is clothed in maggots and clod of dust, my skin rotted and fouled afresh". The condition in which magots infest human flesh is known technically as myiasis. There was in 1971, a newspaper report of the case of a derelict in Chicago Skidrow who appeared at a clinic with complaint of rumblings in his head (perhaps like the Biblical Titus who was punished for destroying Solomon's Temple with his Roman legion by a small fly gnawing his brain for seven years). Myiasis was amply confirmed by the Chicago clinic when 35 maggots were washed from the patients' ear. According to Plutarch (in Edney, 1947) the Persian kings employed myiasis in criminal justice. The most serious offenders were exposed with honey smeared faces to the sun and flies. The outcome was certain, and the torture exceedingly painful. According to Saint Augustine, flies were created by God to punish our arrogance. Among the ancient Jews, fly in food is an offence and its presence therefore is ground for divorce (Anonymous, 200-500 A.D.).

Insects have played a lot of role in the religion of ancient civilizations. The scarab beetle images were very prominent and widespread in ancient Egypt because the dung the beetle forms and rolls to provide oviposition (Fig. 1) site was considered to represent the sun. Hence, the scarab hieroglyphic pronounced 'khopi' or 'kleipper' means "to create" (Southwood, 1977).

the Great, aged 32 in 336 B.C., Oliver Cromwell aged 59 in 1658 Lord Biron aged 36 in 1824. The disease killed Popes and Cardinals in amazing numbers and was no doubt responsible for the moving of the Papal seat from Rome to Avignone (Fletcher 1974). In the 1 Century Europe, the disease was cured by Jesuits bark, the bark of quinine tree which was first brought to Europe by the Jesuits. Oliver Cromwell was reported to have refused Jesuits' bark and died a strong protestant of malaria. The fall of the Greek and Roman Empires and civilizations has been partially attributed by some historians to malaria transmitted by mosquitoes in the mashes of Rome, (Celli, 1933). The scourge of malaria is not just a matter of historical record only. We must not forget that it is very much with us and pose a serious threat to very many millions of people in tropical Africa. Malaria reached one of its peaks in 1940 when it was reckoned that it was responsible for the death of about 3 million people annually. The discovery of DDT in about 1945 brought about a dramatic reduction in the number of death toll caused by malaria; for at one period during the Second World War, it was estimated that the number of soldiers incapacitated before they engaged the human enemy was over 90%. Most of the casualities were due to insect borne diseases. Today diseases transmitted by insects are still widespread. Millions of people in the world suffer from filariasis, a disease known as 'Calabar swelling' or loa-loa and the estimate is that at least one in six of human population carries some insect-borne disease (Edney, 1947).

Insects' Attack on Livestock

Man's personal insect pests are not the only insects he has to face in his struggle for survival. The menace caused by insects in attacking his crops and livestock has been nearly as catastrophic. Both the speed and skill of attack have been quite staggering. Diseases of domestic animals to which dipterous flies are vectors are legion. A few of the examples are foot and mouth disease of cattle, pigs, sheep and goats, the causative organism of which is a virus transmitted by house flies *Musca* species; (Fig. 5) African horse sickness, a viral disease transmitted by mosquitoes, sand flies and horse flies, *Tabanus* species; Blue tongue, a disease of ruminant sheep, a viral disease transmitted by *Culicoides* gnats; vesicular stomatitis, an infectious viral disease of cattle transmitted by horse flies, black flies mosquitoes, Rinderpest (or cattle plague) a highly infective viral disease transmitted by biting flies such as *Stomoxys* and Tabanids; hog cholera (otherwise known as swine fever) a viral disease the vector of which is suspected to be stable fly or the house

fly; Brucellosis, a bacterial disease of goats, cows, swine, sheep and sometimes man, transmitted by house and stable flies; Bovine mastitis a bacterial disease principally of dairy cattle but which also attacks sheep and goats; anthrax, a bacterial disease (caused by *Bacillus anthracis*) which is cosmopolitan in that all domestic animals and man are susceptible to it and is transmitted by Tabanids and muscoid flies; Cutaneous actinomycosis, a disease caused by aerobic actinomycetes in domestic herbivores including cattle, horses, sheep and goats and flies are suspected to be vectors of the zoospores; trypanosomiasis, common among domestic animals (and in man is called sleeping sickness) and its causative organism is the protozoon of the genus *Trypanosoma* carried by tsetse flies known as *Glossina* spp. (Fig. 6) All these are just a few of the examples of the diseases caused by pathogens or organisms which are carried by insects and which therefore reduce productivity of domestic animals and in very acute forms can be fatal and therefore kill the animals

Attack on Crops by Insects

There are references again in the Bible of great plagues of locusts that have devastated expansive areas of vegetation stripping them bare of all available foliage. Today, the same locust is still a potential pest over eleven million square miles of southern Europe, Africa and Asia ranging from Southern Spain to North Africa through Iran, Bangladesh and India. The locust is a strange insect. In the solitary phase, locusts are like grasshoppers (which indeed they are) but when in the gregarious phase under the influence of certain climatic factors not yet understood, they multiply to give rise to crazy mass of locusts. The swarm may cover at one time a hundred kilometers and the weight of insects concerned has been estimated at about seven thousand tons. When they descend on a crop or a cereal there may be up to four locusts per leave blade and with each giving three or four quick bites with its mandibles, that ensures a complete stripping of the field in less than one hour. It is an incredible devastation. It is just a typical example of when nature runs amock and creates immense number of insects. The locust plagues are eventually brought to an end by bad weather. The few survivors eventually revert to the solitary phase in which they are relatively harmless. In the locust zones of distribution, the interval between one plague and the next usually lasts about six or more years. The last very serious major locust plague in Nigeria was in 1935, although there have been minor outbreaks several times since then.

The account of locust damage just given, typifies the range and magnitude of pest damage to our crops. There are other pests of crops that are less devastating than locust but rather perenial in their mode of attack. Termites damage a variety of crops throughout the tropics (Harris 1961, 1969; Ronwall 1972, Sands 1973), but there has been no sustained efforts to study the population ecology of movement or feeding habits in relation to the level of damage inflicted on the crop. Neither has there been any accurate assessment of crop loss due to termites. However, the ODM Research Scheme Report (1973-1976) confirms that *Microtermes* attacks maize by entering the subterranean root system eating out roots and eventually reaching the stem either through the prop roots or through the main root system. The excavated roots are packed with subsoil. From the outside the attack is only apparent when the plant falls over, a process described as lodging. Groundnut is also attacked and Sands (1973) has indicated that root, stem base and the shell of groundnuts are targets of termites' attack. On the roots and stem base the attack causes wilting but on the shell the manifestation is scarification. In one field of cowpeas, it is possible to count up to about four hundred species of insects and nearly four hundred species in a maize field. The Saturnid larva, (Fig. 7) for example, causes defoliation of cowpea leaves and a similar damage is also caused by *Luperodes lineata*. Thrips and Mites defoliate the leaves and also cause flower abortion. *Acanthomia* (Fig. 8) damages the pods and flowers and the species of *Anoplocnemis curvipes* (Fig. 9) causes the pods to shrievel and die. *Ophiomyia* (*Melanogromyza* spp.) (Figs. 10 & 11) use the leaves and stems as oviposition sites and pupate in cowpea seeds. These are just a few examples of damage that insects can cause.

Post-Harvest Losses

In most food deficient countries, actual food shortages represent 4-6% of requirements whilst losses have been estimated as 20 to 40% of products. Parpia (1977). These losses are due to insect attack and spoilage brought about by micro-organisms. When one realises that for 80% of mankind the primary food, such as cereals and grain legumes or pulses provide the main sources of calories and proteins and that in Nigeria the losses are 46% and 41% for sorghum and cowpeas respectively (Colon Research Publication 1952 No. 1240), one will appreciate the quality of energy that can be saved through the prevention of post-harvest losses. Prevention of losses in food-stuffs after harvest has received very little attention until fairly recently. (Figs. 12 & 13 a & b) The widespread

interest recently generated has been due to (i) the realization that any effort to increase food production without improvement of our conservation methods is bound to be wasteful; (ii) that in any effort to overcome stagnation and stimulate progress towards self-reliance in agriculture, the development of post-harvest conservation and processing industries can make valuable contribuitions. Even though the Nigerian Institute for Stored Products Research is one of the oldest research institutes in Nigeria, its first early research efforts were concentrated on the preservation and protection of cash crops like cocoa, groundnuts, palm kernel, etc. etc. Attention on the prevention of damages done to food crops by insects and pathogens was secondary, but now there is a widespread interest in and concern about losses that occur in food crops after harvest not only in Nigeria but also throughout the developing world. In the past, most of technical assistance given by the developed world to the developing countries has been chiefly in the area of pre-harvest production sector. Hence the knowledge, experience, infrastructure and interest in these countries were built up mainly in this sector of production. There are possibly two reasons for this situation:

(1) In developed countries themselves, the post-harvest sector has always lagged behind the pre-harvest one in the attention and inputs in form of research, development and training and extension personnel.

(2) Even the application of little technological information available is hindered by the fact that there is no premium for wholesome clean grains or other food products, as volume is the unit of sale of commodity and there is no standardization of the quality of foodstuff that can be offered for sale in the market. Both weeviled and clean cowpeas, for example, tend to attract the same price per unit measure in the market, particularly, at period of scarcity. Hence, when the personnel of the Institute of Stored Products Research offered to fumigate the cowpeas of the market women at Dugbe so many years back, they refused because they saw no financial benefit to be derived from such an exercise. As long as there is no market rationalization in this country, so long will the consumer always get the 'short end of the stick' and buy more frass and less food at higher cost.

Beneficial Insects

The descriptive account of Aristotle (in Peck, 1965) and Pliny the Younger (Holland, 1635) on insects touched on three main groups (1) The first group consisted of ecto-parasites, which as we have noted, have more or less evolved with man from his ape-like ancestors. The second group consisting of bees, silkworms, wasps, etc. provides food, medicine, wax and silk for man. The third group is made up of locusts, mosquitoes and lepidopterous plant-devastating worms, etc. (Fig. 14) It should be noted, however, that the number of useful insects, even now does not seem much less than the number of descructive and annoying ones. But we seem to notice and feel the effect of the latter than the former group. Besides, the advancement of knowledge has helped the development of alternative sources of useful products, for example, medicine, clothing and food, formerly derived from insect sources. For instance, the silkworms which have played such a very important role in trade, commerce and travel between the east and west (Konishi and Ito, 1973) have had their importance now very much reduced due to the synthesis of artificial silk. Marcopolo (1294-1324) referred to silk as if it were jewellery like silver and gold. I still remember that, as a young boy, the roasted lepidopterous worms, (*Antheraea* sp *Bombyx* and *Philosamia* spp) form a very important protein intake of my diet at a particular season of the year. These insect larvae roasted in ash form good meat in melon and vegetable stew and a good concomitant with pounded yam or 'Eba'. They are becoming increasingly rare to come by these days. So also do I recollect with relish my boyhood hunt for the white beetle grubs of genus *Oryctes* usually found in decaying stems and frond bases of oil palm. The indiscriminate deforestation and over-exploitation of our forests for timber and other resources have made such experiences rare to children in the cities nowadays. In many rural parts of Africa however large crickets are still important items of diet. Abdullah (1973) gave various recipes for locust dishes. Judging from the ancient literature it is apparent that insects were very significant for food in the past than today. John the Baptist (Mark 1:6) relied on insects as food for a period eating locust and wild honey.

Bee farming has become an important source of income to many bee keepers in several areas of the world, namely, United States of America, USSR and Tanzania. Both the honey and wax are money makers. The honey produced by bees was the only source of sweetening available to man in many parts of the world until the cultivation of sugarcane developed. Its importance in this respect continues particularly in tropical Africa, Asia and among some of the peoples of tropical America. Bees wax which has long been used for making church candles has become increasingly important in organised societies and has today over two hundred uses, the most important of which are in the manufacture of cosmetics, polishes and pharmaceutical preparations. Above all, bees have been trained to pollinate particular flowers, thanks to the experiments of Von Frisch it is now possible to lead a colony of bees to particular flowers in order to pollinate them just in the same way as a pastor leads his sheep to graze.

The Endless Struggle

Today our major preoccupation as economic entomologists is in relation to insects and the food they consume without overlooking their role as pollinators, parasites and predators. If human beings must continue to exist in this world, it is imperative to gain mastery over insects. Up till now it appears that insects are better equipped to occupy the earth than human-beings. It is hardly surprising for they have been here much longer than us. The human race evolved only five hundred thousand years ago, whereas, insects have occupied the earth for about 15 million years now. The struggle between man and insects will continue as long as human race endures because insects constantly want the same things as man and sometimes more. As we have noted, some insects not only want the blood from our domestic animals but also from our own veins and they use us as well as the bodies of our animals for shelter. In this struggle, there seems to be no enduring victory for either side as man and insects seem equally matched. The insects help themselves to our crops at their leisure and we cannot even exterminate them from our houses permanently (Figs. 15 & 16). Every advance man makes, makes him more vulnerable to insect attack. For example, modern agricultural efforts provide conditions for development of insect pests. In his efforts to provide the most favourable condition for his crops he creates, unwittingly, an artificial environment and thereby automatically provides conditions which are favourable to some of these insect pests. This is because cultivation, disturbs the natural balance which would otherwise regulate or to some extent control insect pests. Through cultivation, he simply provides insect pests with extensive areas of suitable host plant on which they can feed and reproduce. The situation has been further complicated by the fact that as man bred for qualities in domestic plants most desirable to him, such as high yield, flavour and colour, the artificial selection in these plants has caused many of the characters which conferred resistance to insect attack in the naturally (Fig. 17) occurring wild plants to be eliminated. Most animals and other organisms are influenced by man in various ways, usually as a consequence of agriculture which is really a form of interference with nature. Before crops can be grown or livestock raised, the natural vegetation must be cleared or radically changed. The process causes disruption of most natural fauna and destroys the various species of animals and plants. Disruption of the vegetation and cultivation of the soil drastically change the habitat which becomes hasher because of the exposure of the soil surface directly to weather resulting in physical deterioration of the physical properties of the soil and erosion. Few animals survive the change, the herbivorous species of animals that do are thus able to withstand and adapt to the new environment and feed on crops planted or the weeds that colonise the exposed soil. Where a succession of different crops is grown, polyphagous species which feed on many species of plants are favoured but where mono-culture is practised, species that previously fed on wild plants related to the crop grown may survive. Relics of the old fauna remain in the woodlands, edge-rows, ditch sides and waste lands.

Where agriculture is intense and permanently practised, the habitats are mostly man-made. It is rather inevitable because in order to find food for the teeming population of our people the process of alteration and destruction to natural vegetation goes on at an increasing pace. Where areas of virgin-land are brought under cultivation, the surviving species of animals generally fail to fill all the available niches provided by the crop. Alien species that find such niches suitable would move in from distant habitats. It is therefore a matter of time before a potentially harmful species from one place finds a vacant niche well suited to its way of life in another. What applies to animal pests equally applies to organisms causing plant diseases and to noxious weeds. For those species which adapt to the new plant, there is an opportunity for unlimited reproduction because of the super-abundance of the food and extermination or reduction of natural enemies. It follows therefore that agricultural systems are designed to alter a given ecosystem to increase the flow of energy to man. Within this scope, crop mono-cultures are extreme examples of environmental simplification and specialized management. Although highly productive and efficient, this system has been criticized because of its genetic and horticultural uniformity which results in continuous pest suscepti-bility (Pimentel 1962; Southwood and Way 1970 and Nickel, 1973).

Over the centuries our farmers have developed systems of rotation over large areas which maintain long term usefulness of the land. It is this system that is often referred to as shifting cultivation and it involves clearing and burning of forests, growing crops for one to three years depending on the fertility of the soil

and then abandoning the land after this circle of activities for between 5 to 20 years to allow regeneration of secondary forest before starting another circle. In shifting cultivation most of the land is devoted to mixed culture in which several types of crops are grown, interplanted in the same piece of land. This feature generates a high degree of diversity both in terms of flora or fauna. Diversity is closely associated with stability (Odum, 1959 and Hanson, 1972) and Utilda (1957) has shown that the amplitude of insect population oscilation is smaller in more diverse populations. It is not surprising, therefore, that although the problem of insect pests still exists under shifting cultivation, they are sufficiently minimized that major outbreaks are rather infrequent. In spite of such advantage and because of the low productivity and inefficient use of the land that shifting cultivation involves, it has proved inadequate a farming system for providing food for the rapidly growing population of our people. This has necessitated increasing the cropping period in some areas, cropping frequently and shortening the fallow period tending towards continuous cultivation.

Insect Abundance

Insects have special attributes that confer special advantages on them as pests of crop. Firstly, insects have high rates of repro-duction which enable them to build enormous numbers in a short time. The biomass of insects in one acre of land comes to an appreciable weight, not to talk of using social insects, like the termites, bees or ants as an examples. Chauvin (1967) reckons that every hive requires annually over 100 kilograms of nectar and about 25 kilograms of pollen collected grain by grain from anthers of flowers. The weaver ants, *Oecophylla longinoda,* in a cocoa farm which induce their young larvae to secret silken threads that bind the leaves together by holding them with the mandibles and moving them back and forth like shuttle, live in colonies each of which contains a great number of individuals sometimes up to a million built up by a large number of queens. A single nest of *Formica polyctena* has been known to have about five thousand sexually active queens. Such colonies of ants are very active predators gathering daily huge quantities of food made of complete but dead insects and others that have been cut into fragments.

There have been reports that in the Italian Alps counts have been made of more than a million nests of red ants comprising of three hundred billion individuals (Chauvin, 1967). And it is estimated that up to fifteen thousand tons of alps insects can be destroyed each year by these ants. Such figures staggering as they may seem, can be greatly exceeded in certain circumstances as has occurred on occasions when nature runs amock and creates a swarm of locusts, the mechanism of which has been earlier described.

Any one who has travelled the road up north would have noticed the huge mounds of termites scattered all over the savannah areas. A vast number of the individuals is required to produce these prodigious structures. A single mature *Macrotermes natalensis* nest contains approximately two million living individuals at any given time. (Fig. 18 a & b) According to Fenton (1952) the primary queen of these species lives for an average of ten years. She lays 30 thousand eggs per day or 10 million per year and a total of 10 million in her life time. Bodot (1964) found that egg production by *Cubitermes* is subject to seasonal variation being greatest towards the end of the lesser rainy season. It is, however, highly conceivable that the lifetime production of the primary queen is at least in tens of millions and perhaps even higher. The queen is literally a living egg factory and the activity around her is intense with dozens of workers constantly leaking her body, feeding her with regurgitated saliva secretions and taking away her eggs as quickly as they are laid. (Fig. 19) But when her egg production declines below that required by the colony, she is liquidated by the workers, evidently by leaking her abrasively for three or four days and her body gradually shrinks until a shrivelled skin is left. She is then replaced by a number of secondary or tertiary queens.

Secondly, insect's adaptability to every kind of environment is unique. Thus insects which can be everywhere can also build up in one place a colossal mass of living matter. They can be found everywhere because their habits, behaviour and their capacity to withstand extremes of unfavourable conditions, allow them to become adapted to every kind of environment. The only environment where insects are few is the ocean which is colonised by insects with extreme reluctance. In contrast, insects invade every other environment in vast numbers. Up in the air, to a height of about two thousand meters, insects form an aerial plankton comparable to sea plankton and many birds depend on them for food. Insects heavily colonize the superficial layers of fresh water because their mode of respiration obliges them to be near the surface to take atmospheric air regularly. The water they inhabit does not have to be clean. The degree of foulness of the water does not deter flies and mosquitoes from breeding in it. In very hot geysers in the temperature range of 70 to 80 degrees centigrade mosquitoes develop very well and are almost the only creatures

Fig. 1 The scarab beetle rolling a dung she uses for oviposition

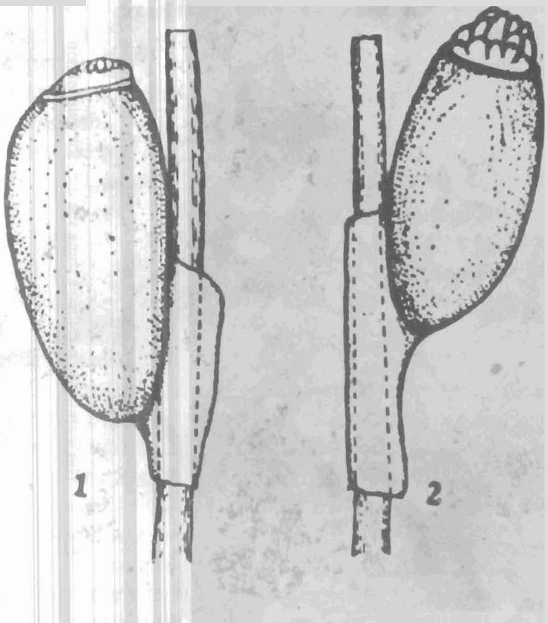

Fig. 2 (1) *Pediculus humanus capitis* (egg of head louse)
(2) *Phthirus pubis* (egg of pubic louse)

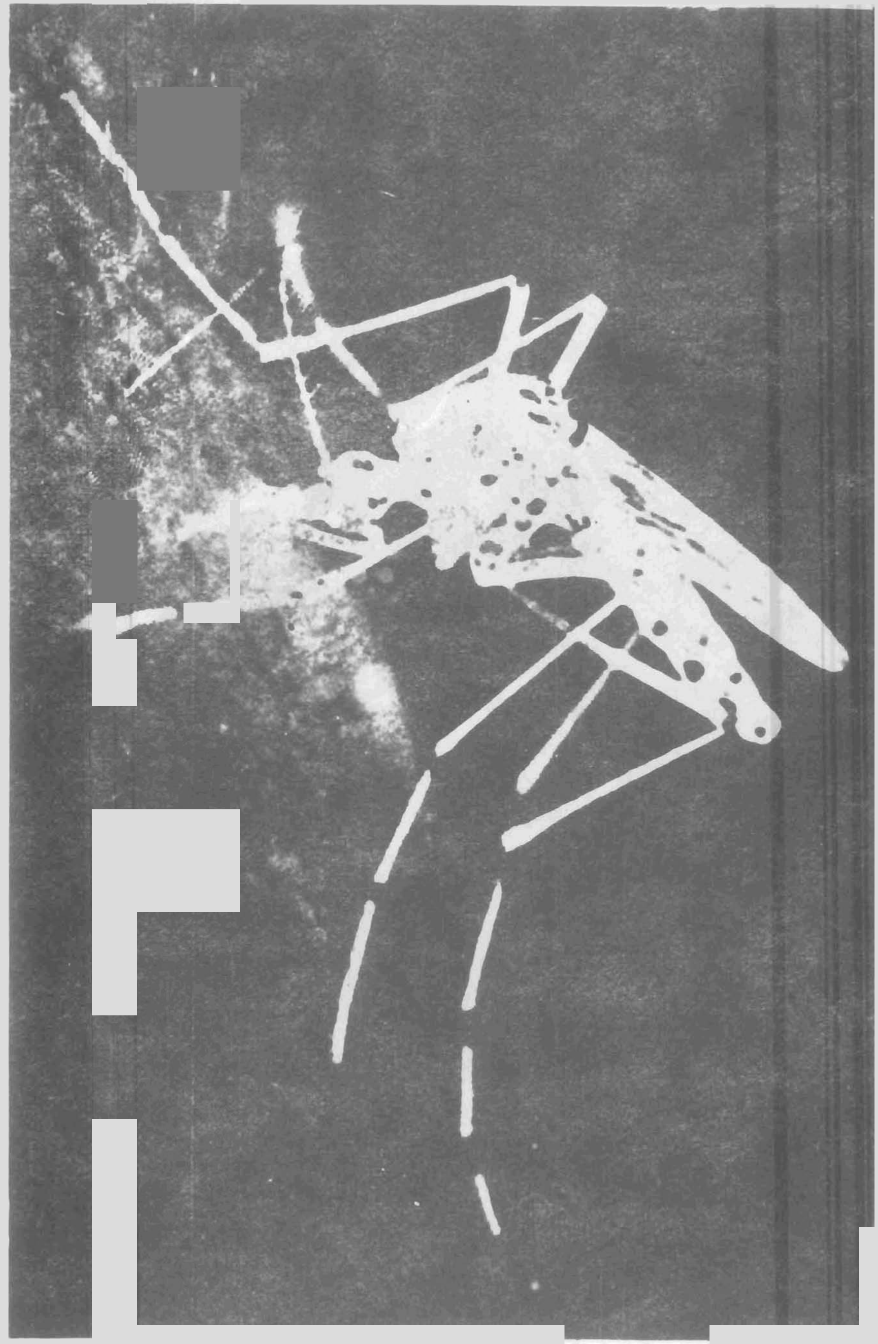

Fig. 3 Adult fema mosqu (pre-feeding)

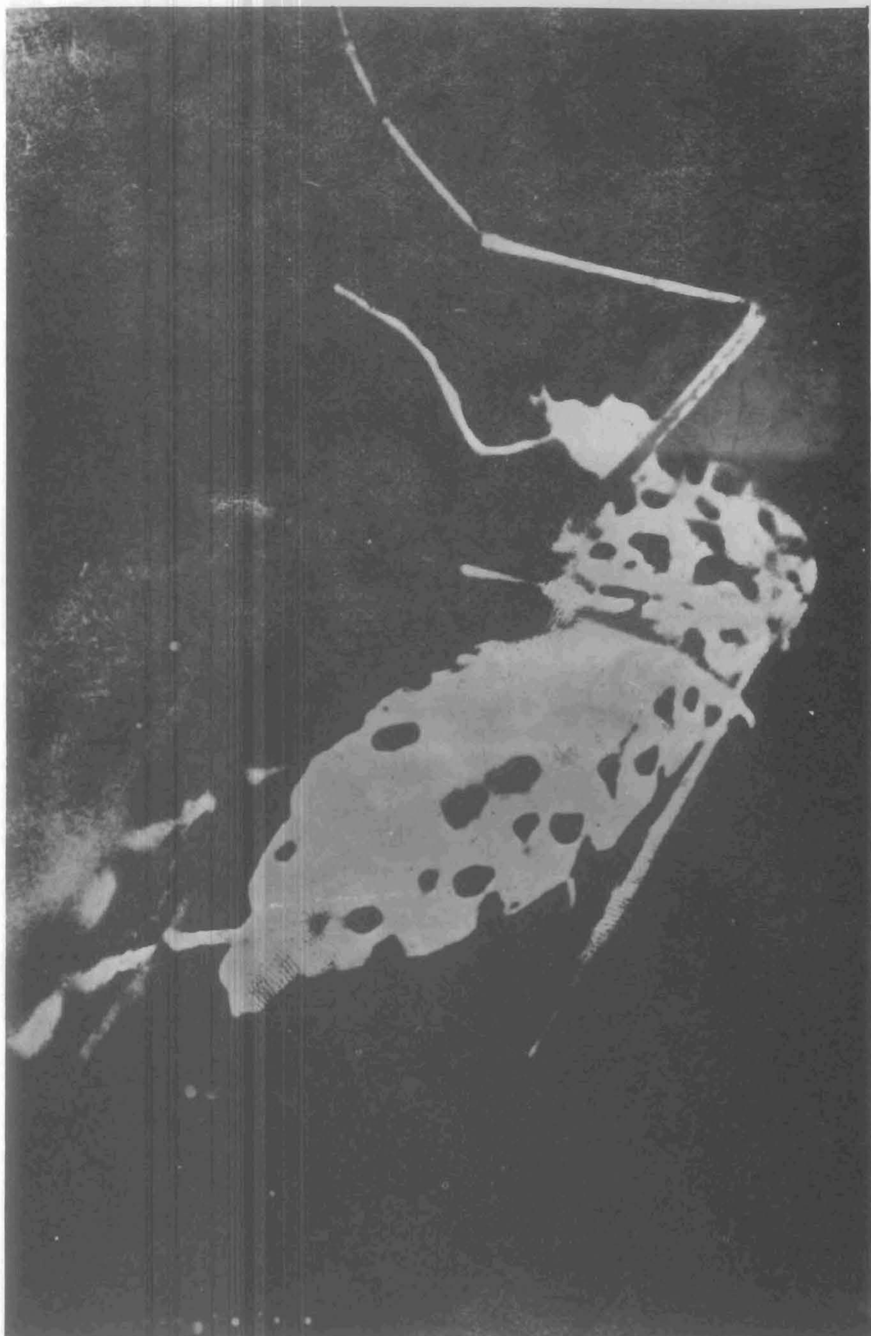

Fig. 4 Adult female mosquito (after a blood meal)

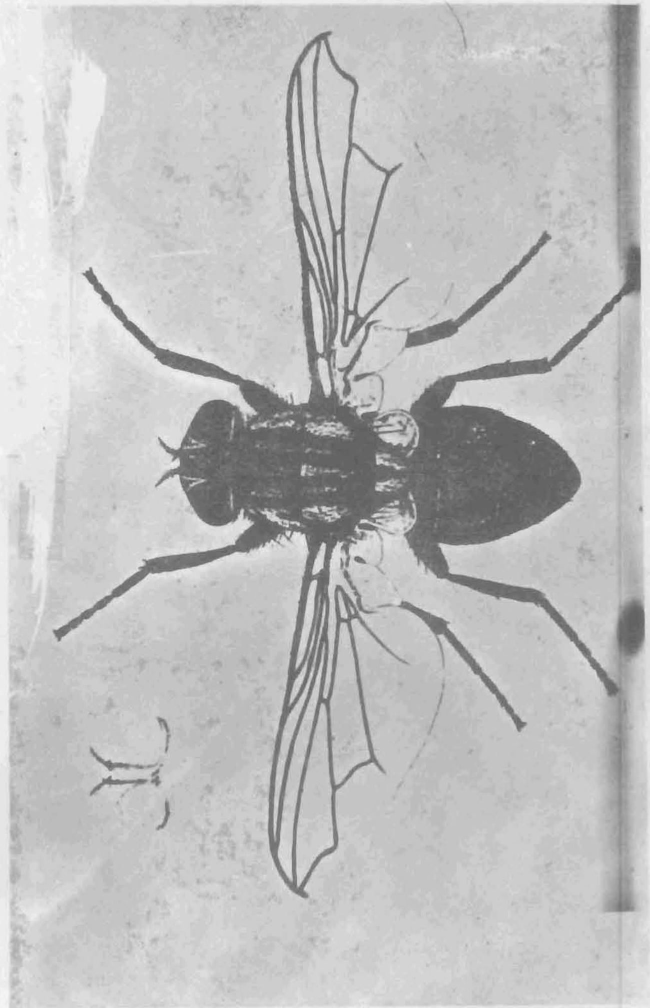

Fig. 5 *Musca domestica* (common house fly)

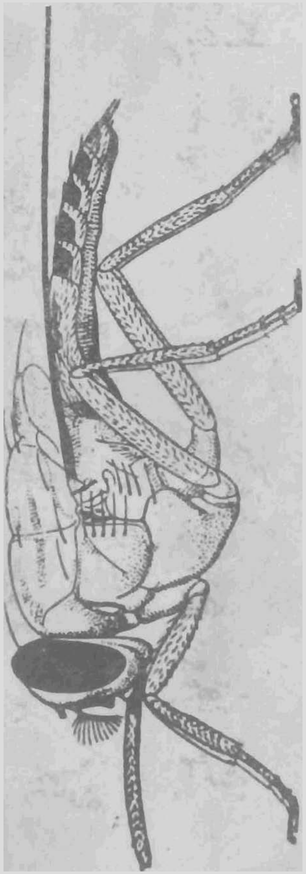

Fig. 6 A Tsetse-fly (Glossina morsitans, Westw., ♀), before feeding

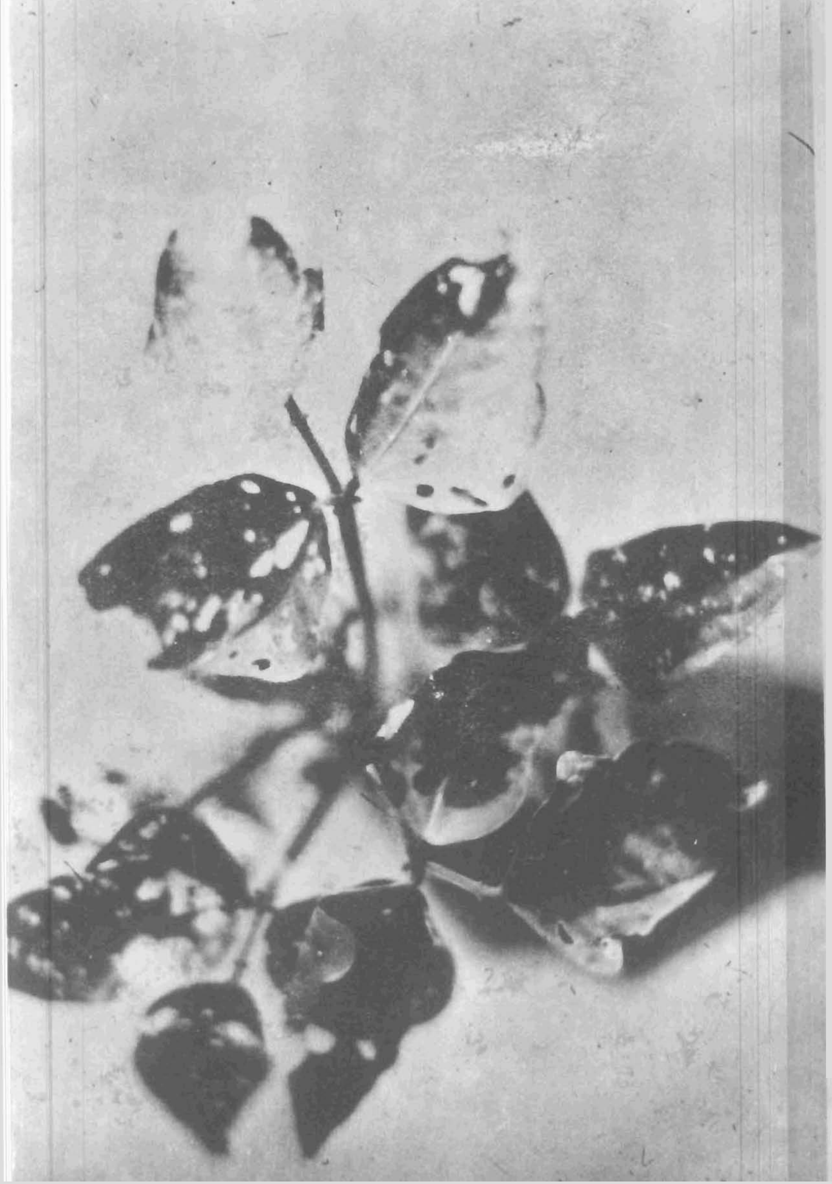

Fig. **7 Defoliation of cowpea leaf by ootheca mutabilis**

Fig. 8 *Acanthomia Shadabi* on cowpea

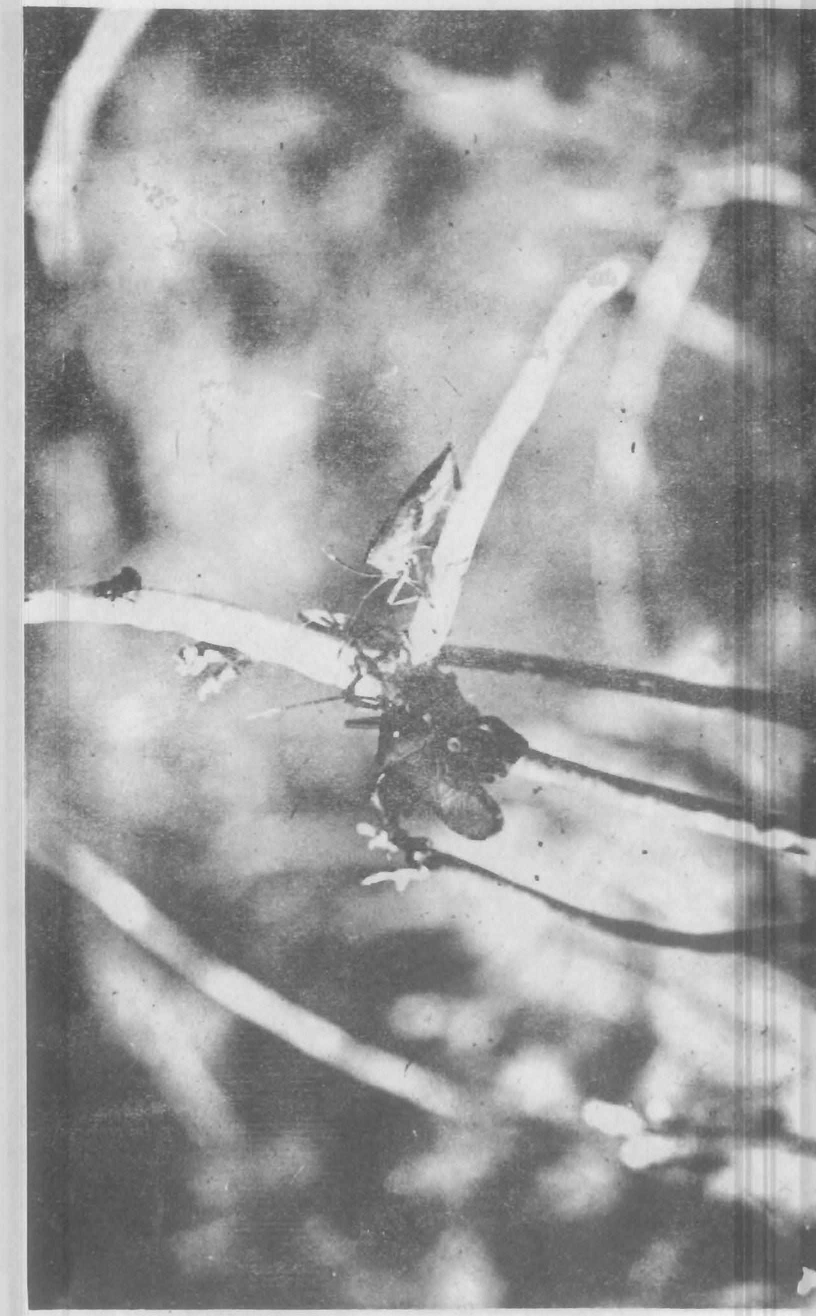

Fig. 9 *Anoplocnemis curvpes*

Fig. 10 Ophiomyia sp uses cowpea leaves for oviposition

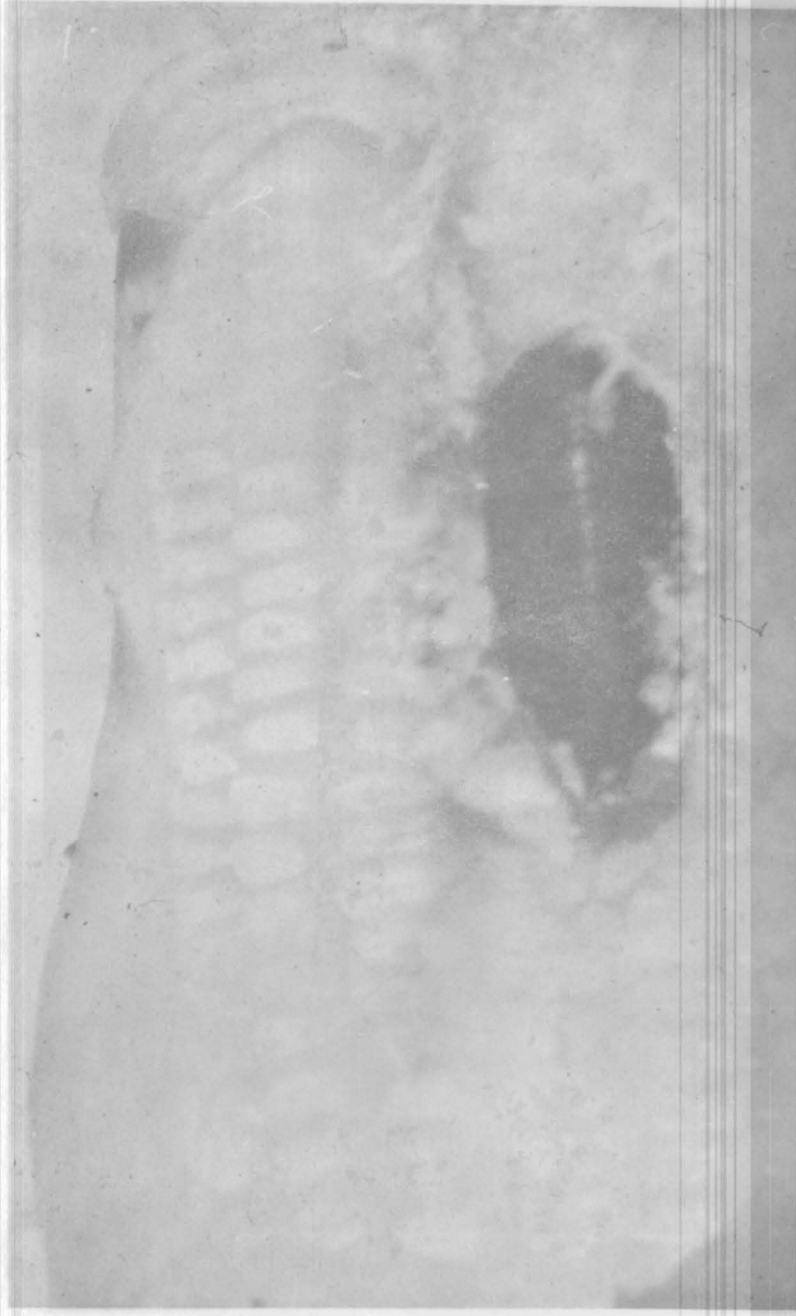

Fig. 11 Puparium of *Ophiomyia* on Cowpea seed

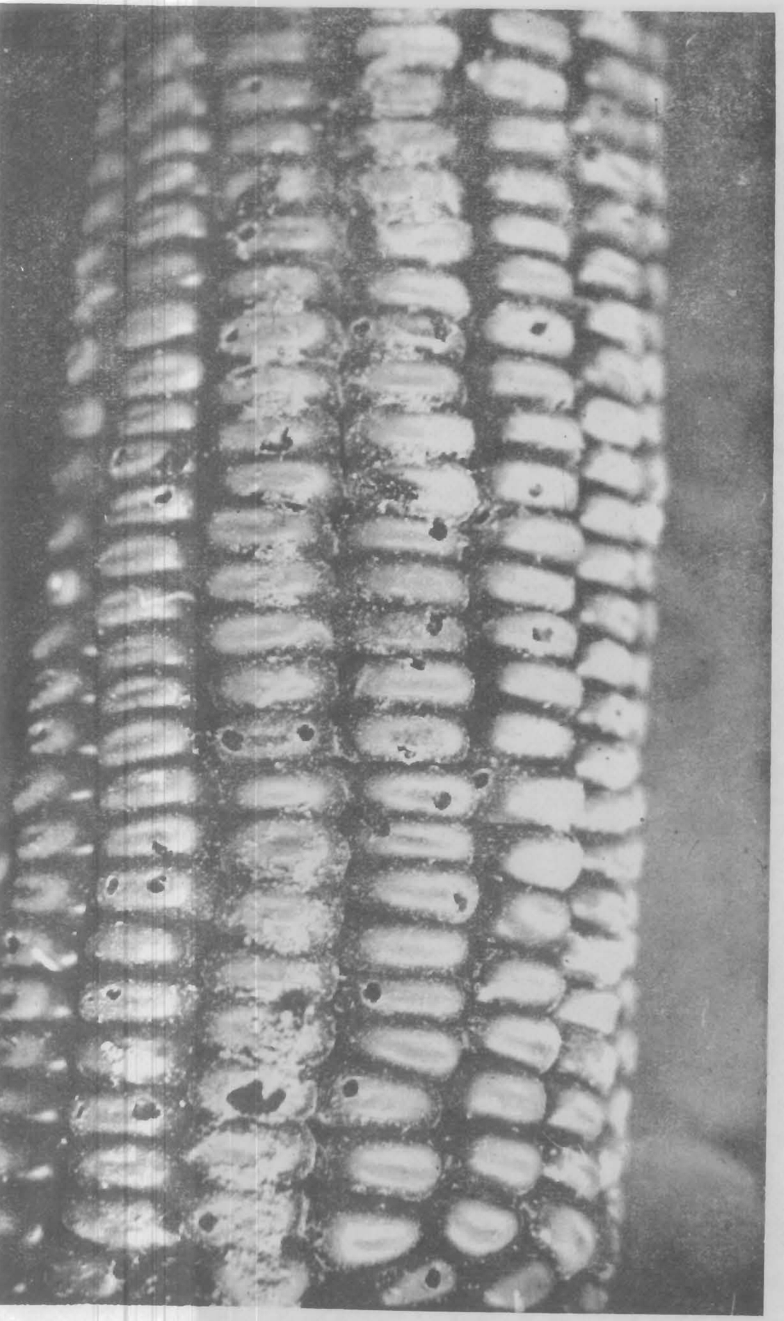

Fig. 12 Sitophilus Weevil in maize

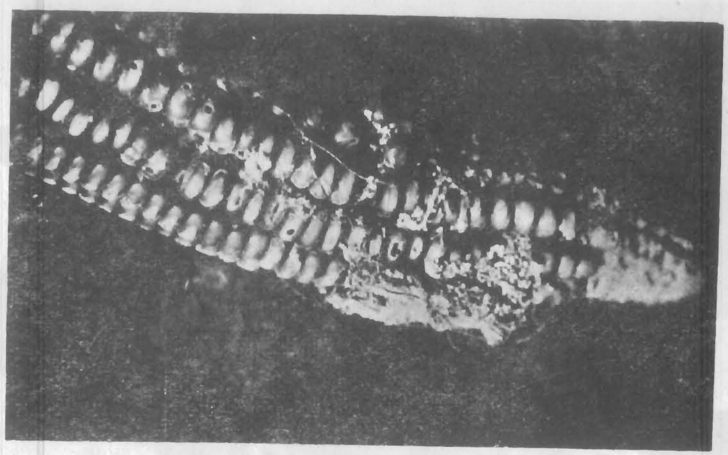

Fig. 13*a* Mussidia & Sitophilus damage to maize

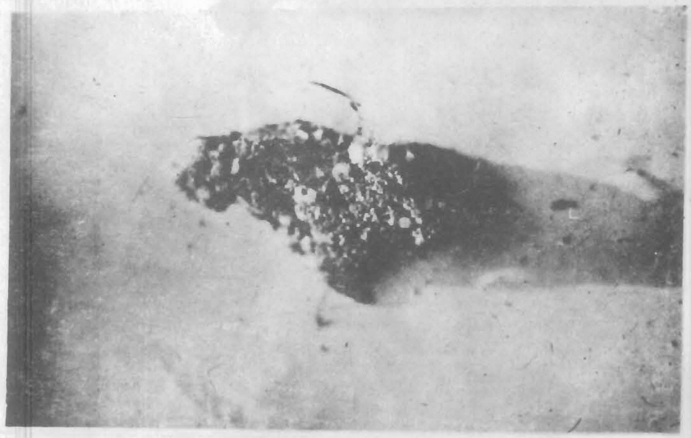

Fig. 13*b* Advanced stage of maize damage by insects in storage

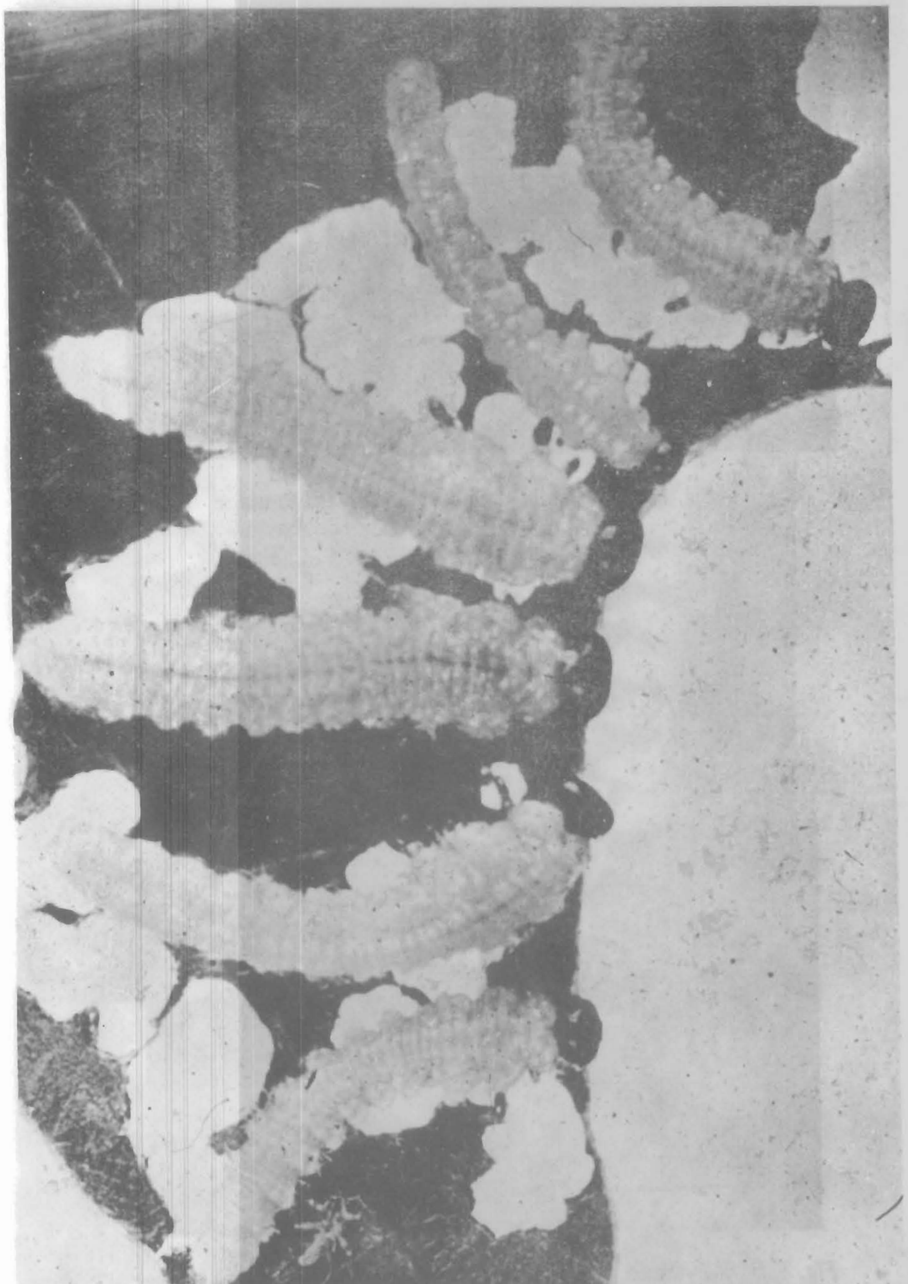

Fig. 14 Leaf worms (Sodoptera sp) destroying Okra leaves

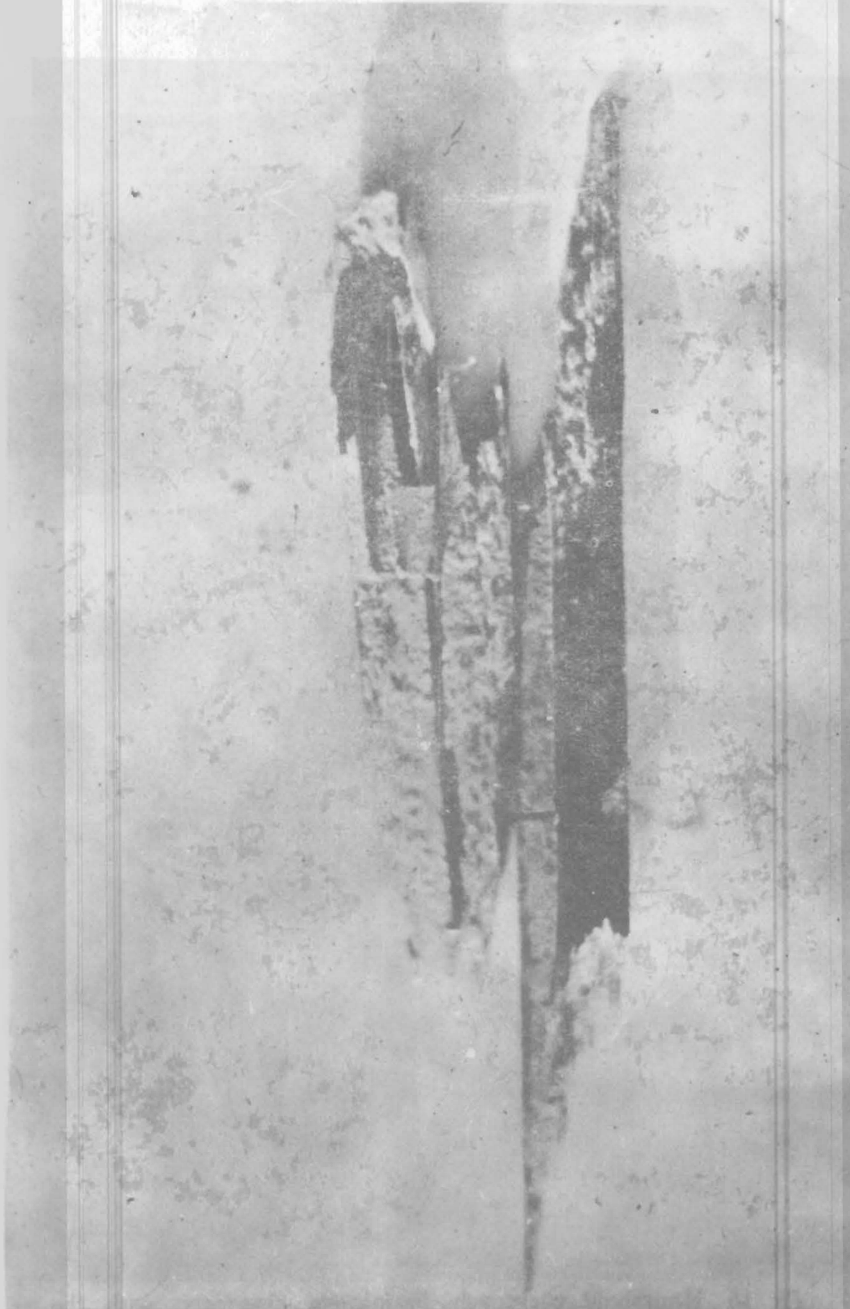

Fig. 15 Damage by powder post beetle to wood construction

Fig. 16 Household cockroach, *Periplaneta americana* with the egg pod

Fig. 17 *Heliotis armigerd* on cowpea pod

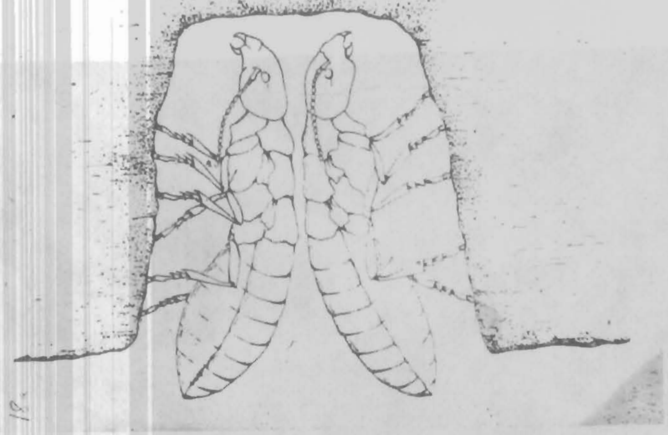

Fig. 18(*a*) **How they begin, A male and A female lay colony foundation**

Fig. 18(*b*) Months later, mounds develop

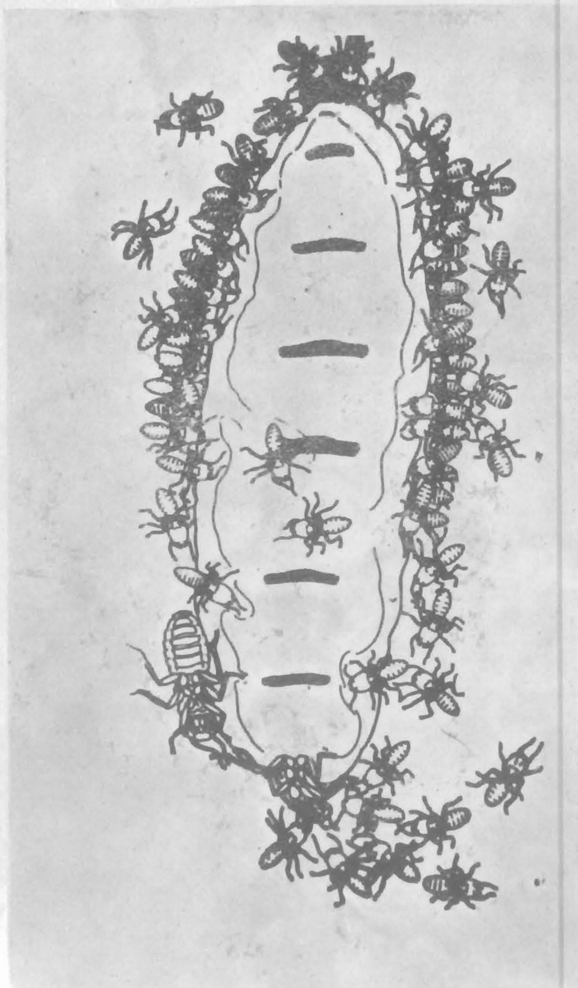

Fig. 19 Termite queen being licked by workers termites

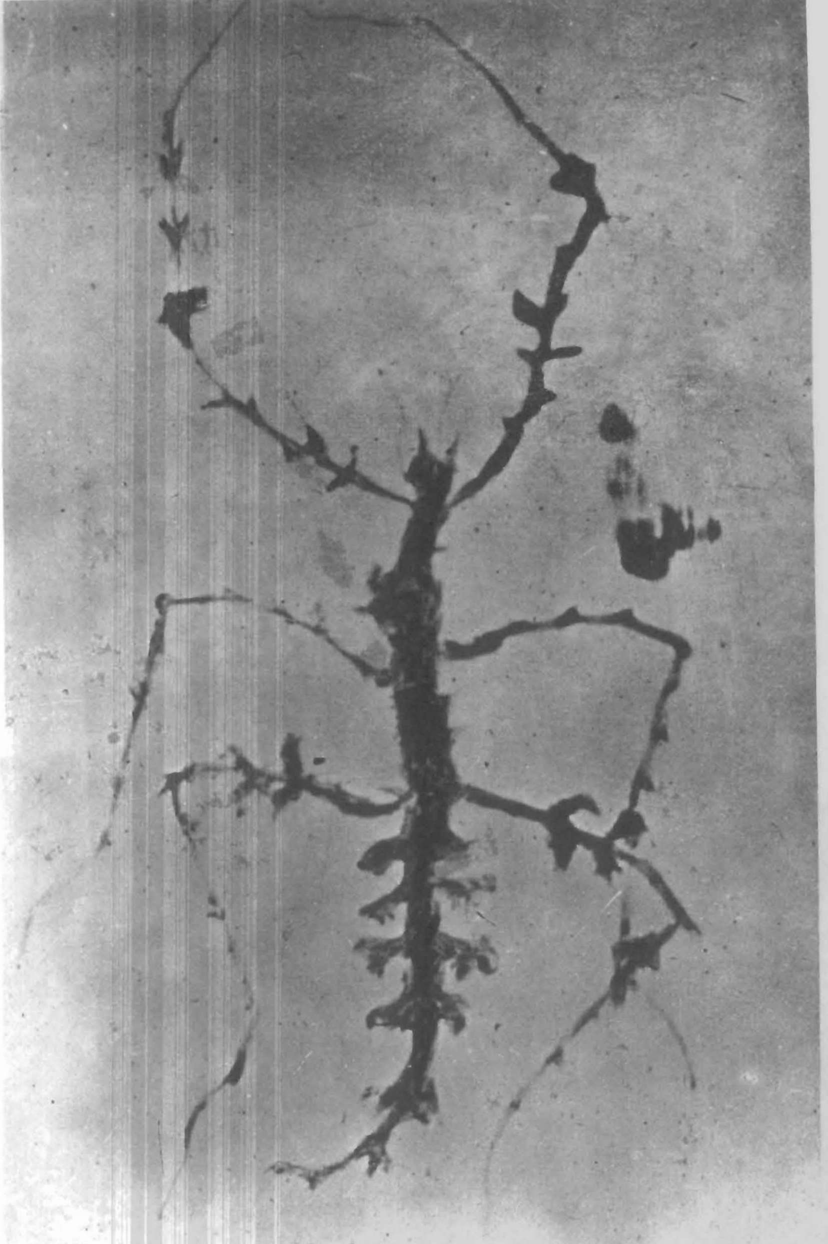

Fig. 20 Spiny form to reduce predation risk

Fig. 21 Stick insects of host plant— A display of mimicry

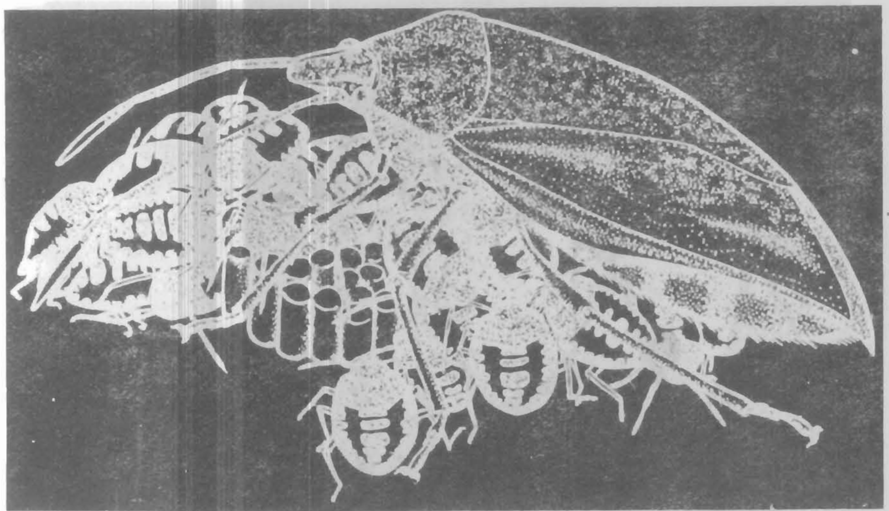

Fig. 22 A female Stink-bug (Mecistorhinus tripterus) guarding her four-day-old first-instar nymphs. Length of adult bug about ½ inch

Fig. 23 Damage to Maise stem by stem borer moth, *Sessamia calamistis*

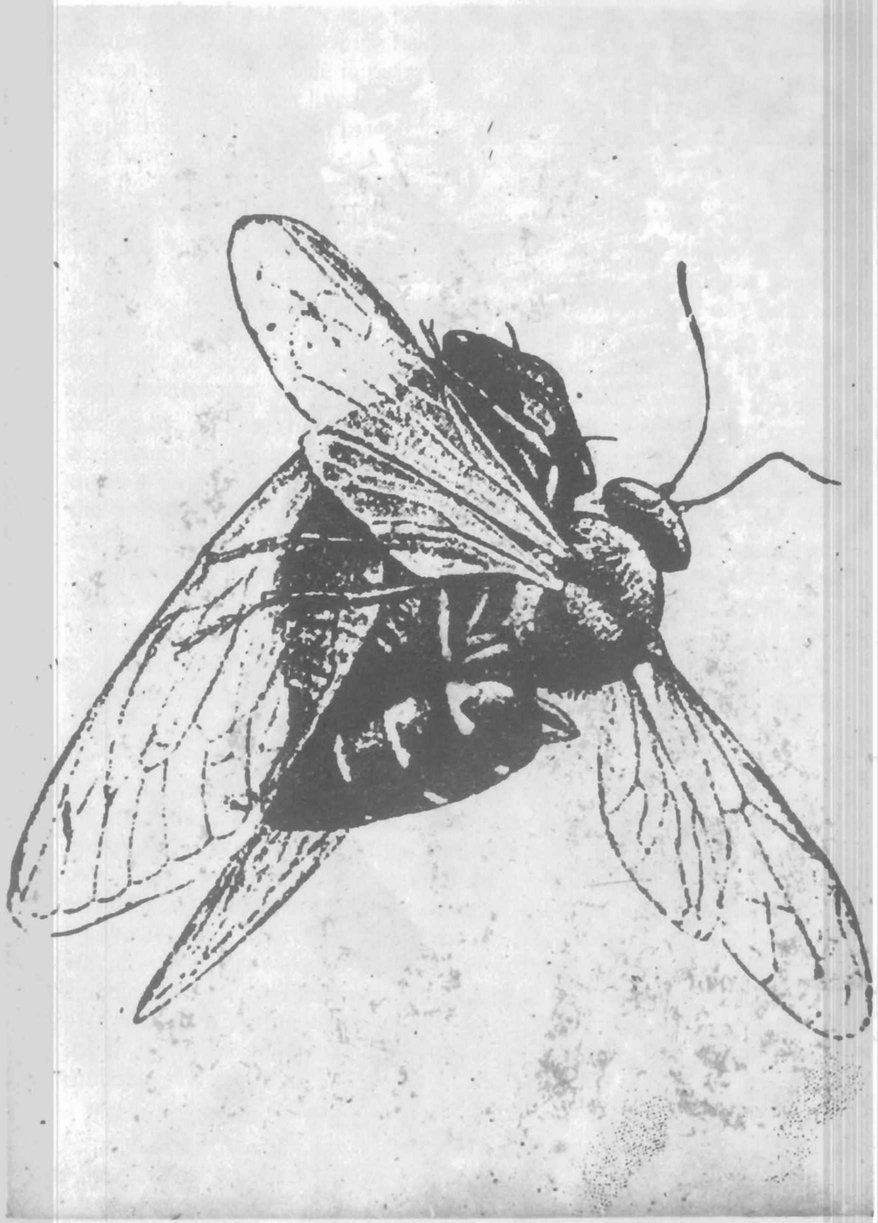

***Fig.* 24 Natural Control: Sphecoid wasp laying eggs on a pentatomid bug after paralysing it temporarily**

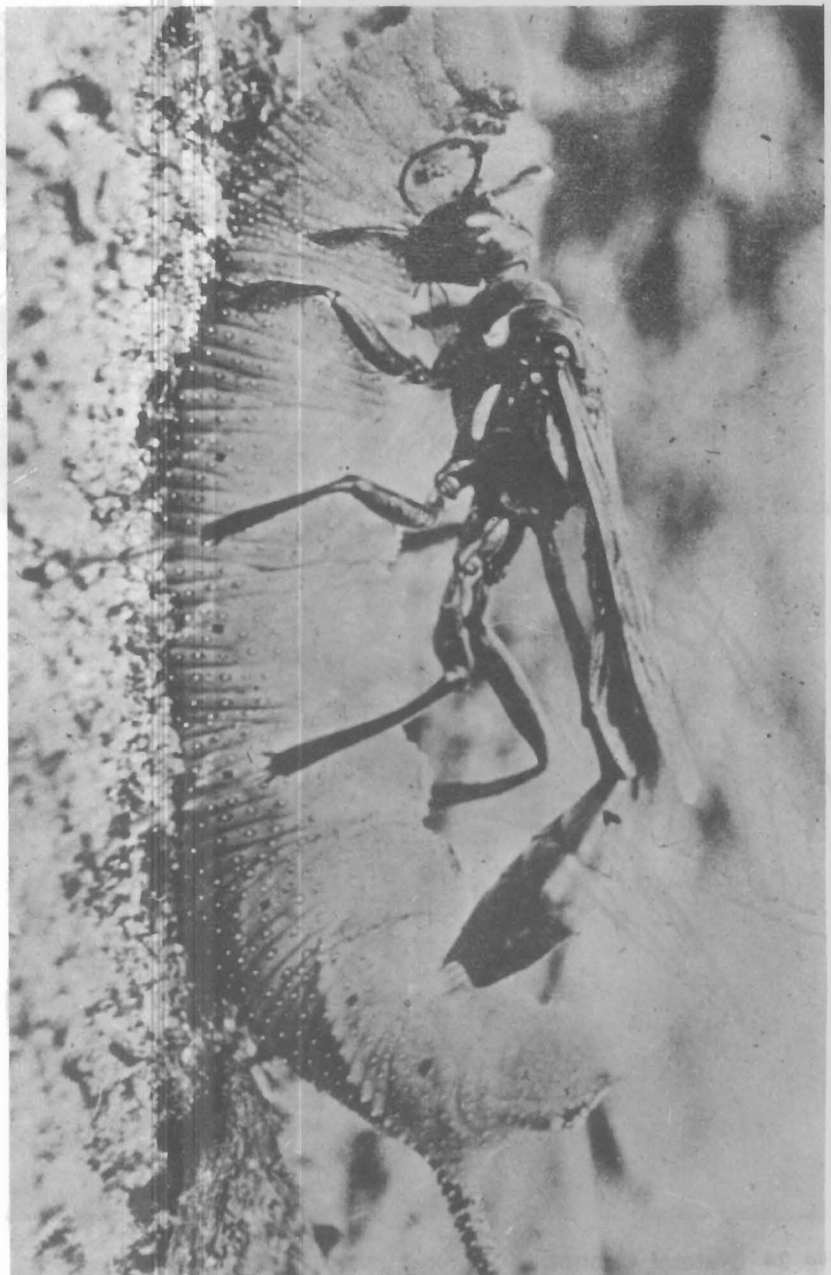

Fig. 25 Natural Control: ♀ Wasp laying her eggs on Saturnid larva

except the heat loving bacteria that can withstand such temperatures. Other liquids beside water sometimes support insect life, a notable example is petroleum, which is inhabited by the fly *Psilopa petrolei* that lives in the seepage pools of crude oil. The fly feeds on dead bodies of insects that fall in, but its gut also contains symbiotic bacteria that can convert petroleum into proteins which the fly can further digest. Research workers who hope to extract edible materials from petroleum products will therefore find that they have been anticipated by insects. Even the desert, in spite of its harsh conditions contains insect fauna which is by no means small in number. The desert insects avoid the heat wave of the day (when the temperature can rise up to 80°C or 176°F) by hiding in holes and only coming out at night when the temperature is low to chew vegetable matters which are moist with dew that condenses during the night. Ants and termites that live in open desert take a more active part in digging themselves in by excavating pits which may be up to 40 meters deep as far down as the permanent water table in the soil. A continuous chain of workers bears the liquid to the surface in such abundance that one finds in the middle of those arid surroundings that a termite's nest is sometimes so humid that one can raise drops of water by pressing the surface with ones hands.

Thirdly, the high rate of reproduction of insects favours gene mutation which enables the insect to adapt rapidly to changes in environment and confers resistance to chemical control measures.

Strategies for Controlling Insect Pests

The losses to national economy resulting from insect damage are enormous and sometimes rarely comprehended. Thus Neave (1930) computed that on conservative estimate-basis a ten percent loss in total crop yield is due to degradation by insects. Cramer's (1967) estimate of 10 to 15% as the world crop losses is very much close to Neave's figure. Having consideration for the fact that 20% of world's ever growing population is without adequate food and since crop losses caused by insects seem to be heaviest in just areas afflicted with malnutrition (Southwood, 1977) there is an ample justification to claim that applied entomology has a role to play in the future of mankind.

To the average farmer, successful pest control may often represent the margin between ruin and prosperity and therefore suitable methods whereby insect damage may be held within economic bounds have become a necessity in the world today with its demand for increased food production. The problem of pest control may be approached in a number of ways of which the most important are cultural practices, the application of insecticides and biological control methods.

Cultural Practices

There are certain cultural practices which can aid the farmer in the fight against insect pests. Some of these are primarily designed for other purposes but also have significance in reducing pests. For example, plowing may destroy the habitat of the soil insect and thus expose it to desiccation by the action of sunlight and it may also expose it to predation by natural enemies. Also crop rotation which is primarily designed for the conservation of soil fertility is an important potential factor in the reduction of pests by withholding the necessary host plant and so starving the pest out. There are other farm operations the sole aim of which is to discourage the build-up of pests. Among them are alterations (a) in the date of sowing or planting out either to avoid periods of high pest incidence or to ensure that plants are well advanced in growth when they are not so vulnerable to pest attack, (b) farm and orchard sanitation in which thrash and prunnings which harbour pests are destroyed by fire.

All these are empirical cultural strategies for dealing with insect pests of crops. Much research is still called for in dealing with specific crop situation. The information available through past research shows clearly that it is not often wise to transfer the technology of control derived from the research results of one crop to the other. As Nickel (1973) rightly points out "In reviewing the pest situation in changing agricultural systems, we are not contrasting disturbed versus undisturbed ecosystems". For it is as a result of investigating various possible types of artificial ecosystems with particular reference to a given crop that applied entomologists can hope to find a workable solution to the problem of cultural control of an insect pest. For him, the choice of what method to adopt is not an easy one for two reasons, namely: (1) the aims of modern agriculture tend to produce conflicting results and consequently, (2) as we have noted earlier, it is not often the case that we can transfer the solution for one pest problem on a given crop to another. To substantiate these statements, I want to illustrate by a few examples. In a highly technical agriculture, monoculture has some inherent advantages such as ease of mechanization of planting, cultivation, harvesting and efficiency of pest control as well as economy of scale of production and marketing. Nevertheless, monoculture has the disadvantage of being highly attractive to insect and disease outbreaks especially where monophagous insect pest species are involved. The natural enemies of such insect species may not be equally favoured to be able to bring about a natural control. For as Hargen et al (1971) pointed out, entomophagous insects (i.e. insects that feed on other insects) are often discriminated against in a monoculture environment where no alternative host or prey exists on which to survive. So, instead of adopting a monoculture system it may be more advantageous in some instances to introduce some elements of diversity into the cropping system in order to reduce the damages brought about by insects. Way (1963) for example, showed that the biological control of coconut pest (*Pseudotheraptus wayi*) in Zanzibar was enhanced by interplanting other species of trees between coconuts to provide better resting conditions and alternative sources of food for the predatory ant, *Oecophylla* species. Many other examples abound in the literature and this is a useful concept in agronomic practice to reduce pest ravages. But there are also examples of cases where monoculture appears to have advantages over mixed culture in terms of pest control work especially when plantings of alternative hosts near a particular crop can worsen the pest situation, particularly if the larvae of the insect feed on one crop and the adults feed on the other. Such instances are cases of spatial proximity that confer deleterious effects by increasing the infestation rate. It is also possible, as we adopt more and more irrigation agriculture, to envisage a new dimension of pest problem inherent in temporal continuity of crop plants. In Nigeria, as in most tropical regions of the world for that matter, temperature and sunlight conditions are favourable for agricultural production all the year round provided that there is availability of water. With an intensification of agriculture and a rapidly growing population, Government has rightly embarked on the development of a number of river basin projects to supply water for planting crops during the dry season so that where only one crop per year is hitherto being grown, it will now be possible, when the projects are completed, to grow two or more crops per year. Unless there is enough care to ensure that the crops that follow each other from one planting to the next are not the same or do not belong to the same family group, great intensive insect problems can arise. Research results on short season crops like maize (Adeyemi et al 1966; Adenuga, 1977) confirm that the build-up of stem borers *Busseola fusca* and *Sessamia calamistis* (Fig. 23) in the late season planting is by far higher than in the early season planting. In Ghana Nye and Greenland (1960) demonstrated that when a second yam crop is grown in the same year, it is very often seriously damaged by yam beetles *Heteroligus meles* and *H. claudius*. The same type of prediction can be made for the accentuation of pest problem of kenaf, *Hibiscus cannabinus*, should we decide to grow two crops in Nigeria under irrigation facility, for as it has been already demonstrated (Adenuga. 1971) chrysomelid beetles *Podagrica* spp whose adults defoliate kenaf leaves and the larvae feed on the roots hibernate as adults in the soil during the dry season and will happily go through two generations per year instead of one if the plant food (kenaf) is planted under irrigation during the dry season.

The introduction of new technology in the farming practices has tended to produce conflicting results. For example, fertilization is a very common farm practice but there are many reports of changes in the severity of pest infestation as a result of fertilizer application. It is conceivable that changes in the quality of a plant as a food source or the attractiveness of the plant as oviposition site may be responsible for the increased pest attack observed. Fertilization of rice by nitrogen application was reported to have elicited increased stem borer attack *Chilo suppressalis* (Walker) and *Tryporyza incertulas* (Ishii and Hirano, 1958). Singh and Shekhawata (1964) also reported increase in the abundance of stem borer of maize as a result of nitrogen application. On the other hand some authors have reported that insect pest incidence is less as a result of fertilization. Haseman (1946) Broadbent et al (1952) and El-Tigani (1962) found that aphids which thrive well under low potassium supply were reduced by high potassium application to the plant. All these just illustrate the necessity for conducting research for each specific crop in order to strike a balance between good agronomic practices that can increase crop yield and at the same time offer optimum crop production measures against insect pest damage.

Application of Insecticides

By and large, insecticides have been a blessing to mankind in the war against insect pests. But for the malaria eradication programme brought about by the use of insecticides many more would have died of malaria in several parts of the world. Of all the effective control methods available to man against insects, insecticide is the oldest and most widely used one. Even before the advent of modern science, our farmers had traditional herbs which can be classified as organic insecticides and which are used in storing crops. The odour of such plant materials served as insect repellants. Some of these traditional crop protection measures persist till today.

Insecticides were at the height of glory as weapons of war against insects when in 1945 the discoverer of DDT won a nobel prize for this discovery. Little did people realize then that within fifteen years, it would be possible to lead a vicious campaign against its use

and to advocate its total ban. The crusade led by Rachael Carlson in her book "Silent Spring" was really the tip of the iceberg. Later, the later-day-ecologists joined the bandwagon, some advocating even total ban of all insecticides and organic fertilizers as well. The campaign gained momentum not merely only because of the desire to maintain a clean environment devoid of insecticidal residues in the food chain but also because of the non-specificity of a good number of these insecticides to non-target organisms in the environment thereby causing a disruption of the ecosystem by killing beneficial insects as well. The problem became compounded when a good number of these pests started developing resistance to the insecticides. The resistance problem, although, not the only one associated with the use of the insecticides, is perhaps the most serious. Resistance is developed not only among parasites of man but more or less universally among insects that are subjected to synthetic poisons regularly and over a long period.

Here in Nigeria, the cocoa mirids *Sahlbergella singularis* and *Distantiella theobroma* were found to be resistant to Lindane (BHC) and the cyclodane group of organo-chlorine insecticides in 1963 and 1964 respectively, (Gerard, 1967). In Iran, *Anopheles stephensi mysoensis,* the main vector of malaria was found to have developed resistance to DDT and Dieldrin (Eshgly and Janbakhish, 1976). Other classical examples are (i) the San Jose scale, a very devastating coccid in the USA which in a few years became resistant to hydro-cyanic acid, one of the strongest toxins and (ii) certain Sweedish houseflies in the town of Annas that have become resistant to DDT (Chauvin, 1967). When it is remembered that the financial input in the development of a single insecticide by the pesticide industry is in the order of 2 to 3.5 million naira and can occasionally rise above 15 million naira for both developing work and building the manufacturing plant, one can understand why the chemical industries are reluctant in developing new ones once an insecticide loses its effectiveness because of insect resistance to it.

An increasing attention is therefore being turned to alternative methods of control of insect pests. However, this does not mean that interest and research in the use of conventional chemical insecticides for pest control should not continue to allow the use of specific but safe and bio-degradable insecticides. Indeed as we expose more land to cultivation in this country in the clarion call to "Operation Feed the Nation" (OFN) and the "Accelerated Food Production" schemes, we will need to use insecticides even though judiciously more than ever before. Insecticides will continue to be an important tool in a successful co-existence with insects, in spite of their shortcomings. While recognising that they do not provide the whole answer, their tremendous advantages make them a very vital supplement to other methods and an immediate remedy before we have had time to study the merits of the other methods closely. This is even more so in the area of health control programmes. It is therefore necessary for Government to formulate policy on pesticide usage in order to protect our environment and ensure that this country does not become a dumping ground for pesticides. I shall return to this aspect later on.

Alternative Methods of Pest Control

(1) *Biological Methods:* At a professional meeting of the Entomological Society of Nigeria hosted at Ife here, I have had the occasion to survey the potentials of cultural and biological methods of pest control in Nigeria. What I have to say here is therefore a supplement rather than a repetition of my contribution on that occasion (Adenuga, 1974).

(a) *Use of Insect Predators and Parasites.* Rigid principles of pest management to which conflicting results cannot be found are rather rare. So the young Nigerian entomologist is bound to be confused about what strategies to adopt in his fight against agricultural insect pests. The redeeming feature, fortunately, is that certain patterns have emerged in the success so far achieved against these pests. It is now possible to generalize that the greater the stability of the environment of the target pest the greater the possibility of biological control using predator or parasite in the control of a given insect pest, (Simmonds and Bernett, 1977). (Figs. 24 & 25) There are a few exceptions to such generalizations, such as the success achieved in the biological control of olive scale, *Parolatoria oleae* (Huffaker & Kennett, 1966) and the aphid, *Therioaphis trifolii* on alfalfa (DeBach, 1974). Although biological control of insect pests is more appropriate for low value crops such as vegetables and plantation crops like citrus, etc., where the final product has to be blemish free and where the excessive use of insecticides is economically prohibitive, successes recorded so far have been more in the area of plantation crops like coconut, sugarcane, cocoa and coffee, where the ecosystem is fairly stable from year to year rather than in annual crops, which are completely turned over at the end of each year.

(b) *Use of Pheromones:* The recent large measure of success in the control of the pink bollworm (moth larvae) a pest of cotton by the discovery, synthesis and use of a compound named gossyplure, demonstrates the high level of effectiveness possible with biological control method. Gossyplure is a synthetic compound chemically identical with the female moth mating odour which she uses to attract the male. Harry Shorey of the University of California-Riverside, who pioneered the use of scents in pest control sprinkled gossyplure liberally over the cotton fields in the evenings. The male moth smelling the scent fluttered down to the to the cotton bolls where the smell originated, not knowing that the trail was false and artificial. They found no females waiting to be mated, but they have already tuned themselves to the premating floating or "dancing" rituals. By the time they gave up, they were already too exhausted to search for the real female moths who were located elsewhere in the field. The females who had had their sex life so interrupted after waiting in vain for the males for copulation laid infertile eggs and flew off to die. What Shorey has done was to mask the natural odour of the females in the field by putting the analogue, gossyplure liberally everywhere. The substance has been impressive in controlling the moths whose caterpillars cause up to 40 million dollars of damage annually in California and Arizona cotton fields. In field tests that led the US Environmental Protection Agency to approve the use of the compound in April this year, gossyplure was found to reduce cotton crop spoilage by 85 per cent.

This synthetic sexual lure is a pheromone and is just one example of the growing new technique of pest control which aims to curb unwanted species by disruption of its sexual life. A similar sex attractant is already in use in enticing male house flies to trap where they are killed with chemicals.

(c) *Use of Natural Diseases.* Another method of biological control is to expose the insect pest to natural diseases caused by saprophytic and aerobic bacteria and fungi and viruses. Sprays containing natural viruses lethal to gypsy moths which are pests of forest trees in north east of U.S.A. have been used to check this insect pest by a team led by Frank Lewis of US Forest Services.

Bacillus thuringiensis, a bacterium that causes diseases in more than thirty related species of caterpillars has also been used to control insect pests of crops like corn, beans and tomatoes.

(d) *Juvenile Hormones.* Juvenile hormones have joined the new 'biologicals' (as the chemical analogues are called) devised by man to combat insect pests. Applied at the appropriate stage in the insects' lives, the man-made analogues of natural insect hormones prevent their victims from reaching adulthood and reproducing. Last April, the U.S. Department of Agriculture awarded Egyptian Scientists a grant to test Juvenile hormones in controlling 50 species of insects. Among other targets of such research efforts are fire ants mosquitoes and house flies.

'Biologicals' have two major advantages over chemical pesticides. They are species specific, killing only the insects at which they are targeted. They do not endanger other beneficial bugs or higher forms of life. Secondly unlike insecticidal treatments they do not spawn 'super-bugs' that are genetically immune to their action. Nevertheless, they do not produce the ultimate answer. For one thing, they do not pack as effective a knock-out punch as chemical pesticides. They may take weeks rather than minutes to kill and are rarely able to cope with the very large plagues of pests. Moreover, they are more expensive than chemical pesticides and may not be economical for controlling pests of low-value crops. Pesticide Companies cannot earn as much from these narrow-ranging 'biologicals' as from broad spectrum insecticides.

Integrated Pest Management

It is, therefore, for these reasons that biologicals are not likely to be used in isolation. The current approach to the problems of insect pests is not to rely exclusively on one method but to adopt instead a multi-pronged attack called *Integrated Pest Management.* The idea is to control pests by applying a judicious combination of predatory or parasitic insects where applicable, insect resistant crop variety, insecticides and such cultural or farming systems with apropriate effectiveness.

Gossyplure, the example I have just cited for instance, could be the first line of protection of the cotton crop against the boll-worm. But if the bugs continue to multiply as a result of random matings, the farmers can then apply insecticides against them. That means that the farmers can now make fewer insecticidal applications than would have been the case without gossyplure.

It is this integrated pests and diseases management system that is the top research priority of the Department of Plant Science at Ife in embarking on three commodity crops, namely: cowpeas, tomatoes and yams. A multi-disciplinary approach involving plant breeders, pathologists, agronomists, nematologist and entomologists is brought to bear on our research efforts geared towards improving these commodity crops. Supported by finances from the University Research Committee we endeavour to improve the promising lines, to find out the optimum conditions for growing and protecting these crops from insects, nematodes and pathogens and harvesting the best yields from them. By the time Government launched its 'Operation Feed the Nation Programme,' the Department was ready and had the capacity to help Government in high quality seed production and multiplication for distribution to farmers. We in fact applied to Government and submitted a proposal through the National Committee of OFN but there was not even an acknowledgement.

Finally, I will like to submit that for our country to really achieve a green revolution and not be robbed of the increases in yields of our agricultural production by insect pests, Government must. as a matter of urgency, take the following measures:

(1) That Government should establish a museum of natural history. The first task of a scientist in crop protection is to know the identity of the pest he is dealing with. This work of identification is facilitated by having a Natural History Museum to which such materials can be referred for identification. Such a museum will be the depository of all the holotypes of our plant and animal fauna. At the moment, such materials are being sent abroad for identification and the foreign museums insist on keeping the type specimens after identification. This University has made a modest beginning in establishing a Museum of Natural History and I suggest that the Federal Government adopts this for expansion and development.

(2) Government should create a centre for Integrated Pest Management. This will facilitate and coordinate a planned scheme of introduction of beneficial insects (predators and parasites) of promise to control some of the insect pests of our crops. This is a form of pest control that is better done on a national basis in order to maximize the use of resources. It will also enable Nigeria to participate actively in an institutionalized way in the activities of the newly established Regional Centre for Biological Control of Insect Pests and Noxious Plants

located in Ghana.

(3) Government should enact laws to control and regulate the importation of pesticides to this country. At the moment any company can import and sell any pesticides in the country. Government should set up a similar body to the Food and Drug Administration of the United States whose functions are:

(i) to vet that a chemical to be imported into the country is not too hazardous for the use of the farmers;

(ii) ensure that the chemical is still potent at the time it is offered for sale and

(iii) determine the residue level that is tolerable and safe on the crop at the time of harvest. In other words, there should be a Pesticides-Use Policy, such as I had advocated at the Zaria Conference of Entomological Society of Nigeria (Adenuga, 1975).

(4) (a) It is of primary importance that Government and other central planning agencies and ministries of agriculture in the states appreciate that a post-harvest loss problem exists and be committed to deal with it.

(b) It is necessary to quantify the size of the loss of each foodstuff at the post-harvest stage and to consider the cost-effectiveness of procedures to reduce such loss.

(c) The next stage will be to train staff to implement any programme of action necessary in the reduction of such post-harvest loss. Such action should extend beyond the farm gate to the towns and cities. It is generally difficult to apply new technology of intervention of post-harvest loss to the primary producer who grows and stores most of his harvest for the subsistence of his own family. One successful way of attacking the problem is to form Marketing Boards for the major food crops, with special food conservation units or central storage facilities built in the main collecting stations. This sort of organisation apart from reducing losses will stabilize prices over the seasons and give the farmers incentives to produce more.

Although there are still gaps in our knowledge of how to reduce post-harvest losses, there is a considerable body of information available throughout the world and our main preoccupation should be to adapt and apply this knowledge to the situations of our country. This calls for applied research in trying out sets of alternative strategies with appropriate assessments of their cost-effectiveness relationship. The mistake that we must never repeat (we made it in the late fifties and sixties with the importation of huge aluminium silo bins for grain storage) is the transplanting of inappropriate "captive" technologies obtained on unfavourable terms which can have a negative effect on development. There should be proper rationalization of the market system so that foodstuffs are sold by weight rather than by volume. Mr Vice-Chancellor, Sir, Distinguished Ladies and Gentlemen, if I have succeeded in this short span of time in initiating or extending your appreciation on the role of insects in human welfare, particularly, in relation to agricultural activities, this lecture would largely have served its purpose.

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