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Integrated insect pest management of tropical forest insect pests: an eco-friendly approach

Forests in India contribute one of the principal natural resources even with mere coverage of 21.71% or 7,13,789 sq km (ISFR, 2021) of the total geographical area. Vegetation also varies from tropical evergreen in Andaman and Nicobar Islands to dry Alpine forests high up in the Himalayas. Insect pests, which form an integral part of the existing ecosystem, are also the major biological determinants influencing development and destruction of forest and its forest products from seeds in stands to timber in depots, besides medicinal plants as minor forest produce. Unlike agriculture, longer gestation period crops, make it difficult to make frequent assessments of the revenue losses caused by forest insect pests in a vast and diverse country like India. However, as per an estimate in 1950s, forestry insect pests cost Rs.53.70 million (10% of the total revenue, which was 537 million at that time).

The tropical forests are found between Tropic of Cancer (23.5°N latitude) and the Tropic of Capricorn (23.5°S latitude). They occupy 10% of the total land mass of the world above sea level. Tropical forest cover approximately is about 1,700 million hectares of geographical area (FAO, 1993), under the political barriers of more than 90 countries of North America, Central America, South America, Caribbean, Central Africa, East Africa, West Africa, Southeast Asia including India, under the tropical region (Redublo, 2016). Most of these are the biodiversity hotspots with similarly diverse entomofauna, as high as 30 million living species, which includes beneficial and insect pest fauna.

Insects have their essential roles in forest ecosystem processes, such as facilitating removal of weakened trees, decomposition of dead or decaying trees, nutrient cycling, biodiversity maintenance, and forest regeneration and succession. However, their population outbreak is a major biotic disturbance (FAO, 2007; Sambaraju *et al*., 2024). Insect pests infesting forest trees at various stages, viz., inflorescence, fruits, seeds on standing trees and storage (Kulkarni and Joshi, 1998), seedlings in forest nurseries (Thakur, 2000), plantations and natural forests (Kulkarni, 2014) in India have earlier been compiled. With global perspective, Wylie and Speight (2012) have compiled an excellent book describing a number of insect species.

The widespread concern about the negative impacts of pesticides in developing countries, besides feasibility of application of conventional methods in forests (Kulkarni, 2014), development of ecofriendly and biorational methods, their logical integration, coupled with education and training has become more relevant today. However, there are only a few limited examples of IPM as a programme, or the individual components are available in the world, as compared to the agricultural counterparts (Wylie and Speight, 2012), possibly due to various reasons like complexity in generating base-line field data, long gestation period crops and resulting longer life-cycles of the insect pests and feasibility of application, are the factors which govern successful adoption of Integrated insect pest management program.

Some of the examples of IPM measures abroad are management of Masson pine caterpillar, *Dendrolimus punctatus*, defoliating Pine plantations in Vietnam, management of insect pests of eucalyptus psyllids *Ctenarytaina spatulata* and *Glycaspis brimblecambei* in eucalypt plantation of Brazil, eucalyptus cerambycids longhorn beetles, *Phoracantha semipunctata* and *P. recurva*, in tropical, sub-tropical and even Mediterranean regions of the world (Paine *et al*., 2011) through IPM measures (Paine *et al*., 1995; Wylie and Speight, 2012), Sirex wood wasp (*Sirex noctilio*), affecting *Pinus radiata*, *P. taeda* and some other *Pinus species* in Australia.

Similarly, in India a few researches include management of defoliators *Clostera fulgurita* and *C. restitura* (Lepidoptera: Notodontidae) coupled with other stem and shoot borers and root feeders in nursery and Poplar, *Populus deltoides* stands in Uttar Pradesh, Himachal Pradesh, Punjab and Kashmir in India (Singh *et al*., 2004; Sangha, 2011), through pruning, encouraging predatory bugs in stands; neem oil spray after rains and monitor pest populations in alternative winter hosts like other poplars and *Salix* spp., encouraging predatory ladybird beetles to manage aphid, *Eriosoma* spp.; manipulation in weeding time of the nursery beds; dress soil with slow release of insecticidal formulations against white grubs, *Holotrichia* spp.; application of

insecticides in water or dust to soil or base of tree to manage termite, *Odontotermes* spp. and *Coptotermes* spp. (Wylie and Speight, 2012), IPM module for the management of white grub, *Holotricia rustica*, *H. mucida* and *Schizonycha ruficollis* in teak nursery in Maharashtra, India. The local populations of entomopathogenic nematodes (EPNs) were also experimented against white grub, defoliators and termites species in India (Kulkarni *et al*., 2008), including a new species, *Steinernema dharanaii* (Kulkarni *et al*., 2012).

Sal (*Shorea robusta*), which is one of the most important natural forest tree species after teak, occupies broadly over 10% of the total forest cover of the country and fruits/seeds are infested by insect pests on standing tree and seeds in storage. Out of the above, *Sitophilus* (*Calandra*) *rugicollis* Casey is the most important and a true storage pest (Khatua and Chakrabarti, 1990; Choubey *et al*., 2013a). IPM measures were experimented by Choubey *et al*. (2012) as direct fumigant effect of some botanicals or safer insecticides (Choubey *et al*., 2013b), and fumigants with persistent effect up to five weeks (Choubey et al., 2013c).

Sal heartwood borer (*Hoplocerambyx spinicornis*) (Coleoptera : Cerambycidae) is one of the most dreaded and tough-to-manage insect pest of tropical region, with an annual life cycle. The management options mainly concentrate on silvicultural options and baiting by natural tree logs through kairomonal attraction (Kulkarni et al., 2004) with other associated essential components, like monitoring and surveillance, periodical assessment of state of infestation, maintaining forest hygiene by removing dead and near to dead, baiting of beetles emerging from affected stands, training and demonstrations of these measures to the front-line executing forest staff in the affected areas, periodical re-assessment of status of incidence (Kulkarni *et al*., 2018; Kulkarni and Chander, 2022).

Teak (*Tectona grandis*), the most valued timber tree species in India and abroad is defoliated by successional or overlapping incidences of two oligophagous pests; teak defoliator, Hyblaea puera (consumes whole leaf leaving only mid rib) and teak skeletonizer (*Eutectona machaeralis*)(consumes only mesophyl tissues making leaf look like a skeleton). Although, the pests do not cause any mortality in nursery as well as plantations and natural forests, but reportedly affect 65% incremental growth in plantation in a cumulative period of five years (Nair *et al*., 1998) and 55% in forest nurseries in a year. Management options ranging from identifying resistant teak clones (Roychoudhury, 2001), chemicals to the classical biological control have been experimented against these defoliators. The efforts included isolation and field testing of Nuclear Polyhedrosis Virus (NPV) (Nair *et al*., 1998).

In central India, successful classical biological control of teak defoliator complex began with collection, identification of native population, *Trichogramma raoi* and led to the development of TFRI-TRICHOCARD. Demonstration trials with TFRI-TRICHOCARD introduction of T. raoi alone in teak plantations or forests @ 1.25 lakh wasps per hectare prevented 50% incidence of the defoliator complex (Sambaraju *et al*., 2024).

Besides many other biological control agents identified and evaluated in the recent past, Entomopathogenic Nematodes (EPNs) belonging to parallel families steinernematidae and photorhabditidae with their symbiotic bacteria (Xenorhabdus in Steinernematidae and Photorhabdus in Heterorhabditidae) offer promises in Integrated Insect Pest Management (IIPM) programmes. Their attributes like quick kill, wide host range, efficient mass-culturing techniques, exemption for registration, high virulence, presence of chemoreceptors and thus searching capabilities, amenability for *in vitro* production, safety for vertebrates, non-targets and plants, compatibility with many chemical pesticides and wider genetic diversity, etc., make them promising component of IPM (Kulkarni *et al*., 2008). However, the environmental factors, which are always a limiting factor with any other biological system, affect its exploitation.

Although a good pace of research on isolation from the agriculture ecosystem and their evaluations have been done, there have been less isolates from the forest floor and their evaluations against forestry insect pests in the country. In line with all the above, the EPNs, explored from the native forest floor, could become an important component of IPM programme against forest insect pests.

EPNs against forestry and plantation crops is in its infancy in India with only reports available on preliminary trials with Heterorhabditis and Steinernema against important insect pests of coconum, arecanut, palm and cachew from South India. Recently, work on the use of EPNs against white grubs and termites has been carried out using native strains of *Heterorhabditis indica* and *Steinernema carpocapsae*, and local populations/species of *Heterorhabditis* and *Steinernema* isolated from the local Central Indian forest floor. The local isolates have shown promising results against the teak defoliator and teak skeletonizer larvae in laboratory. Like the other known EPN species, their compatibility with the insecticides is also excellent making combination treatments possible (Paunikar *et al*., 2020 a-d).

The nematode based products are available in international market for the control of wide spectrum of insects. However, there is still a long way to go in the formulation technology of the EPNs. It is only recently that formulation methods like alginate gel, flowable gels, attapulgite clay chips, talk-based and water dispersible granules (WDG) were experimented with four different EPN species with shelf life

ranging from 1.0 to 12 months. WDG preparations proved the best. Till date, 17 registered products are available for 6 species of EPNs in countries like U.S.A., U.K. Switzerland, Germany and Canada. In India, talk-based product has been developed by Project Directorate of Biological Control and flowable-gel based product by Indian Agricultural Research Institute, New Delhi. However, a lot has to be done in this field for developing habitate-pest-specific products to be able to popularize this potential biological agent.

No matter how the IPM has been defined over the years, purpose is to judiciously and strategically combine all appropriate pest management tactics into a package to reduce the infestations and the economic losses to the tolerable levels (Wylie and Speight, 2012). In forestry, different strategies may work for forest nurseries, which are the agriculture-like ecosystem and thus management of soil insect pests along with others might be more pertinent. However, for plantations and natural forests, strategies might include self-multiplying biological control agents, in judicious combination with other IPM components. In any case, for more acceptability of the IPM strategy locality-specific, species-specific model guidelines in easy terms for direct applications by the users need to be evolved, which are meagre in forestry, unlike agricultural sector.

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