

Monitoring and Testing Different Doses of Disparlure for Indian Gypsy Moth, *Lymantria obfusca*, in a Temperate Region of India (Kashmir Valley)

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Pheromone traps with different doses of disparlure [(Z)-7,8-epoxy-2-methyloctadecane] were tested for a local strain of the Indian gypsy moth (*Lymantria obfusca*) at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (India). Disparlure at 500 µg dose proved to be effective in trapping gypsy moth populations. The first adults were caught on the third week of June in 2007–2009 with peak catches a week later. Catches in disparlure-baited traps at all dosage levels (0.5, 50 and 500 µg) were significantly higher as compared to control traps. The regression equation revealed strong (99%) correlation between moth catches and applied doses. The accumulated degree day model predicted 65.31 to 117.97 heat units for larval hatch and 794.66 to 928.15 heat units for adult emergence. The principal component analysis showed significant variability between weather variables and adult *L. obfusca* population.

Keywords: pheromone, dosage, *Lymantria obfusca*, monitoring, forecasting.

The Indian gypsy moth, *Lymantria obfusca* Walker (Lepidoptera: Lymantriidae), is an important pest of forest and fruit trees in Kashmir Valley in India (Beeson, 1941), and is prevalent in mountain and sub-mountain regions of the northwestern Himalayas and in the rest of the country. Caterpillars are voracious nocturnal foliage feeders, which, during the day, aggregate in large numbers on the ground under fallen leaves or on the lower parts of well-shaded branches. Tender leaves are preferred by the larvae. Adult males fly actively, while females are wingless. *Lymantria* spp. are polyphagous, damaging plantations of *Alnus nitida* Mill: *Betulaceae*; *Cydonia vulgaris* Mill: *Rosaceae*; *Juglans regia* L: *Juglandaceae*; *Populus* spp L: *Salicaceae*; *Pyrus malus* L: *Rosaceae*; *Quercus dilatata* L: *Fagaceae*; *Robinia pseudoacacia* L: *Fabaceae*; *Salix alba* L: *Salicaceae*; *S. babylonica* L: *Salicaceae*; and *S. fragilis* L: *Salicaceae* (Roonwal, 1953; Zutshi, 1967).

Pheromone-baited traps are effective tools in integrated pest management, because they are easy to operate, species-specific, and effective at low population densities (Munshi et al., 2008). They can be used, in combination with other methods, to provide estimates of population densities and to monitor populations for the implementation of envi-

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ronmentally sound management strategies (Sanders, 1988), with examples including insect pests of forest (Granett, 1974; Shepherd et al., 1985; Evenden, 2005) and agricultural ecosystems (Shelton and Wyman, 1979; Tingle and Mitchell, 1981; Ngollo et al., 2000). Also, disruption of chemical communication between the sexes can also be an option for control (Hussain et al., 2014)

Studies have been conducted on the use of disparlure [(Z)-7,8-epoxy-2-methyloctadecane], sex pheromone of *L. dispar* L., for monitoring population dynamics (Schwalbe and Mastro, 1988; Webb et al., 1988), but no such reports are available for *L. obfuscata*, which is considered to be one of the most destructive defoliators of hardwood trees in Kashmir. Furthermore, the degree day model for different developmental stages of *L. obfuscata* is still not available. This study was aimed: (i) to evaluate the optimal pheromone dose for trapping males; and (ii) to develop a degree day model to establish the heat units required from one developmental stage to another. Also, trap catch data of *L. obfuscata* from 2007–2009 were correlated with weather variables to create a platform for forecasting population trends of *L. obfuscata* in India and in Kashmir Valley.

Materials and Methods

Study area

Studies were carried out in newly established apple tree blocks of Red Delicious variety planted with pollinizers such as Golden Delicious, Gala mast and Red Gold, aged between 10–15 years, at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) Shalimar, Srinagar, India.

Field trials of different doses of disparlure

Disparlure and delta traps with sticky sheets to capture moths were supplied by Horticulture Research International, New Zealand, free of cost, as no company in India is manufacturing gypsy moth lures. Traps baited with 0.5, 50 and 500 μg amounts of disparlure on rubber septa, and those baited with hexane (control), were hung 1.5 meter above the ground on apple trees, with ten meters between treatments. Each treatment was repeated five times. Traps were installed on 10th of June each year and gypsy moth males caught were recorded on a weekly basis until the end of the flight season.

*Monitoring the population dynamics of *L. obfuscata**

Delta traps baited with 500 μg disparlure were used for monitoring the population dynamics of adult male *L. obfuscata* in an apple orchard block at SKUAST-K, Srinagar, India. Twenty delta traps were installed in a 20-year old apple orchard of Red Delicious variety during 2007–2009, and the population dynamics of *L. obfuscata* were studied throughout the whole season.

Seasonal activity of *L. obfuscata*

The life cycle of *L. obfuscata* was studied in the laboratory at the Division of Entomology, SKUAST-K, during 2008–2010. Fully grown caterpillars were collected from abandoned orchards, and were reared in wooden cages (30 × 30 × 30 cm) at room temperature. Fresh leaves of *Salix* spp. served as food for the larvae, and were provided daily. A 5 cm thick layer of dry soil was put at the bottom of the cages to aid pupation. Pupae were transferred daily into another cage for adult emergence. Newly emerged moths were released in pairs in wooden cages for egg-laying, and cotton swabs soaked in 10 per cent sucrose solution were provided as food to adults. The eggs laid by each female on the walls of the rearing cages were removed daily with the help of a moist camel hair brush.

Degree day model for *L. obfuscata*

A degree day model for *L. obfuscata* was developed during a two-year period for egg, larvae, pupae and adults. Degree-days (oD) is a measurement unit to determine the heat units necessary for development in order to forecast pest outbreaks (Arnold, 1960). Degree days (often referred as “growing degree days”) are accurate because insects have a predictable development pattern based on heat accumulation. The weather data used for the degree day modeling of *L. obfuscata* was taken from a mini-weather station at Shalimar Campus.

Degree days were calculated by the following method:

$$\text{oD} = [(T_{\text{max}} + T_{\text{min}}) / 2] - \text{TL}$$

Where: TL = Threshold Temperature (10 °C),

T_{max} = Maximum temperature for the particular day,

T_{min} = Minimum temperature for the particular day.

Data analysis

Trapping data at different doses of disparlure were statistically analyzed by the best power fit line using computer assisted Statistical Software SPSS (15.1), and by analysis of variance (ANOVA). Cumulative trapping data, maximum and minimum temperature and maximum and minimum relative humidity were evaluated by principal component analysis.

Results and Discussion

Field trials with different doses of disparlure

When testing different doses (0.5, 50 and 500 µg) of disparlure, lowest catches were recorded at 0.5 µg dose, and highest at 500 µg ($P=0.05$, ANOVA). Dose response curve (Fig. 1) was calculated by regression equation as $Y=10.41x-10.2$, with a regression coefficient ($R^2=0.9959$) of 99%, revealing strong correlation between applied doses

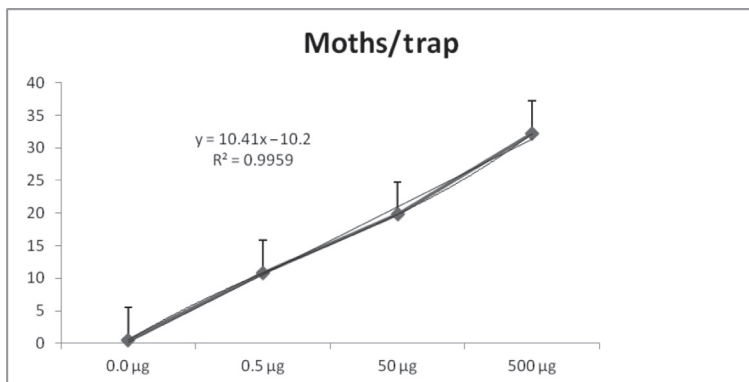


Fig.1. Linear regression trend line for male *L. obfuscata* at various dosage levels of disparlure in Kashmir Valley

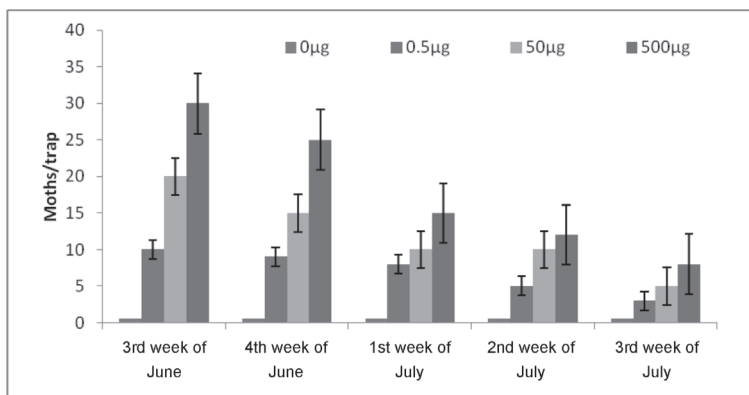


Fig. 2. Monitoring the population of adult male *L. obfuscata* at different dosage levels in Kashmir Valley

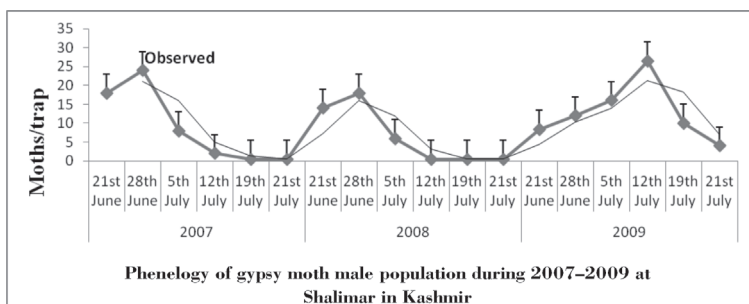


Fig 3. Monitoring the population of *L. obfuscata*, using 500 µg disparlure, from appearance to disappearance in Kashmir valley

and trap catches. Trapping at high population densities of *L. dispar* (Thorpe et al., 1999) showed decrease in moth capture with increasing doses of disparlure (Schwalbe and Mastro, 1988; Webb et al., 1988), but the results of the present investigation may suggest that the highest dosage is effective even at low population densities of *L. obfuscata*. Sex pheromone lures have been used to study the behavioral polymorphism of *L. dispar* (Berzoza et al., 1973; Punjabi et al., 1974), but no such studies have yet been undertaken for *L. obfuscata*. In general, trap catches are likely to vary depending on the parameters of the trap design, height of the lures and ratio of the components of the lure and environmental conditions (Thorpe et al., 1999).

Monitoring the population dynamics of *L. obfuscata*

Monitoring the population dynamics of *L. obfuscata* during 2007–2009, using 500 µg disparlure/trap, revealed first catches of *L. obfuscata* in the 3rd week of June, and peak catches from mid June to mid July, declining after the 2nd week of July (Fig. 2). *L. obfuscata* catches during 2007 and 2008 were highest between the 3rd and 4th weeks of June. However, in 2009, highest catches were recorded between the 1st and 2nd weeks of July, and catches were still recorded up until the 4th week of the month. During the years 2007–2009 as depicted in Fig. 3, highest catches were observed on the 4th week of June. Simple trend line of the three years data showed variability in trap catches (Fig. 3), which could be attributed to fluctuation of weather factors.

Disparlure-baited traps are therefore suggested to be utilized in monitoring and surveillance programs in the Kashmir valley against *L. obfuscata*. Trapping and phenology of *L. obfuscata* males could be exploited to determine the approximate timing of control strategies against this pest.

Seasonal activity of *L. obfuscata*

L. obfuscata overwinters in egg stage, followed by larval hatch from the last week of March until the end of the month. Newly hatched larvae are small and buff-coloured, but turn black within a few hours. The latter instars are hairy and blackish, with several light orange dots on the last half of the back. Total larval period lasts for 66 days (Table 1). The pupae are mahogany-coloured, and pupation lasts for about 4–12 days. Females are

Table 1

Seasonal activity and appearance of different phenological stages of *L. obfuscata* in Kashmir valley

Stages	Minimum days	Maximum days	Range	Mean ± S.E.	Period of activity
Egg	242	270	242–270	260 ± 0.04	Mid June to last week of March
Larval	50	66	50–60	57 ± 0.50	Last week of March to end of May
Pupal	4	12	4–12	9 ± 0.30	First week of June to mid June
Adult	3	30	3–30	26 ± 0.70	Mid June to mid July

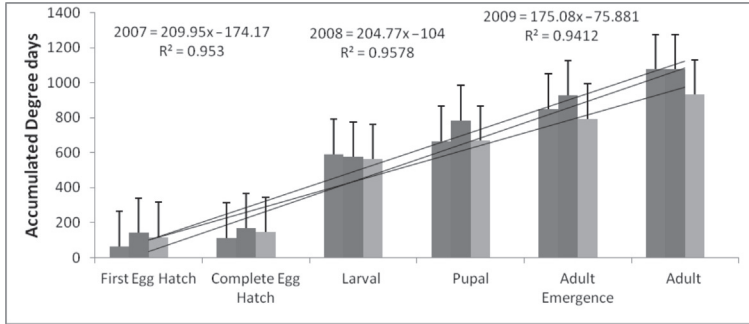


Fig 4. Degree day model for *L. obfusata* at different phenological stages accumulated at each stage during 2007–2009

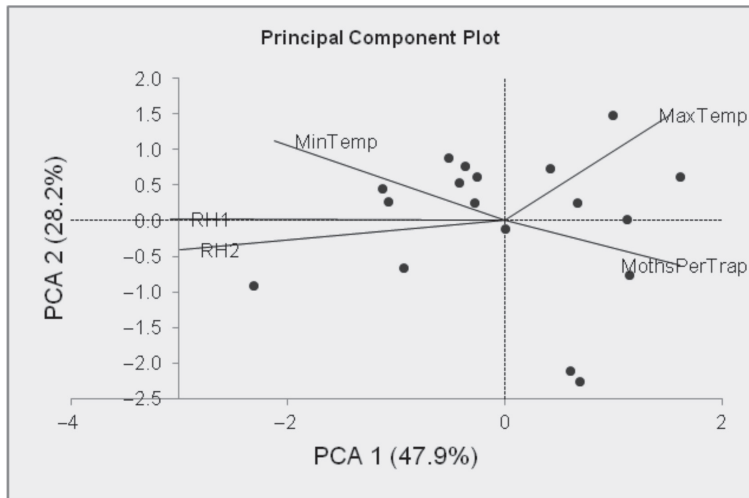


Fig 5. Principal component analysis of trap catch data of *L. obfusata* and different climatic variables

wingless, unable to walk and white in colour. Males are smaller, dark brown with blackish markings and are strong fliers, being active from mid June to mid July.

Degree day model for *L. obfusata*

Cumulative degree day model at different phenological stages of *L. obfusata* revealed egg hatch between 65.31 to 117.97 heat units. Larvae accumulated 562.66 to 592.55 heat units, whereas adults 794.66 to 928.15 heat units. To acquire the exact number of heat units required from egg to adult stage is based on cumulative degree days to forecast different phenological stages of *L. obfusata*, which could be used as biofix (a biological event or indicator of a developmental event, usually in the life of an insect pest, that initiates the beginning of growing-degree-day calculations) in the degree day model for egg hatch.

On the other hand, accumulated degree days varied between 2007 and 2009 and could be attributed to weather and other factors prevailing during the spring season (Andresen et al., 2001). Degree day models may be potential tools for the management of *L. obfuscata* populations. Management strategies are thus predicted to be applied at about 562.66 to 592.51 degree days for the larvae. Regression model developed between 2007 and 2009 (Fig. 4) revealed strong regression coefficient of $R^2 = 0.94\%$ as compared to 2007 and 2008. Larval emergence between 562.66–592.55 degree days should therefore be viewed with caution. Also, first instar larvae can be transferred by the wind from infested to non-infested areas. Adult average degree days of 857.33 can be a sign of starting monitoring (Arnold, 1960). Principal component analysis revealed (Fig. 5) that maximum temperature showed more variability as compared to other variables for *L. obfuscata* populations.

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