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Efficacy of Soapnut Based Emulsifiable Concentrate (EC) Formulations against Land Snails *Ariophanta bajadera* (Pfeiffer) Under Field Conditions

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Abstract
The present field investigation on the efficacy of soapnut based Emulsifiable Concentrate (EC) formulations against land snails *Ariophanta bajadera* (Pfeiffer) was carried out during the *Kharif* season of 2024 at the Vegetable Improvement Scheme, Central Experiment Station (CES), Wakawali, under the jurisdiction of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, District Ratnagiri (Maharashtra). A total of six EC formulation Products were developed using a 1:10 solid-liquid ratio of soapnut rind powder with different solvents, including water, boil water, water-ethanol, ethanol, acetone and water-acetone, each emulsified using Tween 20. The formulations were evaluated on two vegetable crops, okra and cucumber under natural field conditions. In the field evaluation, EC Product IV - [Ethanol + Soapnut Powder (1:10) + Tween 20] was the most effective, recording the highest 91.90 per cent snail mortality in okra and 88.29 per cent snail mortality in cucumber and was significantly superior over the other treatments. This was followed by EC Product I - [Water + Soapnut Powder (1:10) + Tween 20], which resulted in 78.25 per cent snail mortality in okra and 72.96 per cent snail mortality in cucumber. EC Product II - [Boil Water + Soapnut Powder (1:10) + Tween 20] showed 72.70 per cent snail mortality in okra and 70.27 per cent snail mortality in cucumber. EC Product III - [Water-Ethanol + Soapnut Powder (1:10) + Tween 20] gave 68.93 per cent snail mortality in okra and 68.99 per cent snail mortality in cucumber. EC Product V - [Acetone + Soapnut Powder (1:10) + Tween 20] recorded 68.33 per cent snail mortality in okra and 67.46 per cent snail mortality in cucumber, while the least effective was EC Product VI - [Water-Acetone + Soapnut Powder (1:10) + Tween 20], which resulted in 65.46 per cent snail mortality in okra and 66.06 per cent snail mortality in cucumber. The results indicated that the choice of solvent played a crucial role in enhancing the field efficacy of EC products, with ethanol based formulations proving most effective under natural infestation conditions.

Keywords: Soapnut powder, Emulsifiable Concentrate (EC), ethanol formulation, snail mortality, field evaluation, Tween 20

Introduction
Land snails comprise the second largest phylum after arthropods in terms of species, with over one lakh species identified. They include multiple lineages of terrestrial gastropods (Lydeard *et al*., 2004) [7] and are mainly found in tropical regions. Molluscs derive their name from the Latin *mollus*, meaning "soft," and are typically protected by a hard calcium shell (Zala *et al*., 2018) [11]. Due to their high reproductive capacity, even a single snail or slug can multiply rapidly, making population control difficult. These pests hide in moist, shaded areas during the day and emerge at night to damage crops, causing financial losses.
In the Konkan region, the prevalence of the land snail *Ariophanta bajadera* (Pfeiffer) (Order: Stylommatophora, Family: Ariophantidae) has increased over the past fifteen years. The region's high rainfall and humidity promote their growth, offering them ample food sources. It is a polyphagous pest that affects the ecosystem, ornamentals like *Monstera*, *Tagetes* and *Portulaca* and a variety of crops including okra, groundnut, sun hemp, yams, tuber crops, cowpea, cucurbits, brinjal and papaya (Rahul Patil, 2005) [9].
Although the World Health Organization has tested many synthetic pesticides for snail control, these have not proven fully satisfactory. Due to environmental concerns, research is now focused on plant-based molluscicides, which may be biodegradable and safer.

Various plant compounds like saponins, tannins, alkaloids, alkenyl phenols, glycoalkaloids, flavonoids, sesquiterpene lactones, terpenoids and phorbol esters have shown snail toxicity even at <1-100 ppm (Ajay Singh *et al*., 1996) [1].

Sapindus mukorossi (Gaertn.), also known as ritha or Indian soapberry, belongs to the Sapindaceae family. It grows up to 1200 m in the Himalayas and is native to Maharashtra, Goa, coastal Karnataka, Taiwan and Southern China. It thrives in tropical/subtropical climates and is well known for its insecticidal properties. A single tree yields 30-35 kg of fruit annually (https://www.inaturalist.org). Its saponins have demonstrated a wide range of biological activities, including molluscicidal, pesticidal, antiviral, antifungal, antioxidant, anti-inflammatory and immunostimulant effects (De Geyter *et al*., 2012) [2]. In the absence of effective synthetic molluscicides, hand-picking is the only common method for snail control. However, phytochemicals from plants like soapnut offer promising molluscicidal potential. The pericarp extract and saponins from *S. mukorossi* have shown activity against the golden apple snail *Pomacea canaliculata* (Huang *et al*., 2003) [3].

Due to these potential environmental and pest control benefits, the present study attempts to utilize the molluscicidal property of soapnut through soapnut-based formulations for the management of land snails.

Materials and Methods

Soapnut berries were collected and dried in a hot air oven at 70°C for 5 hours. The dried rind was then ground in a mixer to make a fine powder. Saponin was extracted from *Sapindus mukorrossi* and its insecticidal properties were studied (Kose *et al*., 2016) [5]. For extraction, soapnut powder was added into solvents with different solid-liquid ratios of 1:10. For the 1:10 solid-liquid ratio, 10 g of powder was added to 100 ml of each solvent. The solutions were mixed using a magnetic stirrer for six hours. To enhance emulsification, 1 ml of Tween 20 (an emulsifying agent) was added per 100 ml of solvent; it helps stabilize the emulsion and improve the dispersion of the extract. This EC formulation was tested against land snails under field conditions on okra and cucumber crops at the Vegetable Improvement Scheme, Central Experiment Station, Wakawali.

Weight/volume percent concentration (w/v%) = mass of solute ÷ volume of solution×100

Experimental Details: (EC Formulations for Okra)

Location	Vegetable Improvement Scheme, Central Experiment Station Wakavali, Dapoli
Crop	Okra
Season	*Kharif*
Method of planting	Ridges and Furrow
Date of Sowing	10th June 2024
Gross Area	756 m^2
Net Area	228 m^2
Spacing	60cm×45cm
Experiment Design	Randomized Block Design (RBD)
No. of Products	6
No. of Treatments	10 (Each Product)
No of Replication	3

Experimental Details: (EC Formulations for cucumber)

Location	Vegetable Improvement Scheme, Central Experiment Station Wakavali, Dapoli
Crop	Cucumber
Season	*Kharif*
Method of planting	Ridges and Furrow (With vertical support)
Date of Sowing	12th June 2024
Gross Area	722 m^2
Net Area	259 m^2
Spacing	3m×50cm
Experiment Design	Randomized Block Design (RBD)
No. of Products	6
No. of Treatments	10 (Each product)
No of Replication	3

Table 1: Treatment details (EC) -

Pr. No.	Solvent type	Solid - liquid ratio	Emulsifying agent	Dose (gm/lit)
I.	Water	1:10	Tween 20	7 ml to 15 ml
II.	Boil water	1:10	Tween 20	7 ml to 15 ml
III.	Water - Ethanol	1:10	Tween 20	7 ml to 15 ml
IV.	Ethanol	1:10	Tween 20	7 ml to 15 ml
V.	Acetone	1:10	Tween 20	7 ml to 15 ml
VI.	Water - Acetone	1:10	Tween 20	7 ml to 15 ml

Time and application

The application of different EC formulations was carried out immediately after the incidence of land snails was observed in the field. The desired concentrations of each product were prepared and sprayed on the crop. Spraying was conducted early in the morning, with efforts made to cover the crop canopy from both sides. As far as possible, direct contact between the toxicant and the snails was ensured to achieve effective results.

Observations recorded

Observations were recorded by noting the pre-treatment count of live snails on okra and cucumber crops, followed by post-treatment counts of dead snails at 1 hour and 24 hours after spraying. The percentage mortality for each treatment was calculated based on the number of snails that died following application of the respective formulations. The data thus obtained on per cent mortality was transformed into arcsine transformation and presented in tables.

I. Experimental Results

Effect of EC Formulations on Management of Snails in Okra Crop

Table 2: Efficacy of EC Product I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under Field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	27.04 (31.21)	49.26 (44.57)
T_2	8	30.92 (33.69)	49.46 (44.68)
T_3	9	31.67 (34.15)	50.56 (45.32)
T_4	10	32.23 (34.52)	55.83 (48.35)
T_5	11	36.71 (37.20)	56.98 (49.07)
T_6	12	37.83 (37.92)	64.81 (53.87)
T_7	13	42.99 (40.97)	68.25 (55.72)
T_8	14	46.83 (43.12)	72.09 (58.66)
T_9	15	49.05 (44.45)	78.25 (62.34)
SE ±		2.63	3.14
CD at 0.05%		7.81	9.32

*Figures in parentheses indicate arcsine transformed values.

A field study was conducted to evaluate the effectiveness of EC Product-I [(Water + Soapnut Powder (1:10) + Tween 20)] against snail infestation on okra. The per cent snail mortality data at 1 hour and 24 hours post-treatment are summarized in Table 2. All treatments outperformed the untreated control, with per cent snail mortality ranging from 27.04 to 78.25 per cent.

At 1 hour after treatment, the highest per cent snail mortality (49.05%) was recorded in T_9, followed by T_8 (46.83%), T_7 (42.99%) and T_6 (37.83%). T_8 was statistically at par with T_9. Moderate effects were observed in T_5 (36.71%) and T_4 (32.23%), while T_3 (31.67%), T_2 (30.92%) and T_1 (27.04%) showed lower efficacy. T_0 recorded zero per cent snail mortality.

At 24 hours post-treatment, per cent snail mortality increased across all treatments. T_9 remained the most effective (78.25%), followed by T_8 (72.09%), T_7 (68.25%) and T_6 (64.81%), which were statistically similar. T_5 (56.98%) and T_4 (55.83%) showed good control, while T_3 (50.56%), T_2 (49.46%) and T_1 (49.26%) had lower efficacy. T_0 again recorded zero per cent snail mortality. The results clearly indicated that per cent snail mortality increased with both higher concentration and longer exposure duration, with T_9 (15 ml/l) being the most effective treatment.

Table 3: Efficacy of EC Product II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	27.51 (31.55)	44.29 (41.71)
T_2	8	29.74 (33.05)	46.76 (43.13)
T_3	9	31.74 (34.25)	52.63 (46.51)
T_4	10	35.56 (36.59)	56.30 (48.62)
T_5	11	36.77 (37.32)	61.43 (51.85)
T_6	12	37.91 (37.95)	63.24 (52.69)
T_7	13	38.80 (38.52)	65.37 (54.06)
T_8	14	41.49 (40.04)	65.51 (54.12)
T_9	15	49.05 (44.45)	72.70 (58.62)
SE ±		2.01	2.59
CD at 0.05%		5.97	7.69

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to evaluate the efficacy of EC Product-II [Boil Water + Soapnut Powder (1:10) + Tween 20] in managing snails infesting okra. Per cent snail mortality at 1 hour and 24 hours after treatment is presented in Table 3. All treatments were significantly more effective than the untreated control, with per cent mortality ranging from 27.51 to 72.70 per cent.

At 1 hour post-treatment, the highest per cent mortality (49.05%) was recorded in T_9, followed by T_8 (41.49%) and T_7 (38.80%). T_7 and T_8 were statistically at par with T_9. Moderate mortality was observed in T_6 (37.91%), T_5 (36.77%), T_4 (35.56%) and T_3 (31.74%), while lower values were noted in T_2 (29.74%) and T_1 (27.51%). The untreated control (T_0) recorded zero per cent mortality.

After 24 hours, per cent snail mortality increased across all treatments. T_9 again recorded the highest mortality (72.70%), followed by T_8 (65.51%), T_7 (65.37%), T_6 (63.24%) and T_5 (61.43%), which were statistically at par

with T_9. Moderate control was observed in T_4 (56.30%) and T_3 (52.63%), while T_2 (46.76%) and T_1 (44.29%) showed lower efficacy. The control (T_0) again recorded zero per cent mortality. These results confirm that per cent snail mortality increased with both higher concentrations and longer exposure, with T_9 (15 ml/l) proving to be the most effective.

Table 4: Efficacy of EC Product III [Water- Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	25.56 (30.36)	39.17 (38.74)
T_2	8	27.53 (31.21)	40.45 (39.48)
T_3	9	34.09 (35.71)	46.52 (43.00)
T_4	10	34.86 (36.15)	48.59 (44.19)
T_5	11	36.57 (37.19)	54.85 (47.79)
T_6	12	38.43 (38.28)	55.56 (48.25)
T_7	13	39.10 (38.61)	57.26 (49.28)
T_8	14	43.30 (41.14)	63.43 (52.81)
T_9	15	48.32 (44.03)	68.93 (56.28)
SE ±		2.22	2.33
CD at 0.05%		6.58	6.91

*Figures in parentheses indicate arcsine transformed values.

A field trial was undertaken to evaluate the effectiveness of EC Product-III [Water-Ethanol + Soapnut Powder (1:10) + Tween 20] in controlling snails infesting okra. Per cent snail mortality at 1 hour and 24 hours after treatment is summarized in Table 4. All treated plots showed significantly greater per cent snail mortality compared to the untreated control, with values ranging from 25.56 to 68.93 per cent.

At 1 hour post-treatment, the highest per cent mortality (48.32%) was recorded in T_9, followed by T_8 (43.30%), T_7 (39.10%) and T_6 (38.43%). Treatments T_6 to T_8 were statistically on par with T_9. Moderate mortality was noted in T_5 (36.57%) and T_4 (34.86%), while lower mortality was recorded in T_3 (34.09%), T_2 (27.53%) and T_1 (25.56%). The untreated control (T_0) recorded zero per cent mortality.

By 24 hours after treatment, per cent snail mortality increased across all treatments. T_9 again recorded the highest mortality (68.93%), followed by T_8 (63.43%) and T_7 (57.26%), which were statistically at par with T_9. T_6 (55.56%) and T_5 (54.85%) also showed good effectiveness, while moderate mortality was observed in T_4 (48.59%) and T_3 (46.52%). The lowest values were recorded in T_2 (40.45%) and T_1 (39.17%). The control (T_0) once again showed zero per cent mortality. These findings confirm that higher concentrations and longer exposure increased per cent snail mortality, with T_9 (15 ml/l) being the most effective under field conditions.

Table 5: Efficacy of EC Product IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	37.04 (37.45)	60.00 (50.85)
T_2	8	38.68 (38.40)	61.80 (51.86)
T_3	9	40.19 (39.14)	64.81 (53.87)
T_4	10	47.65 (43.64)	71.52 (57.80)
T_5	11	48.33 (44.04)	72.22 (58.32)
T_6	12	52.96 (46.70)	80.37 (63.74)
T_7	13	56.67 (48.85)	81.11 (64.26)
T_8	14	59.72 (50.66)	84.26 (66.82)
T_9	15	59.88 (50.70)	91.90 (76.45)
SE ±		2.52	3.35
CD at 0.05%		7.50	9.94

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to evaluate the efficacy of EC Product-IV [Ethanol + Soapnut Powder (1:10) + Tween 20] for managing snails infesting okra. Per cent snail mortality at 1 hour and 24 hours after treatment is presented in Table 5. All treatments exhibited significantly higher effectiveness than the untreated control, with per cent mortality ranging from 37.04 to 91.90 per cent.

At 1 hour post-treatment, the highest per cent snail mortality (59.88%) was recorded in T_9, followed closely by T_8 (59.72%), T_7 (56.67%), T_6 (52.96%) and T_5 (48.33%). These, along with T_4 (47.65%), were statistically at par with T_9, indicating strong efficacy even at slightly lower concentrations. Moderate control was observed in T_3 (40.19%), T_2 (38.68%) and T_1 (37.04%). The untreated control (T_0) recorded zero per cent mortality.

At 24 hours, snail per cent mortality increased across all treatments. The highest value (91.90%) was again recorded in T_9, followed by T_8 (84.26%), T_7 (81.11%) and T_6 (80.37%). T_8 was statistically at par with T_9, confirming similar effectiveness. Good control was also recorded in T_5 (72.22%) and T_4 (71.52%), while T_3 (64.81%), T_2 (61.80%) and T_1 (60.00%) showed comparatively lower mortality. As expected, the control (T_0) recorded zero per cent mortality. These results clearly demonstrate that both concentration and duration of exposure positively influenced per cent snail mortality, with T_9 (15 ml/l) proving most effective under field conditions.

Table 6: Efficacy of EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	17.00 (24.20)	31.18 (34.04)
T_2	8	19.25 (25.40)	33.17 (35.06)
T_3	9	20.00 (26.14)	39.72 (39.07)
T_4	10	29.60 (32.85)	49.05 (44.45)
T_5	11	33.33 (34.79)	51.39 (45.81)
T_6	12	33.90 (35.39)	54.56 (47.71)
T_7	13	39.81 (38.94)	56.94 (49.08)
T_8	14	41.11 (39.83)	58.89 (50.17)
T_9	15	46.67 (43.08)	68.33 (55.97)
SE ±		3.78	3.17
CD at 0.05%		11.22	9.43

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to evaluate the efficacy of EC Product-V [Acetone + Soapnut Powder (1:10) + Tween 20] for the management of snails infesting okra. Per cent snail mortality at 1 hour and 24 hours after treatment is displayed in Table 6. All treatments demonstrated significantly higher effectiveness than the untreated control, with per cent mortality ranging from 17.00 to 68.33 per cent.

At 1 hour post-treatment, the highest per cent mortality (46.67%) was recorded in T_9, followed by T_8 (41.11%), T_7 (39.81%), T_6 (33.90%), T_5 (33.33%) and T_4 (29.60%). Treatments T_4 to T_8 were statistically at par with T_9, indicating comparable efficacy at moderately lower concentrations. Lower per cent mortality was observed in T_3 (20.00%), T_2 (19.25%) and T_1 (17.00%). The untreated control (T_0) recorded zero per cent mortality.

At 24 hours after treatment, per cent snail mortality increased across all treatments. T_9 again recorded the highest mortality (68.33%), followed by T_8 (58.89%), T_7 (56.94%) and T_6 (54.56%), which were statistically at par with T9. Moderate effectiveness was seen in T_5 (51.39%) and T_4 (49.05%), while T_3 (39.72%), T_2 (33.17%) and T_1 (31.18%) recorded lower mortality. The control (T_0) again showed zero per cent mortality. The results clearly indicate that per cent snail mortality on okra increased with both longer exposure and higher concentrations, with T_9 (15 ml/l) being the most effective treatment under field conditions.

Table 7: Efficacy of EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	14.80 (22.21)	30.66 (33.59)
T_2	8	17.84 (24.67)	34.84 (36.13)
T_3	9	21.65 (27.60)	38.53 (38.36)
T_4	10	29.95 (32.78)	46.82 (43.17)
T_5	11	35.00 (36.12)	50.56 (45.32)
T_6	12	38.33 (37.99)	53.33 (46.92)
T_7	13	43.89 (41.48)	53.89 (47.24)
T_8	14	46.63 (43.07)	60.56 (51.11)
T_9	15	48.90 (44.37)	65.46 (54.07)
SE ±		3.30	1.87
CD at 0.05%		9.81	5.57

*Figures in parentheses indicate arcsine transformed values.

A field-based study was conducted to evaluate the efficacy of EC Product-VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20] for managing snail infestation in okra. Per cent snail mortality at 1 hour and 24 hours after treatment is summarized in Table 7. All treatments proved significantly more effective than the untreated control, with mortality percentages ranging from 14.80 to 65.46 per cent.

At 1 hour post-treatment, the highest per cent mortality (48.90%) was recorded in T_9, followed by T_8 (46.63%), T_7 (43.89%), T_6 (38.33%) and T_5 (35.00%). Treatments T_5 to T_8 were statistically on par with T_9, indicating high effectiveness even at slightly reduced concentrations. T_4 (29.95%) showed moderate control, while T_3 (21.65%), T_2 (17.84%) and T_1 (14.80%) resulted in lower per cent mortality. The control plot (T_0) recorded zero per cent mortality.

After 24 hours, snail per cent mortality increased in all treatments. T_9 again led with the highest mortality (65.46%), followed by T_8 (60.56%), T_7 (53.89%) and T_6 (53.33%). T_8 was statistically comparable to T_9, reflecting similar efficacy. T_5 (50.56%) and T_4 (46.82%) also provided effective control, while lower per cent mortality was observed in T_3 (38.53%), T_2 (34.84%) and T_1 (30.66%). The untreated control (T_0) continued to show zero per cent mortality. These findings clearly indicate that increased exposure time and higher concentrations led to greater per cent snail mortality, with T_9 (15 ml/l) emerging as the most effective treatment under open-field conditions.

II. Effect of EC Formulations on Management of Snails in Cucumber Crop

Table 8: Efficacy of EC Product I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under Field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	31.02 (33.79)	42.95 (40.92)
T_2	8	33.24 (35.20)	47.09 (43.32)
T_3	9	34.09 (35.70)	51.68 (46.03)
T_4	10	34.47 (35.93)	52.56 (46.47)
T_5	11	38.39 (38.22)	56.86 (48.95)
T_6	12	39.53 (38.95)	57.68 (49.43)
T_7	13	43.05 (40.99)	62.99 (52.80)
T_8	14	47.64 (43.64)	66.98 (55.09)
T_9	15	48.52 (44.14)	72.96 (58.79)
SE ±		1.84	2.89
CD at 0.05%		5.46	8.58

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to evaluate the efficacy of EC Product-I [Water + Soapnut Powder (1:10) + Tween 20] against snails infesting cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is presented in Table 8. All treatments were significantly more effective than the untreated control, with per cent mortality ranging from 31.02 to 72.96 per cent.

At 1 hour post-treatment, the highest per cent mortality (48.52%) was recorded in T_9, followed by T_8 (47.64%) and T_7 (43.05%). Treatments T_7 and T_8 were statistically at par with T_9, indicating similar efficacy at slightly lower doses. Moderate control was observed in T_6 (39.53%), T_5 (38.39%) and T_4 (34.47%), while lower mortality was seen in T_3 (34.09%), T_2 (33.24%) and T_1 (31.02%). The untreated control (T_0) showed zero per cent mortality.

At 24 hours, per cent snail mortality increased across treatments. The highest mortality (72.96%) was again recorded in T_9, followed by T_8 (66.98%) and T_7 (62.99%), which were statistically at par with T_9, confirming comparable efficacy. Moderate control was observed in T_6 (57.68%) and T_5 (56.86%), while lower effectiveness was seen in T_4 (52.56%), T_3 (51.68%), T_2 (47.09%) and T_1 (42.95%). The control again recorded zero per cent mortality. Overall, per cent mortality increased with both concentration and exposure duration, with T_9 (15 ml/l) being the most effective treatment under field conditions.

Table 9: Efficacy of EC Product II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	22.82 (28.33)	44.23 (41.68)
T_2	8	24.52 (29.48)	47.29 (43.44)
T_3	9	25.32 (29.60)	50.41 (45.19)
T_4	10	26.05 (30.67)	50.52 (45.30)
T_5	11	28.99 (32.35)	56.11 (48.52)
T_6	12	30.62 (33.38)	59.49 (48.79)
T_7	13	37.05 (37.42)	62.08 (52.00)
T_8	14	42.61 (40.74)	65.51 (54.15)
T_9	15	47.37 (43.49)	70.27 (56.98)
SE ±		2.93	2.60
CD at 0.05%		8.70	7.73

*Figures in parentheses indicate arcsine transformed values.

A field evaluation was carried out to assess the performance of EC Product-II [Boil Water + Soapnut Powder (1:10) + Tween 20] in controlling snails infesting cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is displayed in Table 9. All treatments were significantly more effective than the untreated control, with per cent mortality ranging from 22.82 to 70.27 per cent.

At 1 hour post-treatment, the highest per cent mortality (47.37%) was recorded in T_9, followed by T_8 (42.61%) and T_7 (37.05%). These three treatments were statistically at par, indicating similar effectiveness at slightly reduced concentrations. Moderate control was observed in T_6 (30.62%) and T_5 (28.99%), while lower mortality was recorded in T_4 (26.05%), T_3 (25.32%), T_2 (24.52%) and T_1 (22.82%). The untreated control (T_0) showed zero per cent mortality.

By 24 hours, per cent mortality increased across all treatments. T_9 again recorded the highest mortality (70.27%), followed by T_8 (65.51%) and T_7 (62.08%), which remained statistically at par with T_9. Effective control was also observed in T_6 (59.49%) and T_5 (56.11%). T_4 (50.52%), T_3 (50.41%), T_2 (47.29%) and T_1 (44.23%) recorded lower mortality levels. As expected, the control treatment (T_0) recorded zero per cent mortality. These results clearly indicate that snail per cent mortality in cucumber increased with both higher concentrations and prolonged exposure, with T_9 (15 ml/l) emerging as the most effective treatment under open-field conditions.

Table 10: Efficacy of EC Product III [Water- Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	18.90 (25.61)	34.76 (36.11)
T_2	8	21.31 (27.22)	38.23 (38.13)
T_3	9	23.04 (28.51)	41.56 (40.14)
T_4	10	25.84 (30.55)	42.64 (40.76)
T_5	11	29.24 (32.71)	47.17 (43.36)
T_6	12	30.65 (33.56)	49.75 (44.86)
T_7	13	41.75 (40.24)	60.94 (51.36)
T_8	14	46.90 (43.21)	65.51 (54.06)
T_9	15	49.60 (44.77)	68.99 (56.20)
SE ±		2.05	1.84
CD at 0.05%		6.09	5.48

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to assess the efficacy of EC Product-III [Water-Ethanol + Soapnut Powder (1:10) + Tween 20] against snails infesting cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is presented in Table 10. All treatments showed significantly higher efficacy than the control, with per cent mortality ranging from 18.90 to 68.99 per cent.

At 1 hour post-treatment, the highest per cent mortality (49.60%) was recorded in T_9, followed by T_8 (46.90%) and T_7 (41.75%). These were statistically at par with T_9, indicating similar efficacy at slightly lower doses. Moderate control was observed in T_6 (30.65%) and T_5 (29.24%), while lower mortality was seen in T_4 (25.84%), T_3 (23.04%), T_2 (21.31%) and T_1 (18.90%). The control (T_0) recorded zero per cent mortality.

At 24 hours, per cent mortality increased across all treatments. T_9 again showed the highest mortality (68.99%), followed by T_8 (65.51%) and T_7 (60.94%), which remained statistically at par with T_9. Moderate control was observed in T_6 (49.75%) and T_5 (47.17%), while T_4 (42.64%), T_3 (41.56%), T_2 (38.23%) and T_1 (34.76%) recorded comparatively lower mortality. The control (T_0) again showed zero per cent mortality. The results clearly showed that snail per cent mortality increased with higher concentration and exposure time, with T_9 (15 ml/l) proving to be the most effective under field conditions.

Table 11: Efficacy of EC Product IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	30.93 (33.22)	55.27 (48.04)
T_2	8	36.44 (37.06)	60.32 (50.97)
T_3	9	37.81 (37.91)	62.73 (52.40)
T_4	10	38.87 (38.49)	65.70 (54.20)
T_5	11	40.57 (39.57)	65.97 (54.33)
T_6	12	41.78 (40.25)	70.37 (57.03)
T_7	13	53.66 (47.10)	79.40 (63.11)
T_8	14	58.43 (49.87)	81.72 (64.70)
T_9	15	59.94 (50.79)	88.29 (70.54)
SE ±		2.39	1.61
CD at 0.05%		7.09	4.79

*Figures in parentheses indicate arcsine transformed values.

A field experiment was conducted to evaluate the efficacy of EC Product-IV [Ethanol + Soapnut Powder (1:10) + Tween 20] for the management of snails infesting cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is displayed in Table 11. All treatments showed significantly higher effectiveness than the untreated control, with per cent mortality ranging from 30.93 to 88.29 per cent.

At 1 hour post-treatment, the highest per cent mortality (59.94%) was recorded in T_9, followed by T_8 (58.43%) and T_7 (53.66%), which were statistically at par with T_9, indicating that similar control could be achieved at slightly lower concentrations. Moderate mortality was observed in T_6 (41.78%), T_5 (40.57%), T_4 (38.87%), T_3 (37.81%), T_2 (36.44%) and T_1 (30.93%). The untreated control (T_0) recorded zero per cent mortality.

At 24 hours, the highest per cent mortality (88.29%) was again observed in T_9, with no other treatment statistically at par, indicating its superior standalone efficacy. Other effective treatments included T_8 (81.72%), T_7 (79.40%), T_6 (70.37%), T_5 (65.97%) and T_4 (65.70%), while relatively lower mortality was seen in T_3 (62.73%), T_2 (60.32%) and T_1 (55.27%). The control (T_0) again recorded zero per cent mortality. These findings confirm that per cent snail mortality on cucumber increased with both exposure duration and concentration, with T_9 (15 ml/l) emerging as the most effective treatment under field conditions.

Table 12: Efficacy of EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	20.04 (26.55)	37.86 (37.97)
T_2	8	21.65 (27.08)	40.85 (39.69)
T_3	9	24.29 (29.33)	44.89 (42.06)
T_4	10	25.80 (30.45)	45.02 (42.13)
T_5	11	27.29 (31.43)	48.50 (44.12)
T_6	12	31.48 (34.11)	49.51 (44.90)
T_7	13	39.29 (38.63)	59.05 (50.30)
T_8	14	42.59 (40.69)	62.50 (52.26)
T_9	15	47.22 (43.40)	67.46 (55.24)
SE ±		2.80	1.84
CD at 0.05%		8.31	5.46

*Figures in parentheses indicate arcsine transformed values.

A field investigation was undertaken to assess the efficacy of EC Product-V [Acetone + Soapnut Powder (1:10) + Tween 20] for controlling snails infesting cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is presented in Table 12. All treated plots showed significantly greater effectiveness compared to the untreated control, with per cent mortality ranging from 20.04 to 67.46 per cent.

At 1 hour post-treatment, the highest per cent mortality (47.22%) was recorded in T_9, followed by T_8 (42.59%) and T_7 (39.29%). Treatments T_7 and T_8 were statistically at par with T_9, suggesting similar levels of efficacy at slightly reduced concentrations. Moderate per cent mortality was recorded in T_6 (31.48%), T_5 (27.29%) and T_4 (25.80%), while lower mortality was seen in T_3 (24.29%), T_2 (21.65%) and T_1 (20.04%). The control treatment (T_0) recorded zero per cent mortality.

After 24 hours, per cent mortality levels increased across all treatments. T_9 again showed the highest mortality (67.46%), followed by T_8 (62.50%) and T_7 (59.05%). These treatments remained statistically at par with T_9, confirming comparable performance. T_6 (49.51%), T_5 (48.50%) and T_4 (45.02%) showed moderate efficacy, while T_3 (44.89%), T_2 (40.85%) and T_1 (37.86%) recorded lower values. The control treatment (T_0) once again recorded zero per cent mortality. These findings clearly demonstrate that per cent snail mortality on cucumber increased with both longer exposure and higher concentrations, with T_9 (15 ml/l) being the most effective treatment under open-field conditions.

Table 13: Efficacy of EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under field conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)	
		1h	24hr
T_0	0	0.00 (0.00)	0.00 (0.00) *
T_1	7	25.51 (30.31)	36.63 (37.24)
T_2	8	27.17 (31.24)	42.83 (40.81)
T_3	9	28.22 (32.08)	43.31 (41.15)
T_4	10	31.67 (34.15)	49.44 (44.68)
T_5	11	36.26 (37.00)	53.84 (47.20)
T_6	12	36.94 (37.42)	56.67 (48.93)
T_7	13	39.76 (39.05)	60.46 (51.10)
T_8	14	41.99 (40.36)	65.34 (53.95)
T_9	15	47.13 (43.34)	66.06 (54.39)
SE ±		2.09	2.32
CD at 0.05%		6.21	6.89

*Figures in parentheses indicate arcsine transformed values.

A field study was conducted to assess the efficacy of EC Product-VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20] for managing snail infestation in cucumber. Per cent snail mortality at 1 hour and 24 hours after treatment is summarized in Table 13. All treatments resulted in significantly higher snail per cent mortality compared to the untreated control, with values ranging from 25.51 to 66.06 per cent.

At 1 hour post-treatment, the highest per cent mortality (47.13%) was recorded in T_9, followed by T_8 (41.99%), T_7 (39.76%) and T_6 (36.94%). These treatments (T_6 to T_8) were statistically at par with T_9, indicating similar efficacy at slightly lower concentrations. T_5 (36.26%) and T_4 (31.67%) showed moderate per cent mortality, while lower effectiveness was observed in T_3 (28.22%), T_2 (27.17%) and T_1 (25.51%). The untreated control (T_0) recorded zero per cent mortality.

At 24 hours, per cent mortality further increased in all treatments. The highest value (66.06%) was again seen in T_9, closely followed by T_8 (65.34%), T_7 (60.46%) and T_6 (56.67%). These treatments remained statistically at par with T_9, confirming comparable efficacy. T_5 (53.84%) and T_4 (49.44%) demonstrated moderate control, while lower per cent mortality was recorded in T_3 (43.31%), T_2 (42.83%) and T_1 (36.63%). The control treatment (T_0) again showed zero per cent mortality. These findings clearly illustrate that snail per cent mortality on cucumber increased with both longer exposure and higher concentrations, with T_9 (15 ml/l) proving to be the most effective treatment under field conditions.

Discussion

The present investigation was undertaken to evaluate the efficacy of six soapnut-based emulsifiable concentrate (EC) formulations using different solvent systems, under field conditions on okra and cucumber crops. The results revealed considerable variation in snail per cent mortality depending on the type of solvent used, with ethanol-based formulations showing the highest efficacy.

On okra, the ethanol formulation recorded the highest snail mortality (91.90%), followed by water (78.25%), boiled water (72.70%), water-ethanol (68.93%), acetone (68.33%) and water-acetone (65.46%). A similar pattern was observed on cucumber, where ethanol again resulted in the highest mortality (88.29%), followed by water (72.96%), boiled water (70.27%), water-ethanol (68.99%), acetone (67.46%) and water-acetone (66.06%).

Ethanol emerged as the most effective solvent, likely due to its excellent solubilizing properties and its disruptive action on snail cell membranes. Water-based formulations also showed considerable effectiveness, while boiled water produced slightly lower results, possibly due to the thermal degradation of bioactive components. The combination of water and ethanol gave substantial mortality but slightly less than ethanol alone, suggesting a dilution effect. Acetone provided moderate efficacy; however, its high volatility may have reduced its field persistence and snail contact time. The water-acetone formulation consistently showed the least mortality, indicating limited effectiveness.

These field findings are in close agreement with earlier studies on soapnut's molluscicidal properties. Rao (1999) [10] reported 100 per cent mortality of *Zonitoides arboreus* using a bait formulation of soapnut and shikakai extract in water, indicating the strong potential of soapnut for snail control. Mehendale and Bhagwat (2005) also observed significant mortality of *Ariophanta bajadera* at higher concentrations of soapnut rind extract, highlighting a clear dose-dependent effect, which was also evident in the present study where all 15 ml/l treatments showed increased efficacy.

Koysap *et al*. (2022) [6] further demonstrated approximately 90 per cent mortality of *Lissachatina fulica* using a 30 per cent crude extract of *Sapindus rarak* under semi-field conditions, without phytotoxic effects on *Brassica rapa*, confirming the environmental safety of soapnut-based molluscicides.

The present field outcomes closely match the laboratory findings of Jadhav (2024) [4], who evaluated the same formulations at identical concentrations. In that study, ethanol showed 100 per cent mortality, followed by water (95%), boiled water (91.66%), water-ethanol (88.33%), acetone (76.66%) and water-acetone (61.66%). This strong correlation between lab and field performance reaffirms that both solvent type and formulation concentration are critical factors influencing the molluscicidal efficacy of soapnut EC products.

Collectively, these results validate ethanol-based EC formulations as the most effective, reliable and sustainable solution for snail management in vegetable production systems.

Conclusion

Ethanol emerged as the most effective solvent, likely due to its strong solubilizing power and action on snail cell

membranes. Water also caused notable mortality, while boiled water was slightly less effective. The water-ethanol mix showed substantial but reduced efficacy, indicating possible interaction. Acetone performed moderately, better than the water-acetone mix, but its high volatility limits field use. Overall, solvent type and physical properties significantly affect the snail-killing potential of EC formulations.

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