Nagpur Shikshan Mandal's
SHRI MATHURADAS MOHOTA COLLEGE OF SCIENCE
Nagpur - 440009

Final Report

of

MAJOR RESEARCH PROJECT

on

"BIOLOGICAL BASED INTEGRATED *PARTHENIUM* MANAGEMENT TO SAVE ENVIRONMENT, HEALTH AND BIODIVERSITY IN NAGPUR"

Submitted to

University Grants Commission
Bahadur Shah Zafar Marg,
New Delhi- 110 002

By

Dr. (Mrs.) Rina S. Saha
(Principal Investigator)
M. M. College of Science, Nagpur

Period of Report

April 2013- March 2017

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UNIVERSITY GRANTS COMMISSION

BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. **Title of the Project:** "Biological based integrated *Parthenium* management to save environment, health and biodiversity in Nagpur"

2. **NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR:**

   Name: Dr. (Mrs.) Rina S. Saha

   Address (Office): S. M. Mohota College of Science, Sakkardara Square, Umred Road, Nagpur, Maharashtra-440009

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3. **NAME AND ADDRESS OF THE INSTITUTION:** Shree Mathuradas Mohota College of Science, Sakkardara Square, Umred Road, Nagpur, Maharashtra-440009

4. **UGC APPROVAL LETTER NO. AND DATE: F.No.** 42-624/2013 (SR) **dated** 31st March 2013

5. **DATE OF IMPLEMENTATION:** 01st April 2013

6. **TENURE OF THE PROJECT:** 03 Years (From 01.04.2013 To 31.03.2016) + 01 year extension (From 01.04.2016 to 31.03.2017)

7. **TOTAL GRANT ALLOCATED:** Rs. 9,52,800/-

8. **TOTAL GRANT RECEIVED:** Rs. 5,98,800/- (1st Installment)

9. **FINAL EXPENDITURE:** Rs. 9,29,764/-

10. TITLE OF THE PROJECT: "Biological based integrated *Parthenium* management to save environment, health and biodiversity in Nagpur"

11. OBJECTIVES OF THE PROJECT:

The project has four objectives;

1. Collect accurate information on the distribution, and spread of *Parthenium* in Nagpur and assess its socio economic impact in agriculture;

2. Determine the effect of *Parthenium* on plant diversity;

3. Evaluate and release insect agents for the control of *Parthenium;*

4. The major focus of this new project is to rear, release and assess the impact of *Zygogramma* in Nagpur urban region.

12. WHETHER OBJECTIVES WERE ACHIEVED: Yes

13. ACHIEVEMENTS FROM THE PROJECT:

a. A technique have been developed for mass multiplication of the host specific beetle *Zygogramma bicolorata* to control the *Parthenium hysteroporus* locally called Gajar ghas.

b. The technology generated by our project is being adopted by the some farmers.

c. The Mexican beetle *Zygogramma bicolorata* was successfully adopted and acclimatized in the natural climatic conditions of the Nagpur, Maharashtra.

d. Environmentally beneficial competitive plants like cassia tora and Marigold for the growth of *Parthenium* was successfully grown in *Parthenium* infested areas of Nagpur.

e. Five research papers have been published in reputed journals.

14. SUMMARY OF THE FINDINGS:

Parthenium hysterophorus L. (family: Asteraceae), a pernicious exotic weed, is known as parthenium, carrotgrass, congressgrass, star weed, white top, etc. It is a native of Mexico, America and West Indies, spread to Australia, Africa, India, China, Israel, Taiwan, Nepal, etc. Now days, it has been considered as one of the worst weeds responsible for causing health problems in men and animals besides loss to crop productivity and plant biodiversity. It is not just a weed that reduces crop yield, but also causes health hazards in human and livestock besides narrowing biodiversity. Hence, it is an evil that is not leaving anything without harm. Thus, thorough understanding about biology and how to get rid of this menace is of utmost importance in present as well as future perspectives.

Systematic field surveys for *parthenium* weed and *Z. bicolorata* were carried out throughout Nagpur region of central India during 2013-2017. The surveys followed the major road networks out from the core infestation of parthenium weed. Wastelands and cropped areas outside of the core infestation were also surveyed for its density per square metre, Plant height, shoot length, root length, stem diameter and plant biomass.

For the control of *Parthenium hysterophorus v*arious methods, for example, physical, chemical and biological are being practiced. In an attempt of biological control we found that the Mexican beetle *Zygogramma bicolorata* is an effective biological control agent of *Parthenium hysterophorus* as it feeds mainly on this weed. The egg, larval and adult stages of the beetle were collected from the field. Mass rearing of the beetles was undertaken in laboratory condition at 27 ± 2^{0}C Temperature and 65±5% Relative Humidity in Biotechniques B.O.D. incubator. After the successful multiplication of the life cycle, the beetles were released in *Parthenium* invaded field and monitored for the three consecutive years. The abundance of *Parthenium* in the infested area is declined after three months of application of *Z. bicolorata.* At the start of second year we found that, the adults of Mexican beetles were emerged out from the soil indicated that the insect was successfully acclimatized in the climate of Nagpur region.

In the present study, the stress of high and low temperature (20^0C & 32^0C) as compared to normal (Control at 27^0C) was investigated on the reproductive performance and different life cycle stages of the mexican beetle *Zygogramma bicolorata*. Potential fecundity (number of eggs matured) and realized fecundity (number of eggs laid) are both influenced by temperature variation. Fecundity and per cent egg viability increased significantly with increase in the temperature from 20^0C to 27^oC and thereafter declined with further increase in temperature. The development and survival of different life stages were also affected by the temperature stress. Egg hatching (in days), larval period, pupal period were affected by the temperature variation. The ideal temperature for the maximum egg laying, high percentage of egg hatching, maximum survival and complete development were recorded at 27 ± 2^0C.

The biological control through competitive plants was checked with the search of Cassia sericea which lead to more attempts to manage *Parthenium* by competitive plant species. Casia tora and C. sericea have been found to be most suitable plant species for management of *Parthenium* in wasteland, on the raod side and community land.

Nevertheless the weed has not been completely checked and is still creating nuisance in Nagpur region, because of high regeneration capacity, large seed production ability, germination ability throughout the year and extreme adaptability of Parthenium in wide range of ecosystem. The *Z. bicolorata* has been proved to be a successful bioagent but this bioagent alone is not sufficient to manage Parthenium because of the reason that this beetle is able to make sufficient population build up only during July to September in the area where monsoon rains are received. But, *Parthenium* is able to germinate throughout the year. Augmentation of *Z. bicolorata* can be achieved through mass multiplication. More concentrated efforts are needed to mass multiply *Z. bicolorata* throughout the season.

15. CONTRIBUTION TO THE SOCIETY:

- By the biological control, a ecofriendly approach for the control of *Parthenium hysterophorus* have been developed in important ecosystems like westland, community land and forest areas for the human health, animals and biodiversity.

- The use of chemical herbicides is reduced due to the adoption of biological control method which will saved biodiversity in the form of environmental safety and sustainability.

- It is economically beneficial to the farmer as they control the weed *parthenium hysterophorus* in a very low cost and increase their crop production.

- The "Lab to land" strategy of research have been done through this project

16. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT: No

17. NO. OF PUBLICATIONS OUT OF THE PROJECT: 05 (Five)

Dr. (Mrs.) Rina S. Saha **Dr. S. G. Charalwar**

(Principal investigator) (Principal)

BIOLOGICAL BASED INTEGRATED *PARTHENIUM* MANAGEMENT TO SAVE ENVIRONMENT, HEALTH AND BIODIVERSITY IN NAGPUR

INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L.) is an annual herb of Asteraceae family, originating from tropical Americas and now a weed of global significance in many countries around the world (Dhileepan, 2009). It is not just a weed that reduces crop yield, but also causes health hazards in human and livestock besides narrowing biodiversity. Hence, it is an evil that is not leaving anything without harm. It reduces crop and pasture productivity, reduces native plant community biodiversity and negatively affects human and animal health (Nath, 1981; McFadyen 1995; Shabbir & Bajwa 2006). In India, it was first noticed in Pune (Maharashtra) during 1955 as a stray plant on the garbage. But in a short period, it has spread all over Pune covering wastelands, railway yards, marshy patches, fallow cultivable lands, grasslands, roadsides, along the canals and other areas.

Control of *Parthenium* in most areas of the world is by chemical, physical or by biological methods. The chemical herbicides prohibits their use in perennial grasslands and its high cost. When individual *Parthenium* weeds are found, or the weed is a problem in certain crops, control can be achieved by using 2,4-D or residual herbicides such as atrazine (Holman 1981). Control can be achieved by maintaining good grass growth to maximize competition against the weed; this is achieved is by lowering stocking rates (Holman 1981). Biological control is feasible and the search for natural control agents is on-going in Australia and India.

A leaf defoliating beetle, *Zygogramma bicolorata* Pallister (Chrysomelidae: Coleoptera), was found in forest reserves of central india. The *Z. bicolorata* had been tested and released as a classical biological control agent in 1980 in Queensland, Australia, where this biological control agent had a significant effect on *parthenium* weed (Dhileepan, 2001/2003). The beetle was independently tested and released as a biological control agent against *parthenium* weed in India in 1984 (Jayanth, 1987). To date, there is very little data on present distribution of *Z. bicolorata* in the core *parthenium* weed infestations of central India. The main objective of this study was to

record the current distribution of *parthenium* weed and its biological control agent, *Z. bicolorata*, in central India to aid in future weed management planning.

OBJECTIVES OF THE PROJECT:

The project has four objectives;

5. Collect accurate information on the distribution, and spread of *Parthenium* in Nagpur and assess its socio economic impact in agriculture;
6. Determine the effect of *Parthenium* on plant diversity;
7. Evaluate and release insect agents for the control of *Parthenium;*
8. The major focus of this new project is to rear, release and assess the impact of *Zygogramma* in Nagpur urban region.

METHODOLOGY:

- **Study Area:**

The present research work was conducted in Nagpur, Maharashtra india. It is located at North Latitude- 210.07'; East longitude- 790.07' Height above mean sea level- 312.42 mtrs and practically at geographical center of India. All major highways NH-7 & NH-6 and major railways trunk route (Mumbai, Chennai, Howrah and Delhi) pass through the city. Important Central & State Government offices and institutions are located in Nagpur. Industrial Development is existing along the fringe areas like Kamptee, Hingna, Wadi, Khapri, Butibori and Kalmeshwar.

The surrounding region is an undulating plateau rising northward to the Satpura Range, from 889 to 2,142 feet (271 to 653 m) high and is drained by the Kanhan and Pench rivers in the center, the Wardha in the west, and the Wainganga in the east. Both these rivers later merge as tributaries into the Godavari river. The soil is fertile black in the west and the north and alluvial in the east. The average annual rainfall is 45 inches, with more rain in the east than in the west. In the west, the hills are forested.

- **Field Survey:**

Systematic field surveys for *parthenium* weed and *Z. bicolorata* were carried out throughout Nagpur region of central India during 2013-2017. The surveys followed the major road networks out from the core infestation of *parthenium* weed. Wastelands and cropped areas outside of the core infestation were also surveyed. The presence and absence of *parthenium* weed and *Z. bicolorata* was recorded. If *parthenium* weed was present, its density per square metre, Plant height, shoot length, root length, stem diameter and plant biomass were also recorded.

- **Sampling description**

In each site one field site was randomly selected for data collection. Distribution of the *Parthenium hysterophorus* weed was determined as presence or absence of the weed in the crop lands, grazing lands, along roadsides and near residential areas. Quadrates were used to determine number of *parthenium* weeds in

each of the selected field; and 30 quadrates were randomly located at approximately 3 m intervals throughout the 75 m length of the field. Number of *parthenium* weeds was counted within 30 randomly placed quadrates (1 m x 1 m) across the 30 m x 75 m of the fields. Density frequency and abundance, of *parthenium* weeds were determined in a total of 30 (1 m x 1 m) quadrates. Density, frequency and abundance of *parthenium* weeds were determined by the formula described by El-Azazi *et al*.

$$Density = \frac{\text{Total No. of } Parthenium \text{ weeds in all quadrants}}{\text{Total No. of quadrant used}}$$

$$\%\ \text{frequency} = \frac{\text{Total No. of quadrant in which } Parthenium\ weed\ occur}{\text{Total No. of quadrant studied}} \times 100$$

$$Abundance = \frac{\text{Total No. of } Parthenium \text{ weeds in all quadrants}}{\text{Total No. of quadrant in which } Parthenium\ weed\ occur}$$

- **Establishment of Laboratory and Stock culture**

The temperature and humidity control rearing room was established in Mathuradas Mohota College of Science, Nagpur. Adults of *Z. bicolorata* were obtained from *Parthenium* plants during July to August in the laboratory and temporarily rearing of it were carried out under desire environmental factor. Beetles were reared in the plastic jars and fed daily on excised leaves of *Parthenium* weed at 27±2^{0}C Temperature and 65±5% Relative Humidity in Biotechniques B.O.D. incubator. The wilted leaves were replaced daily with fresh ones. Newly hatched larvae were reared in petriplates and when fully grown were transferred to plastic jars filled with moist sand, for pupation. Freshly emerged adults from the stock culture were isolated for use in experimental work according to the work plan of project for the year 2013-2017 was carried out as follows (Figure 1 A).

- **Experimental set-up to study the biology, life cycle and effect of temperature variation on reproductive attributes and life cycle of Mexican beetle *Z. bicolorata***

Freshly emerged adult beetles were sexed and 10 replicates consisting of 3 female and 2 male each were taken out from stock culture and placed in each plastic petriplates (9.0 × 2.0 cm) maintained at 20±2^{0}C, 27±2^{0}C and 32±2^{0}C, and 65±5%

Relative Humidity in Biotechniques B.O.D. incubator containing fresh *Parthenium* leaves (Figure 1 B).

The beetles were allowed to mate and eggs laid each day were counted and transferred to another petriplate in aseptic condition at the same temperature. Eggs were checked daily for hatching and empty egg shells were counted to assess hatching success. Pair of male and female beetles was maintained on *Parthenium* weed diet and reproductive attributes like pre-oviposition period, oviposition period, post-oviposition period, total fecundity and per cent egg viability were recorded.

To study the life cycle, duration of each stages of life history the larval hatch was recorded each morning. During larval development, cast exuviae were noted and removed daily to determine the number of moults, the duration of each stage and the survival rates of various developmental stages. Fully grown grubs were transferred from petriplates to plastic container (6.5 × 9.5 cm) filled with sand for pupation at the same temperature. The number of first, second, third and fourth instars and the periods of different instars prior to adult emergence were recorded. Newly emerged beetles were sexed and further released on the *Parthenium* plant.

Fig. 1(A) - Stock culture in natural condition; 1(B) - Experimental setup in laboratory condition

- **Analysis of food utilization efficiencies**

For these purpose the male and female of *Z. bicolorata* were collected from the field and reared in caged potted plants of *P. hysterophorus* and multiplied for laboratory experiment. A gravimetric method was used to estimate quantitative food utilization and food utilization efficiencies were computed following Waldbaueur (1968).

- **Biochemical studies of *P. hysterophorus* leaves**

Leaves of *P. hysterophorus* of different ages (young, mature and senescent) were subjected to analyses for total proteins (Lowry *et al.* 1951), carbohydrates (Dubois at al. 1956), lipids (Folch *et al.* 1957 and phenols (Bray and Thrope 1954).

- **Scanning electron microscopic studies**

Scanning electron microscopic studies to understand the nature of sensory structures present in the antennae and mouth parts were made through SEM studies. The mouth parts and antennae were dissected from fresh, etherized specimens, dehydrated in increasing grades of alcohol and fixed to aluminum stub using double baked tape and then coated with gold for 2-3 minutes in a ion coater. Scanning electron micrographs were taken under 15 KV emissions current at Visvesvaraya National Institute of Technology (VNIT), Nagpur.

OBSERVATIONS AND RESULTS

A. Distribution, and spread of *Parthenium* in Nagpur

Parthenium weed was found growing in crop lands, grazing lands, residential areas and alongside the road at Nagpur (Figure 2). Results of the present study show that *parthenium* weeds invasion was found in grazing land, crop lands and along the road sides. The mean number of *parthenium* weeds were significantly between grazing lands, crop lands. Invasion and distribution of *Parthenium* weed in Nagpur might be due to ecological and morphological characteristics of the weed that enable to adapt a wide climatic and soil conditions, photo insensitivity, and drought tolerance (Khan, *et al.,* 2014). The weed has short life cycle of 3-4 weeks that might contributed to the rapid spread in different areas in Nagpur. Furthermore, *parthenium* weed produce large number of seeds 15, 000 to 25, 000 per plant) which are small in size and light in weight. With these characteristics the seeds can spread over long distances through moving water, winds and animal and human dispersal. Results of this study correspond to the findings of the previous studies (Khan, *et al.,* 2014; Javaid, *et al.,* 2011) who found that *parthenium hysterophorus* weed invaded and spreads on road sides, residential, crop and grazing lands in Tanzania and Ethiopia.

Data from the field survey shows that the highest *parthenium* weed densities were recorded in grazing land, crop land and alongside road at Nagpur. The percentage frequency of occurrence of *parthenium* weed alongside road, grazing and crop lands was high at some sites compared to other. The highest population and wide spread of *Parthenium* weed at Rubwera and Kagenyi might be attributed to soil disturbance due to construction of road, agricultural practice and lack of natural enemies of *parthenium* weed (Khan, *et al.,* 2014).

In three surveyed villages, *parthenium* weed was observed along the road side, crop and grazing lands. The presence of this weed alongside road might have helped the dispersal and spread of *parthenium hysterophorus* weed in crop and grazing lands in Nagpur. Also the quick spread of *parthenium* weed in non-infested areas of Nagpur could be attributed to dispersal of seeds by winds, water movement, animal and human activities such as using the weed as groom for cleaning the environment at residential areas.

Figure 2: Photographs of the *Parthenium* infested areas in Nagpur

B. The biology of *Parthenium* weed

Parthenium weed is an annual or short-lived perennial, growing up to 2 metres tall. Several aspects of the ecology of *parthenium* weed contribute to its success, including the production of large numbers of seeds, the ability to form large and persistent soil seed banks, the longevity of the seeds when buried, rapid germination and emergence rates, and a seed dormancy mechanism. These attributes facilitate the species' persistence in seasonally dry habitats.

As *Parthenium* weed does not reproduce vegetatively, the only method of reproduction and dispersal is by seeds (Figure 3 and 4). Although wind-dispersal is limited, dispersal of seeds in flowing water is much more significant. Most long-distance dispersal of seeds is by vehicles and farm machinery, as evidenced by the major spread of *Parthenium* along roads and the large numbers of seeds found in wash-down slurry pits. A period of drought followed by rain provides ideal conditions for germination. Drought reduces pasture cover (competition) and increased movement of stock and stock fodder also helps to spread the seeds. In particular, heavy rain after drought is advantageous to the weed because floodwater disperses the seed and mud allows the seed to stick to vehicles.

In summer, in ideal conditions, plants can flower and produce seeds four weeks after germination. Buried seeds can remain viable much longer than seeds on the soil surface. Timing of chemical control is critical to ensure that *Parthenium* weed is removed when plants are small and have not produced seeds, and when grasses are actively growing and seeding to decolonize the infested area (e.g. in early summer). Studies suggest that after six years, 50% of seeds buried 5 cm below the surface remain viable (Navie *et al.* 1998b). However, unlike other weed species, there is no critical point where intervention is required, because *Parthenium* weed can produce flowers and seeds at any time of the year under favorable conditions.

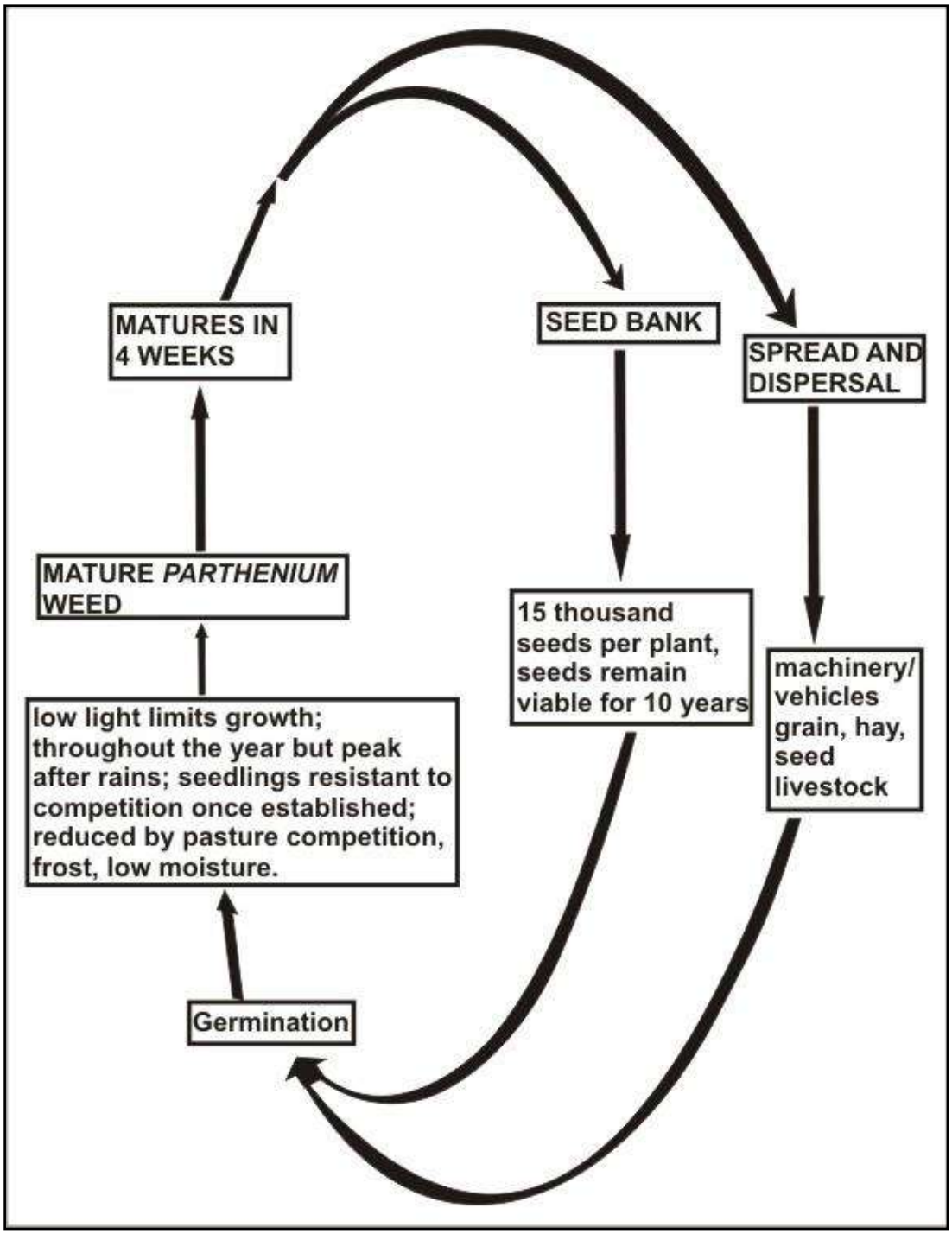

Fig. 3: Diagramatic representation of life cycle of *Parthenium hysterophorus*

C. Harmful effects of the *Parthenium hysterophorus*:

Parthenium weed affects a range of land uses, human health and the environment as summarized below.

Primary production

Pasture production is reduced because *Parthenium* weed competes with beneficial forage plants; estimated cost is $109 million per year. The weed is toxic to cattle and may cause death after 30 days if significant amounts are consumed.

Health

Dermatitis, hay fever and asthma can be managed by over-the-counter antihistamine medications but are not always effective. Stronger, prescription-only drugs can have a sedative effect that may result in a potential accident risk and occupational health issues for people operating machinery. Where sensitisation has developed, any contact with contaminated clothing or airborne plant fragments may exacerbate the allergy.

Environment

Infestation of *Parthenium* weed can degrade natural ecosystem because it has a very high invasive capacity and allelopathic properties which has the potential to disrupt any type of natural ecosystem. There was a sharp decline in the native biodiversity index, evenness and species richness over the time, clearly indicating the threat of *Parthenium* on native biodiversity of other weeds. Its allelopathic effect coupled with absence of natural enemies like insects and diseases are the two important factors responsible for its spread in India.

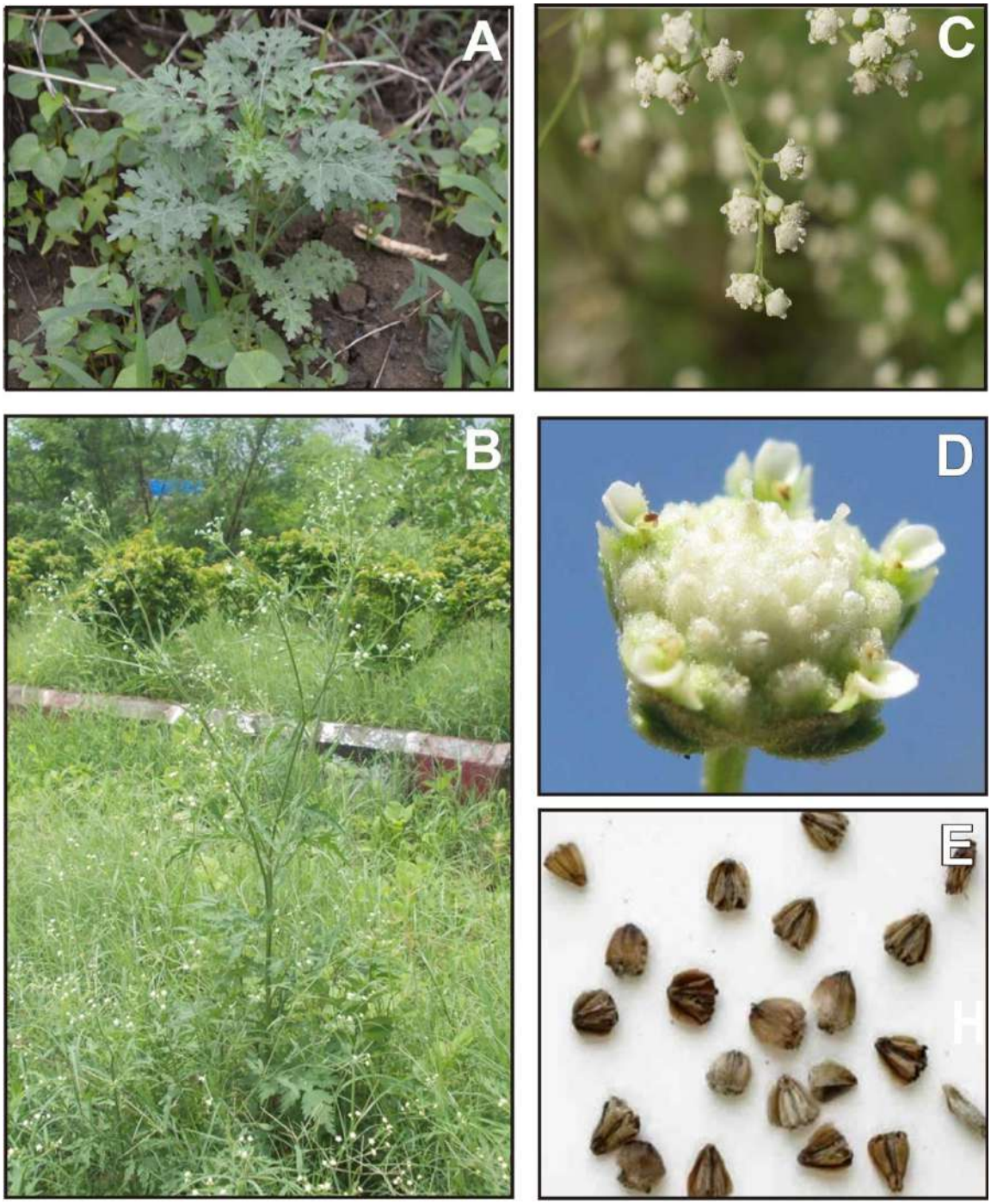

Figure 4: Different life stages of *Parthenium hesterophorus*

A. Seedling, **B.** Mature *Parthenium* plant, **C.** Inflorescence, **D.** Mature flower, **E.** Seeds

D. Control of *Parthenium hysterophorus*:

Control In most areas of the world the high cost of herbicides prohibits their use in perennial grasslands. Control can be achieved by maintaining good grass growth to maximize competition against the weed; this is achieved is by lowering stocking rates (Holman 1981). When individual *Parthenium* weeds are found, or the weed is a problem in certain crops, control can be achieved by using 2,4-D or residual herbicides such as atrazine (Perth Mathukia 2013). Biological control is feasible and the search for natural control agents is on-going in Australia and India.

Biological Control:

Biological control is the international manipulation of natural enemies by man for the purpose of controlling harmful weeds. *Parthenium* is mainly a weed of waste and fallow lands; hence biological control is most economical and practical way to keep the weed under check.

- By competitive plants
- By using microorganisms
- By using biocontol agents

Biological control by using Mexican beetle *Z. bicolorata* a biocontrol agent of *P. hysterophorus:*

I. Biology of Mexican beetle *Zygogramma bicolorata*:

- Peak Period- July to October
- 3-4 Cycles in one season
- During October to November it goes into diapause and remain in diapause for 6-7 months
- *Life cycle of* Mexican beetle *Z. bicolorata* comprises egg, four larval instars, pupa and adult stage.

II.Life cycle:

Figure 5 shows all the life stages of mexicam beetle *Z. bicolorata* which are described as follows.

The Eggs:

Eggs of *Z. bicolorata* are oblong in shape, elongated, smooth and the surface was finely reticulated. They varied from light yellow to yellowish orange in color. Yellowish orange colored eggs turned slightly reddish just before hatching. These observations are in accordance with the description made by Pandey *et al.* (2001).

I and II Instar Larvae:

Newly hatched larvae were yellowish in color and gradually turned creamy white with the advancement in age. Head was yellowish and larval body was covered with minute hairs and slightly curved with protrusible proleg like structure at the posterior end of body. First and second instar larvae were similar in their appearances except in size. In case of first instar larvae, a faint line located centrally on dorsal side of larval body was visible while body segments were not easily distinguishable. All the body segments were distinguishable in second instar.

III and IV Instar Larvae:

Third and fourth instar larvae could be easily differentiated from the earlier instars by their spiracles. Nine pairs of spiracles were seen on the thoracic and abdominal region of the third instar larvae. Dorsal surface of the larvae had irregular shaped and colored mosaic pattern. There were scattered setae on larval body. A set of six, black, button like spots were clearly visible on each lateral side of head. These spots were situated just below the base of antennae. Larval body in this instar was more curved than the earlier instars. These posterior abdominal segments were reduced in their size as compared to remaining abdominal segments. Fourth instar larvae were found to be similar in appearance as like third instar, except in size. Larval body became more convex in this instar (Pawar and Khorat 2013).

Pupa:

Fully-grown larvae remained as pre-pupae for about a day before entering in the pupal stage. They pupated in the soil within the self created earthen chamber. The pupae were exarate type and yellowish in colour. Saruk (2001) also reported exarate type pupae of the beetle which is in agreement with the present finding. Body surface of the pupae was transparent and creamy-white.

Adult:

Adults were elongate and oblong in shape. Dorsal surface was strongly convex and glabrous. Head was black in color. These insects bear dark brown or blackish lines on elytra that run longitudinally over an off-white black- ground. The pattern of longitudinal markings on the elytra was not uniform. Prominent blackish elongated spot was observed at the base of each elytra. However, longitudinal markings on the elytra were found to be varying in beetles. The black marking originated at the costal margin of elytra was found either as serpentine fashion or somewhat bifurcate type. Similar description regarding elytra marked with dark brown longitudinal lines has been made by Pandey *et al.* (2001). Hind wings were transparent and folded beneath the elytra. Costal and sub-costal veins of hind wings were reddish-brown in color.

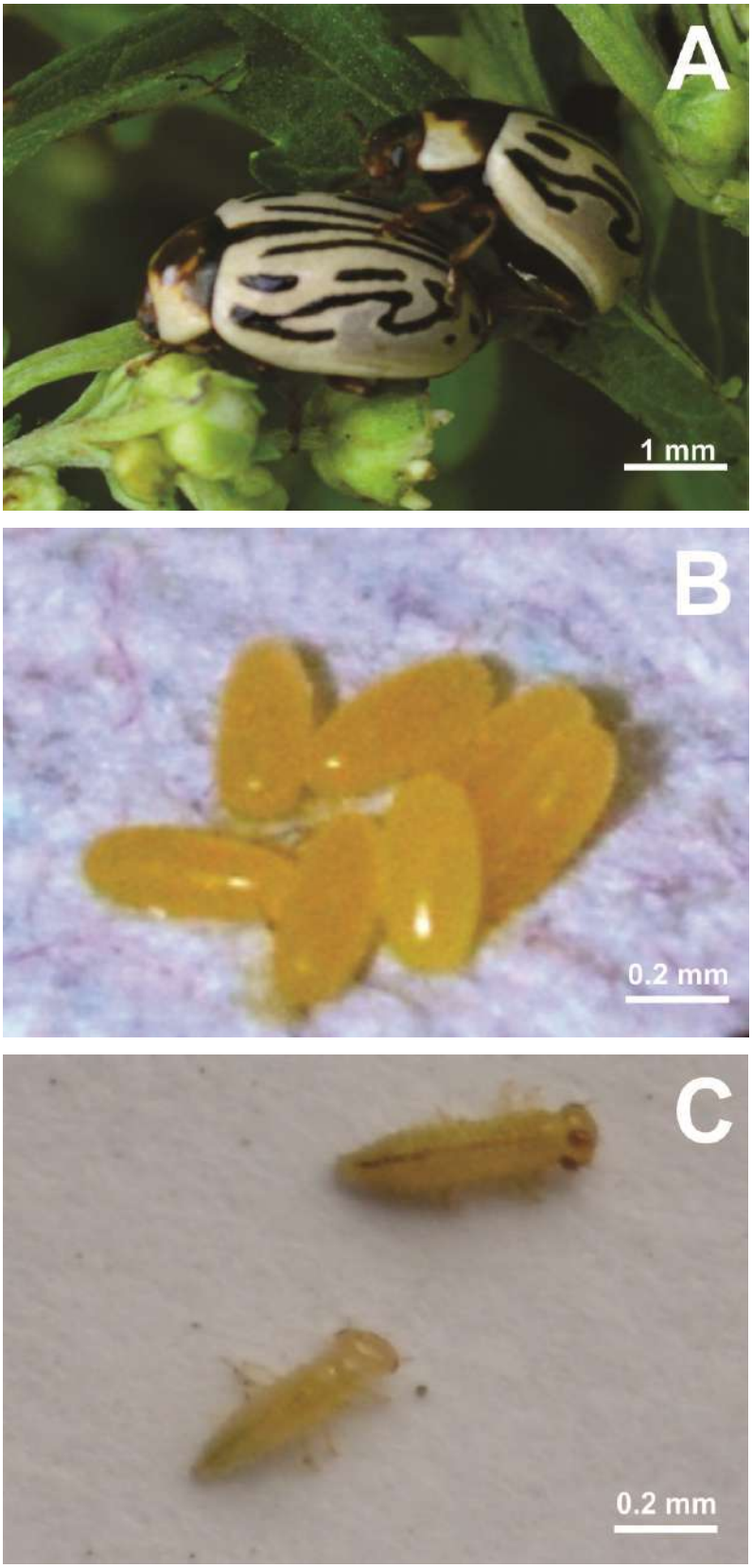

Fig. 5: Different life stages of Mexican beetle Z. bicolorata, A. Adult male and female, **B.** Eggs and **C.** I Instar larvae

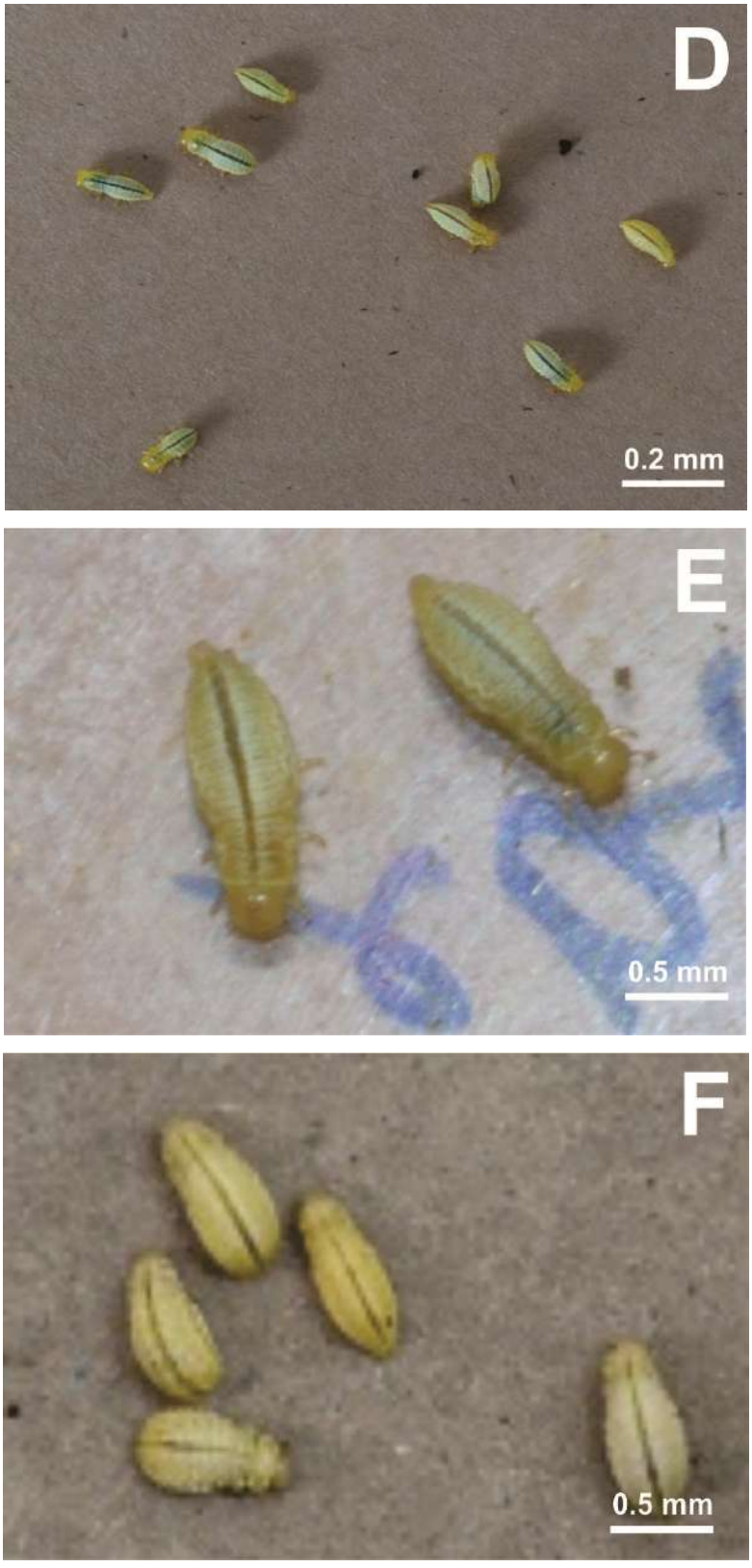

Fig 5: Different life stages of Mexican beetle Z. bicolorata, D. II Instar larvae, **E.** III Instar larvae and **F.** IV Instar larvae

Fig. 5: Different life stages of Mexican beetle Z. bicolorata, G. Fully grown adult ready to pupation and **H.** Pupa

III. Effect of temperature variation on reproductive behavior and development of *Z. bicolarata*:

In *Z. bicolorata*, the developmental period of all the immature stages are shown in table 1 and all the stages were affected due to temperature variation. A decrease in total developmental period was recorded with an increase in temperature from 20^0C to 32^0C. Data from table 1 clearly indicate that the larval development period was around 20 days at 20^oC and it went on decrease at 27^oC (around 18 days) and at 32^oC (16.50 days). Thus, the larval development was accelerated with the

increase in temperature. First instar larvae suffered the highest mortality, while the pupal stage had the lowest mortality at all constant temperatures. These results established that temperature plays a determining role in the development and survival of the life history stages of *Z. bicolorata.* The role of temperature in influencing all levels of biological organization in phytophagous insects has been previously proved by Ivanovic and Nenadovic (1999) and S. R. Pawar *et al.* (2013) and they reported that potential fecundity (number of eggs matured) and realized fecundity (number of eggs laid) are both influenced by temperature.

The effects of temperature variation on the reproductive attributes of the Mexican beetle *Z. bicolorata* are shown in table 2. The results revealed that all the reproductive attributes i.e. Preoviposition period, oviposition period, postoviposition period, fecundity and egg viability were influenced significantly due to temperature (Table 2). The number of egg laying female^{-1} in its complete life span was found to be the highest at 27^{0}C (987.30 eggs female^{-1}) and it fells down with increase or decrease in temperature from 27^{0}C to 32^{o}C (679.90 eggs female^{-1}) and 27^{0}C to 20^{0}C (608.50 eggs female^{-1}) (Manjunath 2010; Brajesh mishra *et al.* 2012.

Temp. (^{o}C)	Egg hatching (days)	I larval period (days)	II larval period (days)	III larval period (days)	IV larval Period (days)	Pupal period	Total development period (days)
At 20±2^{o}C	5.36± 0.43	5.25± 0.138	4.824± 0.247	5.1± 0.16	4.28± 0.238	12.30± 0.60	37.11± 1.813
At 27±2^{o}C	4.40±0.43	4.873±0.24	4.32±0.34	4.55±0.16	3.49±0.318	9.90±0.59	31.533±2.078
At 32±2^{o}C	3.82±0.30	4.19±0.209	3.84±0.23	3.89±0.18	3.57±0.268	8.90±0.38	28.21±1.567

Table 1: Effect of temperature variation on the larval developmental period of the Mexican beetle *Z. bicolorata*

Temperature (^{o}C)	Pre-oviposition period (days)	Oviposition period (days)	Post-oviposition period (days)	Fecundity	Egg viability (%)
At 20±2^{o}C	13.10±0.31	87.80±1.40	21.50±0.78	608.50±18.33	65.40±1.69
At 27±2^{o}C	7.10±0.38	63.00±1.20	14.40±0.69	987.30±15.56	89.20±1.51
At 32±2^{o}C	9.60±0.31	31.40±0.99	17.40±0.60	679.90±13.79	60.30±1.67

Table 2: Effect of temperature variation on the reproductive attributes of the Mexican beetle *Z. bicolorata*

The decrease in the incubation period of *Z. bicolorata* with increase in temperature probably results from accelerated embryogenesis, causing early hatching of neonate instars. In phytophagous insects, temperature probably has an indirect action on a host plant that accelerates/decelerates its development and changes the qualitative and quantitative composition of nutritious matter, as well as of allelochemicals (Ivanovic and Nenadovic, 1999). The reduction in larval period with increase in temperature owing to increased metabolic activity and feeding activity has also been suggested in predaceous coleopterans (Srivastava and Omkar, 2003 and Omkar and Pervez, 2004). It is probable that the pupa spent more of its time in soil at 20^0C so as to avoid the low ambient temperature. The soil probably works as a protective layer. Exposure to higher temperature reduces the developmental period of different immature stages and consequently increases the developmental rate, was also reported in other studies (Obrycki and Tauber, 1982; Ali Khan and Yousuf, 1986; Orr and Obrycki, 1990; Ponsonby and Copland, 1998 and Levesque *et al.*, 2002).

IV. Feeding behavior of *Z. bicolorata*

The exotic monophagous beetle *Zygogramma bicolorata* feeds voraciously as larvae and adults on *Parthenium hysterophorus.* Studies relating to the pattern of food utilization, feeding behavior and different food choice indicate there performance for young leaves which results in high fecundity and better multiplication rate enabling easier mass production of *Z. bicolorata* under laboratory condition. A possible correlation is also indicating between host preference in terms of such biochemical parameters of the host plants. And the consequent change in the reproductive ability of the insect. Reproductive potential, relative food utilization efficiency within the host plant leaves, survival of larvae and adult, and host plant suitability based on biochemical composition are important parameters which have been studied. Observation present here relate to these aspects, which are of considerable relevance in the biological control programme.

The events encountered during the feeding behavior of *Z. bicolorata* provided in figure 6. Adults tended to hide on the adaxial side of the leaves, exhibiting very sluggish movements, and were observed flying occasionally to adjacent leaves of branches. While feeding, the leaf edges were cut first and then swallowed, result in loss of several leaf bits; only one third of the damaged leaf area was swallowed. The

preference of larvae and adults was: young leaves, followed by mature leaves and senescent leaves. Group feeding among larvae was a common feature and they preferred terminal buds.

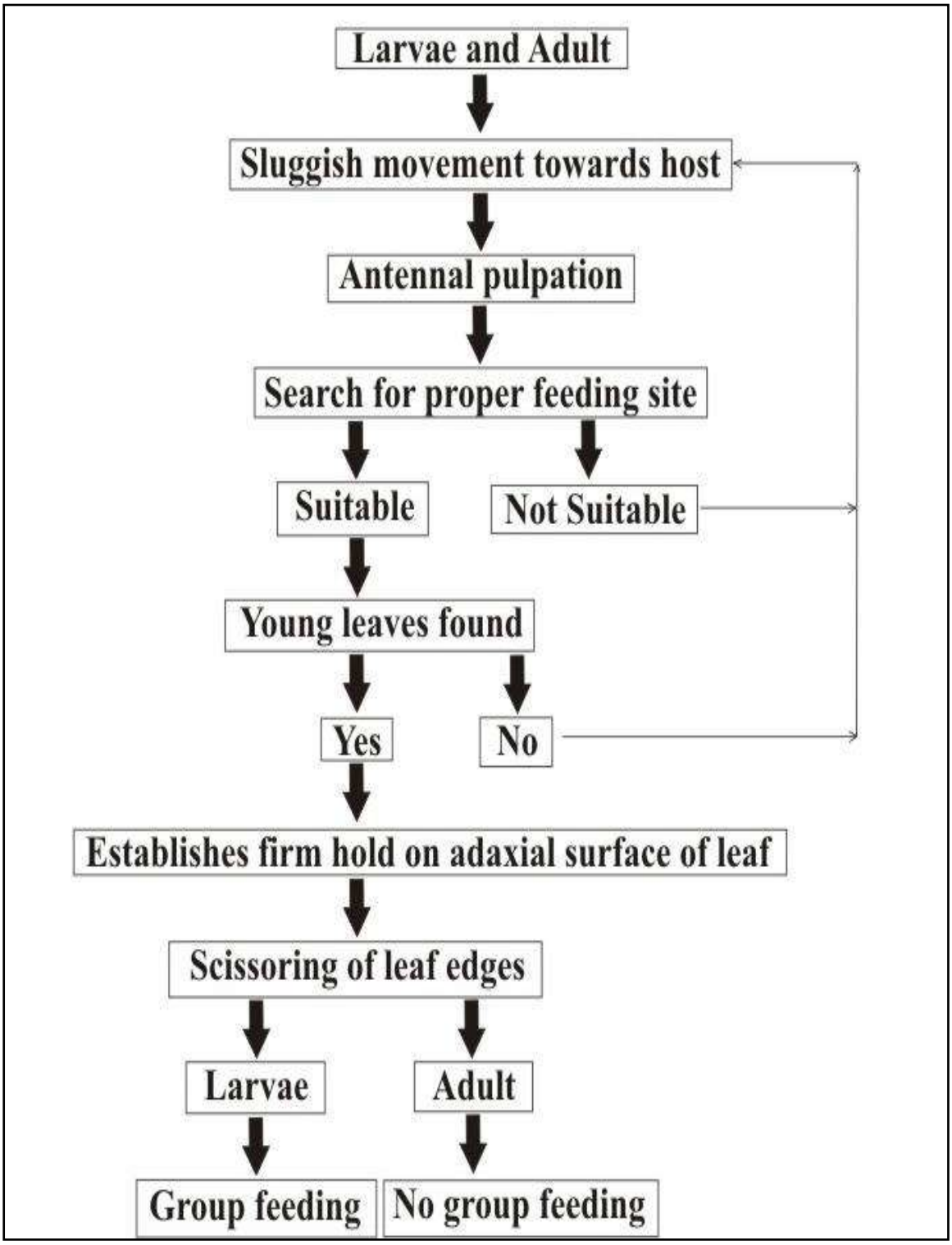

Fig. 6: Flow chart showing feeding bahaviour og *Z. bicolorata*

V. Quantitive food utilization:

The quantity of food utilized by *Z. bicolorata* and food utilization efficiencies are provided in table 3 the amount of food ingested was maximum on young leaves of *P. hysterophorus* (80.045±0.005 gm) and senescent leaves (0.027±0.002 gm). The same trend was followed with consumption index (CI) as for food utilization, but the growth rate was higher with mature leaves (0.04±0.007; 0.02±0.001). However the efficiency of conversion of ingested food (ECI) were maximum on young leaves, followed by mature and senescent leaves.

VI. Growth, Longevity and Survival:

Growth, longevity and survival appeared to be important parameters in assessing the qualities of host plant parts. The leaves of different ages had a marked influence on the growth, longevity and survival of *Z. bicolorata.* Adult females weighed about 41.21±0.02 mg when fed with young leaves; individuals fed with senescent leaves weighed only 33.66±0.95 mg. mature leaves (38.37±0.87 mg) did not affect growth as much as senescent leaves. This trend was discernible in all over stages of *Z. bicolorata*, indicating the suitability of young leaves for successful development. The longevity of adults and larvae of *Z. bicolorata* had a marked dependence on the quality of the leaves they feed on. Females fed with young leaves of *P. hysterophorus* lived for 122±2.8d, whereas males lived only for 103±1.4d. Whereas males survived only for 89±2.8d. Senescent leaves were least suitable. The larval duration exhibited a similar trend to that of the adults. Larvae which fed on very young leaves pupated within 28±3.2d. However, larvae which fed on mature and senescent leaves required 33±2.8 and 37±1.1d respectively for pupation. Larval survival on senescent, mature and young leaves was 36, 58.62 and 98%, respectively. Adult survival followed the same trend, but was affected less (Table 4).

VII. Chemical composition of host leaves:

The quantitative analysis of protein, carbohydrate, lipid and phenol indicate some stricking relationship among the different leaf stages. A young leaf has low proteins, carbohydrates and phenols and high lipids. The mature leaves showed a higher trend than the young leaves and senescent leaves showed the highest nutrient concentration (Table 5).

Host leaves	Amount of food ingested (gm)	Wt. of faces (gm)	CI	GR	AD (%)	ECD (%)	ECI (%)
Young	0.049±0.0038	0.007±0.0003	1.84±0.24	0.022±0.0017	85.49±1.21	6.78±0.41	12.39±2.08
Mature	0.037±0.004	0.006±0.0005	1.46±0.16	0.076±0.01	82.52±0.759	6.21±0.799	5.97±0.71
Senescent	0.021±0.003	0.0004±0.0005	1.12±0.18	0.042±0.005	77.29±2.13	3.94±0.61	3.70±0.46

Table 3: Quantitative food utilization of *Z. bicolorata* on *P. hysterophorus* L. values are means of three replicates±SD, on a wet weight basis.

Age	Larvae	Adult longevity (d)		% Survival	
		Female	Male	Larvae	Adults
Young	28.60±2.44	118.40±5.88	105.40±3.23	96±0.93	94.40±1.20
Mature	33.00±2.47	104.00±3.73	92.40±3.54	57.92±3.53	83.00±3.97
senescent	39.00±3.30	83.80±3.47	74.20±2.67	35.40±3.20	67.80±4.066

Table 4: longevity and percent survival of *Z. bicolorata* on the elaves of different ages of *P. hysterophorus* L. values are means of five replicates±SD

Parameter	Host leaves		
	Young	Mature	Senescent
Protein (mg/g)	9.49±0.85	13.77±1.16	19.21±1.51
Carbohydrates (mg/g)	2.66±0.30	3.01±0.26	3.61±0.42
Lipids (mg/g)	4.40±0.499	3.68±0.37	2.99±0.38
Phenols (mg/g)	1.48±0.14	1.75±0.13	1.90±0.16

Table 5: biochemical analysis of *P. hysterophorus* L. (values on a wet weight basis)

VIII. Scanning electron microscopic study of the antenna and mouth part of beetle *Z. bicolorata*

A pair of antennae of adult Mexican beetle *Z. bicolorata* is located on the head capsule. The antenna consists of an elongated scape, followed by a pedicel and a flagellum of 9 segments. Each segment is called as flagellomere. The length of complete antenna from base to apex is measuring about 2502.25±66.65 µm (fig. 7- A). Surface of the antenna is covered with placoid scales and contain various types of sensillae on it. A pore like pit gland of 1.37±0.03 µm diameter is present throughout the surface of antenna (fig. 7- G and H). The terminal five segments are densely covered with sensilla.

A single segment scape is measuring about 240.65±14.29 µm in length and 172.05±9.25 µm in width (Table 8). Small numbers of sensilla trichodea type I and sensilla trichodea type II as well as curved sensilla trichodea type I and curved sensilla trichodea type II are found on the surface of scape (Table 6 and Fig. 7- B).

Pedicel is continued after the scape and composed of a single segment and fits in a comparatively large cavity at the distal end of the scape (Fig. 7- B). Pedicel is measuring about 163.85±20.82 µm in length and 122.85±13.08 µm in width. On the surface of pedicel sensilla trichodea type I and sensilla trichodea type II as well as curved sensilla trichodea are found (Table 6 and 8).

Flagellum is composed of a nine segments, first four segments are collectively called as funicle and last five segments are collectively called as club (Fig. 7- C and D). Flagellum is measuring about 2137.56±66.21 µm in length. The last flagellomere being the longest (324.28±6.04 µm) while the fourth flagellomere is shortest (167.75±10.01µm) (Table 8). On the surface of funicle a small numbers of sensilla trichodea type I and curved sensilla trichodea type I are found. A very dense sensilla trichodea type I, sensilla trichodea type II, sensilla trichodea type III and sensilla trichodea type IV as well as curved sensilla trichodea type I and curved sensilla trichodea type II are found on the surface of club (Table 6). On the tip of distal segment of flagellomere a uniporous cones and multiporous pegs are observed.

Trichodea sensillae type I, II and III were found on all segments of the antenna of *Z. bicolorata.* This sensilla is innervated by a single sensory neuron, attached to the base of the hair shaft. The average length of sensilla trichoidea type I, II and II was found to be 89.13±3.36, 55.53±4.40 and 26.46±1.63 respectively and average width of sensilla trichoidea type I, II and II was found to be 2.53±0.05, 2.30±0.08 and 2.05±0.05 respectively (Table 7).

Similar sensillas are also found on pedicel but they are small in number as compared to scape. First four segments of the flagellomere is called as funicle and contain small numbers of sensilla trachoidae type I and curved sensilla trachoidae type I but the last four segments is called as club and consist of very dense sensilla trachoidae type I, II, III and type IV whereas curved sensilla trachoidae type I and II. On the tip of distal segment of flagellomere a uniporous cones and multiporous pegs are found. A surface of the antenna is covered with placoid scales and contain numerous sensilla basiconica and a pore like pit gland on it.

	Type of Sensilla
Scape (Sc)	ST-I, ST-II, STC-I and STC-II
Pedicel (Pd)	ST-I, ST-II, ST-III, STC-I and STC-II
Flagellum (Fl)	STC-I, STC-II, SB, UC and MP

Table 6: Type of Sensilla present on Antenna of *Z. bicolorata*

Type of Sensilla	Length (µm)	Width (µm)
ST-I	89.13±3.36	2.53±0.05
ST-II	55.53±4.40	2.30±0.08
ST-III	26.46±1.63	2.05±0.05
STC-I	72.23±3.88	3.57±0.06
STC-II	42.56±2.72	3.45±0.11
STC-III	38.56±3.79	2.66±0.07
SB	1.45±0.03	0.63±0.03
UC	5.97±0.28	3.26±0.06
MP	12.38±0.49	1.61±0.04

Table 7: Average length and width of different type of sensilla found on antennae of *Z. bicolorata*

	Length (µm)	Width (µm)
Scape (Sc)	240.65±14.29	172.05±9.52
Pedicel (Pd)	163.85±20.82	122.85±13.08
Flagellum (Fl)	2137.56±66.21	-
F-1	298.18±8.26	104.23±6.10
F-2	223.33±6.15	114.49±5.08
F-3	234.84±6.05	113.20±6.03
F-4	167.75±10.01	134.95±6.45
F-5	174.37±6.42	193.97±8.09
F-6	224.26±6.33	235.56±5.42
F-7	233.14±9.60	235.89±6.30
F-8	251.10±7.78	236.02±7.11
F-9	324.28±6.04	223.53±6.17

Table 8: Average length and width of various segments of Antenna of *Z. bicolorata*

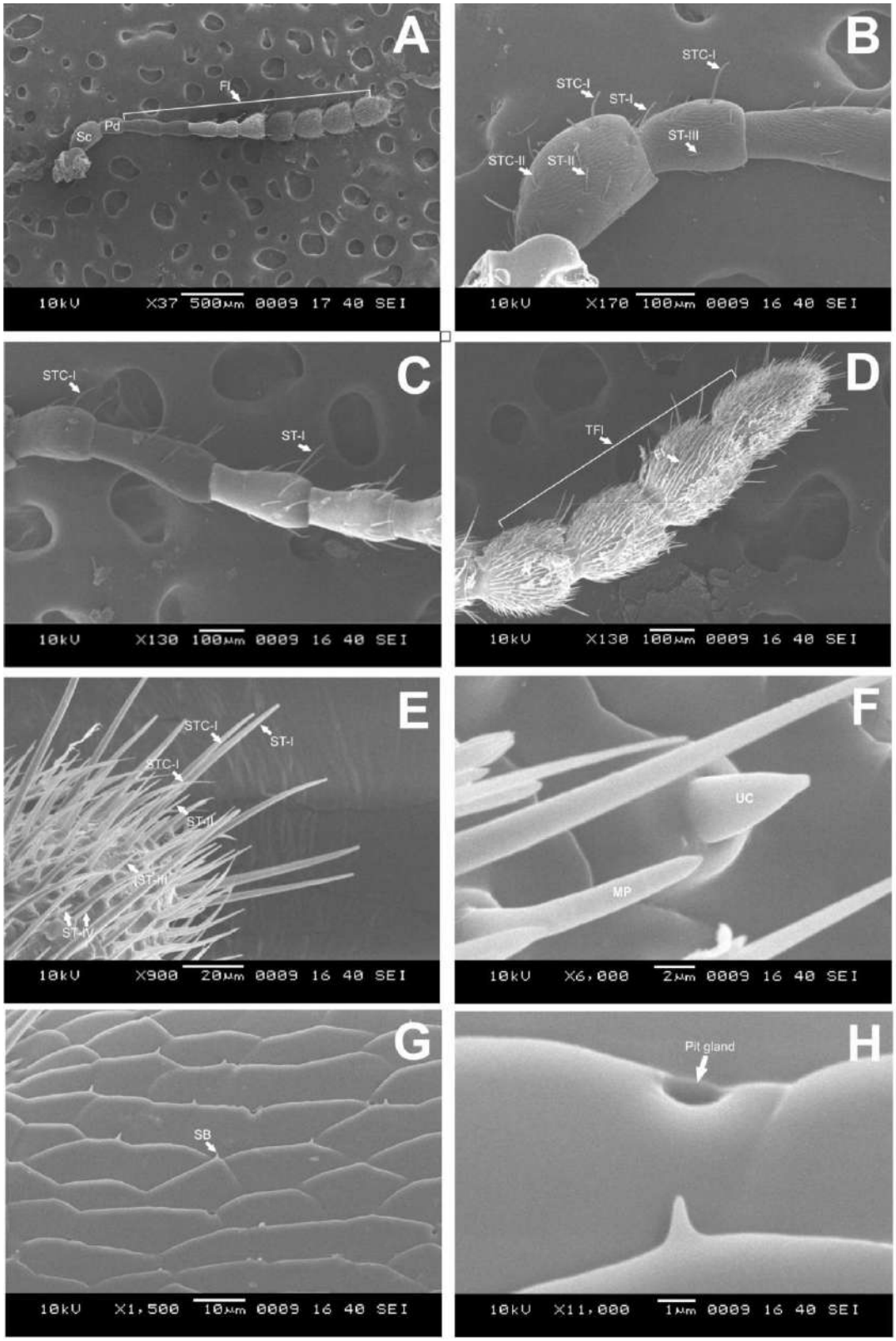

Fig. 7: Scanning electron micrographs of Antenna of Z. bicolorata

A. Antenna; **B.** Scape (Sc) and Pedicel (Pd); **C.** Antennal segments from the base of antenna; **D.** Flagellomere (Fl); **E.** Distal flagellomere segment; **F.** Magnified view of distal flagellomere segment; **G.** Magnified view of flagellomere and **H.** Pit gland.

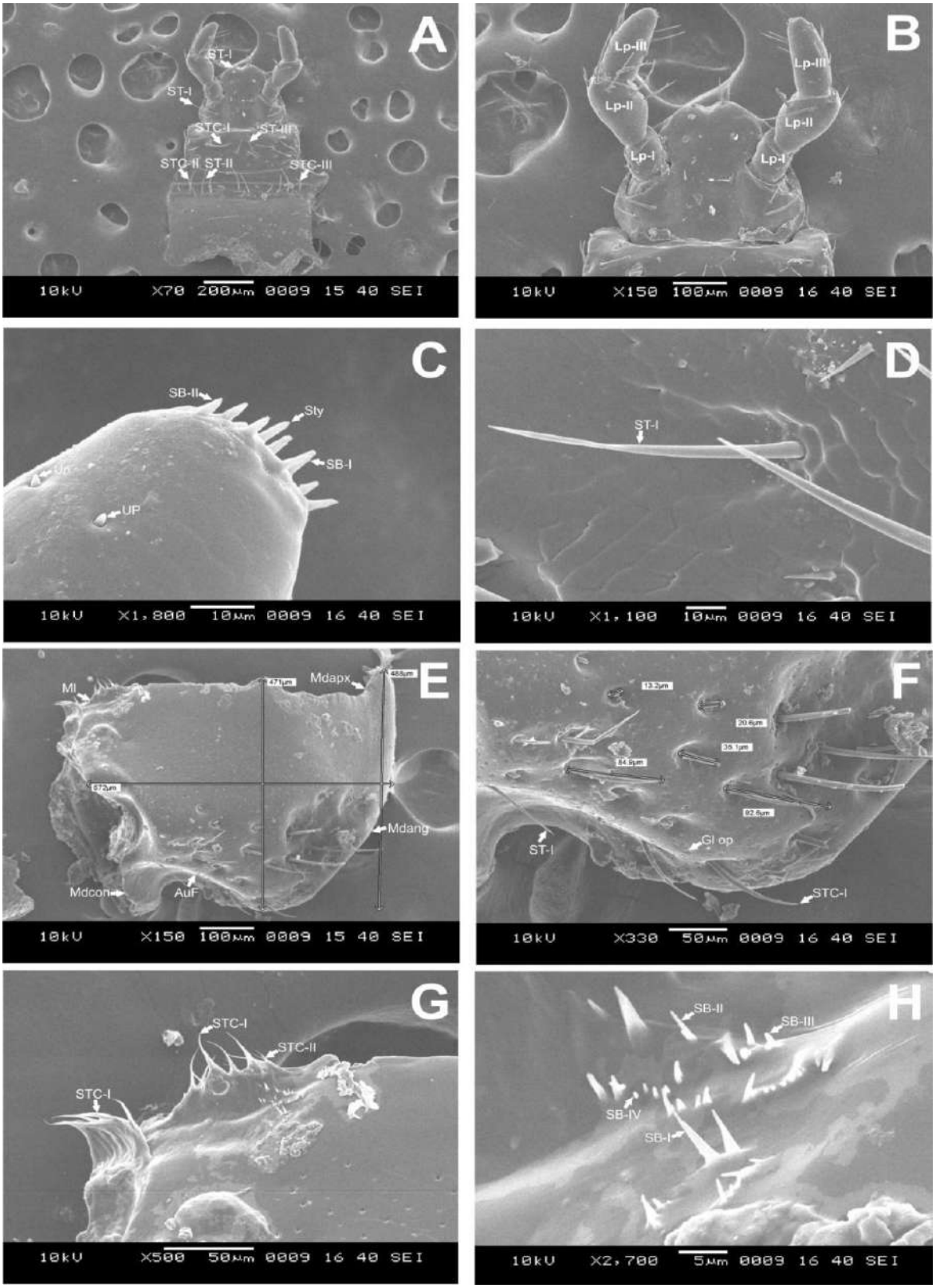

Fig. 8: Scanning electron micrographs of Labium and Mandible of Z. bicolorata

A. Labium (Lb); **B.** Labial Palp (Lp); **C.** Labial palpus apex; **D.** Magnified view of labial palpus; **E.** Mandible (Md); **F.** Magnified view of Mandible; **G.** Mola of mandible and **H.** Magnified view of Mola of mandible

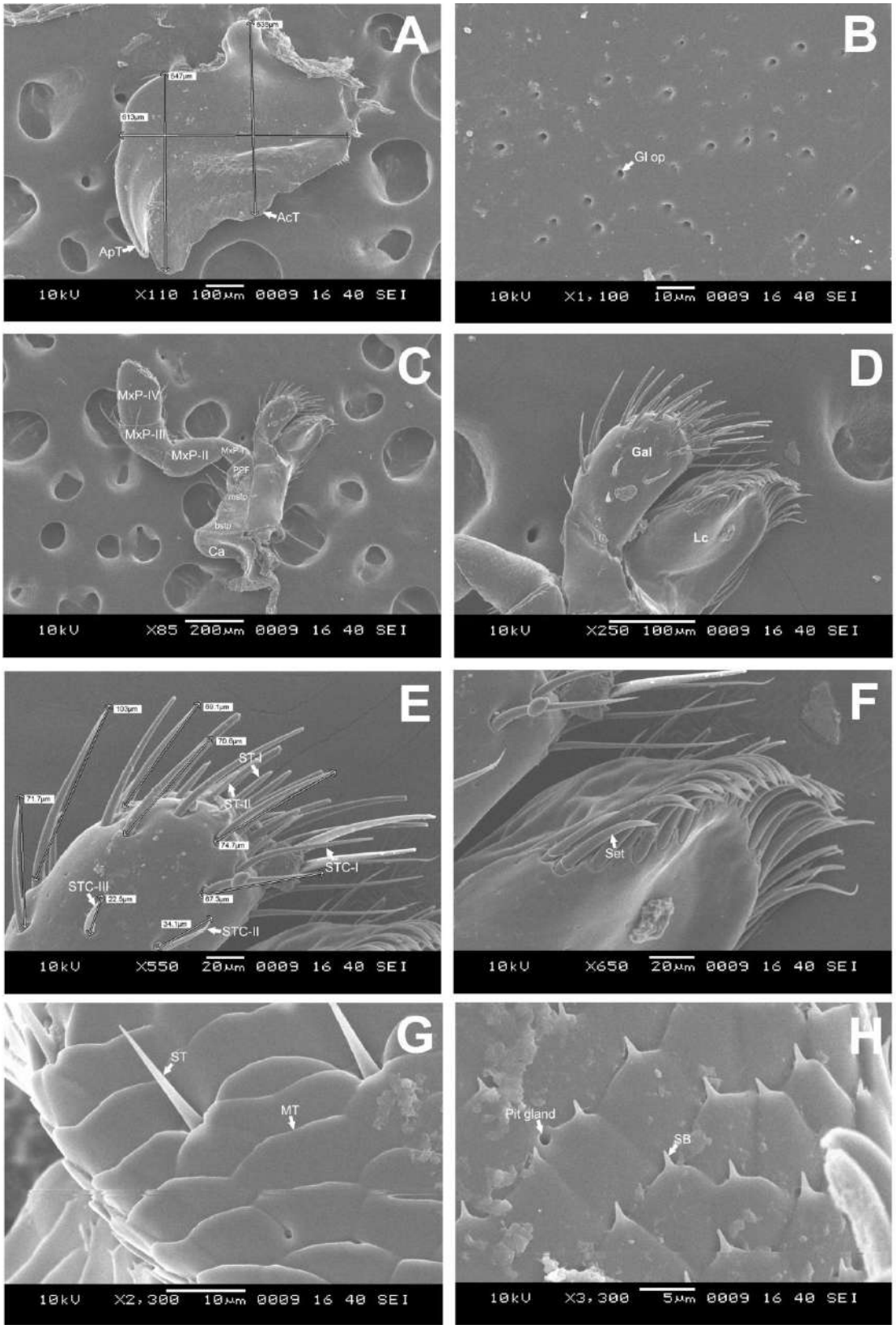

Fig. 9: Scanning electron micrographs of Mandible and Maxilla of Z. bicolorata

A. Ventral view of Mandible; **B.** Magnified view of AcT; **C.** Maxilla; **D.** Galea (Gal) and Lacinia (Lc); **E.** Apex of Galea; **F.** Apex of Lacinia; **G.** Magnified view of apex of galea and **H.** Surface of galea

A pair of labial palp is composed of three segments each and consists of sensilla trachoidae, sensilla basiconica type I, II and uniporous peg. Number of sensilla are more on the tip of each segment than the remaining portion of the segment. Sensilla basiconica present only on the tip of 3rd segment of the labial palp.

Mandibles measuring approximately about 500 µm length and height. The base of mandible is called mandibular condyle and body consists of auricular fossa, mandibular angle and mandibular apex. For the cheving of food accessory teeth and apical teech is present on each mandible. The surface of mandible is not smooth and contains variety of sensilla. The gland opening is also observed on the surface of the mandible (Figure 8 and 9).

The maxillary pulp of the *Z. bicolorata* consists of four segments, in which the proximal segment of maxillary palp is shorter as compared to other three segments (Figure 9) It is covered with the chitinous cuticular elements which are made up of a set of hexagonal plates interlocking regularly with one another (Figure 9) A small number of sensilla trachoidae and curved sensilla are found on all segments but most of them are near the tip of pulp. The tip of distal segment is not smooth; it is rather concavo-convex and consists of number of small sensilla on it. It is noticed that the group of setae is often truncated in several heights on the apex of lacinia.

E. Effects of Mexican beetle, *Zygogramma bicolorata* on *Parthenium* weed:

After releasing of beetle in *Parthenium* infested area, it started feeding on *Parthenium* which caused reduction in *Parthenium* vigour. Beetle also laid eggs from which soon tiny larvae emerged and eat *Parthenium* growing point thus checked the *Parthenium* growth. After about 02 month, the whole *Parthenium* infested area was found attacked by the beetles. Continuous attack of adult and larvae of the bioagent caused complete defoliation of the *Parthenium* in the area.

Next year larvae and the adults of the bioagents were found attacking on the *Parthenium* which was germinated after monsoon rain. The attack of the beetle was so severe that *Parthenium* was defoliated in large area. The beetles from *Parthenium* of non-cropped area entered in the adjoining fields of the rice and cotton and defoliated *Parthenium* admist the crop.

Due to this technique the density and growth of *Parthenium* was significantly reduced by the action of bioagents in large area not only in non-cropped area but also in cropped fields. While in the area where bioagents were not released, density and growth of the *Parthenium* was high and *Parthenium* infestation was not checked.

The conservation of natural resources like soil, water, etc were saved by the use of biocontrol agent to control *Parthenium* as it saved the local biodiversity in the form of environmental safety and sustainability.

F. Awareness related work

A rural awareness camps regarding *Parthenium* awareness were conducted at Soundarh village on Bhandara road in association with NSS (National service scheme) of college where in students took out awareness rally with placards and oral presentation and distributed flyers (information brochures) explaining the ill effects of utilization of chemicals weedicides. They explained the benefits of ecofriendly way of controlling weeds. An open forum was conducted with the villagers where experiences were shared with the students about the effects of weeds like *Parthenium* on mulching animals and farm laborers. The villagers were then informed about the method of controlling *Parthenium* with Mexican beetles (*Zygogramma*) and every villager, who attended was given 5-6 beetles in packets to release in *Parthenium* affected areas in their field. In coordination with the Government Superintendent of Agriculture, awareness camps were conducted in different colleges of the city like Sindhu Science College and Sevadal Mahila Mahavidyalaya where colored posters were put up and lectures were conducted (Figure 10).

Our project is engaged in transfer of technology and extension work. Several programmes on skill development. Awareness and entrepreneurship were organized for various categories of stakeholders including school, teachers, farmers and extension workers.

Fig. 10: Photographs of Awareness related work, A. Involvement of students during N.S.S. camp, **B.** Involvement of Students

Fig. 10: Photographs of Awareness related work, C. Awareness programme in N.S.S. Camp, **D.** Presentation in Villages

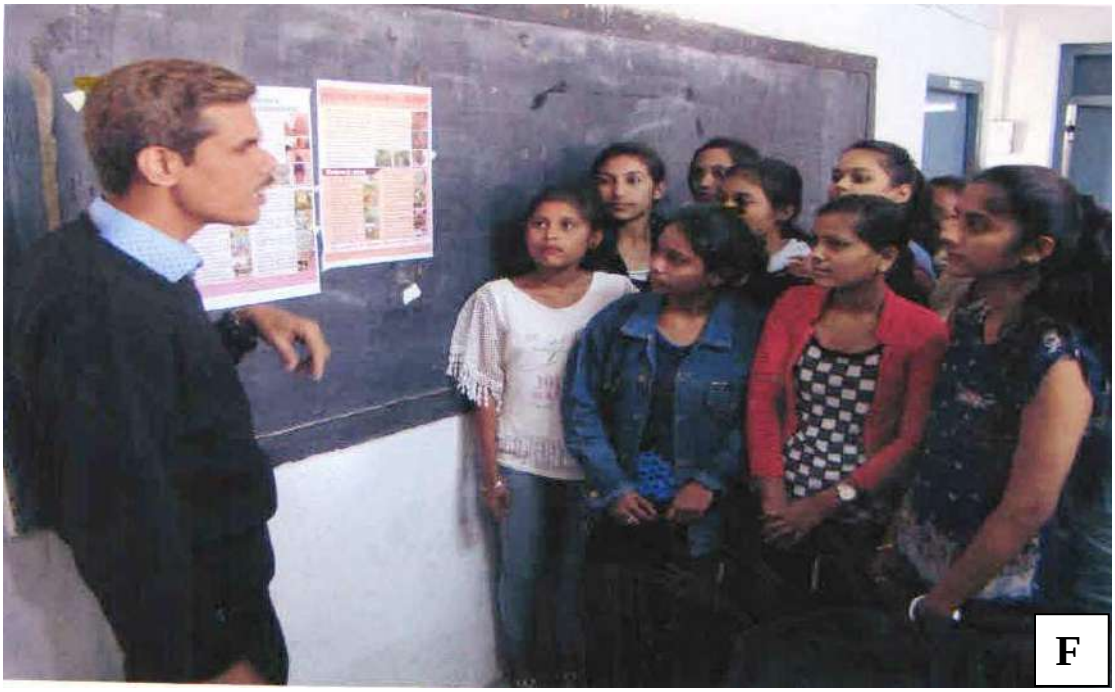

Fig. 10: Photographs of Awareness related work, E. Field work in Rajbhavan, **F.** Awareness in Sindhu Mahavidyalaya, Nagpur.

OUTPUT OF THE PROJECT:

Parthenium was a great problem in the area but after releasing the Mexican beetles by us, the problem of the *Parthenium* was reduced drastically not only in the released area but also in the adjoining area. Farmers were also facing problems of health particularly skin allergy and asthma. The labors were not ready to uproot *Parthenium* due to allergic reaction of the *Parthenium.* Soon after releasing of the beetles, other farmers and people live in urban area also realized the effect of technology given by us. Many farmers collected the beetles from the infested area and released the same in and around the fields. This caused the rapid spread of the bioagent in large area of the Nagpur and subsequently the reduction the reuction in the density of *Parthenium* and reduction in health problems of the farmers and also saved the local biodiversity of Nagpur.

Some peoples and farmers from the villages near the Nagpur also saw the results of the biological agents of *Parthenium* in Nagpur. They took interest and collected the bioagents from the same village and releases were made in adjoining areas. Subsequently they informed the establishment of the bioagent in their area and killing of *Parthenium* in large area. This is a free technology. At the time of population build up of the beetles, particularly during the rainy season, farmers and interested persons may collect the beetles and may release on the *Parthenium* infested area.

Awareness among the peoples about the *Parthenium hysterophorus* is important for the strategic control of this weed. Our project is engaged in awareness related work like transfer of technology and extension work. Several programmes on skill development. Awareness and entrepreneurship were organized for various categories of stakeholders including school, teachers, farmers and extension workers. Now the peoples are aware about the impact and ways of control of the *Parthenium.*

From the above outputs of the project the density and the growth of the *Parthenium* in Nagpur is reduced. Due to these the environment. Health and local biodiversity of the Nagpur will be under check. These will useful for the welfare of the society.

REFERENCES:

Ali Khan M. A. and M. Yousuf, 1986. Temperature and food requirements of *Cheilomenes sexmaculata (Coleoptera: Coccinellidae). Environ. Ento*. **15**: 800-802.

Brajesh Mishra and P. H. Pathak, 2012. Role of Physical Character of the Ovipositional Substrate for Preferential Egg Laying and Viability in *Zygogramma bicolorata*. *World J. Zool*. **7** (3): 264-266.

Bray, H.G. and Thorpe, W.V., 1954. Analysis of phenolic compounds of interest in metabolism. *Methods in Biochemistry Analysis*. **1**: 27-52.

DuBois, M., Gilles, K., Hamilton, J., Rebers, P., and Smith, F., 1956. Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*. **28**(3):350-356

El-Azazi, E.-S., et al., 2013. Ecological Studies of some Acacia species grown in Egyptian Derserts. Earth, 7: p. 3.8542.

Folch J, Lees M, Sloane-Stanley GH., 1957. A simple method for the isolation and purification of total lipids from animal tissues. *J Biol Chem*. **226**:497-509.

Holman, D.J., 1981. *Parthenium* Weed threatens Bowen Shire. *Queensland Agricultural Journal.* **107**: 57-60.

Ivanovic J. and Nenadovic V., 1999. The effect of diet and temperature on the life cycle of phytophagous insects. *Pesticides.* **14**: 309–327

Javaid, A., S. Shafique, and S. Shafique, 2011. Management of *Parthenium hysterophorus* (Asteraceae) by Withania somnifera (Solanaceae). Natural Product Research, 25(4): p. 407-416.

Khan, H., et al., 2014. Distribution of *Parthenium* weed in Peshawar valley,Khyber Pakhtunkhwa-Pakistan. Pakistan Journal of Botany, 46(1): p. 81-90.

Levesque, K. R., M. Fortin and Y. Mauffette, 2002. Temperature and food quality effects on growth, consumption and post- ingestive utilization efficiencies of the

forest tent caterpillar *Malacosoma disstria* (Lepidoptera: Lasiocampidae). *Bulle. Ent. Res*. **92**: 127 136.

Lowry, O.H., N.J. Rosebrough, A.L. Farr, and R.J. Randall, 1951. Protein Measurement with the Folin Phenol Reagent. *J. Biol. Chem*. **193**:265-275

Manjunath, T. M., 2010. Biological control of wasteland weed, *Parthenium hysterophorus*- An overview. *A paper presented in third International Conference on Parthenium held at New Delhi on December*. **8-10**: 64-70.

Navie, SC, Panetta, FD, McFadyen, RE & Adkins, SW., 1998b. Behaviour of buried and surface-sown seeds of *Parthenium hysterophorus*', *Weed Research*. **38**: 338-341.

Obrycki, J. J. and M. J.Tauber, 1982. Thermal requirement for the development *of Hippodamia convergens C*oleoptera: Coccinellidae). *Annals ent. Soc. America.* **75**: 678-683.

Omkar, Singh S. K., Pervez A. and Mishra G., 2004. Agespecific fecundity and natality life-table of an aphidophagous ladybird, Cheilomenes sexmaculata. *Biological Memoirs.* **30**: 20-25.

Orr, C. J. and J. J. Obrycki, 1990. Thermal and dietary requirements for development of *Hippodamia parenthesis* (Coleoptera: Coccinellidae). *Environ. Ent*. **19**: 1523-1527.

Parth R. Mathukia, 2013. Biology and Control of *Parthenium* Weed. *Int Multidisciplinary J. Appl. Res.* **1**(3) 2320-7620.

Pawar S. R. and D. M. Korat, 2013. Effect of temperature on biological attributes of different stages of Mexican beetle, *Zygogramma bicolorata* Pallister, *Insect Environment*. **19**(1): 47-49

Ponsonby D. J. and Copland M. J. W., 1998. Environmental influences on fecundity, egg viability and egg cannibalism in the scale insect predator, Chilocorus nigritus. *BioControl.* **43**:39-52.

Rao, R.S., (1956). *Parthenium*- A new record for India. *J. Bombay Natural History Soc.* **54:** 218-220.

Srivastava, S. and Omkar, 2003. Influence of temperature on certain biological attributes of a ladybeetle, Coccinella septumpunctata Linnaeus. *Entomologia Sinica*. **10:** 185–193.

Waldbauer GP, 1968. The consumption and utilization of food by insects. *Advances in Insect Physiology*. **5**:229-288.

Appendix I

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Appendix III

LIST OF ABBREVIATIONS USED

AcT	Accessory teeth
ApT	Apical teeth
AuF	Auricular fossa
B.O.D.	Biological Oxygen Demand
bstp	basostipe
Ca	Cardo
F	Flagellomere
Gl Op	Gland opening.
Gm	Gram
KV	Kilovolt
L	Linn
Lp	Labial palpus
Mdapx	Mandibular apex
Mdcon	Mandibular condyle
Ml	Mola
MP	Multiporous Peg
mstp	mesostipe
MT	Microtrichia
MxP	Maxillary palpus
^{o}C	Degree celcius
P	*Parthenium*
PPF	Palpi Fur
SB	Sensilla basiconica.
Set	Setae
ST	Sensilla trichoidea
STC	Sensilla trichoidea curvata
Sty	Sensilla Styloconica
TFl	Terminal flagellomere
UC	Uniporous cone
UP	Uniporous peg
Z	Zygogramma

गाजरघास जागरूकता कार्यक्रम

गाजरघास यानी पार्थेनियम को देश के विभिन्न भागों में अलग–अलग नामों जैसे कांग्रेस घास, सफेद टोपी, चटक चांदनी, गंधी बूटी आदि नामों से जाना जाता है। हमारे देश में 1955 में दृष्टिगोचर होने के बाद यह विदेशी खरपतवार लगभग 35 मिलियन हेक्टेयर क्षेत्र में फैल चुकी है। यह मुख्यतः खाली स्थानों, अनुपयोगी भूमियों, औद्योगिक क्षेत्रों, बगीचों, पार्कों, स्कूलों, रहवासी क्षेत्रों, सड़कों तथा रेलवे लाइन के किनारों आदि पर बहुतायत में पायी जाती है। पिछले कुछ वर्षों से इसका प्रकोप सभी प्रकार की खाद्यान्न फसलों, सब्जियों एवं उद्यानों में भी बढ़ता जा रहा है । वैसे तो गाजरघास पानी मिलने पर वर्षभर फल–फूल सकता है परंतु वर्षा ऋतु में इसका अधिक अंकुरण होने पर यह एक भीषण खरपतवार का रूप ले लेती है। गाजरघास का पौधा 3–4 महीनें में अपना जीवन चक्र पूरा कर लेता है तथा एक वर्ष में इसकी 3–4 पीढ़ियां पूरी हो जाती है।

गाजरघास से होने वाले दुष्प्रभाव

गाजरघास से मनुष्यों में त्वचा संबंधी रोग (डरमेटाइटिस), एक्जिमा, एलर्जी, बुखार, दमा आदि जैसी बीमारियाँ हो जाती हैं। अत्यधिक प्रभाव होने पर मनुष्य की मृत्यु तक हो सकती है। पशुओं के लिए भी यह खरपतवार अत्याधिक विषाक्त होता है। गाजरघास के तेजी से फैलने के कारण अन्य उपयोगी वनस्पतियों खत्म होने लगती हैं। जैव विविधता के लिये गाजरघास एक बहुत बड़ा खतरा बनती जा रही है। इसके कारण फसलों की उत्पादकता बहुत कम हो जाती है।





नियंत्रण के उपाय

1. वर्षा ऋतु में गाजरघास को फूल आने से पहले जड़ से उखाड़कर कम्पोस्ट एवं वर्मी कम्पोस्ट बनाना चाहिए।
2. घर के आस–पास एवं संरक्षित क्षेत्रों में गेंदे के पौधे लगाकर गाजरघास के फैलाव व वृद्धि को रोका जा सकता है।
3. अक्टूबर–नवम्बर में अकृषित क्षेत्रों में प्रतिस्पर्धात्मक पौधे जैसे चकौड़ा (कैसिया सिरेसिया या कैसिया तोरा) के बीज एकत्रित कर उन्हें फरवरी–मार्च में छिड़क देना चाहिये। यह वनस्पतियां गाजरघास की वृद्धि एवं विकास को रोकती हैं।
4. वर्षा आधारित क्षेत्रों में शीघ्र बढ़ने वाली फसलें जैसे ढैंचा, ज्वार, बाजरा, मक्का आदि की फसलें लेनी चाहिए।
5. अकृषित क्षेत्रों में शाकनाशी रसायन जैसे ग्लायफोसेट 1.0–1.5 प्रतिशत या मेट्रीब्यूजिन 0.3–0.5 प्रतिशत घोल का फूल आने के पहले छिड़काव करने से गाजरघास नष्ट हो जाती है।
6. ग्रीष्म एवं शरद ऋतु में अकृषित क्षेत्रों में अंकुरित होने पर कुछ बढ़वार करने के बाद पानी न मिलने के कारण इनका विकास नहीं हो पाता है पर वर्षा होने पर यही पौधे शीघ्र बढ़कर बीजों का उत्पादन कर देते हैं। अतः ऐसे समय इन्हें शाकनाशियों द्वारा नष्ट करना चाहिये।
7. फसलों में गाजरघास को रसायनिक विधि द्वारा नियंत्रित करने के लिये खरपतवार वैज्ञानिक की सलाह अवश्य लें ।
8. मेक्सिकन बीटल (*जाइग्रोग्रामा बाइकोलोराटा*) नामक कीड़े को वर्षा ऋतु में गाजरघास पर छोड़ना चाहिए।
9. जगह–जगह संगोठियां कर लोगों को गाजरघास के दुष्प्रभाव एवं नियंत्रण के बारे में जानकारी देकर उन्हें जागरूक करें।








हमने अब यह ठाना है । गाजरघास मिटाना है । पर्यावरण बचाना है ।

अधिक जानकारी के लिये संपर्क करेः डॉ. रिना एस. सहा, श्री. मथुरादास मोहता विज्ञान महाविद्यालय, नागपूर
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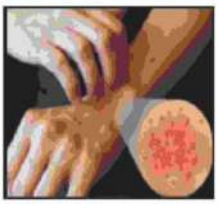
Awareness poster (Hindi)

PARTHENIUM AWARENESS PROGRAMME

Partheninm hysterophours is an alien weed of national significance. It is popularly known as congress grass, carrot weed, white cap or top, gajar ghas, chatak candani, asadi, gajari, phandriphuli, nakshatra gida, vayyari bhama and safed topi. Since its introduction into country in 1950s, it has invaded 35 million hectares of cultivated, uncultivated, waste lands, road side, railway tracks *etc.*

It is a fast maturing annual which can grow to a height of 1.5 to 2 m having branched and leaves covered with fine hairs. It produces large number of small white flowers and seeds of light weight that are easily dispersed to distant places. A single plant can produce 5000 to 25,000 seeds.

It causes health hazards like skin allergy (dermatitis), hay faver and asthma in human beings and also toxic to livestock. It threats native biodiversity besides loss to crop productivity. It is a nuisance in public amenity areas like parks, residential colonies and orchards. The weed squeezes grasslands and pastures hence reducing the fodder supply.



How to control it ?

- As it is mainly a weed of no-man's land, therefore, community efforts involving all the sections of the society like colony residents, farmers, municipalities, NGOs, school children *etc.* are required to keep their respective surroundings free from the Parthenium.
- Uproot the weed before flowering and make compost by pit method. It may also we used for vermi-composting.
- Organize meetings, demonstration to make people aware about Parthenium menace and its management.
- Spray herbicides like glyphosate (1-1.5%) for total vegetation control or metribuzin (0.3-0.5%) if grasses are to be saved in non-agricultural land. Spray herbicides for controlling dwarf rosette formation during summer and winter.
- For controlling Parthenium in cropped areas, use herbicide only after consultation of weed scientist.
- Release bioagent ***Zygogramma bicolorata*** in infested areas during June-August.
- Broadcast seed of self-perpetuating competitive plant species like ***Cassia sericea, Cassia tora, Tagetus erecta, Tephrosia purpurea to replace Parthenium.***

Eliminate Parthenium: Save Health, Environment and Biodiversity

For more information, please contact: Dr. Rina S. Saha, Principal Investigator (UGC-MRP) S.M.Mohota College of Science, Nagpur. Mobile– 09822724232

कैसे पायें इस पर काबू ?

गाजरघास की रोकथाम निम्न तरीके से की जा सकती है –

- खरपतवारों के प्रवेश एवं उनके फैलाव को रोकने हेतु नगर एवं राज्य स्तर पर कानून बनाकर उचित दंड का प्रावधान रख इस पर काफी हद तक काबू पाया जा सकता है। सभी राज्यों को गाजरघास को अधिनियम के अन्तर्गत रखकर इसके उन्मूलन की प्रक्रिया युद्ध स्तर पर करनी चाहिए।
- नम भूमि में इस खरपतवार को फूल आने से पहले हाथ से उखाड़कर इकट्ठा करके जला देने से काफी हद तक नियन्त्रित किया जा सकता है। इसे उखाड़ते समय हाथ में दस्तानों तथा सुरक्षात्मक कपड़ों का प्रयोग करना चाहिए। चूंकि गाजरघास एक व्यक्ति की समस्या न होकर जन साधारण की समस्या है अतः पार्कों, कालोनी आदि में रहवासियों को समूह बनाकर इसे उखाड़कर नष्ट करना चाहिये।
- शाकनाशियों के प्रयोग से इस खरपतवार का नियन्त्रण आसानी से किया जा सकता है। इन शाकनाशी रासायनों में एट्राजिन, एलाक्लोर, आइसूरान, मैट्रीब्यूजिन, 2,4–डी, ग्लाइफोसेट आदि प्रमुख हैं। गाजरघास के साथ सभी प्रकार की वनस्पतियों को नष्ट करने के लिये ग्लाइफोसेट (1 से 1.5 प्रतिशत) और घास कुल की वनस्पतियों को बचाते हुए केवल गाजरघास को नष्ट करने के लिए मेट्रिब्युजिन (0.3 से 0.5 प्रतिशत) नाम के रसायनों का उपयोग करना चाहिए ।
- गाजरघास का नियन्त्रण उनके प्राकृतिक शत्रुओं, मुख्यतः कीटो, रोग के जीवाणुओं एवं वनस्पतियों द्वारा किया जा सकता है। मेक्सिकन बीटल (जाइगोग्रामा बाइकोलोराटा) नामक केवल गाजरघास को ही खाने वाले गुबरैले को गाजरघास से ग्रसित स्थानो पर छोड देना चाहिये इस कीट के लार्वा और व्यस्क पत्तियों को चट कर गाजरघास को सुखा कर मार देते हैं। इस कीट के लगातार आक्रमण के करण शनःशनः गाजरघास कम हो जाती हैं जिससे वहाँ अन्य वनस्पतियों को उगने का मौका मिल जाता है। यह कीडें खरपतवार विज्ञान अनुसंधान निदेशालय से मुफ्त में लिये जा सकते है।
- प्रतिस्पर्धी वनस्पतियों जैसे – चकोडा, हिप्टिस, जंगली चोलाई आदि से गाजरघास को आसानी से विस्थापित किया जा सकता है। अक्टूबर–नवम्बर माह में चकोडा के बीज इकट्ठा कर उनका अप्रैल–मई में गाजरघास से ग्रसित स्थानों पर छिडकाव कर देना चाहिए। वर्षा होने पर शीघ्र ही वहां चकोड़ा गाजरघास को विस्थापित कर देता है।

उसी स्थान पर चकोड़ा से विस्थापित गाजरघास

संभव उपयोग

गाजरघास के पौधे की लुगदी से हस्त निर्मित कागज एवं कम्पोजिट तैयार किये जा सकते है। बायोगैस उत्पादन में इसको गोबर के साथ मिलाया जा सकता है गरीब एवं झुग्गी–झोपड़ियों में रहने वाले इसका प्रयोग ईंधन के रूप में भी करते है। किसान भाई इसका उपयोग बहुत अच्छा कम्पोस्ट बनाने में कर सकते है जिसमें पौष्टिक तत्व नाईट्रोजन प्रोटेशियम फासफोरस आदि गोबर घास से अधिक होते है।

इस संबंध में अधिक जानकारी के लिये सम्पर्क करें:
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गाजरघास का एकीकृत नियंत्रण

University Grant Commission- Major Research Project (UGC-MRP)
Shree Mathuradas Mohota College of Science, Nagpur

गाजरघास का वैज्ञानिक नाम पारथेनियम हिस्टोफोरस है। गाजरघास को अन्य नामों जैसे – कांग्रेस घास, सफेद टोपी, छतक चांदनी, गधी बूटी आदि नामों से भी जाना जाता है। यह एस्टीरेसी (कम्पोजिटी) कुल का पौधा है। इसका मूल स्थान वेस्टइंडीज और मध्य व उत्तरी अमेरिका माना जाता है। भारत में सर्वप्रथम यह गाजरघास पूना (महाराष्ट्र) में 1955 में दिखाई दी थी। ऐसा माना जाता है कि हमारे देश में इसका प्रवेश 1955 में अमेरिका अथवा कनाडा से आयात किये गये गेहूँ के साथ हुआ परन्तु अल्पकाल में ही यह गाजरघास पूरे देश में एक भीषण प्रकोप की तरह लगभग 35 मिलियन हेक्टेयर भूमि पर फैल चुकी है। विश्व में यह गाजरघास भारत के अलावा अन्य देशो जैसे अमेरिका, मैक्सिको, वेस्टइंडीज, भारत, नेपाल, चीन, वियतनाम तथा आस्ट्रेलिया के विभिन्न भागों में भी फैला हुआ है।

कैसी होती है गाजरघास ?

यह एकवर्षीय शाकीय पौधा है जिसकी लम्बाई लगभग 1.0 से 1.5 मी. तक हो सकती है। इसका तना रोमेदार एवं अत्याधिक शाखायुक्त होता है। इसकी पत्तियां गाजर की पत्ती की तरह नजर आती है जिन पर सूक्ष्म रोयें लगे रहते है प्रत्येक पौधा लगभग 10000–25000 अत्यंत सूक्ष्म बीज पैदा कर सकता है। बीजों में सुषुप्तावस्था नहीं होने के कारण बीज पककर जमीन में गिरने के बाद नमी पाकर पुनः अंकुरित हो जाते हैं। गाजरघास का पौधा लगभग 3–4 महीने में अपना जीवन चक्र पूरा कर लेता है तथा इस प्रकार यह एक वर्ष में 2–3 पीढ़ी पूरी कर लेता है। चूंकि यह पौधा प्रकाश एवं तापक्रम के प्रति उदासीन होता है अतः पूरे वर्ष भर उगता एवं फूलता–फलता रहता है।

कहाँ उगती है गाजरघास ?

गाजरघास का पौधा हर तरह के वातावरण में उगने की अभूतपूर्व क्षमता रखता है। इसके बीज लगातार प्रकाश अथवा अंधकार दोनों ही परिस्थितियों में अंकुरित होते हैं । यह हर प्रकार की भूमि चाहे वह अम्लीय हो या क्षारीय, उग सकता है। इसलिए गाजरघास के पौधे समुद तट के किनारे एवं मध्यम से कम वर्षा वाले क्षेत्रों के साथ–साथ जलमग्न धान एवं पथरीली क्षेत्रों की शुष्क फसलों में भी देखने को मिलते हैं। बहुतायत रूप से गाजरघास के पौधे खाली स्थानों, अनुपयोगी भूमियों, औद्योगिक क्षेत्रों, सड़क के किनारों, रेल्वे लाइनों आदि पर पाये जाते है। इसके अलावा इसका प्रकोप खाद्यान्न दलहनी, जिलहनी फसलों, सब्जियों एवं उद्यान फसलों में भी देखने को मिलता है।

कैसे फैलती है गाजरघास ?

भारत में इसका फैलाव सिंचित से अधिक असिंचित भूमि में देखा गया है। गाजरघास का प्रसार, फैलाव एवं वितरण मुख्यतः इसके अति सूक्ष्म बीजों द्वारा हुआ है। शोध से ज्ञात होता है कि एक वर्गमीटर भूमि में गाजरघास लगभग 1,54,000 बीज उत्पन्न कर सकता है। एक स्वस्थ गाजरघास के अकेले पौधे से ही लगभग 10,000–25,000 बीज उत्पन्न हो सकते हैं। इसके बीज अत्यन्त सूक्ष्म, हल्के और पंखदार होते हैं। सडक और रेल मार्गों पर होने वाले यातयात के कारण भी यह संपूर्ण भारत में आसानी से फैल गयी हैं। नदी, नालों और सिचाई के पानी के माध्याम से भी गाजरघास के सूक्ष्म बीज एक स्थान से दूसरे स्थान पर आसानी से पहुँच जाते हैं।

गाजरघास से होने वाली हानियां

इस गाजरघास के लगातार संपर्क में आने से मनुष्यों में डरमेटाइटिस, एक्जिमा, एलर्जी, बुखार, दमा आदि जैसी बीमारियां हो जाती है। पशुओं के लिए यह गाजरघास अत्यधिक विषाक्त होता है। इसके खाने से पशुओं में अनेक प्रकार के रोग पैदा हो जाते हैं एवं दुधारू पशुओं के दूध में कडुआहट के साथ साथ दूध उत्पादन में भी कमी आने लगती है। इस खरपतवार द्वारा खाद्यान्न फसलों की पैदावार में लगभग 40 प्रतिशत तक की कमी आंकी गई है। पौधे के रासायनिक विश्लेषण से पता चलता है कि इसमें "सेस्क्युटरपिन लैक्टोन" नामक विषाक्त पदार्थ पाया जाता है जो फसलों के अंकुरण एवं वृद्धि पर प्रतिकूल प्रभाव डालता है।

IPM folder

Appendix VI

List of Research Papers Published

1. Published research paper entitled, "Effect of temperature variation on reproductive behaviour of *Zygogramma bicolorata:* A potential biocontrol agent of *Parthenium hysterophorus*" in Journal of Soils and Crops, Dec 2015.
2. Saha R. S. and Bangadkar M. K. (2015). Antennal Sensilla in Mexican Beetle Zygogramma bicolorata (Coleoptera: Chrysomelidae): A Potential Biocontrol Agent of Weed Parthenium hysterophorous. *International Research Journal of Biosciences, Agriculture and Technology*, 7(II): 323-327
3. Presented a research paper entitled, "Effect of temperature variation on the life cycle stages and reproductive behaviour of Mexican beetle" in Biennial Conference on Emerging Challenges in Weed Management held at Directorate of Weed Science Research Jabalpur, MP, India on 15-17 February, 2014.
4. Saha R. S. and Bangadkar M. K. (2015). Impact of *Parthenium hysterophorus* L. (Asteraceae) On Natural Ecosystem of Nagpur (Maharashtra). *International Research Journal of Biosciences, Agriculture and Technology*, Special Issue I: 163-166.

List of Research poster presented in Conferences/Seminar Symposia

1. Saha R. S. and Bangadkar M. K. (2015). Parthenium - A Review Of Its Weed Status And The Possibility For Biological Control. *In National Conference on Sustainable Development and Green India held at Nagpur.*
2. Saha R. S. and Bangadkar M. K. (2013). Effect of temperature variation on the reproductive behaviour of Mexican Beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae)*:* A biocontrol agent of weed *Parthenium hysterophorus*. *In International Conference on Comparative Endocrinology and Physiology held at Nagpur.*