https://doi.org/10.29321/MAJ.10.A04878

AGRICULTURAL METEOROLOGY IN ITS RELATION TO INSECT PESTS

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Introduction. In India, the study of Economic Entomology on scientific lines may be said to have been started from 1903 when the Department of Agriculture under the Central and Provincial Governments were re-organised. During the past three decades, the main work in connection with Entomology was confined to Agricultural Entomology and consisted in a sort of survey of the pests—major and minor, the comparative incidence of the different forms with the extent and nature of loss caused, studies on the important phases in the life histories and habits of some of the more important ones, some observations into the bionomics of some of their natural enemies and, finally, the adoption of such control measures as have become possible. In fact, in spite of our meagre knowledge of the ways of several of these insects, it was the last item on which greater attention had to be paid for obvious reasons. It is believed that, with some valuable data so far collected, the time has now come to enter upon another important phase of the work which might lead both the farmer and the Economic Entomologist to adopt prophylactic and direct methods of pest control which might supplement or even replace with advantage those which are now in vogue—; one such important line of work appears to be the investigations on the various relations existing between the insects on the one hand and weather and climatic conditions on the other, the two latter constituting what is popularly known as the science of Meteorology. That a knowledge of weather conditions is in certain cases very necessary and in other cases very helpful to the farmer in his agricultural operations is well known to most of our agriculturists; but it is doubtful whether the subject has received sufficient attention from an Entomological point of view, in this country. An attempt is made in this paper just to indicate the influence exerted by meteorological conditions on some of our well known insect pests, the possible ways in which useful studies may be made of weather conditions in relation to insects and the convenient lines on which such a knowledge could be utilised by the farmer with advantage not only to forecast insect out-breaks but also to adopt prophylactic measures.

The Importance of the Relation Between Insects and Climate. The value of a study of Agricultural Meteorology in relation to insects (Entomoclimatology) will be found very useful to farmers in all areas where there are major insect pests appearing year after year

nd causing serious damage to crops. Beyond the knowledge that one est or other appears every year in various degrees of intensity, the armer has hardly any definite ideas as to the why or wherefore of uch phenomena though, of course, he has his own explanations ex- ressed in such trite expressions as no rains, early rains, late rains, too nuch rains, no winds, unfavourable winds, etc. In practical experience, n most of the cases where pest outbreaks in large scale have been eported by ryots "we are constantly reminded—it is the weather" nd it is often felt that "at an earlier stage of attack" even the avail- ible means of control could have been applied with maximum effect. But it is the very question of locating the outbreak at its earliest stage that is the most perplexing problem before us, more so in the case of an ordinary ryot. At every outbreak, whether a crop is affected seriously or not the plant tissue which is eaten away by insects is never made good, though, in many cases, the insects that cause the damage are destroyed by human or natural agencies at a later stage. There is in fact very little benefit derived (especially in the case of mass out- breaks of insect pests which appear once or twice a year only or only once in so many years) by simply destroying the insects in turn for the damage they have done to the crop. For really effective control of plant pests, the first appearance of the pest on the crop should be studied in detail and all measures meant to destroy it or check its multiplication should be adopted during the earliest generation of the insect. This will minimise injury to the crop and is better than attem- pting such measures at a time when the existence of the pest is known only by the ravages it has wrought on the crop. A knowledge of the nature of response of the insect to its environment and climate has been missed, for want of exact data on the microclimates of the crops and the insects concerned, and hence the particular circum- stances under which an insect multiplies to become a pest, we are quite unaware of. The influence exercised by weather factors—chiefly temperature and humidity on the development and behaviour of insects—has been shown by several eminent scientists in the west, by means of elaborate tests and accurate data, but systematic work on insect ecology and the study of weather in relation to pest outbreaks, are only of recent origin. The results achieved so far, appear so encouraging that in the investigation of all modern entomological problems, the study of weather in relation to pest incidence has come to be considered as important as the work on the life history and bionomics of the insects concerned. In the Meteorological Conference in 1929, as well as in the latest International Locust Conference in 1934 in London, Uvarov, Gryse and many other entomological workers have laid special emphasis on taking microclimatic observations and studying the environment of insect pests.

Insects and Weather Conditions in South India. That weather and seasonal changes contribute a substantial share in shaping the

behaviour of various insects, has been frequently noted in the case of several of our insects and recorded in reports in connection with the numerous biological studies made so far. Mass sporadic outbreaks of the army worm on paddy (*Spodoptera*) every year in some localities or other, the sudden increase in the infestation of coconut palms by the caterpillar *Nephantis* or the sudden increase of the parasites on the latter during certain part of the year, the appearance of the paddy grasshopper (*Hieroglyphus*) in a virulent form during certain years in such distant places as Malabar in the south and Ganjam in the north, the rapid multiplication and the mass emergences of the Red hairy caterpillar (*Amsacta*) after the first rains in certain localities, the very high percentage of attack by paddy stem borer (*Schoenobius*) in certain rainfed areas as compared to other paddy growing centres, the equally surprising and phenomenal recent outbreak of the paddy borer beetle (*Rhizopertha*) in stored paddy in some of the southern districts during the years 1914- 15 and recently in 1934, are but a few of the well known instances which clearly give us some indication of the relationships existing between pest outbreak and weather. The relations of insects to rain and bright sunshine are also striking. Often swarms of butterflies and locusts migrate and this has perhaps some relation to the existing or approaching weather conditions.

Beyond these experiences and references in the reports, there has been no definite records on the subject up to the year 1921 when the senior author published his "Crop pest calendars for the Madras Presidency." * In these calendars which consisted of three in number, the first devoted mainly to the pests of paddy, the second to regular pests of important dry crops and the third to sporadic pests appearing irregularly during certain seasons; a rough idea is attempted to be given of the approximate seasons in the year when particular pests appear in the important agricultural tracts of the Madras Presidency. Such calendars, prepared as a result of continuous observations and with the help of the accumulated experience of the previous years, might help us to roughly forecast the appearance of pests in future; but it must be admitted that we are in need of a good deal of further information as to why some pests do not occur at the expected months, why sometimes the outbreaks are weak, and why sometimes there occur serious outbreaks in unexpected quarters. There are thus several lacunae to be filled up in our knowledge, before we can be in a position to utilise such knowledge to supply accurate and timely predictions of insect outbreaks.

Local studies – Influence of weather on insect life cycle and outbreaks: Within the past few years, some of the various influences by weather conditions, (especially temperature and humidity on insect development) have been worked out, to a certain extent, by various

* Published as, Pusa Bulletin and also as Madras Bulletin No. 80. 1921

scientists, and for many a type, the optimum conditions, under laboratory rearing, have been accurately observed. In a similar manner, some preliminary data have been collected with reference to a few South Indian forms. In connection with the breeding of parasities onthe black-headed coconut caterpillar *Nephantis serinopa* in Malabar, in the case three of the parasites, viz., a Bethylid—*Paraseirola* sp., a Eulophid—*Trichospilus pupivora* and a Braconid—*Microbracon serinopae*, the effect of weather factors has been noted in a very conspicuous manner, interfering with or accelerating the development and activity of the insect at every stage. In brief, the Bethylid finds a favourable condition during warm dry weather and the Eulophid requires a wet cold weather for normal breeding and activities. Under laboratory conditions of given temperature and humidity, the Bethylid was breeding most successfully when a temperature of 80—85° F and a relative humidity of 70—80% was obtained while the Eulophid was at its best at conditions of temperature 78 -82° F and relative humidity 92—94 Detailed observations on the latter are recorded in a paper by the junior author in 1934.* The third parasite *Microbracon* exhibited a totally different phenomenon, viz., yielding greater and greater percentage of males, finally producing no female specimens in the different broods, with the advance of the hot dry weather during three consecutive years 1928—31, though rearing was continued as during other parts of the year and though occasionally fresh specimens from the field were mixed to the lot in the laboratory. Given enough food and due care for rearing, the variations occurring in life periods of the different stages in life cycle, when continuously reared, are by themselves adequate proof of the influence of changing weather on the insect's life cycle. Also the same insect reared in distant localities of changed weather conditions shows such variations in the period of the life cycle, though reared at the same period. Such studies clearly indicate the time of appearance of the insects in nature or the best time for their introduction ; they also serve to interpret their behaviour in nature and to guage their usefulness or otherwise in pest control.

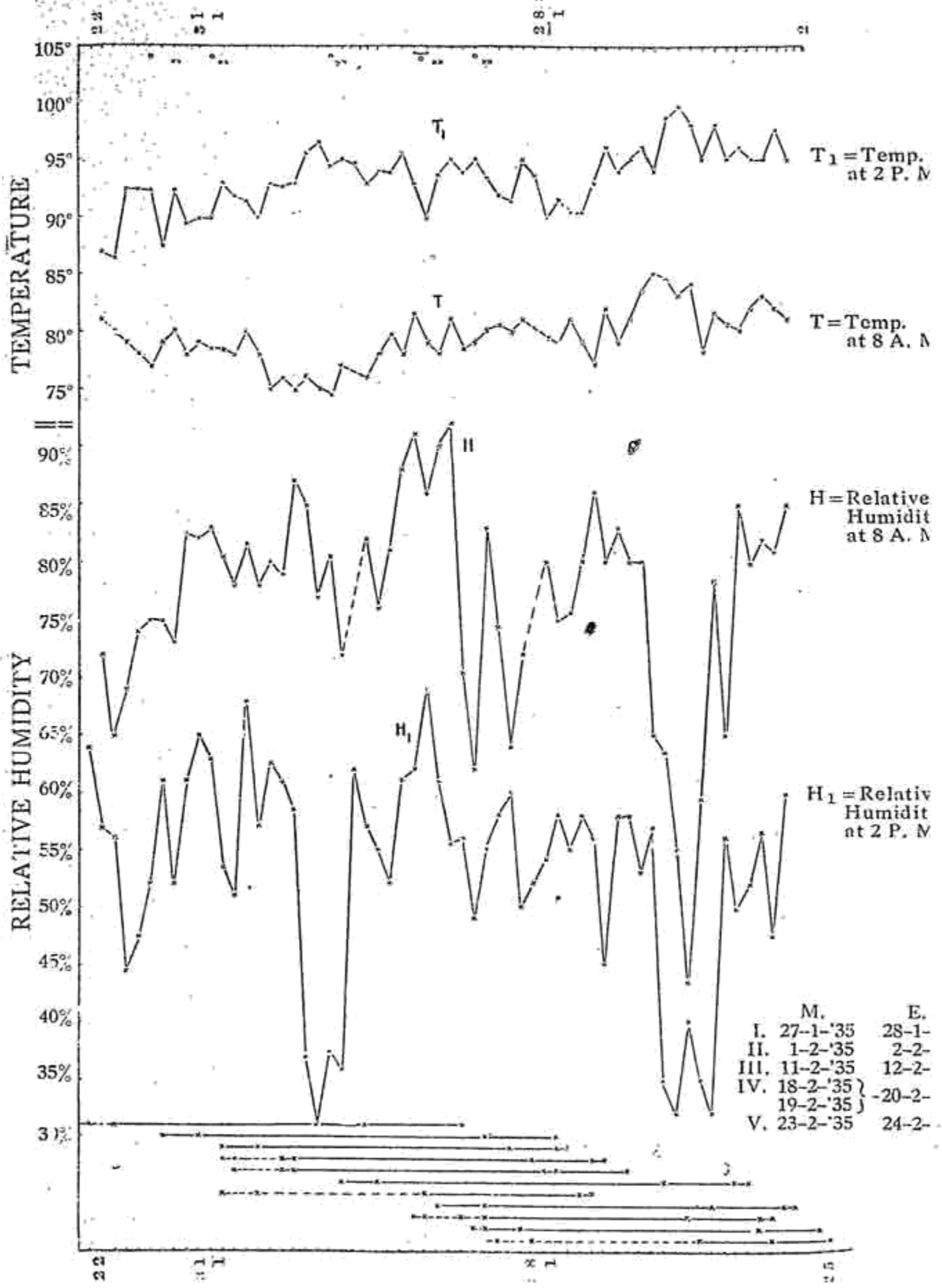
Similarly, in the course of more observations, on the incidence of two of the major pests of paddy, viz, *Spodoptera mauritia* and *Schoenobius incertellus* in the Presidency, during the different parts of the year, some interesting data have been collected, whereby it is being brought out that warning of an insect outbreak is given by preceding weather conditions. The seasonal changes, as well as the changes in the atmosphere induced by the condition of the soil and crop, all alike contribute to the weather affecting insect activity. It has been noted, the stem borer *Schoenobius* is first attracted to growing paddy when the latter is 10—25 days old after planting (2) the incidence

* Bulletin of Entomological Research. Vol. xxv, pt. 1. March 1934.

is greater during wet weather (3) the percentage or damage is greatest in districts of heaviest rainfall (4) the earliest sown crop before the onset of the regular monsoon rains escapes infestation (5) the short duration varieties grown broadcast in dry lands without much standing water, show the least damage (6) the moths are active in still dark cool nights in largest numbers during periods of emergence, and that (7) a variety planted during successive fortnights of summer months has escaped infestation though the presence of moths at the time has been indicated by light trap catches. Besides, the casualities amongst newly hatching larvae, and the extent of parasitism on eggs, are comparatively low when cool weather and continous drizzling prevail during the period when eggs are laid. Under such conditions, heaviest damage to young seedlings is brought about. When the weather conditions and the stage of the crop favour a heavy incidence, an attempt to trap the moths has proved very useful to minimise infestation.

In the case of the army worm *Spodoptera* on paddy, the outbreak is more common in broadcast paddy sown in puddle in ill-drained soils. The sudden appearance of the moths in large numbers from distant sources, is a case of specific attraction by the prevailing atmospheric conditions of humidity, temperature and winds mainly, immediately after sowing and during the simultaneous formation of a tender green crop in a large scale, over an uncultivated area. During the middle of April 1934, uniformly heavy down pour of rain for two or three days, after a prolonged drought flooded many of the low lying fields, all along the coastal tracts of Malabar. As sunny weather followed the water gradually dried up, and it is remarkable that during the moist warm weather, moths appeared and devastated a large share of the then broadcasted paddy crop, simultaneously in several places, all along the coastal tracts. During recent observations in the *Kole* areas in Malabar, it has been possible to note the first appearance of the moths during moist warm weather with cloudy and sultry nights and locate the possible centres of visitation. The daily weather changes obtaining in the locality with reference to temperature and humidity were recorded daily at minimum and maximum epochs using Lloyd's Hygrodeik from January 22nd to March 20th with notes on cloudiness of the sky, the nature of the winds and the number of rainy days, watching at the same time the appearance of the insect in the field and progress of the crop of successive sowings in 15—20 plots. The variation in temperature and humidity together with appearance and progress of infestation are plotted in graph attached. During the period 22--1—35 to 20—2—35, through which the sowing operations continued on successive days, providing stages of the crop of age ranging from 1-28 days, the moths and eggmasses could be observed in plenty, 5 times. It is seen that (1) there were successive arrivals of fresh moths in numbers 5 times during the sowing and early stages of paddy, (2) moths never selected a crop of

Records of weather, and incidence of the Army worm (Spodoptera) on Paddy—in the Kōle areas of Malabar 21—1—'35 to 22—3—'35.



over 20 days in age, (3) most active egglayings were observed on nights preceeding the mornings of temperature 78—82° F. and humidity 78—82% roughly; (4) life cycle was completed at a much quicker pace, and (5) when caterpillars were found later on, these could be traced to any one of the above batches, indicating that 'mothful' nights were particularly characterised by peculiar weather conditions with rise of humidity and temperature, gradual change in direction of winds and associated with cloudy sultry nights. In all these cases, the moths showed particular selective power to discriminate tender paddy aged 4—20 days, growing in miry wet ill-drained plots, leaving crop of the same age growing in dry and high level areas entirely free. By the end of February the days were getting hotter and drier, and the conditions changed, and no more fresh infestations were visible, though crops of suitable age were present in the locality till early in March. By more elaborate equipment to record all weather factors and also the micro-climate within the crop, in detail, it appears possible to gather more definite information on the above.

The latest reports of the appearance of the pest *Soorai* (*Ripersia oryzae*) on young paddy, in a damaging scale, probably for the first time in Malabar in such a severe form, all over a large tract, is possibly but another instance to show our gross ignorance of the ways of some pests in relation to weather, and the incapacity of the cultivator to take proper preventive measures in time. Recognising the above facts, in the case of many insect outbreaks, there is very little by way of direct control, especially in the case of borers, and mass out-breaks of sporadic insects, which remain active for a short interval. These are some of our examples to show the importance of the study of weather factors warning insect outbreaks, and their first appearance, and also of the study of the preventive measures, cannot be over-rated.

Important and Desirable Lines of Work in South India. In the opinion of the writers such data will be found very beneficial to determine the following important aspects of insect pests (1) the probable incidence of the outbreak and its distribution showing important pest centres, (2) the probability of the pests continuing in a particular locality in a virulent or mild form, (3) the necessity or otherwise of taking up feasible measures of minimising injury to the crop, in advance, and (4) the existence and the behaviour of parasites, if present, in the pest infested area.

The main idea in collecting meteorological and microclimatic data in connection with insect studies is to try to correlate, if possible, this data gathered for some periods with the vagaries and behaviour of some pests and then try to predict pest outbreaks and suggest prophylactic or other measures to check the ravages of the pest. It will be found that the results of such studies will be particularly helpful in the case of such insect pests which appear in plague form, cause terrible damage within short periods, and which are not generally

amenable to the ordinary rule of thumb measures like netting, bagging, spraying, etc. We have at least seven or eight such forms in South India and the best examples are the army worm, the red hairy caterpillar, the rice grasshopper, the paddy stem borer, the cholam earhead bug and the rice hispa. We will be well advised therefore if we start the investigation with special reference to these important insects. It is well known that some of these insects are considerably influenced by weather changes and many of our farmers are aware of the fact; but the real problems to be solved in this connection are what these relations actually are, and how a knowledge of such relations can be utilised in forecasting pest incidence and taking the necessary prophylactic measures when necessary. If we, succeed in getting at least some of these relations verified and are enabled to utilise these even to a small degree the farmer would be considerably helped in the control of some of his worst insect pests. These studies may not, of course, be so easy and bring immediate and tangible results, but from what we have seen of the results of such studies in Western countries especially in America, where such work has been done, it might be reasonable to expect that some encouraging results might be reached. Even if such studies are confined for the present to South India, the results of these investigations might help to a great extent workers in other parts of India who have similar or same insect pests to contend against.

Suggestions for work. The work on Agricultural Meteorology so far done in India appears to be mainly confined to the study of various general aspects of weather changes and the principles that govern changes, etc., without any ideas of the application of this knowledge towards insect behaviour and pest control, at least at present. So it is felt that our studies in these lines with the idea of utilising the knowledge gained by weather studies to insect behaviour might open up valuable avenues to the Economic Entomologist for help in pest control.

The writers feel that the plan of the work in these studies might follow the following chronological sequences: (a) select three or four of the major insect pests to be taken up for investigation in the first place. These might be (i) the paddy stem borer, (ii) the army worm of paddy, (iii) the paddy grasshopper, and (iv) the Red hairy caterpillar. (b) Record meteorological observations in selected localities where the pests occur regularly or sporadically in a mild or serious form. The observations chiefly consist of recording the daily weather conditions, as well as the insect incidence all through the year for sufficiently long period-say, for five years. Duplicate observations made on the same pest in different localities and observations according to standard method on more than one pest will be found very essential and helpful in the comparison of data with reference to the insect, time and place.

The different kinds of observations to be made consist of careful and accurate records of weather factors in 'the crop' and in 'the open' taken daily at maximum and minimum epoch periods. These include (i) air temperature, (ii) air humidity, (iii) precipitation. (iv) evaporative power of air, (v) soil temperature, (vi) air movements and (vii) soil moisture. The records of each fortnight may be summarised and maintained as unit for each season and locality. Regarding each insect pest under observation, the habits and intensity of population will have to be recorded noting at the same time the activity and influence of their parasites, if any, at the commencement and decline of the outbreak. In addition to the routine observations, Meteorological and Entomological, some fundamental research may have to be carried on at a central locality for confirmatory tests of field observations on the above insects in and out of season by rearing under controlled conditions. The methods for representing insect population during the different parts of the year at different stages of growth in a suitable form for comparison can be devised in the course of the work independently for each insect according to the nature and needs of insect concerned.

Much useful information can be gathered by work on the above lines and it is highly desirable that Agricultural Departments all over India start such work in the different provinces.

Conclusion. Though it may not be possible to control weather in a manner suitable to the needs of the farmer, the study of weather and its diverse effects on insect life in nature, is of the utmost importance to get a clear insight into the aetiology of insect outbreaks and to use all means of pest control and the proper time and to the maximum advantage. It may not be remote possibility even if some improvements in cultural practices are brought in, in the light of above knowledge, to check the multiplication of insects without impairing the progress of the crop. We may not perhaps be lucky in securing immediate results of a very substantial nature but there is no doubt that investigations on these suggested lines will certainly help us considerably in devising pest control methods.

Discussion.

The President remarked that the paper opened up a valuable avenue of research. He said that primary attention to the fundamental study of the normal life-history of the insect, later with the studies of its bionomics and lastly with its relation to meteorology, would make the problem easier of solution, than if a study of relationship between insect attack and weather is attempted straight away. Citing the instances of large swams of dragon fly in Ponnani and North Malabar, during certain seasons of the year and the outbreak of the *Nephantis* in South Canara in a mass form, he observed that, despite the control measures taken and the success attending them, we have to admit that our knowledge of partial migration in dragon flies and the normal life history of the *Nephantis*, was fundamentally not sufficient. In his opinion, this was just the subject, wherein the field worker with his observations on field could help with considerable advantage the specialist at the laboratory.