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Pest epidemics and role of meteorological services: an overview

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Insect and other pests cause considerable losses to agricultural production throughout the world. The insect population is influenced by climatic factors, in particular temperature, moisture and light and also by the competition for food both within and between species. The relationship between the pest and host is in a stage of dynamic equilibrium, an understanding of which calls for an intimate knowledge of both organisms. With this knowledge, control measures can be established. The success of expansion in agricultural production depends on the climatic and edaphic conditions being satisfactory to the crop and on pest being kept in check. For developing any pest management programme for a specific agro-ecosystem, information on abundance and distribution of pest in relation to weather parameters is basic requirement (Chaudhari *et.al.* 1999). Advance information on forthcoming weather condition would be useful in developing effective preventive methods against pest incidence. An epidemic results from a combination of many factrors interacting with each other, attaining a different level of importance in different locations, seasons and climatic zones. Thus weather and climate are very important in determining the precise epidemiology of an outbreak of either pest or disease. Recent Integrated Pest Management (IPM) and epidemiological studies suggest that the weather conditions play a critical role in pest outbreaks (WMO, 1988). Development in the study of wind movements in the frictional layers of the atmosphere and turbulent transfer processes has contributed an understanding of the long and short distance migration of various pests. The important role of weather in pest outbreaks has been realized as early as 1930 (Uvarov, 1931).

Pest-weather relationship

Climate affects the distribution and pest population in a given area directly through its influence on the rate of development, fecundity and longevity of the organism and indirectly through its influence on the availability of food. The main factors of climate are temperature, moisture, light, and wind and crop architecture.

Influence of temperature

All living organism including animals have a favourable temperature range within which they can live and multiply. Within the favoured temperature range, the organism will show a preferred temperature, the exact position of which is influenced to some extent by acclimatization. Many of the pest/

animal movements into shade or sunshine during the course of a day are determined by efforts to reach an environment having this preferred temperature.

The dispersal of insects is also influenced by temperature. Weevil (*Calandra oryzae*) tends to congregate near the surface of large bins of wheat because of the influence of temperature on the dispersal of the adults. Infested wheat heats up and as the temperature approaches 32 °C, the adult moves to cooler areas. Eventually, the only area cool enough to support the colony is the layer near the surface. Gunn *et al*. (1948) reported on the influence of temperature on the behaviour of migrating swarms of locust (*Schistocera gragaria*) in Kenya. These locusts commence their migratory flight when a certain temperature, the level of which is influenced by the temperature the previous day is reached.

Influence of moisture

Various mechanisms permit organism to keep the proportion of water in their bodies relatively constant. Despite these mechanisms, most of them move away from area of extreme wetness or dryness to areas of preferred humidity where the moisture range is satisfactory for normal growth and reproduction during the active periods of the life cycle. Where the seasonal distribution of temperature and moisture is one of extremes, specialized stages of the life cycle have developed which carry the organism through the period of adverse conditions. Thus, many insects in the temperate areas of the world have a diapause stage in which they can survive in conditions, which are too cool or too dry for normal development. Similarly, the nematodes, which favour saturated conditions, have in their life cycle a resting stage, which is able to survive prolonged periods of desiccation. In many cases, it is difficult to distinguish between the role of temperature and humidity in regulating the life of an organism.

Rainfall and irrigation influence both soil moisture and temperature and can therefore, influence survival rate of insects, particularly those that have part of their life cycle in the soil. Thus Symmons (1960) found a negative correlation between the intensity of red locust infestation and the rainfall in the catchment area of the Rukwa Valley of Tanzania 18 months earlier. Similarly, early flooding will adversely affect the survival rate of insects such as Diparopsis, which over-winter as diapauses pupae in the soil.

Influence of wind

Wind influences insect survival indirectly through its effect on rainfall and temperature but it may also exert a direct influence on dispersal, particularly of migratory insects. Rainey (1951) showed that migratory locust swarms tend to move downwind and that the greatest number of swarms is found in convergence zones between opposing wind streams. Cocheme (1966) demonstrated a similar situation in locusts in the Indo-Pak region.

Table 1: Relationship of pest-weather interaction of some important crops

Crop	Pest	Effective weather parameters	Source
Rice	Stem borer (*Tryporyza incertulas*)	Rainy season, Minimum Temp. 14-27 °C, Maximum Temp. 28-30 °C	Banerjee and Mukherjee (1962), Prakash Rao (1974)
	Gall midge (*Pachydiplosis oryzae*)	Air temp. 16 to 34 °C, Pre monsoon showers, High humidity	Prakash Rao *et.al.* (1971), Fernando 1962), Pathak (1968), Ghosh (1921), Gopalkrishnan *et.al.* (1954)
	Leaf hopper (*Nephotettix* sp.):	Light constant rainfall	Anon.(1974)
Sugarcane	Top borer *Scirpophaga novella*)	Relative humidity > 60%, Relatively low maximum temperature	Singh *et.al.* (1957 a,b), Kalra (1967)
	Leaf hopper (*Pyrilla perpusilla*	High humidity with low maximum temperature, Low rainfall, Break in monsoon, Rainfall of June	Singh and Kalra (1951), Singh *et. al.* (1957 c)
Mustard	Aphid *erysimi Lipaphis* Kalt	Maximum temperature (21.7 to 23.5 °C), Minimum temperature (7.2 to 9.4 °C), Relative humidity (55 to 69%)	Singh *et.al* (1989)
Brinjal	Jassid *Amrasca biguttula biguttula* Ishida	Vapour pressure	Ratanpara *et.al.* (1994)
Cabbage	Aphid *Lipaphis erysimi*	Air temperature (20 to 30 °C), Thermal time, Max. Temp., average temp. and temperature gradeint	Bakhetia and Sidhu (1983), Shekh *et.al* (1993), Chaudhari *et.al.* (2001)
Cotton	Whitefly (*Bemisia tabaci* Gann.)	Air temperature, Relative humidity, Bright hours of sunshine, Rainfall	Gupta *et.al.* (1998)
Okra	Shoot and fruit borer	Maximum temperature, Mean vapour pressure, Morning relative humidity	Zala *et.al.* (1999)

Sorghum	Shoot fly (*Atherigona soccata* Rondani	Lower maximum temperature, Afternoon RH	Venkatesh and Balikai (2002)
Tomato Pigeon pea Cotton	Heliothis *H. armigera*	Minimum temperature (10-14 °C), Soil temperature,	Vaishampayan and Veda (1980), Mehta (1993)

Influence of other factors

Illuminance, direction, photo period, wave length and degree of polarization of light influence the behaviour of the organism and provide the necessary stimuli: to those mechanisms which regulate the life cycle and keep it in step with the season. Thus the Drosophila mates only in light, while the adults of the Noctuidae are active at night. In certain insects, photoperiod and temperature regulate the onset and duration of diapauses (Callahan, 1965; Less, 1955). Most insects move towards the ultra-violet or blue-green light in preference to the yellow to infrared end of the spectrum (Weiss, 1943; Callahan, 1957). Bees are able to utilize the polarization of the light in locating and finding their way back to the same source of food (Von Frisch, 1950).

Influence of crop architecture

Architecture plays an important role in the micro-climate of vegetative stands as it excerts a considerable influence on where the exchange processes of heat, mass and momentum take place. As most exchange processes take place at leaf surfaces, the vertical variation of foliage density is the most important crop architecture influencing the profiles of temperature, wind and water vapour in the crop climate.

The foregoing discussion suggests that various weather parameters play a dominant and decisive role in peat epidemics and development. Some of the important weather parameters for pest incidence and development are presented in Table 1 in brief.

Role of meteorological services and pest outbreak

Efficient and wise use of crop protectants, use of IPM technology, food supply, alternate hosts, host resistance, carriers, phenological technique, biological indicators, bioclimatic analysis, physiological approach and biological control are being practiced now a days to control the pest population. In addition to these approaches, meteorology based approach is recent tool to combat against pest activities (Venkatraman and Krishnan, 1992). Some of the approaches are mentioned hereunder.

Weather based forecast of pest outbreak

The important role of weather in pest outbreak has been realized as early as 1930s. Very high pest epidemics (Sardar Singh, 1968) on introduction of new crops or crop varieties e.g. epidemics of grasshopper (*Oxya bidenta*) in early and mid-fifties in the Punjab state due to cultivation of Egyptian clover, cotton leaf roller (*Sylepta derogate*) in the Doab tracts of the Sutlej in Punjab in the mid-fifties on the introduction of American cotton, red hairy caterpillar in South India on the introduction of the groundnut crop. Planned investigational work to identify the weather conditions predisposing for pest outbreaks have been extremely limited.

A detail cataloging of the pest which is known to be weather sensitive in their proliferation and determination of the meteorological conditions conducive for their growth and speed can help in (i) locating the likely regions and periods of their occurrence, and (ii) initiation of control measures on the basis of weather warnings. Review by Messenger (1959) show the feasibility of anticipating potential occurrence of an epidemic from weather data.

Use of light traps in case of insect pests are resorted to by entomologists as a tool, for understanding the seasonal history of their incidence to relate the weather conditions leading to sudden spurts. However, by this time insect pests would have taken a firm foothold in the area. Therefore knowledge of antecedent weather conditions becomes necessary to resolve some of the apparently perplexing situations faced in research studies on the trapping of insects. De Villiers (1966) noticed that bait trap catches of the codling moth (*Cydia pomonella*) had non-significant effect to wind speed during some periods, while in some other periods the maximum occurred on days of calm or light winds. The former was noticed to be preceded by warm weather, which leads to a marked increase in the maturing eggs and the build up of the egg pressure. When this happened moths flew to deposit the eggs even on windy nights.

Assistance to chemical and biological control

Chemical and biological control of insect epidemics is also affected by weather in many operations. Prevailing weather condition at the time of or immediately after following a chemical application have decisive role on chemical effectiveness. Weather also determines the form in which crop protectant has to be used. Different types of meteorological conditions are required for ground base application of pesticide also has to take into account whether a pesticide will settle down over target area or will drift into nearby area and exert a harmful effect on healthy crop and animals.

If the chemical is to be used as a dust, the presence of a film of moisture on the leaves, due to dew or light precipitation helps in binding the dust against being blown off by the wind, while liquid sprays mixed with a spreader to ensure a low contact angle can be used on dry foliage. Dew or light drizzle is considered beneficial in getting uniform coverage of the foliage by the spray (Bourke *et.al.*, 1960). For most of the chemicals a period of at least 18 hours of rain-free period after an application is considered essential to ensure complete effectiveness.

A light, uniform and smooth air movement helps in maximum coverage and prevents the applied chemical from drifting too far away from the site of control operations. Chemicals should be applied in a direction perpendicular to the wind, commencing from the downwind side and moving towards the windward side.

If ground based operations are delayed due to sudden heavy rainfall, an aerial operation have to be used to nip in the time the build up of strong insect outbreak. An extensive monocrop area for aerial control assumes significance. In an aerial operation grounding of the particles on to the targeted crop area involves considerations of height and place of release. This drift of the applied material depends on the horizontal and vertical speed components of the wind.

The introduction of exotic parasites and predators are also a sound and safe tool to combat pest epidemics. Here, meteorological support for biological control agents are to be similar to those of exotic crops, which needs sound knowledge of seasonal climatology of the respective area or zone. The time of dispatch and introduction of the parasites/predators must be climatically determined to ensure low mortality during transport and rapid multiplication on release at a rate faster than that of pest. On the other hand, biological control of the boll weevil of cotton, reported by Pierce *et.al.* (1912), evinces a sound climatic approach to the problem.

Thus, the meteorological forecast of speed and direction of surface wind, turbulence, dew and convection are required, while low-level inversion, visibility, height of base, amount and types of clouds and air temperature at the point and time of control operations are required for aerial operations.

Pest surveillance approach

The information on early detection of an initiation of insect outbreak is very much helpful in determining whether a given or anticipated weather would lead to their outbreak in an epidemic form. Thus regular survey for detecting the early presence of insect should form part and parcel of a service for warning against biological setbacks. Here also, weather information can aid in issuing indicators to the survey teams regarding likely areas of appearance of the organisms. This knowledge helps in aiding control operations against them.

Empirical approach

Population build up of any pest, studied by pest surveys or recorded on crops under natural conditions have definite relations with weather factors. Here, single station studies in which emphasis on delineation of meteorological conditions in epidemic versus non-epidemic years or multi-station studies in which emphasis is on delineation of meteorological conditions leading to changes in periods or intensity may be used. The work on sugarcane shoot borer (*Chilotraea infucatellus*) in Uttar Pradesh and Rajasthan (Kalra and Sharma, 1963) and on sorghum shoot fly (*Atherigona* sp.) in Karanataka, Tamil Nadu, Delhi, Rajasthan and Maharashtra (Ponnaiya, 1951; Usman 1968; Subbiah and Mohamed Ibrahim 1968; Jotwani *et.al.* 1970; Kundu *et.al.* 1971; Raodeo and Muquum, 1971) belong to the latter category.

The empirical approach used in conjunction with the fundamental method is of great value for the long-term planning of control operations in that it enables the use of the storehouse of climatic data for locating seasons and regions of occurrence of peat. This approach is also of value in delineating the aerial distribution and limitation of severe biological setbacks. For example, in South Africa, the harvester termite (*Hodotermes mossambicus*) has been shown (Nel, 1965) to be confined to areas where the rainfall regime is unable to meet the potential evapotranspiration demands. In Australia, the Lucerne flea (*Smynthurus viridis*) is limited to areas with more than 375 mm of rain per year. The precipitation to evapotranspiration ratio has been reported by DeVillers (1966) to be a factor useful for identifying outbreak centres of the locust (*Chotocetus terminifera*) in Southern Australia. The findings arising from empirical field studies sometimes give misleading results in climatologically analogous areas, so, care should be taken in delineating areas (Venkatraman and Krishnan, 1992).

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