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Population Dynamics of Indigo Psyllid, *Euphaleropsis isitis* (Cotes) (Hemiptera: Psyllidae) on *Indigofera tinctoria* in Kerala

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Abstract

The population dynamics of indigo psyllid, *Euphaleropsis isitis* (Cotes) (Hemiptera: Psyllidae) infesting *Indigofera tinctoria* L. were studied under field conditions at the College of Agriculture, Vellanikkara, Kerala, from September 2024 to August 2025. Fortnightly observations on egg, nymph, and adult were recorded from 15 plants, and the population was correlated with major weather parameters viz., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, bright sunshine hours, rainfall. The egg stage exhibited multiple peaks without any significant correlation with the weather factors. Nymphal population showed distinct peaks during February, May, and August, with a significant positive correlation with rainfall, indicating that humid conditions favoured their development. The adult population showed three major peaks (March, May, and August) and was negatively correlated with maximum temperature and bright sunshine hours, but positively correlated with evening relative humidity and rainfall. Adult and nymphal abundance was highest during the post-monsoon months (July–August), coinciding with vigorous vegetative growth of the host plants. Population reduction was recorded from mid-October to mid-December. The study suggests that rainfall, moderate temperature, and higher humidity promoted population build-up of *Euphaleropsis isitis* in Kerala.

Key words: *Euphaleropsis isitis*, *Arytaina punctipennis*, Correlation, Population dynamics, Indigo, Weather parameters

Indian indigo (*Indigofera tinctoria* L.) is an erect, woody leguminous plant that can grow up to a height of one to two meters. Indian indigo (*Indigofera tinctoria* L.) is a historically and economically important leguminous plant belonging to the family Fabaceae, subfamily Papilionoideae. The plant typically attains a height of one to two meters and is characterized by its well-branched growth habit [1]. The species is characterized by its erect growth habit and semi-woody to woody stem, enabling it to attain a height of approximately 1–2 meters under favorable agro-climatic conditions [2]. This structural architecture plays a crucial role in its adaptability, biomass production, and dye yield potential. Morphologically, the erect and woody nature of the stem provides mechanical strength, allowing the plant to withstand wind stress and repeated harvesting for leaf biomass, which is the primary source of natural indigo dye [3]. As a leguminous plant, *Indigofera tinctoria* possesses a well-developed taproot system with lateral roots bearing Rhizobium nodules, enabling biological nitrogen fixation [4]. This trait not only supports its own nutritional requirements but also improves soil fertility, making the crop valuable in crop rotations and sustainable farming systems. The plant's height of one to two meters reflects a balance between vegetative vigor and reproductive growth, which is essential for maximizing leaf biomass without excessive lodging [5].

It is cultivated across several East Asian countries, particularly in India and China. The species holds considerable ethnobotanical and medicinal significance, being widely used in the Indian system of medicine for the treatment of epilepsy, nervous disorders, bronchitis, and hepatic ailments [6]. In Kerala, the species is notably valued in Ayurvedic medicine and is intercropped in coconut plantations to optimize yield and land use. From a phytochemical perspective, the medicinal efficacy of *I. tinctoria* is attributed to the presence of indole alkaloids, flavonoids, phenolic compounds, glycosides, and tannins, which collectively contribute to its pharmacological activities. Traditional formulations utilize various plant parts leaves, roots, and stems administered as decoctions, pastes, or fermented extracts. In neurological disorders such as epilepsy and nervous ailments, the plant is believed to exert a calming and stabilizing effect on the nervous system, while its use in bronchitis is linked to its expectorant and anti-inflammatory actions [7]. Similarly, its role in managing hepatic ailments is associated with its detoxifying and liver-protective functions, supporting bile secretion and improving hepatic metabolism. The plant is used for its natural blue dye, indigo, which is extracted from its leaves and twigs. The dye is not present in its final form within the plant tissues but occurs as the precursor indican (indoxyl-β-D-glucoside). Upon harvesting, enzymatic hydrolysis and subsequent oxidation during fermentation convert indican into indigotin, the insoluble blue pigment responsible for the characteristic indigo colour. This dye not only serves as a traditional hair tonic and a major component of various Ayurvedic hair formulations but is also used as a natural food colourant [8]. Beyond its application

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in textile dyeing, indigo obtained from *Indigofera tinctoria* holds substantial value in traditional healthcare and cosmetic practices. In Ayurveda, indigo is widely recognized as a natural hair tonic, used to strengthen hair roots, promote hair growth, and maintain scalp health. It forms a major ingredient in various Ayurvedic hair formulations, where it is often combined with other herbal components to impart natural coloration, improve hair texture, and reduce premature greying without the adverse effects associated with synthetic dyes. Furthermore, the methanolic extracts of *Indigofera tinctoria* have been reported to possess strong cytotoxic, antioxidant, and antibacterial properties [9].

Despite its value, cultivation of *Indigofera tinctoria* faces considerable challenges due to pest infestations, including *Arytaina punctipennis*, *Adoxophyes* sp., *Protaetia aurichalcea*, *Paeonia peregrina*, *Clinteria klugi*, *Oxycetonia versicolor*, *Anchon pilosum*, *Tipulpara* sp., *Riptortus pedestris*, *Ranatra linearis*, and *Nezara antennata* [10]. The major pest, *Euphaleropsis isitis* (Cotes), previously designated as *Arytaina punctipennis*, has been responsible for significant damage resulting in leaf yellowing, shoot desiccation, and complete wilting during severe outbreaks. Historical accounts detail the devastation of indigo crops in Bengal in the late nineteenth century due to psyllid infestation. Skaria *et al.* [11] first reported the presence of the psyllid in Kerala, and its occurrence was later documented by Rajan [10]. Psyllids are a diverse group of phloem-feeding insects classified under the suborder Sternorrhyncha of the order Hemiptera, comprising over 4,000 species distributed across seven families [12]. They feed primarily on sugar-rich phloem sap by tapping into the sieve tube elements of host plants. The insect is observed throughout all phenological stages of the host plant and across all seasons.

Indigofera tinctoria L., commonly known as true indigo, is an economically and culturally important leguminous plant cultivated for its natural blue dye, indigo. The species holds considerable historical significance in India, where indigo extraction from leaves and tender shoots has been practiced for centuries. In recent years, there has been renewed interest in *I. tinctoria* owing to the growing demand for natural dyes in textile industries, herbal cosmetics, and eco-friendly products. In addition to its dye-yielding potential, the plant is widely recognized for its medicinal properties and is used in traditional systems of medicine for treating epilepsy, nervous disorders, bronchitis, hepatic ailments, and inflammatory conditions. In Kerala, *I. tinctoria* is cultivated both as a commercial crop and as a component of traditional agroforestry and homestead systems [13].

Despite its multifaceted importance, the productivity and quality of *I. tinctoria* are constrained by several biotic stresses, among which insect pests play a major role. Sucking pests, in particular, cause significant damage by extracting plant sap, reducing photosynthetic efficiency, and impairing overall plant vigor [14]. Among these, the indigo psyllid, *Euphaleropsis isitis* (Cotes) (Hemiptera: Psyllidae), has emerged as a key pest of *Indigofera* species in many parts of India. Both nymphs and adults feed on tender leaves and shoots, leading to leaf curling, yellowing, stunted growth, and in severe infestations, premature defoliation. The secretion of honeydew further promotes the growth of sooty mould, adversely affecting leaf quality and dye yield [15].

The incidence and severity of *E. isitis* infestation vary considerably with crop growth stage, season, and prevailing weather conditions. Psyllid populations are known to be highly sensitive to abiotic factors such as temperature, relative humidity, and rainfall, which influence their development, survival, and reproductive potential. Understanding the seasonal abundance and population fluctuations of this pest is therefore crucial for predicting outbreak periods and devising timely management strategies. However, systematic information on the population dynamics of *E. isitis* on *I. tinctoria*, particularly under humid tropical conditions such as those prevailing in Kerala, remains limited. Population dynamics studies provide essential baseline data on pest occurrence, peak activity periods, and their relationship with environmental variables. Such information is indispensable for developing integrated pest management (IPM) strategies, optimizing monitoring schedules, and reducing indiscriminate pesticide use. In crops like *I. tinctoria*, which are valued for natural dyes and medicinal uses, minimizing chemical residues is especially important to maintain product quality and environmental sustainability [16]. However, detailed information on the population dynamics of *E. isitis* under the environmental conditions of Kerala remains scarce.

In this context, the present investigation was undertaken to study the population dynamics of the indigo psyllid, *Euphaleropsis isitis*, on *Indigofera tinctoria*. The study aims to document the temporal fluctuations in psyllid population, identify periods of peak infestation, and generate information that can support the development of eco-friendly and location-specific pest management practices for sustainable cultivation of indigo.

MATERIALS AND METHODS

Experimental site and duration

The investigation was carried out at the Agronomy Farm of the College of Agriculture, Vellanikkara, Kerala Agricultural University (KAU), Thrissur, Kerala, India, for a period of one year from September 2024 to August 2025. The experimental field consisted of a well-established crop of true indigo (*Indigofera tinctoria* L.), maintained under uniform agronomic practices as recommended by Kerala Agricultural University. No insecticidal applications were made in the field throughout the study period to permit natural infestation and population development of the insect pest.

Experimental design and sampling procedure

The study followed a field observational design with repeated sampling over time. Fifteen healthy and uniformly growing indigo plants were randomly selected from the experimental plot and permanently tagged to serve as fixed sampling units throughout the study. These tagged plants constituted fifteen replications for population observations.

At each fortnightly interval, three actively growing shoot tips of 10 cm length were randomly collected from each tagged plant, resulting in a total of 45 shoot tips per observation. The shoot tip was considered as the basic sampling unit for recording insect population.

Observation and data recording

The collected shoot tips were carefully transported to the laboratory and examined under a stereomicroscope. The population of the insect pest was recorded separately for different life stages, namely eggs, nymphs, and adults. Counts were made meticulously to avoid duplication or omission. The observations were expressed as mean number of eggs, nymphs, and adults per shoot tip for each fortnight.

Meteorological data

Weather data corresponding to the observation period were obtained from the Meteorological Observatory of the

College of Agriculture, Vellanikkara. The meteorological parameters recorded included maximum temperature (°C), minimum temperature (°C), relative humidity (%), rainfall (mm), wind speed (km h^{-1}), and bright sunshine hours (h day^{-1}). Fortnightly mean values were computed for correlation with insect population data.

Data transformation and statistical analysis

The insect population data were subjected to square-root transformation [$\sqrt{(x + 0.5)}$] wherever necessary to stabilize variance and normalize the data prior to statistical analysis. The transformed data were used for statistical interpretation, while original means were presented in tables and figures for clarity. To study population dynamics and the influence of abiotic factors, correlation analysis was performed between the mean population of different life stages and corresponding meteorological parameters. Pearson's correlation coefficients (r) were calculated to determine the nature and degree of association. The significance of correlation coefficients was tested at 5 per cent (P = 0.05) and 1 per cent (P = 0.01) levels of significance using standard statistical software.

RESULTS AND DISCUSSION

Seasonal variation in psyllid population

The egg population exhibited multiple peaks, with a major increase observed between SMW 6 and 10 (February 1st week to March 1st week), followed by another peak around SMW 32 (August 1st week). The nymphal population showed a similar trend but with lower intensity, displaying distinct peaks at SMW 6 (February 1st week), SMW 22 (May last week), and 32 (August 1st week). From SMW 50 to SMW 6 (December last week to February 1st week), the nymph population increased gradually, reached a peak, and then declined steadily until SMW 18 (May 1st week). A second peak occurred at SMW 32 (August 1st week). In the case of adults, the first peak appeared at SMW 10, followed by a sharp decline. A second peak was recorded at SMW 22 (may last week), which again dropped suddenly before reaching the maximum population at SMW 34 (August 2nd week). No adults were noticed from mid-October to mid-December and high adult population was noticed during August. Population of nymph was very low during October to December period.

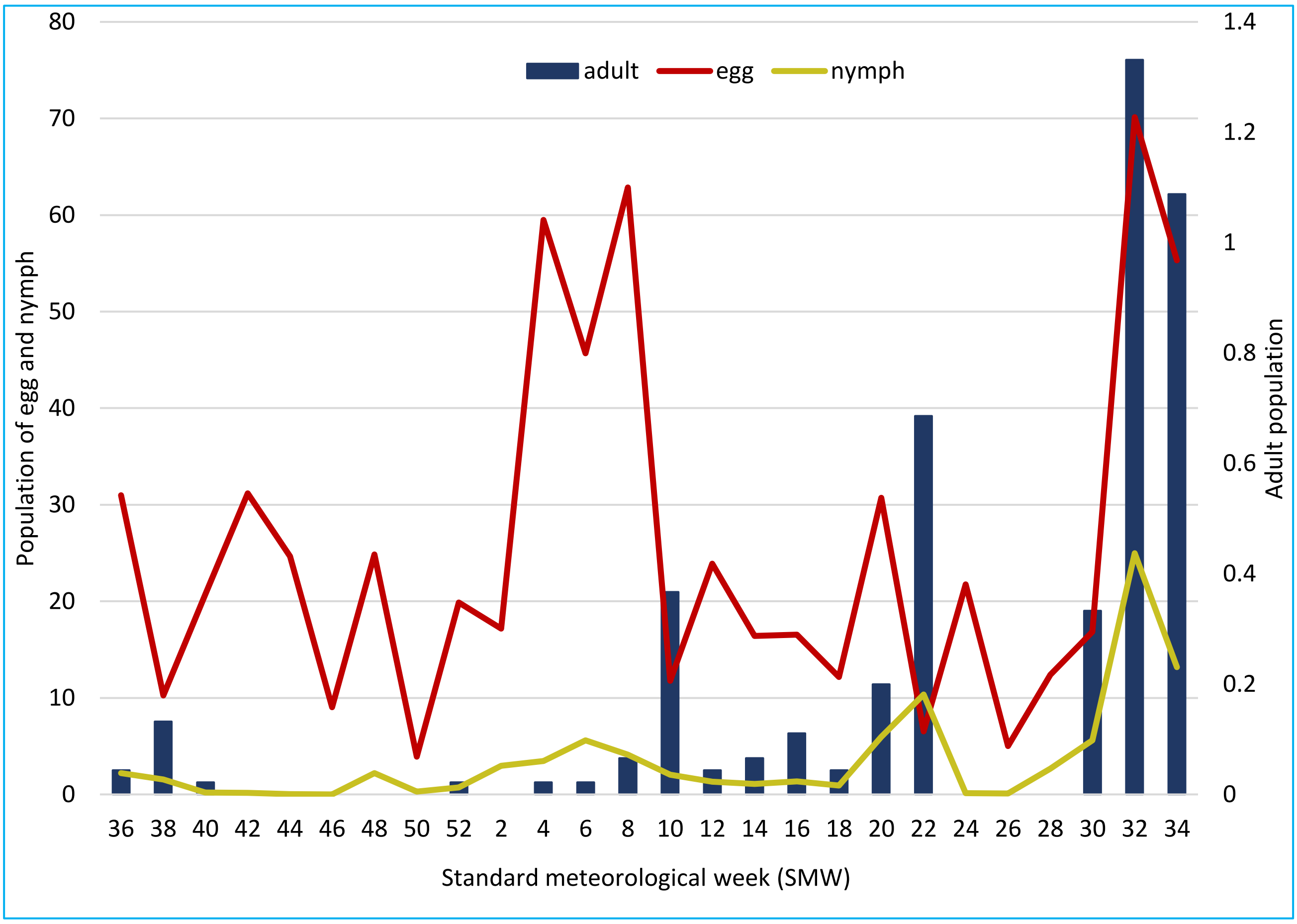

Fig 1 Seasonal variation in psyllid population

Table 1 Correlation of insect population with one-week prior weather parameters

	T_{max}	T_{min}	RH1	RH2	WS	BSS	RF
Egg	-0.028	-0.178	-0.167	-0.109	-0.05	0.017	-0.016
Nymph	-0.343	-0.161	0.171	0.318	-0.031	-0.318	0.401*
Adult	-0.421*	-0.114	0.265	0.430*	-0.106	-0.437*	0.590**

T_{max}- maximum temperature, T_{min}- minimum temperature, RH1-morning relative humidity, RH2-evening relative humidity, WS- wind speed, BSS- bright sunshine hours, RF- rainfall

**Significant at the 0.01 level

*Significant at the 0.05 level

Correlation of psyllid population with weather parameters

There was no correlation with number of eggs and weather factors. Nymph has positive significant correlation with rainfall. Adult stage has significant negative correlation with maximum temperature and bright sunshine hours. The evening humidity showed significant positive correlation with adult population, while rainfall show highly significant postive correlation with adult population. There were no studies conducted previously in the population dynamics of *E. isitis*. Many studies are available showing the relationship between population and weather parameters for psyllids like *Diaphorina citri, Blastopsylla occidentalis* and *Cacopsylla* sp.

Rakhshani and Saeedifar [17] reported trend in *D. citri* population on citrus limon orchards, the first major peak occurred on 22 February, followed by a gradual decline, with a subsequent secondary peak observed on 29 August. Almost similar trend was observed in the case of *E. isitis.*

The nymph population of *E. isitis* showed peaks at February 1st week, May last week, and August 1st week. Similarly, the population of *D. citri* exhibited two distinct annual peaks, occurring in May and August [18]. In contrast the nymphal stage of *D. citri* exhibited two distinct peaks of high infestation, one during April and another in July, in Punjab on Kinnow trees [19]. Rakhshani and Saeedifar [17] noticed the highest peak of nymph population on 22 February, and another rise in nymph numbers was noted on 27 September.

The adult of *E. isitis* demonstrated three main peaks, first at March 1st week, followed by May last week and a maximum peak at August 3rd week. Whereas the adult *D. citri* populations reached maximum levels on 18 February and 13 March, with a distinct secondary peak occurring in late September [17]. The lowest psyllid population of *Diaphorina dakariensis* on Dodi was recorded during the 38th Standard Meteorological Week (fourth week of September 2022) [20].

No adults were noticed from mid-October to mid-December and high adult population was noticed during August. The nymph population was very low during October to December. No nymph population was noticed during November 2nd week. Whereas in Punjab on Kinnow mandarine trees, adult *D. citri* was present throughout the year, whereas nymphs were absent in December and January [19].

The present study observed that the populations of nymph and adult stages of *E. isitis* showed a peak during the months of July and August. This finding aligns with previous surveys conducted in southern Kerala, where the incidence of this pest was notably recorded during the post-monsoon period, specifically in early September [21]. The concurrence of high psyllid populations in these periods may suggest that the post-monsoon climatic conditions in Kerala, characterized by residual moisture and moderate temperatures, create a favourable environment for the proliferation of nymphs and adults. The abundant population of nymphs and adults during the rainy season can be attributed to the lush growth of the plant stimulated by rainfall. Increased moisture and favorable environmental conditions promote vigorous vegetative growth, providing ample food resources and conducive microhabitats for the psyllid's development and reproduction, thereby supporting higher pest populations.

The egg showed weak or negligible correlations with weather parameters. Both nymph and adult population of *E. isitis* correlated positively with rainfall, indicating that humid conditions favour survival and population buildup during immature stages. *Diaphorina citri* showed significant positive association with rainfall on 'Ponkan' mandarin, and 'Murcott' tangor in Taquaritinga region [22] and on Kinnow in the Punjab [19]. Whereas rainfall negatively correlated with *D. citri* on Feuterell's Early, Kinnow, and Musambi [23]. Correlation analysis revealed a negative relationship between rainfall and the numbers of both male and female adults in *Cacopsylla* sp [24]. Higher rainfall reduced psyllid abundance of *Blastopsylla occidentalis* on *Eucalyptus* [25].

The adult population of *E. isitis* showed significant negative correlations with maximum temperature, whereas *D. citri* exhibited positive correlations with maximum temperatures on three citrus cultivars- Feuterell's Early, Kinnow, and Musambi [23] on kinnow in Punjab [18] and on 'Ponkan' mandarin, and 'Murcott' tangor in Taquaritinga [22]. Sharma [19] reported positive association with maximum temperature and both nymphal and adult population on Punjab on kinnow mandarine trees. In the *Citrus limon* orchard in the Sarbaz region no significant relationship was observed with maximum temperature [17]. Temperature showed negative, non-significant correlations with nymphal populations, but positive, non-significant correlations adults of *Cacopsylla* sp. [24]. Temperature was strongly and positively correlated with the number of individuals of *Blastopsylla occidentalis* on *Eucalyptus* [25].

The adult exhibited a significant negative correlation with bright sunshine hours, indicating that prolonged exposure to higher light intensity and heat might adversely affect adult survival or activity. This trend contrasts with the findings of Chachpara and Barad [20], who reported a significant positive correlation between bright sunshine hours and the abundance of *Diaphorina dakariensis* on Dodi plants.

The present study revealed that adult population of *E. isitis* exhibited a significant positive correlation with evening relative humidity, indicating that increased atmospheric moisture favors adult survival and activity. A similar trend was earlier reported in *Diaphorina citri* infesting Kinnow mandarin in Punjab, where both nymphal and adult populations were positively associated with relative humidity [19]. However, contrasting patterns have also been documented. For instance, *D. citri* populations showed a negative association with relative humidity on Kinnow in Punjab [18] and on citrus cultivars such as Feuterell's Early, Kinnow, and Musambi [23]. Likewise, *Blastopsylla occidentalis* on *Eucalyptus* displayed decreased abundance under conditions of high humidity [25]. In *Diaphorina dakariensis* on Dodi, both morning and evening relative humidity were found to have significant negative correlations with psyllid abundance [20].

CONCLUSION

The present investigation provides the first detailed account of the population dynamics of *Euphaleropsis isitis* on true indigo under the agro-climatic conditions of Kerala. The study clearly demonstrated that the psyllid population exhibited marked seasonal fluctuations, with distinct peaks in egg, nymph, and adult stages, indicating strong synchrony between pest development and prevailing environmental conditions. The egg population showed multiple peaks during the study period, with a pronounced increase during SMW 6-10 (February first week to March first week) and another notable peak around SMW 32 (August first week). This pattern suggests that oviposition activity is favoured during periods of moderate temperature and increased plant flush. However, the absence of significant correlations between egg population and weather parameters indicates that egg laying may be influenced more by host plant phenology than by direct climatic factors. The nymphal population followed a trend broadly similar to that of eggs but with relatively lower intensity. Nymphs exhibited distinct peaks during SMW 6 (February first week), SMW 22

(May last week), and SMW 32 (August first week). A gradual increase in nymph population from late December to early February, followed by a steady decline until early May, reflects the influence of seasonal plant growth cycles. The very low nymph population observed during October to December, with complete absence during the second week of November, suggests that unfavourable climatic conditions and reduced vegetative growth limit nymphal survival during this period. The significant positive correlation between nymph population and rainfall highlights the importance of moisture availability and lush vegetative growth in supporting immature stages. Adult psyllids exhibited three major population peaks, the first during SMW 10 (March first week), followed by SMW 22 (May last week), and a maximum peak during SMW 34 (August second to third week). The absence of adults from mid-October to mid-December and the high abundance during August clearly indicate that adult activity is strongly season-dependent. The sharp decline observed after each peak suggests limited adult longevity and possible dispersal following favourable periods. Correlation analysis revealed that adult populations were significantly and positively associated with rainfall and evening relative humidity, while showing significant negative correlations with maximum temperature and bright sunshine hours. These findings indicate that adult survival and activity are favoured by humid, cloudy, and moderately cool conditions, whereas excessive heat and prolonged sunshine may adversely affect adult behaviour and persistence. The weak or negligible influence of weather factors on egg population further supports the hypothesis that adult physiology and nymphal development are more sensitive to environmental fluctuations than oviposition alone. The population trends observed for *E. isitis* closely resemble those reported for other psyllid species such as *Diaphorina citri*, *Blastopsylla occidentalis*, and *Cacopsylla* spp., although notable differences were also evident. The occurrence of major adult and nymphal peaks during February–March and August corresponds well with earlier findings on *D. citri* in citrus orchards, where similar bimodal or trimodal population peaks were reported. However, the absence of *E. isitis* adults during October–December contrasts with observations in *D. citri*, which is often reported to persist year-round in certain regions. Such variations may be attributed to differences in host plant characteristics, regional climate, and species-specific ecological adaptations. The consistent increase in nymph and adult populations during July and August corroborates earlier surveys from southern Kerala, where *E. isitis* incidence was reported during the post-monsoon period. The post-monsoon environment in Kerala, characterized by residual soil moisture, moderate temperatures, and vigorous vegetative growth of indigo plants, appears to provide highly favourable conditions for psyllid multiplication. Rainfall-induced flush growth likely enhances food availability and creates suitable microhabitats, thereby supporting higher survival, development, and reproduction of the pest. Overall, the study establishes rainfall, relative humidity, and temperature as key drivers influencing the seasonal abundance of *E. isitis*, particularly during the nymphal and adult stages. The findings underscore the importance of monitoring psyllid populations during pre-monsoon and post-monsoon periods, especially from February to March and July to August, which represent critical windows for pest buildup. These baseline data on population dynamics and weather relationships will be valuable for developing timely and climate-informed pest management strategies for true indigo cultivation in Kerala and similar agro-ecological regions.

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