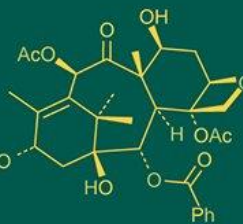
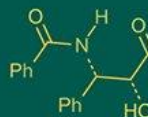


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Hemkant Chandravanshi
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Jayalaxmi Ganguli
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Sanjay Sharma
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

Seasonal abundance and habitat-wise distribution of *Zygogramma bicolorata* pallister (Coleoptera: Chrysomelidae) and associated insect fauna on *Parthenium hysterophorus* L.

Hemkant Chandravanshi, Jayalaxmi Ganguli and Sanjay Sharma

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Abstract

One of the most invasive alien weeds, *Parthenium hysterophorus* L. reduces crop yield, suppresses native vegetation, and endangers biodiversity, all of which lead to serious ecological, agricultural, and environmental issues. The Mexican beetle, *Zygogramma bicolorata* Pallister, is used in biological control, which has been shown to be an efficient and environmentally sustainable method of management. In order to examine the seasonal abundance of *Z. bicolorata* and record the insect fauna associated with *P. hysterophorus* in three habitats agroforestry fields, cropped fields, and roadside vegetation the current study was carried out in 2016 and 2017 at the Indira Gandhi Krishi Vishwavidyalaya (IGKV) campus in Raipur, Chhattisgarh. At each site, ten naturally occurring *Parthenium* plants were chosen at random, and the population of *Z. bicolorata* eggs, larvae, and adults was observed every two weeks. The beetle showed a clear seasonal pattern, with oviposition starting in July and adult, larval, and egg populations peaking in August and September. Roadside vegetation supported the largest beetle population, followed by cropped fields, according to habitat-wise observations, while the agroforestry habitat had the lowest abundance. In addition to *Z. bicolorata*, *P. hysterophorus* was linked to a number of insect species, such as aphids, ants, mealybugs, leaf miners, leafhoppers, semiloopers, ladybird beetles, spiders, reduviid bugs, canthocona bugs, cow bugs, and spittle bugs. Mealybugs were more common in roadside vegetation, whereas aphids and ants were more common in agroforestry and cropped field habitats. According to the study, *Z. bicolorata* is well-established in the agroclimatic conditions of central India and is most active when *P. hysterophorus* is actively growing. The results show that beetle populations can be increased and conserved, especially in roadside habitats during the monsoon season, to improve *P. hysterophorus* biological suppression and promote sustainable integrated weed management programs.

Keywords: *Parthenium hysterophorus*, *Zygogramma bicolorata*, biological control, invasive alien weed, seasonal abundance, habitat distribution, insect diversity, integrated weed management, Chhattisgarh

Introduction

One of the most aggressive invasive alien weed species of worldwide importance is *Parthenium hysterophorus* L. (Asteraceae), sometimes referred to as congress grass, carrot weed, or gajar ghans in Hindi. Due to its abundant seed production, effective dispersal mechanism, broad ecological adaptability, drought tolerance, quick growth, and potent allelopathic qualities, the weed which is native to the tropical and subtropical regions of North and South America has successfully invaded a number of nations in Asia, Africa, and Australia (Adkins and Shabbir, 2014) [1]. *P. hysterophorus* suppresses native vegetation and lowers biodiversity in agricultural fields, horticultural plantations, roadsides, grazing lands, wastelands, forest margins, and other disturbed habitats because of these traits.

Due to tainted imported food grains, the weed was unintentionally brought to India in the middle of the 1950s. Since then, it has spread widely throughout the nation, contaminating around 35 million hectares of land (Sushil Kumar and Varshney, 2007; Sushil Kumar, 2014) [70, 74]. *P. hysterophorus* has emerged as a prominent weed in both agricultural and non-agricultural environments in Chhattisgarh. According to Kumari *et al.* (2014) [46], it grew widely in the Bilaspur district's cultivated fields, where it showed the highest relative density

Corresponding Author:
Hemkant Chandravanshi
Indira Gandhi Krishi
Vishwavidyalaya, Raipur,
Chhattisgarh, India

among the related weed flora, proving its superiority in competition and capacity to inhibit native plant communities. Such dominance has a negative impact on biodiversity and environmental stability in addition to endangering agricultural productivity.

In addition to seriously endangering human and animal health, *P. hysterophorus* causes significant yield losses due to competition for nutrients, moisture, light, and space. Asthma, respiratory allergies, eczema, and allergic dermatitis are all brought on by contact with the cannabis (Kologi *et al.*, 1997) [39]. Additionally, 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, tomato leaf curl virus, and groundnut and sunflower bud necrosis viruses, use the weed as a substitute host (Singh and Singh, 1999; Chakravarthy, 2002; Rao *et al.*, 2003; Ansari *et al.*, 2004) [63, 9, 60, 6]. *P. hysterophorus* is one of the most troublesome invasive weeds in tropical agriculture because of these complex effects.

To reduce *P. hysterophorus*, a number of management strategies have been used, such as integrated weed management, chemical herbicides, cultural techniques, and manual removal. However, for large infestations in roadsides, pasture lands, and wastelands, manual and chemical control approaches are labor-intensive, costly, environmentally unpleasant, and frequently impossible (Krishnamurthy *et al.*, 1977) [40]. As a result, biological control has become the most inexpensive, environmentally safe, and sustainable method for managing this invasive species over the long term (Dhileepan *et al.*, 2000) [16]. The most feasible strategy for reducing parthenium populations, according to Singh (1997) [65], is the use of biological control agents, such as insects, diseases, and competitive plant species. The effectiveness of biological control programs against parthenium in India and several other countries has been further highlighted by thorough reviews by Singh (1989, 1997) [63, 64], Sushil Kumar (1993) [73], Sushil Kumar and Bhan (1995) [72], McFadyen (1992) [52], Dhileepan and McFadyen (1997) [14], Evans (1997) [19], and Dhileepan and Senaratne (2009) [15].

The Mexican leaf-feeding beetle *Zygogramma bicolorata* Pallister (Coleoptera: Chrysomelidae) has proven to be the most successful biological control agent used against *P. hysterophorus*. The Indian Institute of Horticultural Research (IIHR), Bengaluru, brought the beetle from Mexico to India in 1983 as a traditional biological control agent (Jayanth and Nagarkatti, 1987) [31]. The leaves, sensitive shoots, flower buds, and inflorescences of *P. hysterophorus* are heavily consumed by both larvae and adults, resulting in significant defoliation and a significant decrease in blooming and seed production (Annadurai, 1990; Jayanth and Nagarkatti, 1997) [5, 36]. Within a few years of its effective establishment, the beetle spread widely and dramatically decreased the prevalence of parthenium in various regions of India (Jayanth and Bali, 1994; Jayanth and Visalakshy, 1996) [30, 32]. According to Gupta *et al.* (2004) [22] and Gupta (2008) [23], *Z. bicolorata* spread naturally over more than 9,000 km², effectively suppressing the weed in multiple areas.

Z. bicolorata's biology and ecology have been well studied in both lab and field settings. The beetle's mass rearing methods have been standardized (Jayanth *et al.*, 1996; Kulkarni *et al.*, 2000) [32, 41-42], and research on its bio-

ecology has shown that environmental conditions have a significant impact on population dynamics (Dhiman and Bhargava, 2005) [17-18]. When the southwest monsoon arrives, adults emerge to colonize new parthenium plants after going through a seasonal diapause in the soil during the dry months (Visalakshy *et al.*, 1998) [77]. It has been observed that delayed monsoon rainfall considerably lowers adult emergence, which has an impact on the effectiveness of biological control initiatives. The significance of climatic variables in controlling beetle reproduction and field establishment is further demonstrated by Omkar and Pandey's (2009) [55] observation that rising temperatures shortened the pre-oviposition, oviposition, and post-oviposition durations.

The successful establishment of *Z. bicolorata* has been validated by field studies carried out in several agroclimatic areas. The beetle's high degree of host specialization was confirmed by Shenhmar *et al.* (1998) [62], who reported successful colonization of Parthenium-infested areas after beetle releases in Punjab. However, there were few reports of sunflower eating and no oviposition. There have also been reports of additional bug species on *P. hysterophorus* in addition to *Z. bicolorata*. A variety of phytophagous insects and natural enemies may play a role in the natural control of parthenium populations, according to Srikanth *et al.* (1988) [66], who reported severe infestations of the scale insect *Orthezia insignis* on congress grass in Karnataka.

Despite significant advancements in our knowledge of *Z. bicolorata*'s biology and potential for biological control, little is known about its seasonal abundance, habitat-specific distribution, and relationships with other insect species in Chhattisgarh's agroclimatic conditions. Such data is crucial for assessing the success of biological control initiatives and creating integrated weed management plans tailored to individual regions. With a focus on the seasonal occurrence, habitat-wise distribution, and biological control potential of the Mexican beetle, *Zygogramma bicolorata* Pallister, under the conditions of Raipur, Chhattisgarh, the current study was conducted to document the natural enemies associated with congress grass (*Parthenium hysterophorus* L.).

Methodology

Three sample habitats on the campus of Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh, were chosen for the field study based on Parthenium hysterophorus's natural occurrence. The research locations included:

- 1) Research areas related to agriculture and horticulture
- 2) The field of agroforestry
- 3) Roadside vegetation along National Highway-6 (NH-6), which runs from the College of Agriculture, IGKV, Raipur, to the Administrative Building.

The assessment of the habitat-wise abundance of *Zygogramma bicolorata* and other insect species associated with *P. hysterophorus* was made easier by these locations, which represented a variety of ecological situations.

Geographical location and climatic conditions

The experiment was conducted at Raipur, the capital of Chhattisgarh, India, which is located at an elevation of 298 meters above Mean Sea Level (MSL) at latitude 21.16° N and longitude 81.36° E. The area has a tropical climate with three distinct seasons: summer (March-June), monsoon (June-September), and winter (November-February). It is

located within the state's dry sub-humid agroclimatic zone. The majority of the yearly rainfall is contributed by the southwest monsoon, which fosters the growth of *P. hysterophorus* and the seasonal activity of the insect fauna that is connected with it.

Sampling procedure and data collection

Ten naturally occurring *Parthenium hysterophorus* plants were chosen at random and permanently tagged for recurring observations at each study site. Throughout the course of the investigation, observations were made in both years.

The number of egg masses, larvae (grubs), and adults on each chosen plant was counted at each observation to determine the population of the mexican beetle, *Zygogramma bicolorata* Pallister. Concurrently, the presence of additional insect species linked to *P. hysterophorus*, such as herbivores, natural adversaries, and accidental visitors, was noted, and their number was counted whenever they were seen.

Under the agroclimatic circumstances of Raipur, Chhattisgarh, the seasonal abundance, habitat-wise distribution, and population dynamics of *Z. bicolorata* and the diversity of insect fauna associated with *P. hysterophorus* were assessed using the gathered data.

Result and Discussion

Three areas of the IGKV campus the research field area for horticultural and agricultural products, the agro-forestry field area, and the roadside along NH-6 from the administrative building to the College of Agriculture, Raipur were used to record the population of the Mexican beetle, *Z. bicolorata*. The following table (1aa, 1ab, 1ac, 1ad, 1ba, 1bb, 1bc, 1ca, 1cb, 1cc & 1cd) and figure (1aa, 1ab, 1ac, 1ad, 1ba, 1bb, 1bc, 1bd, 1ca, 1cb, 1cc & 1cd) show the number of adults, grubs, and other insect pests associated with parthenium at three randomly chosen plants during the study period.

Agro-forestry field area

The average mexican beetle population (egg, grubs, and adults) on ten randomly chosen plants in the agro-forestry field area survey varied from 0.00 to 1.50, 0.00 to 0.30, and 0.00 to 0.50, respectively. July had the highest amount of Mexican beetle eggs (1.50/plant), followed by August (0.40/plant), while August had the highest number of grubs (0.30/plant) and adults (0.50/plant), followed by July (0.20/plant) and July (0.33/plant), respectively.

In terms of other insect pests linked to parthenium, the highest number of ants (2.60/plant) was seen in December, followed by aphids (2.50/plant) in January. In 2016, semilooper and canthocona bugs were 0.01/plant in January-May, March, and July, respectively.

In 2016, the average number of mexican beetles, *Z. bicolorata* P. (egg, grubs, and adults), was found to be 0.16, 0.04, and 0.07/plant, respectively, while the average number of other insect pests linked to parthenium was found to be highest in aphids (1.17/ten plants), followed by ants (1.02/ten plants), and lowest in Canthocona bugs (0.02/plant).

The average mexican beetle population (egg, grubs, and adults) on 10 plants in the agro-forestry region varied from 0.00 to 0.95, 0.00 to 0.20, and 0.00 to 0.30 in the second year, or 2017. The mexican beetle's maximum eggs

(0.95/plant) were found in July, followed by August (0.30/plant); its grubs (0.20/plant) and adults (0.30/plant) were found to be at their highest in August and lowest in July (0.10/plant and 0.23/plant), respectively. In contrast, other insect pests linked to Parthenium varied from 0.00 to 2.60 per plant. December had the highest ant population (2.60/plant), followed by March (1.60/ten plants) and July (0.01/plant) for semilooper, spiders, and Canthocona bugs. Overall, the average population of Mexican beetles (egg, grubs, and adults) was found to be 0.10, 0.03, and 0.04/plant, respectively. In contrast, the average of other insect pests linked to Parthenium was found to be highest in ants (0.87/plant), followed by aphids (0.71/plant), and lowest in canthocona bugs and cow bugs (0.02/plant).

The Mexican beetle (egg, grubs, and adults) on 10 plants in the agro-forestry area varied from 0.00 to 1.23, 0.00 to 0.25, and 0.00 to 0.40, respectively, according to the pooled analysis of two years of data. July had the highest amount of Mexican beetle eggs (1.23/plant), followed by August (0.35/plant), while August had the highest number of grubs (0.25/plant) and adults (0.40/plant), followed by July (0.15/plant) and July (0.28/plant), respectively.

Other insect pests linked to parthenium ranged from 0.00 to 2.60 per plant. December had the highest number of ants (2.60/plant), and December and January saw the highest number of aphids (2.50/plant). However, in 2016 and 2017, there was a minimum of 0.01/plant in semilooper in March and canthocona bugs in July.

The two-year pooled data showed that the mean population of mexican beetles (egg, grubs, and adults) was 0.13, 0.03, and 0.06/plant, respectively, while other insect pests linked to parthenium were found to be at their highest (0.94/plant) in aphids and ants, followed by mealy bugs (0.45/plant) and canthocona bugs (0.02/plant).

Cropped field area

In farmed fields, the average number of mexican beetles (egg, grubs, and adults) on 10 plants varied from 0.00 to 2.90, 0.00 to 2.30, and 0.00 to 2.30, respectively. August had the highest number of Mexican beetle eggs (2.90/plant), followed by July (2.50/plant), while August and September had the highest numbers of grubs (2.30/plant) and adults (0.80/plant), followed by July and October (2.20/plants and 0.60/plants, respectively).

The range of other insect pests linked to parthenium was 0.00 to 6.20 per plant. In 2016, the highest number of aphids (6.20/plant) was found in October, followed by 6.10/plant in September, and the lowest number of semilooper in March, canthocona bugs in July, ladybird beetles in June and August, and spittle bugs in August (0.01/plant), respectively.

In 2016, the average population of mexican beetles (egg, grubs, and adults) was found to be 0.61, 0.48, and 0.19/plant, respectively, while the average of other insect pests linked to parthenium was found to be maximum (2.03/plant) for ants, followed by aphids (1.88/plant) and minimum for canthocona bugs (0.12/plant).

The average mexican beetle population (egg, grubs, and adults) on 10 plants in the harvested field area varied from 0.00 to 1.90, 0.00 to 1.30, and 0.00 to 0.80 in the second year. August had the highest number of mexican beetle eggs (1.90/plant), followed by September (1.20/plant), grubs (1.30/plant), and adults (0.80/plant), with the lowest numbers (0.50/plant) and (0.33/plant) in October and July,

respectively. Insect pests related to parthenium varied from 0.00 to 4.10 per plant. Aphids had the highest number (4.10/plant) in September, while leaf miners had the lowest (0.01/plant) in March, spittle bugs in August, lady bird beetles in June, July, and August, and canthocona bugs in July.

Overall, the average population of Mexican beetles (egg, grubs, and adults) was found to be 0.43, 0.30, and 0.19/plant, respectively. In contrast, other insect pests linked to parthenium exhibited a maximum of 1.45/plant in ants, followed by aphids (1.22/plant) and a minimum in semilooper (0.14/plant).

The Mexican beetle *Z. bicolorata* P. (egg, grubs, and adults) on 10 plants in cropped field area varied from 0.00 to 2.40, 0.00 to 1.80, and 0.00 to 0.80, respectively, according to a pooled analysis of two years' worth of data. August had the most *Z. bicolorata* eggs (2.40/plant), followed by July (2.00/plant), whereas August and September had the most grubs (1.80/plant) and adults (0.80/plant), followed by July and October (1.70/plant and 0.60/plant, respectively).

Other insect pests linked to parthenium ranged from 0.00 to 4.70/plant, with the highest number of aphids (4.70/plant) occurring in October, followed by 3.00/plant in November, and the lowest numbers of spiders, ladybird beetles, and canthocona bugs (0.01) in March, July, July, August, and July, respectively.

The mean population of mexican beetles (egg, grubs, and adults) was found to be 0.52, 0.39, and 0.19/plant, respectively, in the overall pooled data of two years. Other insect pests linked to parthenium were found to be at their highest (1.74/plant), followed by aphids (1.55/plant) and canthocona bugs (0.09/plant).

Road side area

Ten plants in the roadside area had an average population of *Z. bicolorata* (egg, grubs, and adults) ranging from 0.00 to 7.40, 0.00 to 5.30, and 0.00 to 8.50, respectively. August had the highest number of Mexican beetle eggs (7.40/plant), followed by July (6.50/plant), while August had the highest number of grubs (5.30/plant) and adults (8.50/plant), followed by July (0.20/plant) and September (1.00/plant), respectively. The range of other insect pests linked to parthenium was 0.00 to 2.80 per plant. In 2016, the highest number of mealy bugs (2.80/plant) was noted in September, followed by 1.80/plant in October, while the lowest number of Semilooper bugs (0.01/plant) was noted in March and canthocona bugs (0.01/plant) in July.

In 2016, the average number of mexican beetles (egg, grubs, and adults) per plant was 1.84, 0.46, and 0.90, respectively, while the maximum number of mealy bugs (0.98/plant), ants

(0.70/plant), and canthocona bugs (0.02/plant) were the other insect pests linked to parthenium.

The average number of mexican beetles (eggs, grubs, and adults) on 10 plants in the roadside area in the second year varied from 0.00 to 5.70, 0.00 to 4.30, and 0.00 to 7.50, respectively. August saw the highest number of mexican beetle eggs (5.70/plant), followed by September (5.40/plant); August saw the highest number of grubs (4.30/plant) and adults (7.50/plant), with the lowest numbers (0.20/plant) and (0.33/plant) in July, respectively. The range of other insect pests linked to parthenium was 0.00 to 2.80 per plant. Mealy bugs had the maximum population (2.80/plant) in September, while semilooper and canthocona bugs had the lowest populations (0.01/plant) in March and July, respectively.

Mexican beetles (egg, grubs, and adults) were found to have an overall mean population of 1.43, 0.38, and 0.82/plant, respectively, while other insect pests linked to parthenium were found to have a maximum of mealy bugs (0.94/plant), followed by ants (0.70/plant), and a minimum of canthocona bugs (0.02/plant).

Mexican beetles (egg, grubs, and adults) on 10 plants in the roadside area varied from 0.00 to 2.40, 0.00 to 1.80, and 0.00 to 0.80, respectively, according to a pooled analysis of two years' worth of data. August had the highest number of mexican beetle eggs (2.40/plant), followed by July (2.00/plant), while August and September had the highest numbers of grubs (1.80/plant) and adults (0.80/plant), followed by July and October (1.70/plant and 0.60/plant, respectively). The range of additional insect pests linked to parthenium was 0.00 to 5.10 per plant. In 2016 and 2017, the highest number of aphids (4.70/plant) was found in September, followed by 4.70/plant in October. The lowest numbers of semilooper were found in March, lady bird beetles from June to August, and canthocona bugs in July, or 0.01/plant, respectively.

The mean population of mexican beetles (egg, grubs, and adults) was found to be 0.48, 0.36, and 0.17/plant, respectively, according to the overall pooled data of two years. Other insect pests linked to parthenium were found to be at their highest (1.62/plant), followed by aphids (1.43/plant), and spittle bugs (0.14/plant).

The current findings are consistent with those of Gupta and Sood (2002) [21], who surveyed five districts in Himachal Pradesh, India, in August 2001 to ascertain the ecology of *Zygogramma bicolorata*, a potential biological control agent against parthenium weed, and reported a mean maximum infestation of 8.50/plant in August.

In line with the current research, Dhiman and Bhargava (2005) [17-18] also reported that the incidence of *Z. bicolorata* peaked in August (87.09% and 76.19%).

Table 1aa: Mean data of the associated insects with congress grass, *P. hysterophorus* recorded under agro-forestry field area of IGKV campus, Raipur during 2016

S. No.	Bio-agents/Month	Agroforestry												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.40	0.00	0.00	0.00	0.00	0.16
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.00	0.00	0.00	0.00	0.04
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.00	0.00	0.00	0.00	0.07
4.	Mealy bug	0.70	0.40	0.90	0.70	0.00	0.70	0.20	0.70	0.70	0.80	0.70	0.70	0.60
5.	Aphid	2.50	1.30	1.50	0.50	0.00	0.00	0.00	1.50	1.50	1.20	1.50	2.50	1.17
6.	Ant (small/large)	0.60	1.50	1.60	0.90	0.80	0.60	1.20	0.60	0.60	0.60	0.60	2.60	1.02
7.	Spital bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	1.01	1.03	0.00	0.00	0.00	0.00	0.17
9.	Leaf miner	0.50	0.60	0.70	0.80	0.70	0.40	0.00	0.00	0.40	0.20	0.30	0.70	0.44
10.	Semilooper	0.20	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.20	0.30	0.08
11.	Lady bird beetle	0.10	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.08
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	0.40	0.50	0.60	0.40	0.39	0.30	1.01	0.40	0.40	0.40	0.40	0.40	0.47
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.02
15.	Cow bug	1.30	1.20	1.30	0.20	0.00	0.00	0.00	0.00	0.30	0.20	0.32	0.30	0.43
Total		6.40	5.81	6.93	3.50	1.90	2.00	5.48	5.63	4.10	3.50	4.13	8.11	4.79

The data shows Av. of fortnightly interval

Table 1ab: Mean data of the associated insects with congress grass recorded under field cropped area of IGKV campus, Raipur during 2016

S. No.	Bio-agents/Month	Field cropped area												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	2.50	2.90	1.40	0.50	0.00	0.00	0.61
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	2.20	2.30	0.60	0.50	0.20	0.00	0.48
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.80	0.60	0.00	0.00	0.19
4.	Mealy bug	0.70	0.40	0.90	0.70	0.00	0.70	0.20	0.70	0.00	0.80	0.70	0.70	0.54
5.	Aphid	1.50	0.30	0.50	0.50	0.00	0.00	0.00	1.50	6.10	6.20	3.50	2.50	1.88
6.	Ant (small/large)	1.60	2.50	2.60	1.90	1.80	1.60	2.20	2.60	1.80	1.60	1.60	2.60	2.03
7.	Spital bug	0.10	0.09	0.08	0.04	0.49	0.34	0.30	0.01	0.00	0.00	0.00	0.00	0.12
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.	Leaf miner	0.70	0.60	1.72	0.82	0.75	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.45
10.	Semilooper	0.80	0.90	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
11.	Lady bird beetle	1.10	1.20	1.30	0.20	0.10	0.01	0.01	0.01	0.20	0.10	0.00	0.00	0.35
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	1.40	1.50	1.60	1.40	1.39	1.30	1.10	1.40	0.10	0.00	0.00	0.00	0.93
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
15.	Cow bug	2.30	2.20	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
Total		10.20	9.69	11.01	5.56	4.54	4.75	8.87	11.92	11.00	10.30	6.00	5.80	8.30

The data shows Av. of fortnight interval

Table 1ac: Mean data of the associated insects with congress grass recorded under road side area of IGKV campus, Raipur during 2016

S. No.	Bio-agents/Month	Road side												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	6.50	7.40	5.70	2.50	0.00	0.00	1.84
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	0.20	5.30	0.00	0.00	0.00	0.00	0.46
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	8.50	1.00	0.50	0.46	0.00	0.90
4.	Mealy bug	0.10	0.30	0.40	0.20	0.00	1.70	1.20	1.70	2.80	1.80	0.70	0.80	0.98
5.	Aphid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.80	1.20	1.50	2.50	0.63
6.	Ant (small/large)	0.20	0.50	0.60	0.90	0.60	0.65	0.20	0.80	1.10	1.60	0.60	0.60	0.70
7.	Spital bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.03
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	1.01	1.03	0.00	0.00	0.00	0.00	0.17
9.	Leaf miner	0.50	0.60	0.70	0.80	0.70	0.40	0.00	0.00	0.00	0.20	0.30	0.70	0.41
10.	Semilooper	0.20	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.07
11.	Lady bird beetle	0.10	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.08
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	0.40	0.50	0.60	0.40	0.39	0.30	1.01	0.40	1.70	0.40	0.40	0.40	0.58
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.02
15.	Cow bug	0.30	0.20	0.30	0.20	0.00	0.00	0.00	0.00	0.20	0.10	0.30	0.20	0.15
Total		1.80	2.40	2.93	2.50	1.69	3.05	10.46	25.73	14.70	8.30	4.46	5.99	7.00

The data shows Av. of fortnight interval

Table 1ba: Mean data of the associated insects with congress grass under agro-forestry area of IGKV campus, Raipur during 2017

S. No.	Bio-agents/Month	Agroforestry												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.30	0.00	0.00	0.00	0.00	0.10
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.00	0.00	0.00	0.00	0.03
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.30	0.00	0.00	0.00	0.00	0.04

4.	Mealy bug	0.50	0.30	0.30	0.50	0.00	0.40	0.20	0.50	0.30	0.20	0.20	0.10	0.29
5.	Aphid	1.50	1.01	1.20	0.00	0.00	0.00	0.00	0.50	0.50	1.10	1.20	1.50	0.71
6.	Ant (small/large)	0.60	0.50	1.60	0.90	0.80	0.60	0.20	0.60	0.60	0.60	0.80	2.60	0.87
7.	Spital bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.09
9.	Leaf miner	0.00	0.00	0.00	0.60	0.60	0.40	0.00	0.00	0.20	0.20	0.20	0.60	0.23
10.	Semilooper	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.03
11.	Lady bird beetle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.03
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	0.40	0.50	0.60	0.40	0.39	0.30	0.01	0.40	0.30	0.42	0.40	0.45	0.38
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.02
15.	Cow bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.42	0.32	0.42	0.12
Total		3.00	2.31	3.71	2.40	1.80	1.70	1.72	3.83	2.21	3.04	3.13	6.58	2.95

The data shows Av. of fortnight interval

Table 1bb: Mean data of the associated insects with congress grass under field cropped area of IGKV campus, Raipur during 2017

S. No.	Bio-agents/Month	Field cropped area												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.90	1.20	0.50	0.00	0.00	0.43
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.30	0.60	0.50	0.00	0.00	0.30
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.80	0.60	0.00	0.00	0.19
4.	Mealy bug	0.40	0.20	0.50	0.70	0.00	0.70	0.20	0.70	0.00	0.40	0.20	0.50	0.38
5.	Aphid	0.50	0.30	0.50	0.50	0.00	0.00	0.00	1.50	4.10	3.20	2.50	1.50	1.22
6.	Ant (small/large)	1.60	1.50	1.60	0.90	0.80	1.60	1.20	2.60	1.80	1.60	0.60	1.60	1.45
7.	Spital bug	0.10	0.09	0.30	0.50	0.50	0.34	0.30	0.01	0.00	0.00	0.00	0.00	0.18
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.	Leaf miner	0.34	0.30	0.01	0.82	0.75	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.25
10.	Semilooper	0.80	0.90	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
11.	Lady bird beetle	0.50	0.70	0.00	0.70	0.20	0.01	0.01	0.01	0.20	0.10	0.00	0.00	0.20
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	1.40	1.50	0.50	0.70	0.00	0.70	0.20	1.40	0.10	0.00	0.00	0.00	0.54
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
15.	Cow bug	2.30	2.20	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
Total		7.94	7.69	6.22	5.52	2.25	4.85	5.15	9.92	8.80	6.90	3.30	3.60	6.01

The data shows Av. of fortnight interval

Table 1bc: Mean data of the associated insects with congress grass under road side area of IGKV campus, Raipur during 2017

S. No.	Bio-agents/Month	Road side												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	4.50	5.70	5.40	1.50	0.00	0.00	1.43
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	0.20	4.30	0.00	0.00	0.00	0.00	0.38
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	7.50	1.00	0.50	0.46	0.00	0.82
4.	Mealy bug	0.10	0.30	0.40	0.20	0.00	1.70	1.20	1.70	2.80	0.00	1.70	1.20	0.94
5.	Aphid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.80	1.20	1.50	2.50	0.63
6.	Ant (small/large)	0.20	0.50	0.60	0.90	0.60	0.65	0.20	0.80	1.10	1.60	0.60	0.60	0.70
7.	Spital bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.03
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	1.01	1.03	0.00	0.00	0.00	0.00	0.17
9.	Leaf miner	0.20	0.50	0.60	0.90	0.60	0.40	0.00	0.00	0.00	0.20	0.30	0.70	0.37
10.	Semilooper	0.20	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.30	0.07
11.	Lady bird beetle	0.10	0.20	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.08
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	0.40	0.50	0.20	0.50	0.60	0.90	0.60	0.40	1.70	0.40	0.40	0.40	0.58
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.02
15.	Cow bug	0.30	0.20	0.50	0.60	0.90	0.60	0.00	0.00	0.20	0.10	0.30	0.20	0.33
Total		1.50	2.30	2.63	3.10	2.70	4.25	8.05	22.03	14.40	5.50	5.46	6.39	6.53

The data shows Av. of fortnight interval

Table 1ca: Pooled mean data of the associated insects with congress grass under agro-forestry field area of IGKV campus, Raipur during 2016 &17

S. No.	Bio-agents/Month	Agroforestry												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.35	0.00	0.00	0.00	0.00	0.13
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.25	0.00	0.00	0.00	0.00	0.03
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.40	0.00	0.00	0.00	0.00	0.06
4.	Mealy bug	0.60	0.35	0.60	0.60	0.00	0.55	0.20	0.60	0.50	0.50	0.45	0.40	0.45
5.	Aphid	2.00	1.16	1.35	0.25	0.00	0.00	0.00	1.00	1.00	1.15	1.35	2.00	0.94
6.	Ant (small/large)	0.60	1.00	1.60	0.90	0.80	0.60	0.70	0.60	0.60	0.60	0.70	2.60	0.94
7.	Spital bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.51	1.03	0.00	0.00	0.00	0.00	0.13
9.	Leaf miner	0.25	0.30	0.35	0.70	0.65	0.40	0.00	0.00	0.30	0.20	0.25	0.65	0.34
10.	Semilooper	0.10	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.10	0.30	0.05
11.	Lady bird beetle	0.05	0.10	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.05
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	0.40	0.50	0.60	0.40	0.39	0.30	0.51	0.40	0.35	0.41	0.40	0.43	0.42
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.19	0.02
15.	Cow bug	0.65	0.60	0.65	0.10	0.00	0.00	0.00	0.00	0.30	0.31	0.32	0.36	0.27
Total		4.70	4.06	5.32	2.95	1.85	1.85	3.60	4.73	3.16	3.27	3.63	7.35	3.87

The data shows Av. of fortnight interval

Table 1cb: Pooled mean data of the associated insects with congress grass under field cropped area of IGKV campus, Raipur during 2016 & 2017

S. No.	Bio-agents/Month	Field cropped area												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.40	1.30	0.50	0.00	0.00	0.52
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	1.70	1.80	0.60	0.50	0.10	0.00	0.39
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.80	0.60	0.00	0.00	0.19
4.	Mealy bug	0.55	0.30	0.70	0.70	0.00	0.70	0.20	0.70	0.00	0.60	0.45	0.60	0.46
5.	Aphid	1.00	0.30	0.50	0.50	0.00	0.00	0.00	1.50	5.10	4.70	3.00	2.00	1.55
6.	Ant (small/large)	1.60	2.00	2.10	1.40	1.30	1.60	1.70	2.60	1.80	1.60	1.10	2.10	1.74
7.	Spital bug	0.10	0.09	0.19	0.27	0.50	0.34	0.30	0.01	0.00	0.00	0.00	0.00	0.15
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.	Leaf miner	0.52	0.45	0.87	0.82	0.75	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.35
10.	Semilooper	0.80	0.90	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
11.	Lady bird beetle	0.80	0.95	0.65	0.45	0.15	0.01	0.01	0.01	0.20	0.10	0.00	0.00	0.28
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13.	Spider	1.40	1.50	1.05	1.05	0.70	1.00	0.65	1.40	0.10	0.00	0.00	0.00	0.74
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
15.	Cow bug	2.30	2.20	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
Total		9.07	8.69	8.62	5.54	3.40	4.80	7.01	10.92	9.90	8.60	4.65	4.70	7.16

The data shows Av. of fortnight interval

Table 1cc: Pooled mean data of the associated insects with congress grass under road side area of IGKV campus, Raipur during 2016 &17

S. No.	Bio-agents/Month	Road side												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1.	Zygogramma (Egg)	0.00	0.00	0.00	0.00	0.00	0.00	2.00	2.40	1.30	0.50	0.00	0.00	0.48
2.	Zygogramma (Grubs)	0.00	0.00	0.00	0.00	0.00	0.00	1.70	1.80	0.60	0.50	0.10	0.00	0.36
3.	Zygogramma Adults	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.50	0.80	0.60	0.00	0.00	0.17
4.	Mealy bug	0.55	0.30	0.70	0.70	0.00	0.70	0.20	0.70	0.00	0.60	0.35	0.45	0.43
5.	Aphid	1.00	0.30	0.50	0.50	0.00	0.00	0.00	1.50	5.10	4.70	3.15	2.30	1.43
6.	Ant (small/large)	1.60	2.00	2.10	1.40	1.30	1.60	1.70	2.60	1.80	1.60	1.15	2.60	1.62
7.	Spital bug	0.10	0.09	0.19	0.27	0.50	0.34	0.30	0.01	0.00	0.00	0.00	0.00	0.14
8.	Leafhopper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9.	Leaf miner	0.52	0.45	0.87	0.82	0.75	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.35
10.	Semilooper	0.80	0.90	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
11.	Lady bird beetle	0.80	0.95	0.65	0.45	0.15	0.01	0.01	0.01	0.20	0.10	0.00	0.00	0.26
12.	Reduvid bug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

13.	Spider	1.40	1.50	1.05	1.05	0.70	1.00	0.65	1.40	0.10	0.00	0.00	0.00	0.71
14.	Canthocona bug	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
15.	Cow bug	2.30	2.20	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
Total		9.07	8.69	8.62	5.54	3.40	4.80	7.01	10.92	9.90	8.60	4.75	5.35	6.74

The data shows Av. of fortnight interval

Conclusion

The current study showed that, under the agroclimatic conditions of Raipur, Chhattisgarh, the Mexican beetle, *Zygogramma bicolorata* Pallister, is the most common and efficient herbivorous insect linked with *Parthenium hysterophorus*. The weed's strong vegetative development coincided with the beetle's clear seasonal rhythm, with oviposition starting in July and peak egg, larval, and adult populations taking place in August and September. This correlation between beetle activity and host availability highlights *Z. bicolorata*'s suitability as an effective biological control agent.

Beetle abundance was strongly controlled by habitat; roadside vegetation supported the largest population, followed by farmed fields, while agroforestry sites supported relatively smaller populations. The higher abundance in roadside habitats is probably due to limited anthropogenic disturbance, suitable microclimatic conditions, and ongoing host availability. A variety of insect species, including Aphids, Ants, mealybugs, spiders, ladybird beetles, leaf miners, leafhoppers, semiloopers, reduviid bugs, and canthocona bugs, were observed on *P. hysterophorus* in addition to *Z. bicolorata*, suggesting that the weed supports a varied arthropod ecosystem.

The results attest to *Z. bicolorata*'s successful establishment in central India's climatic conditions and its significant potential for long-term *P. hysterophorus* suppression. Beetle population conservation and augmentation could significantly improve the efficacy of biological control programs while lowering reliance on chemical weed management, especially in roadside and other undisturbed habitats during the monsoon season. In order to establish integrated, environmentally sustainable management strategies for *P. hysterophorus* in central India, the study offers important ecological data on the seasonal abundance and habitat-wise distribution of *Z. bicolorata*.

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