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[Review]

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Sampling, Surveillance and Forecasting of Insect Population for Integrated Pest Management in Sericulture

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Pest monitoring through field surveys and surveillance helps in forecasting the population build up of pest. It reduces the load of pesticides application and forms the basis of Integrated Pest Management in sericulture. Common sampling techniques for quantifying pest populations and damage caused by them are reviewed emphasizing the need for quick and simple sampling methods. Various direct and indirect sampling methods for establishing pest populations are discussed and methods have been discussed to use indirect sampling method under IPM programme in sericulture. The use of pheromone lures and traps forms one of the important ingredients of integrated pest management, which calls for integration of all available methods in a cost effective and environmental friendly manner offering consistent efficacy. Silkworms feed on the variety of silk host plants and spin cocoons. Each silk host plant is attacked in the field by number of insect pest species. Several pests are common to mulberry, tasar, oak tasar, muga and eri host plant but pest status and seasonal abundance differs from each crop. The key pests are serious perennially occurring persistent species which cause considerable yield loss every year on large areas and require control measure. Regular occurrence of minor pest is noticed but sudden increase in its population is not known. The occasional pests are sporadic but potential causing sufficient damage. Silk losses due to attack of all the pests have not been calculated. However, information on pest biology and ecology, and control practices being practiced is available but the period of outbreak of major pests and predators on silkworms and its host plant needs to be reinvestigated. Pest and predators forecasting based on surveillance information may provide an opportunity to minimize the losses, particularly to reduce expenditure involved in pest management.

Key words: Sampling, Surveillance, Forecasting, Trap, Pest population

Introduction

Intensive sericulture has been in practice involving huge capital investment. The modern sericulture technology not only paid rich dividends by increasing silk production but also drastically disturbed natural seri-ecosystem. The pest population of silkworm and its host plants has increased and frequently there is out break of new pest. It causes extensive damage to silk host plants, which resulted in the deterioration of quality and quantity of leaves of silk host plants and ultimately fluctuation in cocoon production (Singh and Thangavelu, 1994). In this context, pest and predator forecasting may provide an opportunity to minimize the losses, particularly to reduce expenditure involved in pest management. Among the various strategies of Integrated Pest Management, Pest sampling, surveillance and forecasting is most important to know accurate information about the distribution, population density and dynamics of pest population in the target field. Pest forecasting is useful in making tactical pest management decisions such as what control measure is to be taken up and when (Knipling, 1973; Norton, 1980). Pest monitoring through field surveys and surveillance helps in tackling build up of any pest/ disease and employment of pheromone traps and lures ensured minimum and need based application of pesticides instead of prophylactic and calendar based pesticide spray schedule thus reducing the load of pesticides formed the basis of IPM. IPM also

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called for integration and utilization of biological methods for control using biocontrol agents such as parasites, predators, pathogens and eco-friendly neem based products (Singh and Saratchandra, 2002).

The principle aim of pest forecasting is to ensure that control measures, notably the use of chemical pesticides, are adopted only when needed to prevent economic damage and at the correct time for maximum effectiveness. This would help to ensure that chemicals are used to supplement "natural controls" as well as minimizing the problems created by overuse and misuse of pesticides. Forecasting is therefore fundamental to many Integrated Pest Management programmes. The major components involved in developing and implementing forecasting schemes are defining the economic threshold for pest attack, developing relevant monitoring and forecasting procedures and providing a means for implementing the forecasting programme within the crop production system. The first consideration is to assess whether a practical forecast is feasible, given the nature of the particular pest problem. Silkworms and its host plants are attacked by large number of predators and pests (Singh *et al.*, 2000).

Insect succession

Thirty insects of different groups appeared in succession at different stages of plant growth. Incidence of all insect associated with primary tasar food plants is presented in Table 1. The survey reveals that the maximum number of insect population was from order lepidoptera, coleoptera, hemiptera, orthoptera, dictyoptera, and archnida. Its population however, fluctuated widely during the pre monsoon season with a lesser variation during post monsoon season period each year. There was an appreciable decrease in the population during summer from May - June. The peak period of seasonal abundance of coleopteran and hemipteran insect was observed during July - August and the lepidopteron insect were most abundant in the month of April - May. Different insects appear in succession at different stages of plant growth. Lepidopteran population varied from 9.40 to 41.8% whereas coleopteran population varied from 10.13 to 80.39% (Table 1). Among lepidoptera Bihar hairy caterpillar and vapourer tussock moth were predominant whereas under coleoptera group scarabeid beetles, weevils and stem borers were predominant during July August. Hemipteran population varied from 10.44 to 64.04%. The most important among them are gall-forming insects. The population build up of this pest is very intimately associated with weather conditions prevailing during the preceding and corresponding periods. The life cycle of this gall insect consists of an egg stage followed by a five nymphal stages. Generally, it increases from June onwards and reaches its peak during July - August. At the end of rainy season, psyllid population gradually declines and from November to February it decreases steadily. Such fluctuation in the population is due to the change in a biotic factors (Singh and Thangavelu, 1994). The climatic condition of June, July and August proved conducive for the growth and development of the nymphal population on the leaves of tasar food plants. The most active period of the gall population coincides with the rainy season (Das *et al.*, 1988).

Singh *et al.* (1992) reported the incidence of coleopteran stem borer on primary tasar food plants. Some cerambycid borers have seriously affected sal plantation where as arjun and asan plantation the buprestid borers have damaged. It has been considered as an important factor limiting the growth of the tasar food plant (Singh and Kumar, 1990). The damage is caused mostly by the grubs

Table 1. Seasonal incidence of insect population on primary tasar food plants

Months	Lepidoptera	Coleoptera	Orthoptera	Hemiptera	Dictyoptera	Archnida
March	20.14	39.45	3.26	15.17	2.12	20.28
April	39.45	15.27	2.68	20.43	21.08	23.18
May	41.8	22.81	3.84	38.7	18.53	27.24
June	23.41	33.41	4.2	45.6	16.34	20.0
July	19.4	80.39	5.97	62.43	9.5	4.73
August	18.65	68.52	7.28	64.04	5.2	5.75
September	17.47	51.07	9.12	32.34	7.37	13.6
October	24.52	31.58	10.15	27.45	9.15	18.24
November	36.03	10.81	4.1	17.79	7.65	22.52
December	33.62	10.13	2.2	28.83	4.55	20.85
January	33.33	20.78	3.5	15.24	4.38	20.78
February	19.08	38.71	2.34	10.44	2.79	22.61

of stem borer. The pest in its larval stage feeds on the bark and burrows into the stems causing dead hearts and ultimately loss of the plants (Mandal *et al.,* 1989). The round headed stem borer, *Aeolesthes holosericea* is wide spread through out the tropical and temperate tasar region of India, causing considerable damage to *Terminalia* and *Quercus* sps. The flat headed stem borer, *Psiloptera fastuosa, Sphenoptera koenbierencis* are key pest of *Terminalia arjuna* and *T. tomentosa* in the tropical tasar region, causing as high as 40 per cent losses at some places (Dhar *et al.,* 1989). Both the grubs and adults are injurious to primary tasar food plants especially, *T. arjuna, T. tomentosa* and *S. robusta*. Grubs are more destructive than the adults. The presence is indicated by the accumulation of granular frass and discolouration *i.e.,* "wet spot" caused by the sap leakage that occurs around the attack site. Singh and Thangavelu (1994) reported the occurrence of various weevils on *Terminalia arjuna* and *T. tomentosa*. The most prominent among them are *Myllocerus undecimpustulatus maculosus, Myllocerus viridanus. M. transmarinus Hbst, M. discolor, M. subfasciatus, Crinorrhinus nobulosus, Atmelonychus peregrinus,* and *Apoderus tranquebaricus* Fab, *Xanthochelus faunus* Oliv. May - June beetle *Anomala blanchardi Blanchardi* (Coleoptera : Scarabaeidae) is another important beetle defoliating large number of plant in summer. The damage is most severe on the marginal trees of the plots. The damaged leaves present a characteristic sieve-like appearance due to shoot holes.

Singh *et al.* (1996) recorded the incidence of lepidopterous pests on primary tasar food plants. Among defoliators *Euproctis fraternal, E. lunata, E. lutifacia, Dasychira horsefield, Notolophus antiqua* and *Orygia antiqua* are more prominent. Primary tasar food plants are attacked by large number of defoliators during July to September (Singh *et al.,* 2000). Feeding injury to the leaves by defoliators disrupt the production, utilization, regulation of growth and survival. When the defoliation is severe and continuous, death of whole plant occurs where as less frequent defoliation causes reduced growth and branch drying (Mishra *et al.,* 1995). Singh and Thangavelu (1993) reported *Notolophus antiqua* as an important defoliator of leaves of *T. arjuna* and *T. tomentosa*. It is a sporadic pest and frequently occurs in such numbers that it seriously injuries the foliage of the plant. Some times the damage is so serious that the plant may be completely defoliated by the caterpillars.

Bagworm *Acanthopsyche bipar* is a very common species in tropical tasar region of India. Besides this rusty tussock moth *Orygia antiqua,* white marked tussock moth, *Hemerocampa leucostigma,* looper caterpillar and leaf roller caterpillar are important defoliators. Among hymenopteran defoliators sawflies and ants are very common. Saw files the female warps has a saw toothed ovipositor. This structure is used for cutting slits in plant tissues in which eggs are placed. Besides this, termites are also reported as serious pests of tasar food plants (Singh *et al.,* 1992). *Odontotermes obesus, Neotermes bosei, Microcerotermes beesoni, Heterotermes indecola, H. malbaricus, Coptotermes heimi,* and *Nasutitermes dunensis* have been reported to cause severe damage to horticultural, sericultural and forestry crops. Although termites are better known taxonomically than most other groups of insect in the country, there are many gaps in our knowledge on the ecology in relation to resource management.

The present methodology adopted for the survey and surveillance, developed in early 1980s, need to be modified. The crops, biodiversity of pests, natural enemies, pollinators, etc., changes in land use pattern, the agronomic practices adopted and changes in weather factors have to be monitored under the proposed improved surveillance programme as part of seri ecosystem analysis. Computer-aided pest forewarning systems should be developed (Aisagbonhi, 1989). Various types of surveys are conducted under the surveillance programme. The most common among them are qualitative and quantitative survey. Generally in sericulture, qualitative surveys precede quantitative ones, which are commonly employed in insect pest management. Such surveys aim at establishing numerical abundance of an insect pest population in space and time for prediction of future population trends and for damage assessments. In quantitative surveys, counting of insects or damage caused by them is carried out by estimating their population density using sampling techniques. A sampling technique is a method used to collect information of a single sample, where as sampling program is the procedure for employing sampling techniques in space and time. Sampling of pest population has been used for a variety of purposes. It is therefore, essential to have a clear perception of the objectives of a sampling programme, which include pest related crop damage assessment, determination of efficiency of control methods, analysis of diversity and dynamics of pest eco system, study of biology and ecology of pest, construction of life table, optimization of sampling programme, defining economic injury level, developing pest forecasting, and IPM decision making.

Sampling technique for IPM

Integrated Pest Management calls for integrating all available tools in cost effective, environmentally friendly and sustainable manner. The philosophy and principle under lying the concept of IPM is to reduce mankind dependence on chemical pesticides by identifying, integrating and employing other methods which are cost effective, eco friendly and lasting in efficacy (Heong, 1981). There are many sampling techniques as there are pests (Andrewartha, 1961; Cochran, 1977; Ananthakrishnan, 1981; Ruesink and Kogan, 1982). Good account of sampling methods (Atwal and Bains, 1974; Kogan and Herzog, 1980; Mathew, 1984; Perry, 1989; Wilson, *et al.*, 1989; Kuno, 1991) and a few survey manuals are also available (Puntener, 1981). Sampling methods for individual pest species have been developed on gall insect, stem borer, aphids, leaf roller and various major defoliators etc. There is no universal method that is efficient for all categories on all the food plants of silkworms, which are growing under diverse ecological conditions. Sampling methods should be quick, simple, inexpensive, and measure the actual pest population or damage as accurately as possible. Sampling technique may be divided into direct counts on the plants or in the environment and indirect counts of some effects caused by pests, such as plant injury or damage. Both can be assessed as an index or on a rating scale for saving time, labour and cost.

Direct sampling methods

A direct count of insect population is the most widely applied method of sampling on silkworm host plants. Larger insects are easily counted in their habitat. There are several ways of direct counting methods but it is counted on standard unit, usually area of the ground (*e.g.*, number of leaf folder larvae per square meter). If counted on non-standard unit, *viz.*, plantation row, number of leaves, shoot, stem, internodes, the unit is converted to a square meter unit. However, various insects are counted on the part of the plants. Nymphal population of gall insect *Trioza fletcheri minor* on the leaves of *T. arjuna* and *T. tomentosa* are counted per unit of the leaf. Stem borer population on tasar silk host plants are counted by cutting the damaged plants. Sampling in the environment, is conducted to relate catches by sweep net, suction trap, light trap or pheromone trap to actual pest population densities on the ground of correcting for difference in the trap of differences in the surroundings.

Soil inhabiting insects are collected by digging the soil with soil core sampler to a standard depth collects soil-inhabiting insects. Pests are then separated from the soil by dry methods, such as the hot water jacketed Barlese's funnel or the Tullgren funnel heated by electric light bulb or oil heater; pests move to collecting tube at the bottom of the funnel (Chiarappa, 1974). In the wet extraction methods, as in the Salt- Hollick method, samples are soaked, shaken, with a detergent and insects are floated off in salt solutions, such as magnesium sulphate and separated by centrifugation (Cochran, 1977). Some insects may be driven off the soil by repellents such as formalin or with an insecticide. In case of termites, placing paper on the soil attracts the insects. When soil samples are taken along the length of row crop, pest densities are expressed on the basis of area.

Use of traps

Various types of trap have been devised for collecting and killing different types of insects. The cricket trap, the house-fly trap, electric traps, air suction trap and light traps are most common (Wood, 1984). Light traps sampling is used frequently for sampling insect pests in the silkworm-rearing field. Three different colours of light, *i.e.*, blue, yellow and red along with natural light has been tested to find out the degree of photo attraction of seven pests associated with non mulberry silkworm host plants. All the seven species showed high degree of attraction towards natural light and least for blue. Marked difference has also been observed in the behavior of predators and parasitoids for yellow and red coloured lights. Bhattacharya *et al.* (1995) reported similar observation of some insects associated with lac. Traps are normally set for a period of time and then catches are picked up. They are used continuously and the number of insects collected depends upon the density over a period of time. Traps can be either attractive or passive in mode of collection of insects. Attractive traps like visual traps and bait traps rely on a physical or chemical stimulus to lure insects into them. Passive traps like malaise, pitfall, sticky traps, water pan and suction traps on the other hand collect insect incidentally (Barakad and Burkholder, 1976; Singh *et al.*, 2000).

Light traps are the most convenient traps to collect the coleopteran and lepidopteron-defoliating insects in sericulture (Abenes, 1990). A light trap basically consists of a light source above a funnel and a container below to collect the catch, and is equipped with a protective roof. The light source is either electric bulb or a fluorescent tube. Generally short wave lengths of light spectrum attract noctuids, the so-called black light emitting ultraviolet lights are now widely used in most traps. Once inside the trap, insects may be collected for counting or killed in collecting container. Insecticides such as Dichlorvos (or Dichlorvos impregnated vinyl strips, *e.g.*, vapona) are sometimes placed in the container for killing the insects, thus reducing pest load. A commonly used light trap is the "Robinson trap". This trap uses a mercury discharge ultraviolet electric bulb. Rothamsted Light trap commonly known as Chinsurah light trap is used thorough out in India under Pest Surveillance Programme. The size of the insect catch is governed by three main factors, *viz.*, density of the adult population in the environment, the responsiveness of the insect towards the trap, and the efficiency of the light trap used (Weathershan, 1989). Another common method for collection of insect is the use of attractants in the rearing field. It is precise, specific and ecologically sound for pest management in sericulture. Mostly, these are the natural products but certain synthetic attractants are also known. Analogues of certain natural products have also been successfully synthesized. Attractants traps are used to catch the uzi fly, ichneumon fly, wasps, mantis and several other parasites and predators of silkworm. These traps are based on natural or synthetic chemicals, which stimulate insects to get attracted in the rearing field. Chemical attraction by crop plants or the chemical constituents of it, or by attractant chemical emitted by an insect is being used in the assessment of insect pests. Chemicals that attract several species are called kairomones and those that attract one species are called pheromones. Sugar and Propionitrile and Sinigrin are good attractants for uzi fly, *Exorista sorbillans* and *Blepharipa zebina*. Ethyl propionate and phenols are used for elterids and scarabaeid beetles.

Pheromone traps

Nowadays Pheromone traps are also used in assessing pest populations. These traps exploit the chemical olfactory stimulants (pheromones or chemical sex attractants) emitted by insects to attract the opposite sex (Borden, 1985). Such sex pheromones are often excreted by females (Gypsy moth to attract males) or in some insects emitted by the males (*e.g.*, ball worm) to attract females (Karlson and Butinandt, 1959). Pheromones are now available commercially for a wide range of lepidopterous pests, certain beetles and scale insects (Shorey *et al.*, 1967; Hallett *et al.*, 1999). In India, different types of traps have been evaluated and some of them have also been now commercialized by the industry. Pheromone lures dispensed in different types of dispensers placed in traps are used either for monitoring or mass trapping specific insect pests of a crop. Even though different kinds of traps have been designed, tried out and evaluated for over a period of three decades in India in different crops, dry traps including funnel type with sleeves have been widely accepted by the farming community on account of their efficiency and high capture capacity. Funnel trap is the best for obtaining maximum captures and this is further improved by fixing a baffle inside the design of the hood on the canopy of the trap. The slippery surface of the funnel further enhances the capture inside the polyethylene sleeves. Funnel traps are effective for trapping adults of *Helicoverp*a and *Spodoptera* spp. (Pawar *et al.*, 1988).

Insects have the tendencies to be attracted towards various colour. Therefore, in sericulture various colour traps are used to catch various pests. This is some sort of behaviour modifying strategy to monitor various insect pests existing in the silkworm rearing field especially in the area where non mulberry sericulture is practiced. Some small foliar pests are attracted to yellow. Yellow traps are effective in attracting various species of aphid, Jassids and bugs. The best colour shape and size of trap is determined through trials. Colour is sometime combined with water traps. A malaise trap consists of a netting tent with one open side. A small container with preservative is placed in the upper corner or highest point of the tent. The insect flies or crawl into the trap through the open side of the trap and move up the netting and are collected in the container. Since the insect enter the trap accidentally, these traps are effective for highly active insects such as adult flies and hymenopterans and are unsuitable for small insects such as aphids (Wall, 1989). Water traps are shallow, plastic or metal trays, 5 – 8 cm deep and 0.1 m^2 in area filled with water, detergent and an oil film. These traps are placed in or near the crop. Sometimes a particular colour, pheromone, or some other attractants incorporate. Water traps are more effective, if raised above ground level, but the height depends on species being sampled and the time of the experiment. The traps are must be protected from weather. The trap refilled regularly. The shape and size of the trap is standardized as per the requirement in the field area. Aphids, plant hoppers are easily trapped in such trap.

Sticky traps

Sticky traps made up of paper, plastic, metal sheet, etc. are commercially available where in insects are captured when they alight and come in contact with the glue on the sticky trap surfaces (Taneja and Jayaswal, 1983). Sticky traps are made by spreading a suitable adhesive or sticky substance (*e.g.*, tree banding grease or car grease) on an plastic card or paper sheet (David and Birch, 1989). The shade of sticky traps may be flat, cylindrical, triangular or spheres, depending on the habits and size of the insect species and the form of attractant. Cylindrical and spherical traps are efficient for passive collection, while triangular or flat structures are used for pheromone trapping. After the captured insects are killed, these traps become messy as often trapping surfaces get coated with unwanted debris. These traps have proved to be very effective in trapping many species of pests, especially aphids, hoppers, flies, hymenopterans, beetles and mites. Flypaper is the most commonly used sticky trap. Sticky red spheres have been used for estimating adult maggot population in the field. Cylindrical sticky traps have been used for trapping mustard aphids, plant hoppers, etc. in India. The protection of sticky traps from rain and dust is essential for their efficient functioning. Most of the time, it is combined with the attraction of colour or pheromones. Depending upon the sticky material used, the catch is washed off with kerosene or a suitable solvent and the insects are identified and counted.

Generally pitfall traps are used for pests on soil surface, such as ground beetles, collembolans and spiders. They consist of smooth sided containers such as glass or plastic jars sunk into groud with their top level on the ground surface. The catch pests fall accidentally into the trap. When baited, they attract individuals from considerable distances. They need protection from predators, which will otherwise devour the catch, and rain, which floods the traps. The use of sweep net is a common technique for sampling pest populations, especially for highly mobile insects such as plant bugs from mulberry gardens. It gives a good catch per unit time at a very low cost of equipment and labour without damaging the crops. Efficiency of a sweep net varies with species, height of plantation, weather (especially wind speed, air temperature and solar radiation), time of day, and style of sweeping. The mouth of the net must be closed down as sweeping is completed. The catch is expressed as average number of pests per sweep. Sweeping can give repeatable results if the diameter of the net opening and the number, extent and frequency of sweeps are constant. Hence, standardizing the sweep, particularly if more than one individual is doing the sweeping is desirable (Jacobson, 1972; Ruesink and Haynes, 1973). Sampling with sweeping net is conducted using a 40 cm diameter sweep net giving a pendulum swing, one stroke for a step while walking with a casual pace. Various crops require different sweeping techniques. For example, in mulberry the net is swept across the top of the plants about 20 cm deep. Sweeping is not suitable for pests normally found near the base of the plants.

Suction trap

Suction trapping is applied only at that place where attraction to light or chemicals is not useful. It is conducted at different levels above the plantation. It provides a format to know the quantity of the pests. Suction traps are of two types, fixed and portable. Flying insects are sampled with field type of suction traps. They usually consist of a metal sieve cone into which air is sucked by an electric fan. In some other suction pumps, cones are enclosed for protection, the air is drawn through, and the opening may be at different heights to sample different kinds of populations. A control mechanism is often used to segregate the catch into the time periods. Another popular method for insect trapping method is also known as graphic method. It is based on the principle that as removing individuals reduce the population from it, the catch per unit time decreases. The population size can be estimated from the rate at which the catch decreases. The rate at which trap catches falls off are be directly related to the size of the total population (unknown) and the number removed (known) (Huffaker, 1980). Direct sampling methods are influenced by many factors *viz.*, the number of insect present, the type and stage of silk host plants; the biology, feeding behaviour, sex ratio, abiotic factors, sampling time and lack of uniformity among individuals in their sampling techniques.

Indirect sampling methods

Population density of pest complex existing on silkworm and its host plants are assessed easily and quickly on the basis of the effects of damaged caused on the plants. It is called indirect sampling methods or population indices (Southwood, 1978). This kind of insect sampling is mostly used for indexing insect populations. The differences between incidence (the number of plants damaged) and intensity or severity (the degree or extent of damage) are generally worked out to measure the effects of insect pests attack. The incidence of pest is a discrete measure, whereas intensity is continuous and finite. Percentages with constant base of 100 are often used. There are a number of ways of measuring the effects of damage caused by the insects on the whole plants, stem, leaves and roots. The number or percentage of plants attacked, missing or showing signs of damage is recorded as an indication of the population of the pest. It is simple and quick method for stem borers of non-mulberry silkworm host plants, cutworms in mulberry, beetle larvae and other soil pests. Some times, the number or percentage of wilted plants or dead central shoots (dead hearts), for example, in mulberry plants, indicate the intensity of attack by lepidopterous stem borers, while shoot flies of defoliating beetles. The number of galls indicates the intensity of attack by gall midges; the number of exit holes or a length of tunnels has also been used. Leaves having holes, spots, mines, rolls, leaf scrapping or lesions etc. are measured for caterpillars, semiloopers, case worms, leaf folders, leaf miners, leaf beetles, bugs, orthoptrans, mites etc. The actual leaf area damaged can be measured by using a dot matrix grid, photography or by a planimeter, electronic scanning, area integration device such as "Lincar" or by comparison with the undamaged leaf using length × breath × constant "formula" (Andrewartha, 1961). Soil inhabiting insects were sampled by calculating the effects of root pests. The damage caused in the root system, in the percentage nodes below the soil surface having injury, percentage roots pruned below the soil surface and the length of root damaged. Damage to tuberous root is measured by counting lesions of areas of damage on the surface.

Relationship between direct and indirect methods

If an indirect method of pest management is used, its relation to a direct method such as pest density per unit area of the ground is examined so that quick and simple indirect assessments can be made to measure the actual populations of a pest. The relation between the percentage of stem borers attack and the borer population per square meter is established by counting the borer population on the plant (Kuno, 1991).

Measurement of population

There are many techniques that take advantage of some characteristic behavior of the target species to maximize the chances of collecting a representative sample of population. The most common techniques for sampling insect in the field crops are visual counts; sweep nets, suction trapping and ground cloth (Norton *et al.*, 1993). Generally, the population counts obtained by a relative sampling method is calibrated against result of absolute population counts (Rousink and Kogan, 1982). Absolute estimation of the population refers to the density per unit area in the habitat, *viz.,* and the number of individual per square meter. This method is very useful in insect population dynamics studies (*e.g.*, for constructing life tables, establishing oviposition, and mortality rates etc.), however, because of the difficulty in measuring it and the cost involved, it is not widely used in IPM programmes (Rausink and Kogan, 1980). In relative methods, the population is measured in unknown units, thus allowing comparison only in space and time. The methods employed are either the catch per unit effort or various forms of the trapping, for example, the number of brown planthopper (BPH) per sweep or insects per some fixed number of sweeps with a sweep net at a particular place and time. Relative methods have many advantages over the absolute methods, being less expensive, they require simple equipment, provide a lot of data, and are appropriate for IPM programmes.

In population sampling, the dispersion of insects in a population is as important as its variance and standard error. Dispersion is the pattern of spread of insects in an area. It gives information about population dynamics of the pest and may influence the way a population is to be sampled in an area (Taylor, 1984). Thus the knowledge of distribution pattern of an insect in a field is important in developing a sampling programme. The dispersion of individuals of a population is generally uniform, random or clumped. Most common ways insects are dispersed in a environment are "random" and "clumped" (Sutherst, 1991). In random "dispersion" an individual insect has as good a chance of being present in an area as in another, and individuals do not affect each other's presence in an area. Random dispersion of insects occurs most often in a relatively uniform environment. However, the most common type of insect population dispersion is "clumped" (contagious). Clumping dispersion in a population indicates that if one individual of the species is found, chances are good that there are others in the same vicinity (Shepard *et al.*, 1986). Clumping may be caused by either environmental (*e.g.,* uneven habitat) or behavioural (*e.g.*, mating and feeding) factors or both. Mathematical models can statistically describe random and clumped dispersions. The most common models used in entomology are the Poisson model to describe a random dispersion and the negative binomial model to describe a clumped dispersion or positive binomial model to describe uniform dispersion. It is essential to select a sample unit, and preliminary sampling is carried out to determine if the insect dispersion (distribution pattern) is poisson (random), negative binomial (clumped), positive binomial or other form of distribution (Waters, 1955; Ruesink and Kogan, 1980).

Insect sampling for IPM programmes is generally taken up at the stage of insect development that causes damage to the crop involved and the likely management strategy for that insect. This provides information on insect populations for taking up management measures to suppress it immediately. However, in some cases, a stage prior to the damaging stage is selected so that prediction of pest population can be made and this gives enough time to take up the management strategy. For example, stem borer eggs are counted to provide information on whether stem borer larvae infestation in mulberry plant is likely to be increased or declined in the next several days. Further, it may be important to know whether the eggs are white or dark in colour because dark eggs hatch in next few hours, where as white eggs will require two to three days to hatch. Similarly, sampling non-feeding adult stage helps in predicting subsequent likely damaging larval population. However, such predictions based on number of non-damaging stage of a pest are not always reliable because beneficial insects, climatic conditions, and other factors can suppress the development of an insect pest population, changing a potentially high infestation into a harmless one at the damaging stage.

Pest surveillance programme and forecasting

Pest surveillance programme play an important role in IPM because they help in pest forecasting and decision making to counteract pest infestation and avoid economic loss in crop yields. In fact, pest forewarning and forecasting are the outcomes of an effective surveillance programme. Pest forewarning is an early warning system based on surveillance information from immediate past. Pest forecasting, on the other hand, requires not only pest surveillance data form field over the years but also information concerning biotic and a biotic factors that affect host and pest interactions and ultimately damage the crop. Thus such surveillance programme has assisted in establishing seasonal abundance of pests rather than data required for pest forecasting programme. Pest surveillance and forecasting programme is conducted on a particular pest problem on a crop or on a major pests of a crop as a whole in an individual field or in a region (Pruthi, 1970). A regional programme is more useful where "infrequent wide spread outbreaks" of pests occur due to mobility of migrant pests and favorable weather conditions. Regional Sericultural Research Stations through coordination and cooperation from Regional Extension centers monitor pest population level and issue forewarning to farmers when an outbreak is expected. For pests that reach outbreak levels regularly during each season and for outbreak years of "infrequent pests", a field level surveillance programme is more useful.

Typically, a surveillance programme for pest forecasting consists of data collection, data processing and storage, and information delivery (Nordlund, 1981). Most developed countries have a well-established and effective pest surveillance and forecasting programmes for the last 50 years or more (Yoshimeki, 1978). Pest forecasting is useful in making tactical pest management decisions such as what control measure is to be taken up and when (Norton, 1980). For regulatory measures, forecasting information can be used as an early warning indicating when intensive monitoring should begin. Simple analysis of data is required for providing such information. The decision to make control recommendations has in the past been based, for example on the economic threshold levels. Efficient pest management information delivery systems are required for providing pest information to extension workers and farmers. In India, the data collection, processing and storage and information delivery system for pest surveillance programme have so far been carried out manually.

Pest surveillance in India

Pest surveillance programme in India are generally carried out by the government agencies, especially the Directorate of Plant Protection Quarantine and Storage (DPPQS), Ministry of Agriculture, Govt. of India through its 26 integrated pest management centers spread in 22 States/Union Territories of the country. A Pest Surveillance programme of DPPQS is to assist State Governments in pest surveillance on major crops. Various crop based Institutes and Directorates of the Indian Council of Agricultural Research (ICAR) also carry out pest surveillance programme. In sixties and seventies, DPPQS organized rapid roving surveys on various crop in collaboration of state departments for detecting green leafhopper population, as well as natural enemies of insect pests in some part of India for advising suitable control measures. Following the success of the programme the surveys were extended to different states. Similar programme have also been taken up for important pests and diseases of various economically important crops by various ICAR institutes in the country from time to time. Central Silk Board has started pest surveillance programme at its main Research institutes in collaboration with its extension units. Several advances have been made in the recent past on specific pest situations modeling, pest simulation modeling by studying its behaviour under controlled or experimental conditions, and pest model design system through non-linear development functions in the case of certain major pests in other crops across the globe. Similar studies for at least major pests of silk host plants like defoliators, leave sucking insect and gall insect, weevil and leaf caterpillars will be highly rewarding to mange their populations well below the economic threshold levels. Regular sampling is done for making IPM decisions by plant protection specialists and farmers.

Since IPM approach is knowledge and skill oriented programme, training of grass root level extension workers is the prerequisite for effective transmission of the message to the farming community. Pest monitoring through field surveys and surveillance helps in tackling build up of any pest/disease and employment of pheromone taps and lures ensured minimum and need base application of pesticides instead of prophylactic and calendar based pesticide spray schedule thus reducing the load of pesticides formed the basis of IPM. IPM also called for integration and utilization of biological methods of control using biocontrol agents such as parasites, predators, pathogens and ecofriendly neem based products (Upadhyay *et al*., 1998). The farmers involved in these activities are trained for identifying the harmful and beneficial insects, sampling of crop field and recording of the field data. The data sheets are designed to provide required information on pests, their natural enemies, growth stages, related factors of crop phonology, location, weather conditions etc. All this information are entered in the computer and based on proper programming the occurrence of pest population is forecasted and accordingly control measures are applied. It helps to increase the productivity of silk

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