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# Evaluation of eco-friendly and chemical pesticides, and attractant solutions against giant African snail, *Achatina fulica* Bowdich on mulberry

**Pallavi HS, Basavaraju BS, Umashankar N, Shivashankar T and Rajegowda**

**Abstract**
The efficacy of eco-friendly and chemical pesticides, and attractant solutions against giant African snail on mulberry was evaluated at H. Kodihalli village of Mandya district of Karnataka during September 2016. Among the eco-friendly pesticides copper sulphate poison bait registered highest per cent snail mortality in both laboratory (100 %) and field situations (99.63 % over one week duration). Whereas, lime+crystal salt (2:1), burnt rice husk+crystal salt (2:1) and rice husk+*Acacia concinna* powder (8:1) were found effective as barriers against the snail in laboratory studies. Among the chemical pesticides evaluated in field condition thiodicarb 75 WP and copper sulphate poison baits registered 120.66 and 87.01 dead snails per 10 $m^2$ area, respectively against methomyl 40 SP poison bait, the standard check which registered 145.01 dead snails per 10 $m^2$ area. Among the attractant solutions tested using bucket traps, cane juice, jaggery solution, buttermilk and tender coconut water were found more efficient in trapping the snails.

**Keywords:** *Achatina fulica*, eco-friendly pesticides, chemical pesticides, attractant solutions

## Introduction
The giant African snail, *Achatina fulica* Bowdich belongs to the Phylum: Mollusca, Class: Gastropoda, Sub-class: Pulmonata, Order: Stylommatophora and Family: Achatinidae. It is known for its destructive nature on cultivated plants wherever it occurs and is one of the world's largest and most damaging land snail pests (Ravikumara *et al*., 2007) [16]. It is a highly polyphagous pest damaging more than 500 plant species including fruit crops, vegetables, ornamental plants and field crops. Raut and Ghose (1984) [15] stated that nearly 90 per cent plants cultivated in India were acceptable to *A. fulica*. Mulberry is one of the important commercial crops growing in Mandya district of Karnataka in an area of 24,000 hectares (Anon., 2016) [1]. Recently, *A. fulica* is attaining major pest status on mulberry in isolated patches of this district causing considerable yield loss. On mulberry the snail feeds on new sprouts and buds, tender leaves, shoots, petiole, tender bark of stem. It feeds on leaves by making circular holes and frequent infestation leads to stunted growth of plants (Jadhav *et al*., 2016) [6]. Besides, the stinking smell of mucus layer released by them has adverse effect on the silkworms feeding (Shree *et al*., 2006) [20]. Keeping in view, experiments were conducted at H. Kodihalli village of Mandya taluk, Mandya district of Karnataka during September 2016 to evaluate the efficacy of eco-friendly and chemical pesticides, and attractant solutions against the snail.

## Material and Methods
### 1. a. Laboratory evaluation of eco-friendly pesticides against *A. fulica*
The efficacy of thirteen eco-friendly pesticides against *A. fulica* was evaluated under laboratory condition along with methomyl 40 SP poison bait as standard check with one untreated control. The pesticides were placed as hollow circle of 6 cm width and 15 cm inner diameter. For poison bait treatments pesticides were mixed with food bait (10 kg wheat bran+ 4 kg jaggery+ 4 l water, fermented for 24 hours) at the rate of 10 ml or 10 g per kg bait and applied. Three circles were maintained for each treatment. For each circle five grown up snails were released at the centre and observations were recorded regarding number of snails died or crossed the circle after 6, 12, 18 and 24 hours of release (Vanitha *et al.*, 2011) [25].

### 1. b. Field evaluation of eco-friendly pesticides against *A. fulica* in mulberry garden
To confirm the results of laboratory study, the pesticides were evaluated for their efficacy against *A. fulica* in mulberry garden using RCBD design with three replications. Before poison

application initial activity of snail count were made by spreading only food bait (10 kg wheat bran+ 4 kg jaggery+ 4 l water, fermented for 24 hours) all along the border. The number of snails in each treatment was recorded during evening hours. Treatments were imposed next day evening by spreading the pesticides all along the border up to 10 m length and 0.3 m width. For poison bait treatments pesticides were mixed with food bait at the rate of 10 ml or 10 g per kg bait and applied. Observations on snail mortality in each treatment were recorded on 1, 3, 5 and 7 days after treatment imposition (Basavaraju *et al.*, 2001) [2].

**2. Field evaluation of chemical pesticides against *A. fulica* in mulberry garden**

The bio-efficacy of eight chemical pesticides against *A. fulica* was evaluated under field condition using poison bait technique along with the standard check, methomyl 40 SP and an untreated control. Three replications and 10 treatments using Randomized Block Design (RBD) in mulberry gardens with plot size of 10 m length*1 m width all along the border were maintained. Observations on previous day snail count were made by spreading food bait (10 kg wheat bran+ 4 kg jaggery+ 4 l water, fermented for 24 hours) in all the treatments and number of snails in each treatment was recorded during evening hours. Next day evening, poison baits were prepared @ 10 g or 10 ml chemical per kg food bait and applied in the respective treatments by spread application and observations were recorded on snail mortality in each treatment on 1, 3, 5 and 7 days after treatment imposition (Basavaraju *et al.*, 2001) [2].

**3. Field evaluation of attractant solutions against *A. fulica* in mulberry garden**

The efficiency of attractant solutions in trapping *A. fulica* was evaluated under field condition in mulberry garden using bucket trap technique. Five traps *viz.*, tender coconut water, Jaggery solution, cane juice, buttermilk and saw dust solution were evaluated in six replications using Randomized Block Design (RBD) and water was maintained as control.

In all the treatments crystal salt was used as common killing agent and yeast as fermenting agent. The bucket traps were kept in separate plots of 25 $m^2$ area nearer to the bunds by burying them in the ground up to the rim level in such a way to facilitate the access of the snails. The observations on number of snails trapped on 3, 5, 7 and 10 days after trap placement were recorded (Vanitha *et al.*, 2008) [23].

## Results and Discussion

**1. a&b. Laboratory and field evaluation of eco-friendly pesticides against *A. fulica***

The results of the laboratory and field experiments on efficacy of eco-friendly pesticides against *A. fulica* are presented in Table 1 and 2.

**Table 1:** Laboratory evaluation of eco-friendly pesticides against *A. fulica*

| Treatments | Number of snails crossed the barrier | | | | Snails crossed (%) |
|---|---|---|---|---|---|
| | 6 HAR | 12 HAR | 18 HAR | 24 HAR | |
| $T_1$: Neem seed powder | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 1.33(1.34)$^b$ | 1.33(1.34)$^b$ | 26.60 |
| $T_2$: Rice husk+ *Acacia concinna* powder (8:1) | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00 |
| $T_3$: Rice husk | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_4$: Burnt rice husk + crystal salt (2:1) | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00 |
| $T_5$: Lantana leaf powder | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_6$: Lime+ crystal salt (2:1) | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00 |
| $T_7$: Charcoal | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_8$: *Madhuca* seed powder | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 1.00(1.22)$^b$ | 1.00(1.22)$^b$ | 20.00 |
| $T_9$: *Pongamia* seed powder | 1.33(1.34)$^b$ | 3.00(1.86)$^b$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_{10}$: Saw dust | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_{11}$: Neem oil @ 10 ml/kg food bait | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_{12}$: Dipel 8 L @ 10 ml/kg food bait | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| $T_{13}$: Copper sulphate @ 10 g/kg food bait | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00 |
| $T_{14}$: Methomyl 40 SP@ 10 g/kg of food bait (check) | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00(0.71)$^a$ | 0.00 |
| $T_{15}$: Untreated control | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 5.00(2.35)$^c$ | 100.00 |
| SEm± | 0.09 | 0.15 | 0.09 | 0.09 | |
| CD @ p=0.05 | 0.33 | 0.58 | 0.33 | 0.33 | |

**HAR:** Hours After Release; Values in the column followed by common letters are non-significant at p = 0.01 as per Tuckey's HSD (Tukey, 1965). Figures in the parenthesis indicate √x+0.5 transformed values.

Among the eco-friendly pesticides copper sulphate poison bait was found most effective as it recorded 100 per cent snail mortality in laboratory studies. In field studies it recorded mean snail mortality (in numbers per 10 m length X 0.3 m width) of 51.33, 22.00, 16.00 and 3.00 on 1st, 3rd, 5th and 7th days after treatment imposition, respectively which accounts total mortality of 92.33 snails over one week duration against the initial snail count of 92.67 snails which accounts 99.63 per cent mortality. This result is in line with the findings of Shevale and Bedse (2009) [19], Chandaragi (2014) [3] and Paul *et al.* (2016) [10] who reported the effectiveness of copper sulphate poison bait against the snail.

However, methomyl 40 SP poison bait, the standard check recorded 100 per cent snail mortality in laboratory studies, and 160.23 per cent mortality in field studies over one week duration, and found to be superior to the present investigation. In field studies on 1st, 3rd, 5th and 7th day after treatment imposition it recorded mean snail mortality (in numbers per 10 m length X 0.3 m width) of 80.67, 35.00, 21.67 and 11.67, respectively which accounts total mortality of 149.01 snails over one week duration against the initial count of 93.00 snails. This result is in line with the findings of Basavaraju *et al.* (2001) [2], Shevale and Bedse (2009) [19], Chandaragi (2014) [3], Radwan (2016) [12] and Sreenivasa *et al.* (2016) [21] who reported the molluscicidal activity of methomyl poison bait against *A. fulica*.

In laboratory trials, in the treatments *viz.*, rice husk+ *Acacia concinna* powder (8:1), burnt rice husk + crystal salt (2:1) and lime+ crystal salt (2:1) none of the snails crossed the circle which indicated the effectiveness of these substances as

barriers against *A. fulica*. However, in field studies no snail mortality was observed in these treatments which might be due to the avoidance of crossing of bands of these substances by the snail.

**Table 2:** Field evaluation of eco-friendly pesticides against *A. fulica* in mulberry garden at H. Kodihalli village of Mandya taluk, Mandya district during September 2016

| Treatments | Dosage(kg or l)/ ha | Snail count ( DBT ) | Mean snail mortality (in numbers) per 10 sq.mt. | | | | Mortality in one week duration | Per cent mortality |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | | |
| $T_1$: Neem seed powder | 25 | 82.67(9.11) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_2$: Rice husk+ *Acacia concinna* powder (8:1) | 25 | 80.00(8.96) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_3$: Rice husk | 25 | 83.00(9.12) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_4$: Burnt rice husk + crystal salt (2:1) | 25 | 83.33(9.13) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_5$: Lantana leaf powder | 25 | 80.67(8.98) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_6$: Lime+ crystal salt (2:1) | 25 | 82.67(9.04) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_7$: Charcoal | 25 | 89.33(9.48) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_8$: *Madhuca* seed powder | 25 | 90.00(9.51) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_9$: *Pongamia* seed powder | 25 | 83.67(9.16) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_{10}$: Saw dust | 25 | 93.00(9.65) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_{11}$: Neem oil @ 10 ml/kg food bait | 0.5 | 81.00(9.02) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_{12}$: Dipel 8 L @ 10 ml/kg food bait | 0.5 | 80.33(8.90) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| $T_{13}$: Copper sulphate @ 10g/kg food bait | 0.5 | 92.67(9.65) | 51.33(7.20)$^b$ | 22.00(4.74)$^b$ | 16.00(4.06)$^b$ | 3.00(1.87)$^b$ | 92.33 | 99.63 |
| $T_{14}$: Methomyl 40 SP@ 10g/kg of food bait (check) | 0.5 | 93.00(9.67) | 80.67(9.01)$^a$ | 35.00(5.96)$^a$ | 21.67(4.71)$^a$ | 11.67(3.49)$^a$ | 149.01 | 160.23 |
| $T_{15}$: Untreated control | - | 81.00(9.02) | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00(0.71)$^c$ | 0.00 | 0.00 |
| SEm± | | NS | 0.79 | 0.34 | 0.23 | 0.09 | | |
| CD @ p=0.05 | | | 2.29 | 0.99 | 0.66 | 0.25 | | |

**DBT:** Day Before Treatment; **DAT:** Day After Treatment; NS: Non-Significant. Values in the column followed by common letters are non-significant at p = 0.05 as per Tuckey's HSD (Tukey, 1965). Figures in the parenthesis indicate √x+0.5 transformed values.

The effectiveness of *Acacia concinna* (shikakai) powder against *A. fulica* is in agreement with the findings of Vanitha *et al.* (2010) [24], Rao (1999) [13] and Chandaragi (2014) [3] who reported higher mortality of snails with sapindus+ shikakai extract. The effectiveness of crystal salt against *A. fulica* is in concoradance with Prasad *et al*. (2004) [11], Kumari (2011) [9], Vanitha *et al.* (2011) [25], Chandaragi (2014) [3] and Paul *et al*. (2016) [10].

The treatments *viz.*, neem seed powder and *Madhuca* seed powder were found next effective barrier substances against *A. fulica* in laboratory studies with only 20 per cent of snail crossing whereas in field studies no snail mortality was observed. The present finding on the effectiveness of neem seed powder against *A. fulica* is in agreement with Selvi *et al*. (2015) [18] who reported the effectiveness of dust formulation of neem coated silica against *A. fulica*.

Other treatments *viz.*, rice husk, lantana leaf powder, charcoal, *Pongamia* seed powder, saw dust, neem oil (poison bait) and dipel 8 L (poison bait) were found ineffective against *A. fulica* in both laboratory and field studies. This finding on the ineffectiveness of neem oil is in agreement with the findings of Ebenso (2003) [5], Vanitha *et al.* (2010) [24], Vartika and Mahendru (2010) [26], and Kumari (2011) [9] but it is in contradictory with the findings of Rao and Singh (2000) [14], and Justin *et al*. (2008) [8].

In case of methomyl poison bait in field studies, the mortality count of *A. fulica* over one week duration exceeded the initial count. This is because of migratory nature of the snail and its attraction towards food bait used in the poison baits. This finding is in agreement with the Basavaraju *et al.* (2001) [2].

Application of copper sulphate and methomyl poison baits resulted in inability of snails to withdraw their exposed body parts inside the shell and profuse mucus secretion, and ultimately snails were died. Whereas neem seed powder, rice husk + *Acacia concinna* powder (8:1), burnt rice husk + crystal salt (2:1), lime + crystal salt (2:1) and *Madhuca* seed powder resulted in profuse mucus secretion from the body of snail at the point of contact and proved as effective dehydrating agents. Hence, the study revealed that application of copper sulphate as poison bait, and rice husk+ *Acacia concinna* powder (8:1), burnt rice husk + crystal salt (2:1), lime+ crystal salt (2:1), neem seed powder and *Madhuca* seed powder as barriers all along the border of snail infested area were effective in managing *A. fulica*.

**2. Field evaluation of chemical pesticides against *A. fulica* in mulberry garden**

The results of the field experiment on efficacy of chemical pesticides against *A. fulica* are presented in Table 3.

One day after treatment imposition among the treatments highest mean snail mortality (in numbers) of 76.67/10 $m^2$ area was recorded in methomyl 40 SP followed by thiodicarb 75 WP, copper sulphate, dichlorvas 76 EC, chlorpyriphos 20 EC, quinalphos 25 EC, carbosulfan 25 EC, cypermethrin 10 EC, dipel 8 L and untreated control with 69.00, 45.67, 45.00, 10.67, 3.00, 2.33, 2.33, zero and zero mortality per 10 $m^2$ area, respectively.

Three days after treatment imposition, the difference in mean mortality (in numbers) between the treatments was significant. Among the poison baits methomyl 40 SP recorded highest mortality of 33.67/10 $m^2$ area followed by thiodicarb 75 WP, copper sulphate and dichlorvas 76 EC with 27.00, 22.00 and 16.00 per 10 $m^2$ area, respectively. These were followed by chlorpyriphos 20 EC, quinalphos 25 EC, cypermethrin 10 EC, carbosulfan 25 EC, dipel 8 L and untreated control with mean snail mortality 2.33, 1.67, 1.67, 1.33, zero and zero mortality per 10 $m^2$ area, respectively and they were found to be on par with each other.

**Table 3:** Field evaluation of chemical pesticides against *A. fulica* in mulberry garden at H. Kodihalli village of Mandya taluk, Mandya district during September 2016

| Treatments | Dose (Poison bait in Kg/ha) | Snail count (DBT) | Mean snail mortality (in numbers) per 10 sq.mt. | | | | Mortality in one week duration | Per cent mortality |
|---|---|---|---|---|---|---|---|---|
| | | | 1 DAT | 3 DAT | 5 DAT | 7 DAT | | |
| $T_1$: Thiodicarb 75 WP | 25 | 83.33(9.16) | 69.00(8.33)$^b$ | 27.00(5.24)$^b$ | 18.33(4.34)$^b$ | 6.33(2.61)$^b$ | 120.66 | 144.80 |
| $T_2$: Dichlorvas 76 EC | 25 | 81.67(9.06) | 45.00(6.74)$^c$ | 16.00(4.06)$^d$ | 7.67(2.85)$^c$ | 2.67(1.77)$^c$ | 71.34 | 87.35 |
| $T_3$: Chlorpyriphos 20 EC | 25 | 80.33(9.00) | 10.67(3.33)$^d$ | 2.33(1.68)$^e$ | 1.67(1.46)$^d$ | 0.00(0.71)$^d$ | 14.67 | 18.26 |
| $T_4$: Quinalphos 25 EC | 25 | 82.33(9.10) | 3.00(1.86)$^e$ | 1.67(1.46)$^e$ | 1.67(1.46)$^d$ | 0.00(0.71)$^d$ | 6.34 | 7.70 |
| $T_5$: Dipel 8 L | 25 | 82.00(9.08) | 0.00(0.71)$^e$ | 0.00(0.71)$^e$ | 0.00(0.71)$^d$ | 0.00(0.71)$^d$ | 0.00 | 0.00 |
| $T_6$: Cypermethrin 10 EC | 25 | 84.00(9.19) | 2.33(1.68)$^e$ | 1.67(1.46)$^e$ | 2.00(1.58)$^d$ | 0.00(0.71)$^d$ | 6.00 | 7.14 |
| $T_7$: Carbosulfan 25 EC | 25 | 86.00(9.30) | 2.33(1.68)$^e$ | 1.33(1.34)$^e$ | 2.00(1.58)$^d$ | 0.00(0.71)$^d$ | 5.66 | 6.58 |
| $T_8$: Copper sulphate | 25 | 85.33(9.26) | 45.67(6.80)$^c$ | 22.00(4.74)$^c$ | 16.67(4.14)$^b$ | 2.67(1.77)$^c$ | 87.01 | 101.97 |
| $T_9$: Methomyl 40 SP (check) | 25 | 84.33(9.21) | 76.67(8.78)$^a$ | 33.67(5.84)$^a$ | 22.67(4.81)$^a$ | 12.00(3.53)$^a$ | 145.01 | 171.96 |
| $T_{10}$: Untreated control | - | 83.67(9.17) | 0.00(0.71)$^e$ | 0.00(0.71)$^e$ | 0.00(0.71)$^d$ | 0.00(0.71)$^d$ | 0.00 | 0.00 |
| SEm± | | NS | 1.09 | 0.78 | 0.54 | 0.23 | | |
| CD @ p=0.05 | | | 3.23 | 2.30 | 1.61 | 0.69 | | |

**DBT:** Day Before Treatment; **DAT:** Day After Treatment; NS: Non-Significant. Values in the column followed by common letters are non-significant at p = 0.05 as per Tuckey's HSD (Tukey, 1965). Figures in the parenthesis indicate √x+0.5 transformed values.

Among the poison baits tested methomyl 40 SP recorded significantly highest mean mortality (in numbers) of 22.67/10 $m^2$ area after five days of treatment imposition. This was followed by thiodicarb 75 WP, copper sulphate, dichlorvas 76 EC, cypermethrin 10 EC, carbosulfan 25 EC, chlorpyriphos 20 EC, quinalphos 25 EC, dipel 8 L and untreated control with 18.33, 16.67, 7.67, 2.00, 2.00, 1.67, 1.67, zero and zero mortality per 10 $m^2$ area, respectively.

Seven days after treatment imposition, among the treatments highest mortality was recorded in methomyl 40 SP (12.00/10 $m^2$ area) followed by thiodicarb 75 WP (6.33/10 $m^2$ area), copper sulphate (2.67/10 $m^2$ area) and dichlorvas 76 EC (2.67/10 $m^2$ area) whereas all other treatments recorded zero mortality.

Over one week duration, among the poison baits tested highest snail mortality (in numbers) of 145.01/10 $m^2$ area was recorded in methomyl 40 SP poison bait treatment against the initial count of 84.33 snails/10 $m^2$ area which accounts 171.96 % snail mortality. The effectiveness of methomyl 40 SP poison bait against the snail was also recorded by Basavaraju *et al.* (2001) [2], Shevale and Bedse (2009) [19], Chandaragi (2014) [3], Radwan (2016) [12] and Sreenivasa *et al.* (2016) [21].

The treatments thiodicarb 75 WP, copper sulphate, dichlorvas 76 EC, chlorpyriphos 20 EC, quinalphos 25 EC, cypermethrin 10 EC, carbosulfan 25 EC, dipel 8 L and untreated control recorded 120.66, 87.01, 71.34, 14.67, 6.34, 6.00, 5.66, zero and zero mortality over one week duration against the initial count of 83.33, 85.33, 81.67, 80.33, 82.33, 84.00, 86.00, 82.00 and 83.67 snails/10 $m^2$ area which accounts 144.80 %, 101.97 %, 87.35 %, 18.26 %, 7.70 %, 7.14 %, 6.58 %, zero and zero mortality, respectively.

The effectiveness of thiodicarb 75 WP against the snail was also reported by Chandaragi (2014) [3] who reported the effectiveness of thiodicarb 75 WP @ 10 g/kg of rice bran (60 kg/ha) against *A. fulica* and Paul *et al.* (2016) [10] who recorded 70.00 % snail mortality in thiodicarb poison bait treatment.

The effectiveness of copper sulphate is in agreement with Chandaragi (2014) [3] who reported copper sulphate @ 100 g/kg of rice bran (60 kg/ha) was effective against *A. fulica*, Paul *et al.* (2016) [10] who recorded 73.33 % snail mortality in copper sulphate poison bait, and Shevale and Bedse (2009) [19] who recorded 64.60 % and 34.00 % snail mortality after 3rd and 7th day of application of copper sulphate @ 100 g/kg of food bait, respectively.

The finding on the effectiveness of dichlorvas 76 EC poison bait against the snail is in agreement with Saxena and Mahendru (2000) [17] who reported >90 % mortality of *A. fulica* in less than 96 hours in bait mixed with dichlorvos. Kumari (2011) [9] and Sreenivasa *et al.* (2016) [21] also reported the effectiveness of dichlorvas against *A. fulica*.

The remaining treatments *viz.*, chlorpyriphos 20 EC, quinalphos 25 EC, dipel 8 L, cypermethrin 10 EC and carbosulfan 25 EC poison baits tested against *A. fulica* were failed to produce satisfactory mortality (Javaregowda (2006) [7], Shevale and Bedse (2009) [19], Chaudhury *et al.* (1997) [4], and Thakur (1999) [22] also obtained similar results).

In case of methomyl, thiodicarb and copper sulphate poison baits, the mortality count of *A. fulica* over one week duration exceeded the initial count. This is because of migratory nature of the snail and its attraction towards food bait used in the poison baits. This finding is in agreement with the Basavaraju *et al.* (2001) [2].

Application of methomyl 40 SP, thiodicarb 75 WP and copper sulphate poison baits resulted in inability of snails to withdraw their exposed body parts inside the shell and profuse mucus secretion, and ultimately snails were died. Hence, the study concludes that methomyl 40 SP, thiodicarb 75 WP and copper sulphate poison baits were most effective against *A. fulica*. However, methomyl 40 SP is not available in the market hence, thiodicarb 75 WP and copper sulphate are the next best alternatives for the effective management of the snail.

### 3. Field evaluation of attractant solution traps against *A. fulica* in mulberry garden

The results of the field experiment on efficiency of attractant solution traps in trapping *A. fulica* are presented in Table 4.

Three days after trap placement, significantly higher number of snails was trapped in buttermilk (14.40/trap) followed by cane juice (5.00/trap), jaggery solution (4.80/trap), tender coconut water (3.80/trap), saw dust solution (2.20/trap) and water (0.60/trap).

After five days of trap placement, among the traps jaggery solution (12.20/trap) trapped significantly more number of snails and was found to be on par with cane juice (11.60/trap). Tender coconut water was the next best treatment which trapped 8.20 snails/trap and differed significantly from rest of the treatments. Buttermilk (4.60/trap) was found to be on par with saw dust solution (3.20/trap). Least number of snails was trapped by water (0.40/trap).

**Table 4:** Field evaluation of attractant solution traps against *A.fulica* in mulberry garden at H. Kodihalli village of Mandya taluk, Mandya district during September 2016.

| Treatments | Dosage (Traps/ha) | Mean number of snails trapped/trap | | | | Mean |
|---|---|---|---|---|---|---|
| | | 3 DAT | 5 DAT | 7 DAT | 10 DAT | |
| $T_1$: Tender coconut (200 ml)+ yeast (5 g)+ crystal salt (10 g)+ water (800 ml) | 25 | 3.80 (2.04)$^{bc}$ | 8.20 (2.94)$^{b}$ | 4.00 (2.12)$^{b}$ | 3.20 (1.91)$^{a}$ | 4.80 |
| $T_2$: Jaggery (200 g)+ yeast (5 g)+ crystal salt (10 g)+ water (1000 ml) | 25 | 4.80 (2.30)$^{b}$ | 12.20 (3.56)$^{a}$ | 5.80 (2.51)$^{a}$ | 3.60 (2.02)$^{a}$ | 6.60 |
| $T_3$: Cane juice (200 ml)+ yeast (5 g)+ crystal salt (10 g)+ water (800 ml) | 25 | 5.00 (2.33)$^{b}$ | 11.60 (3.47)$^{a}$ | 6.20 (2.58)$^{a}$ | 3.80 (2.07)$^{a}$ | 6.65 |
| $T_4$: Butter milk (100 ml)+ yeast (5 g)+ crystal salt (10 g)+ water (800 ml) | 25 | 14.40 (3.86)$^{a}$ | 4.60 (2.25)$^{c}$ | 3.00 (1.86)$^{b}$ | 3.60 (2.02)$^{a}$ | 6.40 |
| $T_5$: Saw dust (200 g)+ yeast (5 g)+ crystal salt (10 g)+ water (1000 ml) | 25 | 2.20 (1.64)$^{cd}$ | 3.20 (1.91)$^{c}$ | 1.40 (1.37)$^{c}$ | 2.00 (1.58)$^{b}$ | 2.20 |
| $T_6$: Water (1000 ml) (control) | 25 | 0.60 (0.99)$^{d}$ | 0.40 (0.91)$^{d}$ | 0.20 (0.81)$^{d}$ | 0.00 (0.71)$^{c}$ | 0.30 |
| SEm± | | 0.48 | 0.50 | 0.28 | 0.25 | |
| CD @ p=0.05 | | 1.40 | 1.48 | 0.84 | 0.73 | |

**DAT:** Day after Treatment; Values in the column followed by common letters are non-significant at p = 0.05 as per Tuckey's HSD (Tukey, 1965). Figures in the parenthesis indicate √x+0.5 transformed values.

Among the traps evaluated cane juice (6.20/trap) and jaggery solution (5.80/trap) recorded significantly more number of traps after seven days of trap placement and were found to be on par with each other. The next best treatments were tender coconut water (4.00/trap) and buttermilk (3.00/trap), and they were on par with each other whereas saw dust solution trapped only 1.40 snails /trap and significantly differed from water which recorded 0.20/trap.

Ten days after trap placement, among the traps tested significantly more number of snails was trapped in cane juice (3.80/trap) and was found to be on par with jaggery solution (3.60/trap), buttermilk (3.60/trap) and tender coconut water (3.20/trap). However, saw dust solution trapped only 2.00 snails /trap and significantly differed from water which recorded zero traps.

Over ten days duration, among the traps highest mean number of snails was trapped in cane juice (6.65/trap) followed by jaggery solution (6.60/trap), buttermilk (6.40/trap), tender coconut water (4.80/trap), saw dust solution (2.20/trap) and water (0.30/trap).

Among the treatments evaluated, buttermilk attracted and trapped maximum of 14.40 snails/trap on third day of trap placement whereas jaggery solution (12.20 snails/trap), cane juice (11.60 snails/trap) and tender coconut water (8.20 snails/trap) attracted more number of snails on fifth day of trap placement by producing strong sour smell by fermentation process thereafter, the number snails trapped by these solutions gradually decreased due to reduced fermentation process. Whereas, Saw dust solution and water (control) attracted very less number of snails because of less sour smell. This finding is in agreement with Vanitha *et al.* (2008) [23] who reported maximum number of traps in fermented neera, sugar solution and beer producing strong sour smell.

Hence, the study concludes that the population of *A. fulica* can be efficiently reduced by placing cane juice, jaggery solution, buttermilk and tender coconut water traps.

## Summary

Among the eco-friendly pesticides evaluated against *A. fulica*, copper sulphate poison bait was found most effective in both laboratory and field studies. Whereas, rice husk+ *Acacia concinna* powder (8:1), burnt rice husk + crystal salt (2:1), lime+ crystal salt (2:1), *Madhuca* seed powder and neem seed powder were found effective as barrier substances against the snail in laboratory study. However, methomyl 40 SP poison bait, the standard check recorded maximum snail mortality in both laboratory and field studies and found superior to the present investigation.

Among the different poison baits evaluated against *A. fulica* on mulberry thiodicarb 75 WP and copper sulphate were found most effective against *A. fulica*. However, methomyl 40 SP, the standard check produced highest snail mortality and found superior to the present investigation.

Among the attractant solution traps evaluated against *A. fulica* on mulberry cane juice, jaggery solution, buttermilk and tender coconut water trapped maximum number of snails/trap and found most efficient in trapping snails.

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