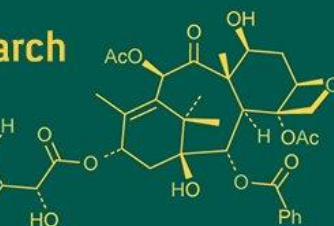
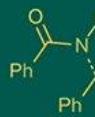


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E-surveillance of *Parthenium hysterophorus* L. and associated insect fauna with special reference to *Zygogrammabicolorata* in Raipur district of Chhattisgarh

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Abstract

One of the most damaging invasive alien weeds, *Parthenium hysterophorus* L. causes serious issues with agriculture, the environment, and public health all over the world. In four blocks of Raipur district, Chhattisgarh Arang, Dharsiwa, Tilda, and Abhanpur an e-surveillance study was carried out during the kharif and rabi seasons of 2016 and 2017 to record the distribution of *Parthenium*, related weed flora, and insect fauna, with particular attention to the Mexican beetle, *Zygogramma bicolorata* Pallister. From each block, five villages were chosen, and GPS-assisted field surveys and 1 m² quadrats were used to capture observations from five randomly chosen places each village. In highland, midland, and lowland environments, the quantity of *Parthenium*, related annual and perennial weeds, and insect populations were evaluated. The survey found 37 related weed species from several botanical families, demonstrating the high diversity of weeds in areas afflicted with *parthenium*. Additionally, a wide variety of helpful and phytophagous insects were recorded. *Z. bicolorata* was the most common biological control agent among the natural enemies and was found in all study blocks, with somewhat higher populations in the lowland habitats of the Abhanpur block. Aphids, mealybugs, hoppers, semiloopers, caterpillars, ants, spiders, ladybird beetles, and predatory bugs were among the other insects that were connected. Insect abundance showed clear seasonal variation, with greater numbers often seen during the kharif season. The results show that GPS-based e-surveillance is a useful method for tracking the insect fauna associated with *Parthenium* infestations and mapping them. *Z. bicolorata* plays a major role in the natural suppression of *P. hysterophorus*, as evidenced by its extensive occurrence and establishment. The data produced by this study offers useful baseline information for improving integrated weed management techniques, biological control programs, and long-term *Parthenium* monitoring in central India.

Keywords: *Parthenium hysterophorus*, *Zygogrammabicolorata*, e-surveillance, biological control, invasive weed, associated weed flora, insect fauna, GPS, Chhattisgarh

Introduction

One of the most aggressive invasive alien weed species in the world is *Parthenium hysterophorus* L. (Asteraceae), sometimes referred to as congress grass, carrot weed, or gajarghans. Due to its abundant seed production, quick growth, drought tolerance, wide ecological adaptability, and potent allelopathic qualities, the weed which is native to tropical and subtropical regions of North and South America has successfully spread to Asia, Africa, Australia, and several Pacific nations (Adkins and Shabbir, 2014). The species may quickly establish and dominate both agricultural and non-agricultural ecosystems thanks to its large reproductive capabilities, effective seed distribution, and capacity to colonise damaged habitats.

P. hysterophorus was unintentionally brought to India in the middle of the 1950s by tainted imported food grains. Since then, it has spread widely throughout roadsides, wastelands, grazing areas, cultivated fields, orchards, and forest habitats (Sushilkumar & Varshney, 2007; Sushilkumar, 2014) [1, 70, 74]. Currently, the weed is prevalent on around 35 million hectares of land, endangering biodiversity, environmental sustainability, and agricultural output. While allelochemicals generated from various plant sections prevent the germination of seeds and

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the growth of nearby plant species, dense infestations restrict the growth of native flora through fierce competition for nutrients, moisture, and sunlight (Adkins and Shabbir, 2014).

P. hysterophorus causes severe allergic dermatitis, eczema, hay fever, asthma, and respiratory diseases in humans and livestock in addition to causing significant productivity losses in crops and pastures (Kololgi *et al.*, 1997). Additionally, it increases the incidence of disease in cultivated crops by acting as a substitute host for a number of economically significant plant viruses, such as tobacco leaf curl virus, mungbean yellow mosaic virus, okra yellow vein mosaic virus, tobacco streak virus, and tomato leaf curl virus (Singh and Singh, 1999; Rao *et al.*, 2003; Ansari *et al.*, 2004).

To suppress parthenium, a variety of management techniques have been used, including chemical herbicides, mechanical removal, and cultural activities. These techniques work well in certain situations, but they are labour-intensive, expensive, and frequently inappropriate for widespread infestations in grazing areas, roadsides, and wastelands (Krishnamurthy *et al.*, 1977). As a result, biological control has become one of the most inexpensive, environmentally safe, and sustainable methods for managing this invasive species over the long term (Dhileepan *et al.*, 2000a).

The most effective defoliating insect among the biological control agents used against *P. hysterophorus* is the Mexican beetle, *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae). After thorough host-specificity testing, the beetle which is native to Mexico was brought to India in 1983 (Jayanth, 1987). Parthenium leaves, tender shoots, flower buds, and inflorescences are the main food source for both larvae and adults, which causes severe defoliation, decreased flowering, and a notable suppression of weed growth (Annadurai, 1990; Jayanth and Nagarkatti, 1997).

Numerous studies have been conducted on the biology, eating habits, laboratory mass multiplication, and seasonal population dynamics of *Z. bicolorata* (Jayanth *et al.*, 1996; Kulkarni *et al.*, 2000; Dhiman and Bhargava, 2005). However, extended diapause under unfavourable environmental circumstances frequently lowers beetle numbers, enabling quick weed recovery following beneficial rainfall (Jayanth *et al.*, 1997). However, *Z. bicolorata*'s robust establishment has produced significant financial gains. According to Sushilkumar (2006), the beetle prevented the growth of parthenium over almost eight million hectares in India and saved almost Rs. 10 million in pesticide costs at Jabalpur alone.

The insect fauna linked to *P. hysterophorus* in various parts of the world has been documented by numerous researchers. Numerous phytophagous insects and pathogens targeting parthenium were reported by Bennett (1977) and McFadyen (1979) after conducting extensive surveys in North and South America. Many of these insects showed significant potential for traditional biological control programs. In North America, McClay *et al.* (1995) identified 262 phytophagous arthropod species linked to *P. hysterophorus*, including a number of host-specific insects that were later assessed as biological control agents. Mealybugs, aphids, and mites linked to parthenium were recorded in India by Char *et al.* (1975), Puttaswamy *et al.* (1976), and Rajulu *et al.* (1976), while Kumar *et al.* (1979) described a varied collection of insects, mites, and illnesses attacking the weed

in Tamil Nadu. Although several related insects were polyphagous and also targeted commercially significant crops, their analysis discovered stem-boring beetles including *Hypothenemus eruditus* and *Oberea* spp. that severely damaged the weed.

The knowledge of insect communities related with parthenium has been broadened by subsequent studies. Parthenium in southern India was severely infested with *Leptocentrus taurus* and *Orthezia insignis*, according to Thangavelu (1980) and Srikanth *et al.* (1988). According to Shenhmar *et al.*'s (1998) investigation of *Z. bicolorata*'s distribution in Punjab and nearby states, beetle populations remained comparatively low in the field, which limited the effectiveness of weed suppression. In the Agra region, Kulshretha and Kumar (2013) tracked the seasonal prevalence of *Z. bicolorata* and found that beetle abundance varied significantly across years. In a similar vein, Dhiman and Bhargava (2005) noted that beetle incidence peaked during the monsoon season, especially in August, underscoring the impact of weather on beetle establishment and efficacy [39, 63, 60, 6, 40, 16, 29, 5, 36, 38, 42, 17].

Although *P. hysterophorus* is widely found in Chhattisgarh, especially in roadsides, horticulture fields, agricultural lands, and uncultivated regions, systematic data on its distribution, related insect fauna, and natural enemies is still scarce. Furthermore, the area lacks thorough GPS-based e-surveillance investigations that document parthenium infection and related insect variety under various land conditions. Understanding the ecological relationships between the weed and its natural enemies is crucial for creating biological weed management plans that are region-specific.

In order to document the occurrence, abundance, and distribution of *Zygogramma bicolorata* and other related insect fauna, an e-surveillance of *Parthenium hysterophorus* and associated weed flora during the kharif and rabi seasons in various blocks of Raipur district, Chhattisgarh, was conducted. The study's conclusions could offer useful baseline data for bolstering biological control initiatives and encouraging sustainable parthenium management in the agro-ecological circumstances of central India.

Materials and Methods

Study Area: The current study used GPS-based e-surveillance to measure the prevalence of *Parthenium hysterophorus* L. and its related insect fauna in the Raipur district of Chhattisgarh, India, during the kharif and rabi seasons of 2016 and 2017. Based on the frequency of parthenium contamination, four administrative blocks Arang, Dharsiwa, Tilda, and Abhanpur were chosen.

At 21.16° N latitude and 81.36° E longitude, Raipur district is located in Chhattisgarh's central plains. Its average elevation is 298 meters above mean sea level. Arang (21°11'41.46' N, 81°58'11.44' E), Dharsiwa (21°24'29.46' N, 81°40'19.16' E), Tilda (21°33'04.88' N, 81°47'51.72' E), and Abhanpur (21°03'14.98' N, 81°45'04.87' E). *Parthenium hysterophorus* may thrive and expand in the area because of its dry sub-humid tropical environment, which is marked by distinct rainy (kharif) and winter (rabi) seasons.

Selection of Study Sites

Based on the prevalence of parthenium infestation, five villages were chosen from each of the four blocks. The villages that were chosen were:

Arang: Rico, Umariya, Sendh, Parshada, and Palaud

Tilda: Neora, Dondekala, Murra, Tulsi, and Dondekhurd;
Dharsiwa: Serikheri, Jora, Temri, Dharampura, and Banrasi

Rakhi, Nardaha, Tekari, Rakhi-2, and Kurud in Abhanpur

Five typical farmers' fields were chosen at random inside each hamlet, yielding 25 sampling locations per block and 100 sampling locations throughout the study region.

E-surveillance of Parthenium and Associated Insect Fauna

In order to record the presence of *Parthenium hysterophorus*, related weed flora, and insect fauna, a GPS-assisted field survey was carried out in 2016 and 2017 throughout both the kharif and rabi seasons. To capture the spatial heterogeneity in weed infestation and insect abundance, observations were made from three different land situations: highland, midland, and lowland.

To record observations, a 1 m x 1 m quadrat was randomly put at each sample position. A Global Positioning System (GPS) receiver was used to record each sampling site's geographic coordinates. To identify *Parthenium* plants, related weed species, and insect fauna, visual observations were combined with a hand magnifying lens.

Insect populations linked to the plant were tracked at various phases of growth, and the quantity of *Parthenium* and related annual and perennial weeds was noted. Aphids, mealybugs, hoppers, semiloopers, caterpillars, spiders, ants, ladybird beetles, predatory bugs, and the biological control agent Mexican beetle (*Zygogramma bicolorata* Pallister) were among the beneficial and phytophagous insects found. Based on observations from the chosen quadrats, population counts were calculated as the average number of insects per square meter.

Data Collection and Analysis

For highland, midland, and lowland habitats, observations from each sample site were combined independently. For every block, season, and year, the average population of each species of insect was determined. The occurrence and distribution of *Parthenium* and its related insect fauna in various agro-ecological conditions in the Raipur district were then compared using pooled means across sites and years.

Result & Discussion

The e-surveillance program for *parthenium* and other related weeds was carried out in four distinct blocks of Raipur, Chhattisgarh: Arang, Dharsiwa, Tilda, and Abhanpur. For this study, weed observations from upland, midland, and lowland areas in one square metre of five locations five farmers' fields under each chosen village during the Kharif and Rabi seasons were recorded using a GPS device and a visual/magnifying glass. To determine the population of insect pests associated at the various key plant stages, *parthenium* and other related weeds, such as annual and perennial, were observed. Tables 1a, 1b, 1c, and 1d show the observations that were made at regular intervals.

1. Upland**1.1. Arang block**

In the first year, or 2016, the highest average population of ants (3.87) per square metre was observed, followed by

spiders (0.89), while the lowest average population of caterpillars (0.01) per square metre was reported in comparison to the Mexican beetle population (0.80) per square metre at Arang block.

In the second year, ants and spiders had the highest number (2.87/sqm), while caterpillars and Mexican beetles had the lowest (0.79/sqm) and canthocona bugs had the lowest (0.04) at Arang block.

The highest number of ants (3.37/sqm) and mexican beetles (0.78/sqm) were found in the pooled analysis of two years' worth of data, while the lowest number of Canthocona bugs (0.04) was found in the Arang block.

1.2. Dharsiwa block

- Ants had the highest average population (2.87/sqm) and mealy bugs had the lowest (0.04/sqm) during the first year, while Mexican beetles had the lowest (0.82/sqm).
- In the second year, ants had the highest number (1.87/sqm), canthocona bugs had the lowest (0.01/sqm), and mexican beetles had the highest (0.86/sqm) at Dharsiwa block.
- Ants had the highest score (2.37) per square metre, followed by mexican beetles (0.84) and canthocona bugs (0.01) per square metre, according to a pooled study of two years' worth of data.

1.3. Tilda block

- Ants had the highest average population (3.87) per square metre during the first year, while canthocona bugs had the lowest (0.01) per square metre, and mexican beetles had the lowest (0.65) per square metre.
- Ants had the maximum number (2.87) per square metre during the second year, cow bugs had the lowest (0.06) per square metre, and Mexican beetles had the lowest (0.61) per square metre at Tilda block.
- Ants had the highest score (3.37) per square metre, Mexican beetles had the lowest score (0.84) per square metre, and canthocona bugs had the lowest score (0.01) per square metre in a pooled analysis of two years' worth of data.

1.4. Abhanpur block

- Ants had the highest average population (3.88) per square metre during the first year, while canthocona bugs had the lowest (0.01) per square metre, while Mexican beetles had the lowest population (1.85) per square metre.
- In the second year, ants had the largest population (2.88/sqm), lady bird beetles had the lowest number (0.02/sqm), and mexican beetles had the highest population (1.61/sqm) at Abhanpur block.
- Ants scored the highest (3.38) /sqm, followed by Mexican beetles (1.73/sqm) and canthocona bugs (0.01/sqm) in a pooled analysis of two years' worth of data.

2. Midland**2.1. Arang block**

- Ants had the highest average population of 2.86/sqm during the first year, whereas cow bugs, semilooper, and ladybird beetles had the lowest average population of 0.02/sqm. The Mexican beetle population was found to be (1.42)/sqm.

- In the second year, ants had the largest number (1.86/sqm), semilooper had the lowest (0.02/sqm) and mexican beetles had the highest population (1.32/sqm) at Arang block.
- Ants and mexican beetles received the highest scores (2.36) and 1.37/sqm, respectively, in a pooled analysis of two years' worth of data, whereas cow bugs received the lowest scores (0.02/sqm).

2.2. Dharsiwa block

- Ants had the highest average population of 2.86/sqm during the first year, whereas semilooper had the lowest average population of 0.01/sqm. In contrast, Mexican beetles had an average population of 1.42/sqm.
- In the second year, mexican beetles had a population of 1.32/sqm at Dharsiwa block, while ants had the highest number (1.86/sqm) and cow bugs had the lowest (0.02/sqm).
- Ants scored the most (2.36/sqm) and mexican beetles (1.37/sqm) in a pooled study of two years' worth of data, whereas semilooper, spittle bugs, and cow bugs scored the lowest (0.02/sqm), respectively.

2.3. Tilda block

- Ants had a maximum average population of 1.95/sqm during the first year, or 2016, whereas canthocona bugs had a minimum of 0.01/sqm and Mexican beetles had a population of 0.40/sqm.
- In the second year, Mexican beetles were found at Tilda block (1.32/sqm), while ants recorded the highest number (1.76/sqm) and the lowest (0.02/sqm) in cow bugs and semilooper, respectively.
- Ants had the highest score (1.76/sqm), mexican beetles had the lowest score (0.36/sqm), and cow bugs and semilooper had the lowest score (0.02/sqm) in a pooled analysis of two years' worth of data.

2.4. Abhanpur block

- Mexican beetles had an average population of 1.40/sqm during the first year, whereas ants had a maximum average population of 3.76/sqm and canthocona bugs had a minimum average population of 0.01/sqm.
- Mexican beetles (1.32/sqm) were found in the Abhanpur block in the second year, whereas ants (2.76/sqm) had the highest population and canthocona bugs (0.10/sqm) the lowest.
- The Mexican beetle (1.36/sqm) and ants (3.26/sqm) received the highest scores from a pooled study of two years' worth of data, while canthocona bugs received the lowest (0.06/sqm).

3. Lowland

3.1. Arang block

- Mexican beetles had the highest average population of 2.70/sqm during the first year, whereas cow bugs and canthocona bugs had the lowest average population of 0.01/sqm.
- In the second year, ants had the largest population (2.76/sqm), semilooper had the lowest (0.03/sqm), and mexican beetles had the highest number (1.70/sqm) at Arang block. Ants had the highest score (2.33) per square metre from a pooled analysis of two years' worth

of data, followed by Mexican beetles (2.20 per square metre) and canthocona bugs (0.01 per square metre).

3.2. Dharsiwa block: Mexican beetles had the highest average population of 1.70/sqm during the first year, whereas mealy bugs and semilooper had the lowest average population of 0.02/sqm.

Ants had the largest number (1.33/sqm) during the second year, semilooper had the lowest (0.02/sqm), and mexican beetles had the highest (0.70/sqm) in Dharsiwa block.

A pooled examination of two years' worth of data yielded the highest score of 1.28/sqm for ants, followed by 1.20/sqm for Mexican beetles, and the lowest score of 0.02/sqm for semilooper and canthocona bugs.

3.3. Tilda block

- Mexican beetles had the highest average population of 2.70/sqm during the first year, whereas caterpillars had the lowest average population of 0.08/sqm.
- The Mexican beetle had the highest population in the second year (2.70/sqm), while the lady bird beetle had the lowest number (0.06/sqm) at the Dharsiwa block.
- Mexican beetles received the highest score (2.20) per square metre from a pooled analysis of two years' worth of data, while cow bugs received the lowest score (0.10) per square metre.

3.4. Abhanpur block

- Mexican beetles had the highest average population of 3.80/sqm during the first year, whereas canthocona bugs had the lowest average population of 0.01/sqm.
- Mexican beetles had the highest number (3.70) per square metre in the second year, while cow bugs had the lowest (0.10) per square metre in the Abhanpur block.
- Mexican beetles had the highest score (3.75) per square metre from a pooled analysis of two years' worth of data, while ladybird beetles received the lowest score (0.05) per square metre.

Overall

In 2016, the highland, midland, and lowland blocks (Arang, Dharsiwa, Tilda, and Abhanpur) ranged from 0.01 to 3.62, 0.01 to 2.81, and 0.10 to 2.73, respectively. Ants had the highest population (3.62/sqm) and canthocona bugs had the lowest (0.01/sqm) on lowland and midland, while mexican beetles had the highest (3.80/sqm) and canthocona bugs the lowest (0.01/sqm).

In 2017, the highland, midland, and lowland blocks (Arang, Dharsiwa, Tilda, and Abhanpur) ranged from 0.01 to 3.62, 0.01 to 2.70, and 0.10 to 2.73, respectively. Ants had the highest population (2.62/sqm) and canthocona bugs had the lowest (0.01/sqm) on lowland and midland, while Mexican beetles had the highest population (3.70/sqm) and canthocona bugs and cow bugs had the lowest (0.02/sqm).

Based on two years' worth of combined data, the upland, midland, and lowland areas of Arang, Dharsiwa, Tilda, and Abhanpur varied from 0.01 to 3.62, 0.01 to 2.70, and 0.10 to 2.73, respectively. Canthocona bugs had the highest population (3.12) per square metre and the lowest (0.01) per square metre in lowland and midland areas. Ants had the highest population (1.76) per square metre, while cow bugs had the lowest (0.03) per square metre. Mexican beetles had

the highest population (2.46) per square metre and the lowest (0.05) per square metre.

The Raipur District's total upland, midland, and lowland statistics ranged from 0.06 to 2.57. Ants had the highest population (2.57) per square metre, while canthocon bugs had the lowest (0.06) per square metre. In contrast, Mexican beetles had the highest number (2.46) per square metre.

Similar results were reported by Kulkarni and Kulkarni (2000), who investigated the presence of *Z. bicolorata* on *P. hysterophorus* plants in 20 locations in north Karnataka, India. They discovered that Dharwad had the densest population of beetles (10.4 beetles/plant), followed by Bijapur (5.6 beetles/plant) and Raichur (3.2 beetles/plant). The number of beetles is consistent with those found in Raichur, Karnataka.

Bennett (1977) and Kumar *et al.* (1979) reported that the stem-boring scolytid *Hypothenemus eruditus* (Westw.) larvae and adults caused widespread wilting of the weed, resulting in good natural control. Additionally, a cerambycid borer, *Oberea* sp., was found to kill the plant; however, neither of these was noted in the current studies from the Raipur district of Chhattisgarh [41, 7, 45].

Associated weeds with *Parthenium* and their insect-pests recorded during 2016-17 at Raipur district

Thirty-seven weed species were identified from studies on parthenium-associated weeds in various Raipur district blocks. Insect pests linked to weeds that were observed during the Kharif and Rabi seasons in 2016 and 2017 showed that sucking pests including hoppers and aphids predominated the weeds, followed by mealy bugs and

caterpillars. Maximum population of aphids were recorded on *Latjira*, *Achyranthes aspera* L., *Kantedarchauli*, *Amaranthus spinosus* L., *Choulai*, *Amaranthus viridis* L., *Satyranashi*, *Argemone maxicana* L., *Aak/madar*, *Calotropis gigantea* L., *Silyari*, *Celosia argentea* L., *Bathua*, *Chenopodium album* L., *Scorpion weed*, *Heliotropium indicum* L., *Gunima*, *Leucas aspera* L., *Chirpoti*, *Physallis minima* L. and *Gokhru*, *Xanthium strumarium* L.; Hoppers, were recorded with nine weed species namely *Sawa*, *Echinochloa colona* L., *T grass*, *Paspalum conjugatum* P., *Baru*, *Sorghum halepense* L., *Motha*, *Cyperus difformis* L., *Kantedarchauli*, *Amaranthus spinosus* L., *Aak/madar*, *Calotropis gigantea* L., *Charota*, *Cassia tora* L. and *Gokhru*, *Xanthium strumarium* L.; Mealy bugs were recorded on five weed species viz; *Aak/madar*, *Calotropis gigantea* L., *Scorpion weed*, *Heliotropium indicum* L., *Pignut*, *Hyptissuaveolens* L., *Ramphul/Barmsiya*, *Lantana camara* L., *Gokhru*, *Xanthium strumarium* L.; The honey dew secreted by the aforementioned sucking pests was discovered to be consumed by ants. In addition, a few spiders and semiloopers were seen. Coccinellid beetles and Canthocon bugs were also noted as predators.

Insect pests are being used worldwide, particularly in India, to manage invasive and locally related weeds in an environmentally friendly manner, hence lowering the demand for pesticides (Heimpel and Mills, 2017) [24]. Aphids, hoppers, mealy bugs, and a few caterpillars and semiloopers were among the insect pests found on the thirty-seven weed species identified in this study. These insects can be investigated further and used as effective instruments for controlling weeds.

Table 1a: e-surveillance of parthenium and associated insects at Raipur District in Kharif - Rabi season during 2016

S. No.	Enemies/Block	UL					ML					LL					GM
		Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	
1	Mexican beetle	0.80	0.82	0.65	1.85	1.03	1.42	1.42	0.40	1.40	1.16	2.70	1.70	2.70	3.80	2.73	1.41
2	Aphids	0.09	0.90	0.10	0.10	0.30	0.00	0.00	0.10	0.10	0.05	0.00	0.10	0.70	0.60	0.35	0.15
3	Mealy bugs	0.19	0.04	0.07	0.66	0.24	0.10	0.20	0.20	0.30	0.20	0.07	0.02	0.20	0.40	0.17	0.27
4	Cow bugs	0.06	0.06	0.05	0.31	0.12	0.02	0.03	0.02	0.20	0.07	0.01	0.00	0.10	0.11	0.06	0.10
5	Hoppers	0.40	0.21	0.21	0.61	0.36	0.50	0.30	0.20	0.40	0.35	0.57	0.27	0.27	0.47	0.40	0.34
6	Semilooper	0.40	0.33	0.14	0.10	0.24	0.02	0.01	0.02	0.10	0.04	0.04	0.02	0.10	0.70	0.22	0.21
7	Caterpillar	0.01	0.11	0.11	0.40	0.16	0.10	0.12	0.15	0.17	0.14	0.80	0.18	0.08	0.70	0.44	0.26
8	Spittle bugs	0.21	0.09	0.01	0.90	0.30	0.08	0.02	0.10	0.30	0.12	0.07	0.04	0.18	0.28	0.14	0.22
9	Spider/mites	0.89	0.79	0.89	0.81	0.84	2.85	1.85	1.95	2.95	2.40	1.48	1.38	1.48	1.58	1.48	0.88
10	Ants	3.87	2.87	3.87	3.88	3.62	2.86	2.86	1.76	3.76	2.81	2.33	1.23	1.83	3.73	2.28	2.24
11	Lady bird beetle	0.20	0.09	0.08	0.20	0.14	0.02	0.10	0.30	0.70	0.28	0.08	0.60	0.60	0.10	0.35	0.13
12	Canthocon bugs	0.03	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.10
13	Others	0.60	0.21	0.70	1.20	0.68	0.59	0.59	0.35	2.00	0.88	0.36	0.27	0.16	1.20	0.50	0.55
	Total	6.69	7.74	6.51	6.88	21.82	10.74	8.56	7.50	5.56	12.39	8.50	8.53	5.81	8.40	13.68	9.11

*Mean population = Average population of egg, nymph/grubs/larvae and adults of five farmer's field in five villages from each block

Table 1b: e-surveillance of parthenium and associated insects at Raipur District in Kharif - Rabi season during 2017

S. No.	Enemies/Block	UL					ML					LL					GM
		Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	
1	Mexican beetle	0.76	0.86	0.61	1.61	0.96	1.32	1.32	0.32	1.32	1.07	1.70	0.70	2.70	3.70	2.20	1.41
2	Aphids	0.20	0.30	0.20	0.20	0.23	0.00	0.00	0.10	0.10	0.05	0.00	0.10	0.00	0.60	0.18	0.15
3	Mealybug	0.13	0.07	0.07	0.67	0.23	0.40	0.30	0.30	0.40	0.35	0.08	0.03	0.30	0.50	0.23	0.27
4	Cowbug	0.06	0.06	0.06	0.61	0.20	0.02	0.02	0.02	0.20	0.07	0.00	0.00	0.10	0.10	0.05	0.10
5	Hoppers	0.52	0.20	0.11	0.51	0.34	0.60	0.30	0.30	0.30	0.38	0.47	0.17	0.27	0.37	0.32	0.34
6	Semilooper	0.44	0.34	0.24	0.14	0.29	0.02	0.02	0.02	0.20	0.07	0.03	0.02	0.20	0.90	0.29	0.21
7	Caterpillar	0.00	0.10	0.10	0.80	0.25	0.12	0.12	0.12	0.10	0.12	0.08	0.08	0.80	0.70	0.42	0.26
8	Spittle bugs	0.21	0.08	0.09	1.09	0.37	0.04	0.02	0.00	0.30	0.09	0.08	0.04	0.38	0.38	0.22	0.22
9	Spider/mites	0.79	0.69	0.79	0.71	0.74	1.85	0.85	0.95	1.95	1.40	0.48	0.38	0.48	0.58	0.48	0.88
10	Ants	2.87	1.87	2.87	2.88	2.62	1.86	1.86	1.76	2.76	2.06	2.33	1.33	1.73	2.73	2.03	2.24
11	Lady bird beetle	0.10	0.10	0.09	0.02	0.08	0.20	0.10	0.00	0.70	0.25	0.08	0.06	0.06	0.00	0.05	0.13
12	Canthocon bugs	0.04	0.01	0.00	0.00	0.01	0.00	0.00	0.10	0.10	0.05	0.00	0.00	0.00	1.00	0.25	0.10
13	Others	0.58	0.08	0.80	1.00	0.62	0.46	0.36	0.35	1.00	0.54	0.26	0.27	0.26	1.20	0.50	0.55
	Total	6.69	4.75	6.02	10.23	6.92	6.89	5.27	4.34	9.43	6.48	5.59	3.18	7.28	12.76	7.21	6.87

*Mean population = Average population of egg, nymph/grubs/larvae and adults of five farmer's field in five villages from each block

Table 1c: Pooled mean of e-surveillance of parthenium and associated insects at Raipur District in Kharif - Rabiseason during 2016 and 2017

S. No.	Enemies/Block	UL					ML					LL					GM
		Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	Arang	Dharsiwa	Tilda	Abhanpur	Mean	
1	Mexican beetle	0.78	0.84	0.63	1.73	1.00	1.37	1.37	0.36	1.36	1.11	2.20	1.20	2.70	3.75	2.46	1.52
2	Aphids	0.15	0.60	0.15	0.15	0.26	0.00	0.00	0.10	0.10	0.05	0.00	0.10	0.35	0.60	0.26	0.19
3	Mealy bugs	0.16	0.05	0.07	0.66	0.24	0.25	0.25	0.25	0.35	0.28	0.08	0.02	0.25	0.45	0.20	0.24
4	Cow bugs	0.06	0.06	0.06	0.46	0.16	0.02	0.03	0.02	0.20	0.07	0.01	0.00	0.10	0.11	0.05	0.09
5	Hoppers	0.46	0.21	0.16	0.56	0.35	0.55	0.30	0.25	0.35	0.36	0.52	0.22	0.27	0.42	0.36	0.36
6	Semilooper	0.42	0.34	0.19	0.12	0.27	0.02	0.02	0.02	0.15	0.05	0.04	0.02	0.15	0.80	0.25	0.19
7	Caterpillar	0.01	0.11	0.11	0.60	0.20	0.11	0.12	0.14	0.14	0.13	0.44	0.13	0.44	0.70	0.43	0.25
8	Spittle bugs	0.21	0.09	0.05	1.00	0.33	0.06	0.02	0.05	0.30	0.11	0.07	0.04	0.28	0.33	0.18	0.21
9	Spider/mites	0.84	0.74	0.84	0.76	0.79	2.35	1.35	1.45	2.45	1.90	0.98	0.88	0.98	1.08	0.98	1.23
10	Ants	3.37	2.37	3.37	3.38	3.12	2.36	2.36	1.76	3.26	2.44	2.33	1.28	1.78	3.23	2.16	2.57
11	Lady bird beetle	0.15	0.10	0.09	0.11	0.11	0.11	0.10	0.15	0.70	0.27	0.08	0.33	0.33	0.05	0.20	0.19
12	Canthocona bugs	0.04	0.01	0.01	0.01	0.01	0.00	0.00	0.06	0.06	0.03	0.01	0.00	0.00	0.51	0.13	0.06
13	Others	0.59	0.15	0.75	6.50	2.00	0.52	0.47	0.35	1.50	0.71	0.31	0.27	0.21	1.20	0.50	1.07
	Total	6.69	7.22	5.64	6.46	16.03	8.84	7.73	6.38	4.95	10.91	7.49	7.06	4.50	7.84	13.22	8.15

*Mean population = Average population of egg, nymph/grubs/larvae and adults of five farmer's field in five villages from each block

Table 1d: Insect-pest reported on other associated weeds with parthenium at different block of Raipur District in Kharif - Rabi season during 2016-17

S. No.	Name of associated weeds		Insect-pests												
			Mexican beetle	Aphids	Mealy bug	Cow bug	Hoppers	Semilooper	Caterpillar	Spittle bugs	Spider/mites	Ants	Lady bird beetle	Canthocona bug	Others
	Local name	Botanical name	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Viper grass	<i>Dinebraretroflexa</i> Vahl.	x	x	x	x	x	x	x	x	✓	x	x	x	✓
2	Sawa	<i>Echinochloacolona</i> L.	x	x	x	x	✓	x	✓	x	x	✓	x	x	x
3	Badasawa	<i>Echinochloacrusgall</i> L.	x	x	x	x	x	x	x	x	✓	✓	x	✓	✓
4	Gantegawta	<i>Heteropogoncontortus</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
5	Blady grass	<i>Imperata cylindrica</i> L.	x	x	x	x	x	x	x	x	✓	✓	x	x	x
6	Badauri	<i>Ischaemumrugosum</i> Sali.	x	x	x	x	x	x	x	x	x	✓	x	x	x
7	T grass	<i>Paspalumconjugatum</i> P.	x	x	x	x	✓	x	x	x	✓	x	x	x	x
8	Beard grass	<i>Polypogonmonspeliensis</i> L.	x	x	x	x	x	x	x	x	x	✓	x	x	x
9	Baru	<i>Sorghum halepense</i> L.	x	x	x	x	✓	x	✓	x	✓	✓	x	x	✓
10	Christmas grass	<i>Themedaarguens</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
11	Sweet signal grass	<i>Urochloaplatiginea</i>	x	x	x	x	x	x	✓	x	x	✓	x	x	x
12	Motha	<i>Cyperus difformis</i> L.	x	x	x	x	✓	x	x	x	x	x	x	x	x
13	Latjira	<i>Achyranthes aspera</i> L.	x	✓	x	x	x	x	x	x	x	✓	x	x	x
14	Mahakwa	<i>Ageratum conyzoides</i> L.	x	x	x	x	x	x	x	x	x	✓	x	x	✓
15	Kantedarchauli	<i>Amaranthus spinosus</i> L.	x	✓	x	x	✓	x	x	x	✓	✓	x	x	x
16	Choulai	<i>Amaranthus viridis</i> L.	x	✓	x	x	✓	x	x	x	✓	✓	x	x	x
17	Satyanaashi	<i>Argemone maxicana</i> L.	x	✓	x	x	x	x	x	x	✓	✓	x	x	x
18	Kukurmuta	<i>Blumealacera</i>	x		x	x	x	x	x	x	x	x	x	x	x
19	Aak/madar	<i>Calotropis gigantea</i> L.	x	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	x	✓
20	Phuggabail	<i>Cardiospermum halicacabum</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
21	Charota	<i>Cassia tora</i> L.	x	x	x	x	✓	x	x	x	x	✓	x	✓	✓
22	Silyari	<i>Celosia argentea</i> L.	x	✓	x	x	x	x	x	x	✓	✓	✓	x	✓
23	Asiatic pennywort	<i>Centella asiatica</i> L.	x		x	x	x	x	x	x	x	✓	x	x	✓
24	Bathua	<i>Chenopodium album</i> L.	x	✓	x	x	x	x	x	x	✓	x	x	x	x
25	Kankaua/Kena	<i>Commelinabenghalensis</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
26	Machharia	<i>Corchorus aestuans</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
27	Tiliaceae	<i>Corchorus olitorius</i> L.	x	x	x	x	x	x	x	x	x	x	x	x	x
28	Amarbel	<i>Cuscuta chinensis</i> Yun.	x	x	x	x	x	x	x	x	x	x	x	x	x
29	Badidudhi	<i>Euphorbia geniculata</i> Ort	x	x	x	x	x	x	x	x	x	x	x	x	x
30	Chotidudhi	<i>Euphorbia hirta</i> Ort	x	x	x	x	x	x	x	x	✓	✓	x	x	x
31	Scorpion weed	<i>Heliotropium indicum</i> L.	x	✓	✓	x	x	x	x	x	x	x	x	x	x
32	Pignut	<i>Hyptissuaveolens</i> L.	x	x	✓	x	x	x	x	x	✓	✓	x	x	x
33	Ramphul/Barmsiya	<i>Lantana camara</i> L.	x	x	✓	x	x	x	x	x	✓	✓	x	x	✓
34	Gunima	<i>Leucas aspera</i> L.	x	✓	x	x	x	x	x	x	✓	✓	x	x	x
35	Chirpoti	<i>Physallis minima</i> L.	x	✓	x	x	x	x	x	x	x	✓	x	x	x
36	Pathar-Chata	<i>Trianthemaportulacastrum</i> L.	x	x	x	x	x	x	x	x	x		x	x	x
37	Gokhru	<i>Xanthium strumarium</i> L.	x	✓	✓	x	✓	x	✓	x	✓	✓	x	✓	x

Conclusion

In the Raipur district of Chhattisgarh, the current study showed that GPS-based e-surveillance is a useful method for tracking the dispersal of *Parthenium hysterophorus* L. and its related insect fauna across various agro-ecological conditions. On *Parthenium*, a wide variety of insect species, including herbivorous insects, predators, and natural enemies, were noted. The Mexican beetle (*Zygogramma bicolorata* Pallister) was the most significant biological control agent linked to the weed and was often seen in all four research blocks. In lowland environments, especially in the Abhanpur block, the beetle population was significantly greater, suggesting good environmental circumstances for its development and activity. While ladybird beetles, predatory insects, and other helpful arthropods were found in comparatively smaller quantities, ants and spiders were also among the predominant insect groups linked to *parthenium*.

The survey also identified 37 weed species linked to *parthenium*, which provided habitats for a variety of beneficial and phytophagous insects. The most common herbivorous insects found on the related weed flora were aphids, hoppers, and mealybugs, although ladybird beetles and canthocon bugs were occasionally seen as predators. These results underline the significance of related weed flora in preserving insect diversity and the ecological complexity of areas dominated by *parthenium*.

Overall, the study demonstrates that *Z. bicolorata* is firmly established in the Raipur district and still plays a major role in *P. hysterophorus*'s natural suppression. Spatial differences in beetle abundance between blocks and land conditions, however, suggest that environmental factors affect its efficacy. Developing location-specific biological control techniques, bolstering integrated weed management programs, and enabling long-term monitoring of *parthenium* infestations in central India would all benefit from the baseline data produced by this e-surveillance initiative. The effectiveness of biological control and sustainable management of this invasive weed will be significantly improved by future studies that combine geospatial technologies with seasonal population dynamics and environmental factors.

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