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Impact of few chemical weedicides and botanicals on the biocontrol agent, *Zygogramma bicolorata* (Pallister) of *Parthenium hysterophorus* (Linnaeus)

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Abstract
Studies on the Impact of few chemical weedicides and botanicals on the biocontrol agent, *Zygogramma bicolorata* (Pallister) of *Parthenium hysterophorus* (Linnaeus) conducted in the Biocontrol laboratory, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) during in the year of 2021-22, indicated that, the effects of commonly used weedicides (glyphosate, atrazine, 2, 4-D, and metribuzin) and botanicals (marigold, charota, and bantulsi) on adult beetles of the *Z. bicolorata*, atrazine at both concentrations (0.7 and 0.14 mg), was most toxic for the all stages. Based on biometric parameters the effect of weedicides and botanicals on F1 progenies, minimum length and width (0.73 mm and 0.32 mm) of egg was recorded in atrazine @ 0.14 mg. Similarly, in bantulsi @ 0.50%, minimum length and width of egg were recorded with an average of 0.81 mm and 0.47 mm. Among the larval stages in case of 1st, 2nd, 3rd and 4th instar larvae minimum length (1.10 mm, 3.04 mm, 3.45 mm and 7.11 mm) and width (0.27 mm, 1.05 mm, 2.07 mm and 2.28 mm) respectively recorded in atrazine @ 0.14 mg and maximum length (1.40 mm, 3.16mm, 4.73 mm and 8.16 mm) and width was recorded in charota @ 0.25% compared to the control. In case of pupa and adults (male and female), similar finding was recorded in atrazine and bantulsi in both concentrations.

Keywords: *Zygogramma bicolorata* (Pallister), *Parthenium hysterophorus* (Linnaeus), weedicides, botanicals, F1 progenies, biometric parameters

1. Introduction
In India, *Parthenium hysterophorus* L., is known by a number of names such as carrot weed, whitetop or congress grass, Gajarghas or Chatakchadani. It is a herbaceous erect, annual plant of the Asteraceae (compositae) family (Sushil kumar 2005) [27] and a globally significant herbaceous weed that originated in central and South America (Dolai *et al*., 2019) [5]. It is now regarded as Asia's (Patel 2011 [19], Hasan and Ansari, 2016 a) [8] and Australia's (Patel 2011) [19] most destructive weed in both agricultural and urban regions (Navie *et al*., 1996 [17], Dhileepan and Strathie, 2009) [3]. It has spread in about 35 million hectares of Indian land, including roadsides, railway tracks, farmed fields, and water lands (Singh *et al*.,2008) [25], after its introduction in the late 1950s in Pune (Rao, 1956) [20].
P. hysterophorus L. (Asteraceae) is effectively controlled by *Zygogramma bicolorata* (Pallister) (Coleoptera: Chrysomelidae), an invasive and important biocontrol agent (Hasan and Ansari 2015 [7], Hasan & Ansari 2016 a, b) [8]. It was originally brought to Australia from Mexico in 1980 (Mc Fadyen and Mc Clay 1981) [16] and then to India in 1983 (Mc Fadyen and Mc Clay 1985 [15], Jayanth, 1987) [14]. Within three years of its introduction, it became abundant, resulting in a considerable fall in *Parthenium* density in local areas (Jayanth & Bali 1994 a,b [12], Jayanth and Visalakshy, 1996) [13]. Neonates eat a lot of young leaves, go through four moults, and are fully developed in 11-13 days (Jayanth and Bali, 1992) [11]. Pupation occurs when the fully grown larvae burrow into the earth; the pupal stage lasts for two weeks (McFadyen and McClay 1981 [16], Jayanth 1987) [14]. In 23-30 days, the life cycle is completed.
The weed infestation affects fodder production by up to 90% and causes yield losses of up to 40% in some crops (Akter and Zuberi, 2009) [1]. Weeds are important factor in agriculture, which influence crop yields. Presently, weeds have been controlled by using synthetic

weedicides. These chemicals have a negative impact on the environment and human health. Use of allelopathy is an environment-friendly option for weed control. Allelopathy is identified as a natural weed control approach. Different plants have different allelochemicals. These chemicals could be utilized for suppressing weeds (Srikrishnah and Begam 2019) [26].

Parthenium can be controlled by herbicides, but their use adversely affects the environment and human health. Hence alternate eco-friendly, cost effective and bioefficaceous methods of weed control are needed. Efforts are being made to use natural plant products for weed management. It has been shown that extracts, residues and essential oils of many allelopathic plant species (herbs, grasses and trees) effectively reduce the germination and growth of *Parthenium* (Javaid, A. 2010) [10].

Parthenium is reported to be controlled by foliar spray of some chemical weedicides such as glyphosate, atrazine, metribuzin, 2,4-D. However, control does not last long enough as expected due to the large amount of seeds deposited in the seed bank and flash germination of the seeds. Allelopathy as an ecological approach and allelochemicals as biological herbicides have been a challenge to current synthetic chemical approaches (El-Rokiek *et al*., 2006) [6]. Numerous allelochemicals are involved in the allelopathic activities of the allelopathic plants; such as phenolics, terpenoids, alkaloids, coumarins, tannins, flavonoids, steroids and quinines (Xuan *et al*., 2005) [28].

Preventing the spread of *Parthenium* is the most cost effective management strategy. Synthetic herbicides are the most effective immediate solution to most weed problems but increased and indiscriminate use of these herbicide resulted in resistance and resurgence in pests. Some natural extract to control this menace, thereby minimizing or avoiding the frequent use of herbicides in future. Furthermore, increasing public concern on environmental issues requires alternative weed management systems, which are less pesticide dependent or based on naturally occurring compounds (Singh *et al*., 2003) [24].

2. Material and Method

2.1 Study Areas

The experiments were conducted at the Biocontrol laboratory, Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), during 2021-22.

2.2 Maintenance of *Parthenium* plants for experiment

Seeds of *Parthenium* were collected from dried *Parthenium* plants from Indira Gandhi krishi vishwavidyalaya, Raipur, Chhattisgarh, fields during 2020-21 and sown in big sized plastic basin filled with soil + vermicompost + sand. After germination one month old healthy plants were transplanted in plastic pots of size 30c.m.

2.3 Culture maintenance of *Zygogramma bicolorata*

The initial culture of *Zyogramma bicolorata* was obtained from the field of Indira Gandhi krishi vishwavidyalay, Raipur, Chhattisgarh during 2020-21, which was used for further rearing in green house behind the Biocontrol laboratory. When the beetles had mass multiplied in sufficient numbers, adult beetles were paired and released on potted plant sprayed with respective weedicides and botanicals and caged.

2.4 Steps for preparing botanical extracts

Preparation of botanical extracts was carried out as per method suggested by Javaid *et al*., 2010: [10]

1. Leaves weighing 10 g weight were taken followed by washing under running water and placing them on blotting paper under shade condition.
2. On complete drying, the leaves were kept overnight in alcohol and distilled water at 1:1 proportion.
3. Then the leaves were blended with the help of mixer grinder.
4. The extract was filtered with Whatman filter paper no.1.
5. Finally 500 ml volume was made by adding distilled water to make 100% of solution.

2.5 Method of weedicides and botanical extracts application

One month old *Parthenium* plants sown from seeds in plastic basins were planted in pots singly. 10 days after planting, weedicides and botanicals were sprayed on the plants. Observations on the mortality of *Z. bicolorata* were recorded at 24, 48 and 72 hrs after treatment.

2.6 Method of recording observations

A pair of adult *Z. bicolorata* was used in each replication. Impact of weedicides and botanicals were assessed for adult stage only. Observations on mortality were recorded at 24, 48 and 72 hours after treatment and calculated the mean mortality in each treatment.

2.7 Life cycle and biology of *Zygogramma bicolorata*

The life cycle and biology of *Z. bicolorata* were studied in same potted plants, sprayed with weedicides and botanicals during February to march, 2022. Surviving F1 generations of Z. *bicolorata* from the 1st experiment, were used for the study.

2.8 Biometrics of *Z. bicolorata* on *P. hysterophorus*

The biometrics of *Z. bicolorata* were recorded from the surviving F1 generation of *Z. bicolorata* at 1st experiment. Biometrical observations were recorded after *Z. bicolorata* beetles laid eggs in the potted *Parthenium* plants, which had been previously sprayed with the weedicides and botanicals. In each potted plant, eggs, grubs, pupae and adults were examined for recording biometrical observations. Body length, body width and body weight of each stages of *Z. bicolorata* were measured by using trinocular microscope, weighing machine and vernier caliper. The biometric parameters were compared with control, i.e. on *Z. bicolorata* reared on untreated plants.

3. Results

Atrazine at 0.14mg caused the maximum mortality with a mean of 1.58, was found to be harmful to the adults of *Z. bicolorata* based on the mortality data collected 24 hours after treatment. The toxicity of remaining weedicides and botanicals in descending order was metribuzin @ 0.6mg with a mean of 1.54 > 2,4-D @ 0.02mg with a mean of 1.50 > atrazine @ 0.7mg with a mean of 1.33> glyphosate @ 0.28mg with a mean of 1.29 > bantulsi @ 0.50% with a mean of 1.08 > glyphosate @ 0.14mg with a mean of 0.92 >

bantulsi @ 0.25% with a mean of 0.75 > marigold @ 0.50% with a mean of 0.63 > marigold @ 0.25% with a mean of 0.58 > charota @ 0.50% with a mean of 0.54> charota @ 0.25% with a mean of 0.50 > control with a mean of 0.42. After 48 hours of treatment, data indicated that atrazine @0.14mg per pot recorded significantly highest mortality with a mean of 1.62, while treatment of 2,4-D @0.02mg with a mean of 1.52 and metribuzin @0.06mg with a mean of 1.48 found moderately toxic to the adult *Z. bicolorata.* In the chemical treatment of glyphosate @0.28 and 0.14mg with a mean mortality of 1.29 and
1.21 respectevily were found less toxic to the adult *Z. bicolorata*. The botanical charota had the lowest mortality rate, @ 0.25 percent, with a mean of 0.48; followed by marigold, at 0.25 percent, with a mean of 0.54; and bantulsi, @ 0.25 percent, with a mean of 0.92. At 72 hours after treatment data showed that significantly higher cumulative mortality with a mean of 1.67 was observed in the treatment of atrazine (0.14 mg), followed by 2,4-D @ 0.02 mg and metribuzin @ 0.6 mg with a mean of 1.58 and 1.63 respectively was found to be moderately toxic to adult *Z. bicolorata.* Among botanicals, charota at 0.25 percent with a mean of 0.67 was less toxic to adult *Z. bicolorata.* The results are in total agreement with Siddhapara (2011) [22] and Pawar who also reported atrazine (0.14mg) as toxic weedicide. After 72 hours, highest hatching percentage of egg of *Z. bicolorata* was observed in charota (72.00%) at 0.25%, whereas lowest egg hatching was observed in atrazine (26.60%) at 0.14mg. Among chemical treatments, highest egg hatching was observed in glyphosate (57.05%) @ 0.14 mg.
In this experiment surviving F1 generations of Z. *bicolorata* from the 1st experiment, were used for the study. Observations were recorded on fecundity, incubation period and duration of larval (grub) instars, pupal and longevity of male and female beetles on each sprayed potted plant are presented in table - (3.2). The male and female beetles were identified on the basis of their body size. The size of female adult is larger than the male beetle. Each sprayed pot was compared with untreated control.
Results of each sprayed pot are presented below:

3.1 Egg period
Adult female of *Z. bicolorata* deposited the eggs singly or in group on leaf surface, stems and flowers in potted plants sprayed with two concentrations of Glyphosate (0.14 and 0.28 mg), atrazine(0.7 and 0.14mg), metribuzin (0.3 and 0.6 mg), 2,4-D (0.25 and 0.50%), marigold (0.25 and 0.50%), charota (0.25 and 0.50%), bantulsi (0.25 and 0.50%) and untreated control, the results are in total agreement with Jayanth, (1987) and Jaiswal and Ganguli, (2020) who also reported egg laying singly or in group.

3.2 Colour and shape
The eggs were shiny, oval shaped and slightly rounded at one end and yellowish for one day turned to golden yellowish and eventually turned to yellowish-red in colour before hatching in all the eight treatments viz glyphosate, atrazine, metribuzin, 2,4-D, marigold, charota, bantulsi and untreated control (Fig-2).

3.3 Incubation period
The incubation period was with an average of 3.33±0.58 days, in untreated control, and 4.00-6.00 on both concentration of glyphosate (0.14 and 0.28mg) respectively. It was on the higher side i.e. 4.66±2.89 days in both atrazine and metribuzin concentrations. In 2,4-D also at both concentrations (0.01 and 0.02mg) the incubation period was similar to that of control showing with an average of 3.31±2.58 days and with an average of
3.33±2.89 days respectively. In the case of marigold (0.25%) the incubation period was with an average of 3.67±0.58 days which was similar to control but at a concentration of 0.50% it was more with an average of 4.33±0.58 days respectively. In pots treated with charota (0.25% & 0.50%) and bantulsi (0.25% & 0.50%) the incubation period was higher than control with an average of 4.67±0.58 days and 5.00±1.00 days respectively.

3.4 Size
The eggs were 1.19±1.26 mm in length with an average of 1.22±0.03 mm and 0.47±0.55 mm in width with an average of 0.52±0.04 mm observed on untreated control pot. The eggs were more or less similar in size of 1.18±1.24 mm in length with an average of 1.21±0.03 mm and 0.49±0.52 mm in width with an average of 0.51±0.02 mm at 0.7mg concentration and 1.17±1.22 mm in length with an average of 1.20±0.03 mm and 0.50±0.55 mm in width with an average of 0.53±0.02 at the concentration of 0.14mg concentration were observed in pots treated with glyphosate. The eggs were comparatively smaller than control with 1.09±1.20 mm in length having an average of 1.14±0.06 mm and 0.32±0.48 mm in width with an average of 0.40±0.08 mm at 0.7 mg and 1.10±1.22 mm in length with an average of 1.15±0.06 mm and 0.35±0.46 mm in width with an average of 0.40±0.06 mm at 0.14mg observed in pot treated with atrazine. Similar parameters of eggs with 1.09±1.20 mm in length with an average of 1.14±0.06 mm and 0.32±0.48 mm in width with an average of 0.40±0.08 mm at 0.03 mg and 1.10±1.22 mm in length with an average of 1.15±0.06 mm and 0.35±0.46 mm in width with an average of 0.40±0.06 mm at 0.06 mg observed in the treatment with metribuzin. Lesser eggs size of than control having 1.09±1.20 mm in length with an average of 1.14±0.06 mm and 0.32±0.48 mm in width with an average of 0.40±0.08 mm at 0.01mg and 1.10±1.22 mm in length with an average of 1.15±0.06 mm and 0.35±0.46 mm in width with an average 0.40±0.06 mm at 0.02 mg were recorded in pots treated with 2,4-D. Reduced size of eggs than control with 1.07±1.19 mm in length with an average of 1.13±0.06 mm and 0.23±0.41mm in width with an average of 0.32±0.09 mm at 0.25% and 1.05±1.13 mm in length with an average of 0.73±0.64 mm and 0.37±0.47 in width with an average of 0.27±0.25 mm at 0.50% were recorded in pots treated with marigold. The reduction in biometric parameters of eggs were comparatively very less in case of charota treated plants with 1.15±1.22 mm in length with an average of 1.18±0.03 mm and 0.42±0.56 mm in width with an average of 0.49±0.07 mm at 0.25% and 1.12±1.16 mm in length with an average of 0.74±0.65 mm and 0.40±0.53 mm in width with an average of 0.34±0.29 mm at 0.50% observed in pot treated with Charota. The eggs were 1.07±1.17 mm in length with an average of 1.12±0.05 mm and 0.42±0.55 mm in width an average of 0.49±0.07 mm at 0.25% and 1.05±1.14 mm in length with an average of 0.41±0.70 mm and 0.40±0.51mm in width with an average of 0.17±0.29 mm at 0.50% observed in pot treated with Bantulsi.

3.5 Larval period

Larvae (grubs) moulted three times during their development and thus there were four distinct instars. This is in accordance with the findings of earlier scientists Panday *et al.* (2001) [18], Dhiman and Bhargava, (2005) [4], Siddhapara, (2011) [22] and Rathod *et al.* (2012) [21], Chandravanshi (2018) [2], Jaiswal and Ganguli (2020) [9].

3.6 Duration of different larval instars:-

Data (table.- 3.2) indicated that first, second, third and fourth instar larvae (grub) duration with an average of 2.67±0.58, 3.33±0.58, 4.33±0.58 and 5.00±1.00 days on untreated control pot, Slightly prolonged duration of various larval/grub instars as compared to control with an average of 3.33±0.58, 3.33±0.58, 2.33±0.58 and 3.67±0.58 days @ 0.14 mg and with an average of 4.50±0.71, 4.00±0.00, 3.50±0.71 and 4.50±0.71 days @ 0.28mg observed in pot treated with glyphosate. In case of atrazine treated plants also duration of first, second, third and fourth instar larvae (grub) were increased to with an average of 3.67±0.58, 3.76±0.58, 3.74±0.58 and 4.67±0.58 days at a concentration of 0.03 mg and an average of 1.00±1.73, 1.00±1.74, 1.67±2.89 and 2.00±3.46 days at the concentration of 0.06mg atrazine. Duration of first, second, third and fourth instar larvae (grub) were a bit longer with an average of 3.33±0.58, 3.67±0.58, 4.00±0.00 and 4.67±0.58 days at 0.03 mg and with an average of 3.00±2.65, 3.33±2.89, 3.33±2.89 and 4.00±3.46 days observed in pots treated with metribuzin. Duration of first, second, third and fourth instar larvae (grub) were with an average of 3.67±0.58, 4.33±0.58, 5.00±1.00 and 4.67±0.58 days in 2,4-D (0.01 mg) and with an average of 3.33±2.89, 4.33±0.58, 3.67±3.21 and 4.00±3.46 days at 0.02 mg observed in pot treated with 2, 4-D (0.02mg). Duration of first, second, third and fourth instar larvae (grub) were slightly longer of with an average of 3.33±0.58, 3.67±0.58, 4.00±0.00 and 4.67±0.58 days in case marigold (0.25%) and with an average of 2.67±2.31, 3.00±2.65, 3.33±2.89 and 4.33±0.58 days in pots treated with marigold (0.50%). Duration of first, second, third and fourth instar larvae (grub) were with an average of 3.00±0.00, 3.67±0.58, 4.33±0.58 and 4.34±0.58 days in case of charota (0.25%) and with an average of 2.33±2.08, 2.67±2.31, 3.33±2.89 and 4.00±0.00 days in pots treated with charota @ 0.50%. Duration of first, second, third and fourth instar larvae (grub) were with an average of 3.33±0.58, 4.00±0.00, 4.67±0.58 and 5.33±0.58 days @ 0.25% and with an average of 1.33±2.31, 1.67±2.89, 2.00±3.46 and 2.00±3.46 days @ 0.50% observed in pots treated with bantulsi.

3.7 Size

In glyphosate @0.14mg length of male and female were recorded with an average of 5.41±0.13mm and width was recorded with an average of 3.49±0.20mm and 4.39±0.19mm, respectively whereas length of male and female were recorded with an average of 5.43±0.13mm and 6.69±0.27mm and width was recorded with an average of 3.56±0.23mm and 4.48±0.29mm, respectively compared with control. In case of first, second, third and fourth instar larvae (grubs) minimum length was recorded with an average of 1.10±0.05mm, 3.04±0.02mm, 3.45±0.16mm and 7.11±0.05mm and minimum width were 0.27±0.03mm, 1.05±0.05mm, 2.07±0.05mm and 2.28±0.15mm recorded in atrazine @ 0.14 mg compared with control.

3.8 Adult (Male and Female)

3.8.1 Longevity

The newly emerged adults were soft, light brown and remained one day in the pupal cases during which their body hardened and the elytra turned shining brown. The beetle was oval, convex dorsally and flat ventrally. The adults were attractive in colour. The elytra were marked with undulating dark brown lines that run longitudinally over an off white background. The rest of body and appendages were dark brown, except that the pronotum with off white patches at the anterior edges. This agreement was similar to Siddhapara *et al* (2012) [23]. Data (table.) indicated that longevity of male was 30.00-33.00 days with an average of 31.67±1.53 days and that of female 32.00-36.00 days with an average of 34.00±2.00 days and observed in untreated control pots, whereas 6.67±2.08 days in male and 9.67±1.53 days in female @ 0.14mg and male was 4.67±2.54 days and female was 3.00±1.41 days @ 0.28 mg observed in pots treated with glyphosate. The longevity of male directly reduced of 2.00±1.00 days and 3.50±0.71 days in female @0.7mg and male was 0.67±1.15 days and female was 0.00±0.00 days @ 0.14mg observed in pots treated with atrazine. Similarly, the longevity of male was very much reduced as compared to control. 4.33±1.08 days and 3.00±1.00 days in female @0.03mg and male was 0.67±1.15 days and female was 1.00±1.73 days @0.06mg observed in pots treated with metribuzin as compared to control. In case of 2,4-D also the longevity of male was very less 3.00±1.00 days in comparison to control and 2.00±2.00 days in female @ 0.01 mg and male was 1.67±2.89 days and female was 1.33±1.04 days at a concentration of 0.02 mg. Lesser longevity of male of 7.67±2.52 days and 3.00±2.00 days in female were recorded in case of marigold at 0.25% and male was 7.33±6.43 days and female was 8.00±7.00 days at marigold (0.50%). In case of charota the longevity of male was 10.00±2.65 days and female were recorded 12.67±2.52 days @0.25% and male was 9.83±2.00 days and female was 10.67±1.53 days @ 0.50%. Similarly the longevity of male was very less 6.67±2.52 days in comparison to control and 7.33±2.52 days with in female @ 0.25% and male was 5.67±2.81 days and female was 6.33±2.97 days @ 0.50% observed in pots treated with bantulsi.

3.8.2 Size

In untreated control pots, the average length and width of male and female were 5.52± 0.23 mm and 3.56±0.23 mm, respectively, and 6.71±0.25 mm and 4.50±0.29 mm, respectively, whereas at a concentration of 0.14 mg in glyphosate, the average length and width were 5.41±0.13 mm and 3.49± 0.20 mm, respectively, and 6.65± 0.23mm and 4.39± 0.19mm, respectively. Male and female @0.28mg measurements of length and breadth were similar, with average values of 5.43± 0.13 mm, 3.56 ±0.23 mm, and 6.69 ±0.27 mm, 4.48± 0.29 mm, respectively. In pots treated with atrazine, length of male and female were recorded with an average of 5.38±0.12mm and 6.48±0.15mm and width was recorded with an average of 3.30±0.12mm and 4.15±0.31mm at 0.14 mg. The size of male and female was recorded with an average of 5.26±0.25 and 6.40±0.15mm and width was recorded with an average of 3.33±0.18mm and 4.28±0.28mm at 0.7 mg. In the case of metribuzin, the average size of the male and female was 5.43±0.13mm and 6.69±0.27mm, respectively, and the average width was 3.50±0.21mm and 4.48±0.29mm at 0.3 mg. The average

length and width were 5.41±0.13mm and 6.65±0.23mm, respectively, and 3.49±0.20mm and 4.39±0.19mm at 0.6 mg. Length of male and female was recorded with an average of 5.41±0.13 and 6.65±0.23mm and width was recorded with an average of 3.49±0.20mm and 4.49±0.20mm at 0.01 mg and length was recorded with an average of 5.43±0.13 and 6.69±0.27 mm and 3.33±3.77 and 4.16±4.72 in width with an average of 3.56±0.23 and 4.48±0.29 mm at 0.02 mg observed in pots treated with 2,4-D. Similarly, the size of male and female was recorded in botanical treatment marigold @0.25% with an average of 5.46±0.19mm and 6.66±0.24mm and width was recorded with an average of 3.62±0.18mm and 4.42±0.17mm at 0.25%. However, length of male and female were recorded with an average of 5.42±0.18mm and 6.50±0.12mm and width was recorded with an average of 3.46±0.19mm and 4.37±0.22mm @ 0.50%.

Table 1: Toxicity of weedicides and botanicals on adult beetles, *Z. bicolorata* during 09 February to 04 March.

S.no	Treatments with conc. mg/%	No. of insects released (1pair)	No. of insect live (24, 48,72hr.)	No. of insect dead (24 hr.)	No. of insect dead (48hr.)	No. of insect dead (72hr.)	No. eggs laid	Hatching percentage
1.	Glyphosate (0.14)	1	2	0.92	1.21	1.29	200	57.05
2.	Glyphosate (0.28)	1	2	1.29	1.29	1.33	100	40.00
3.	Atrazine (0.7)	1	2	1.33	1.29	1.33	96	33.33
4.	Atrazine (0.14)	1	2	1.58	1.62	1.67	60	26.67
5.	Metribuzin (0.3)	1	2	1.04	1.04	1.21	190	40.00
6.	Metribuzin (0.6)	1	2	1.54	1.48	1.63	87	39.08
7.	2,4-D (0.01)	1	2	1.04	1.04	0.92	192	45.31
8.	2,4-D (0.02)	1	2	1.50	1.52	1.58	98	40.82
9.	Marigold (0.25)	1	2	0.58	0.54	0.71	210	71.43
10.	Marigold (0.50)	1	2	0.63	0.62	0.92	198	60.61
11.	Charota (0.25)	1	2	0.50	0.48	0.67	250	72.00
12.	Charota (0.50)	1	2	0.54	0.50	0.71	210	69.04
13.	Bantulsi (0.25)	1	2	0.75	0.92	1.25	150	64.67
14.	Bantulsi (0.50)	1	2	1.08	0.95	1.33	80	57.50
15.	Control	1	2	0.42	0.46	0.50	300	92.67
CD@5%		-	-	0.091	0.102	0.102	-	-
SEm ±		-	-	0.032	0.036	0.036	-	-

Table 2: Duration of survived life-stages of *Z. bicolorata* in the F1 generation

			Duration of different life-stages of *Z. bicolorata*						
Treatments	**Fecundity (Average)**	**Egg (incubation Period) (Average)**	**1st instar (Average)**	**2nd instar (Average)**	**3rd instar (Average)**	**4th instar (Average)**	**Pupa (Average)**	**Male (Average)**	**Female (Average)**
Glyphosate (0.14mg)	66.67±29.02	4.33±0.58	3.33±0.58	3.33±0.58	2.33±0.58	3.67±0.58	8.33±0.58	6.67±2.08	9.67±1.53
Glyphosate (0.28)	33.33±5.86	4.45±0.57	4.50±0.71	4.00±0.00	3.50±0.71	4.50±0.71	9.00±1.41	4.67±2.54	3.00±1.41
Atrazine (0.7mg)	32.00±11.36	3.67±0.58	3.67±0.58	3.76±0.58	3.74±0.58	4.67±0.58	8.33±0.58	2.00±1.00	3.50±0.71
Atrazine (0.14mg)	20.00±1.00	1.67±2.89	1.00±1.73	1.00±1.74	1.67±2.89	2.00±3.46	10.00±1.00	0.67±1.15	0.00±0.00
Metribuzin (0.3mg)	63.33±2.08	3.33±0.58	3.33±0.58	3.67±0.58	4.00±0.00	4.67±0.58	8.33±0.58	4.33±1.08	3.00±1.00
Metribuzin (0.6mg)	29.00±3.61	2.67±2.52	3.00±2.65	3.33±2.89	3.33±2.89	4.00±3.46	9.33±0.47	0.67±1.15	1.00±1.73
2,4-D (0.01mg)	64.00±7.21	4.00±0.00	3.67±0.58	4.33±0.58	5.00±1.00	4.67±0.58	8.33±0.58	3.00±1.00	2.00±2.00
2,4-D (0.02mg)	32.67±1.53	3.33±2.89	3.33±2.89	4.33±0.58	3.67±3.21	4.00±3.46	9.33±0.47	1.67±2.89	1.33±1.04
Marigold (0.25%)	70.00±7.00	3.67±0.58	3.33±0.58	3.67±0.58	4.00±0.00	4.67±0.58	8.33±0.58	7.67±2.52	3.00±2.00
Marigold (0.50%)	66.00±2.00	2.67±2.31	4.33±0.58	4.00±1.00	4.33±0.58	5.00±1.00	9.33±0.47	7.33±6.43	8.00±7.00
Charota (0.25%)	83.33±5.13	3.33±0.58	3.00±0.00	3.67±0.58	4.33±0.58	4.34±0.58	8.33±0.58	10.00±2.65	12.67±2.52
Charota (0.50%)	70.00±2.00	2.67±2.31	3.33±0.58	3.67±1.15	3.33±0.58	4.00±1.00	9.33±0.47	9.83±2.00	10.67±1.53
Bantulsi (0.25%)	50.00±3.00	3.00±0.00	3.33±0.58	4.00±0.00	4.67±0.58	4.67±1.15	8.67±0.58	6.67±2.52	7.33±2.52
Bantulsi (0.50%)	26.67±1.53	1.67±2.89	4.00±1.00	4.33±0.58	5.00±1.00	4.67±0.58	9.00±1.00	5.67±2.81	6.33±2.97
Control	100.00±4.58	3.33±0.58	2.67±0.58	3.33±0.58	4.33±0.58	5.00±1.00	8.33±0.58	31.67±1.53	34.00±2.00

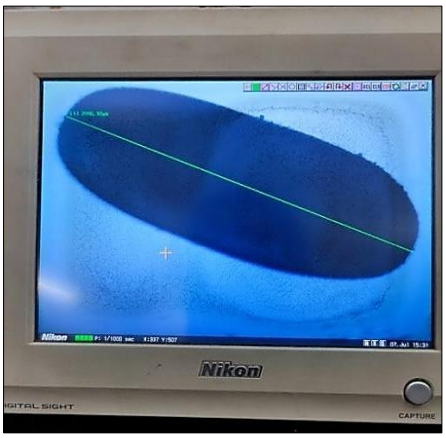
Collection of *Z.bicolorata* from IGKV

Mass multiplication of *Z. bicolorata* in plastic basins

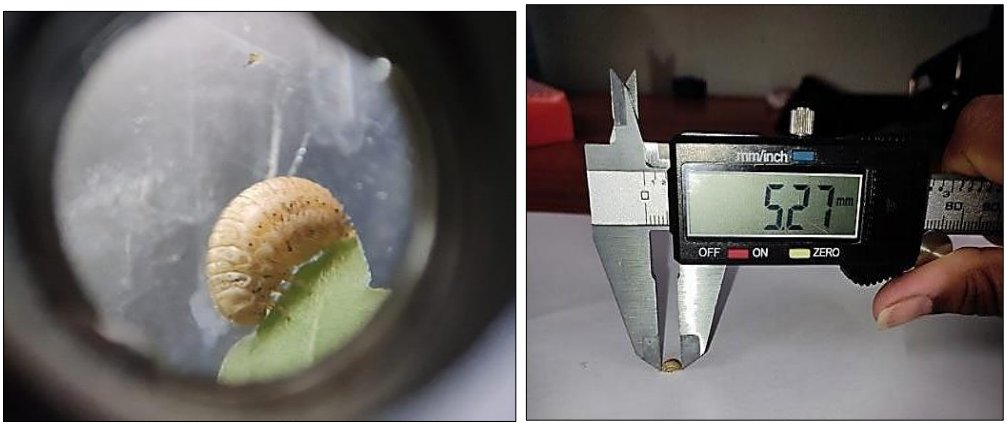
Making concentrations of weedicides, botanicals and spraying on plants

Starved beetles till 24 hrs.

Releasing of a pair of beetles in pots and caged



Measurement of eggs



Measurement of larvae

Measurement of adu

Fig 1: Biometric measurements of different stages of *Zygogramma bicolorata*

4. Conclusion

The highest mortality with mean of 1.67 was recorded in atrazine @ both concentrations (0.7 and 0.14mg) to the Z. bicolorata. Marigold, Charota and Bantulsi were found safe to the adult beetles. Highest percentage of egg hatching was observed in charota (72.00%) @ 0.25% and lowest in atrazine (26.60%) @ 0.14mg. Studies on the biometric parameters of *Z. bicolorata*, revealed that the length and width of 1st, 2nd, 3rd and 4th instar larvae in untreated control were with an average of 1.43±0.05mm, 3.64±0.18mm, 4.91±0.20mm and 8.19±0.06mm, respectively. In atrazine @ 0.7mg, the minimum length of larvae (1st to 4th instar) were recorded with an average of 1.19±0.05mm to 7.14±0.06mm and width were recorded with an average of 0.39±0.03mm to 2.37±0.16mm while, @ 0.14mg the length ranged from 1.10±0.05mm to 7.11±0.05mm and width ranged from 0.27±0.03mm to 2.28±0.15mm, respectively. At 0.14 mg, minimum size of pupa was observed in atrazine with an average of 5.45±0.12mm whereas width was observed with an average of 3.41±0.20mm. The minimum size of adults was recorded in atrazine @0.14 mg with an average of 5.26±0.25mm in male whereas 6.40±0.15mm in female followed by bantulsi @ 0.50% with an average of 5.45±0.21mm in male and 6.52±0.23mm in female respectively.

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