Development of emulsifiable concentrates (EC) formulations for management of snails

Abstract: The research work was conducted to study the Development of emulsifiable concentrates (EC) formulations for management of snails, was carried out at Department of Agricultural Entomology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri, (MS) India during 2023-2024. The study assessed the efficacy of six different EC formulations against snails under laboratory conditions. The experiment aimed to assess the evaluation of emulsifying concentrates for snail control using the topical application method. The highest per cent mortality was observed with ethanol (100 %), followed by water (95 %), boiled water (91.66 %), water-ethanol (88.33 %), acetone (76.66 %) and acetone-water (61.66 %), in that order. In the leaf dipping application method for controlling snails, the effectiveness of emulsifiable concentrate (EC) solvents shows a trend similar to that observed with the topical application method. However, the topical application method is generally more effective than the leaf dipping method. This is because the topical application provides more direct and localized contact with the snails, resulting in better control outcomes compared to the leaf dipping method. Importantly, none of the formulations demonstrated phytotoxic effects on the evaluated crops, indicating their safety and suitability for agricultural applications.

Keywords : Soapnut powder, Emulsifiable concentrates, Ethanol, Acetone, Water

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Introduction

Sapindus mukorossi (Gaertn.), a member of the Sapindaceae family, is commonly known as Indian soapberry, washnut or ritha. This deciduous tree can grow up to heights of 1200 meters (4000 feet) in the lower Himalayan foothills and midhills. It is native to Taiwan, Southern China and regions including Western Coastal Karnataka, Maharashtra and Goa in India. The soapnut plant thrives in tropical and subtropical climates and has been traditionally utilized for various purposes, notably for its insecticidal properties. It is often planted near residences and can adapt to relatively poor soil conditions. Each tree typically yields between 30 to 35 kg of fruit annually (https://www.inaturalist.org).

Land snail species number about 35,000 worldwide and another 30,000 to 60,000 may still ~~be~~ undiscovered (Lydeard *et al.*, 2004). According to Ramakrishna *et al.* (2010), there are 1129 species of land snails within the borders of modern India, representing 140 taxa and 26 families. There are 270 different species of land snails in the Western Ghats hotspot; according to Aravind *et al.,* (2008), 40 per cent of them are micro-gastropods, or snails with a maximum size of less than 5 mm, and 76 per cent are indigenous to the area. The range distributions of many land snail species are constrained, in contrast to the majority of other taxonomic groupings. For example, the ranges of several endemic species are less than 10 km^2, while the ranges of certain

threatened species are less than 5 km^2 (Cameron 1998; Dunk *et al.,* 2004). According to Solem (1984), roughly 50 per cent of all terrestrial mollusk species have a range of less than 100 km^2. There are species in the Western Ghats that are found in the southern zone but not in the northern ~~one~~. Aravind (2005) states that there is minimal overlap between the central and northern, as well as the southern and central regions. There are reports of less than three sites housing about 75 per cent of the land snails found in the Western Ghats. However, Chaieb (2010) states that it is too soon to suggest widespread using saponins as pesticides. The focus of this inquiry revolves around soapnut and its properties, which aims to provide knowledge on a number of different topics.

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Various bioactive compounds have been isolated from different parts of *Sapindus mukorossi.* The fruits of this plant are notably rich in saponins, containing approximately 11.5 per cent saponins and 10 per cent sugars. These bioactive compounds can be extracted using a variety of solvents with different polarities, such as water, ethanol, methanol, acetone and n-hexane depending on the properties of the active ingredients. Therefore, there is a critical need to explore innovative, cost-effective, safe and efficient insecticides for managing crop-damaging insects. Phytochemicals, also known as plant secondary metabolites or botanical pesticides, derived from plants like *S. mukorossi,* offer potential solutions to mitigate financial losses and crop damage for farmers. These botanical insecticides are preferred due to their biodegradability, lower production costs and reduced residual toxicity compared to conventional chemical pesticides. Research has demonstrated the insecticidal properties of *S. mukorossi*. The methanol extract from its leaves and stems has been explored as a bio-control agent (Akhtar *et al.,* 2021). In recent years, there has been increasing interest in utilizing botanical extracts for pest management, driven by their perceived eco-friendly characteristics and potential effectiveness in controlling pest populations.

Material methods

The present investigation entitled, “Standardization of Soapnut rind extract based formulations for management of snails” was conducted at Department of Agricultural Entomology, College of Agriculture, Dapoli, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during 2023-2024. The experiment was laid in Completely Randomized Design (CRD) with 9 treatments and replicated thrice. Soapnut berries were collected from local plants and were dried in a hot air oven at 70°C for 5 hours. The dried rind was ground in the mixer to make a fine powder. For extraction, soapnut powder was added into the solvents with different solid-liquid ratios 1:10. For 1:10 solid-liquid ratio 10 g powder was added 100 ml of each solvent and emulsifying agent Tween 20 added into solution. Solutions were mixed using magnetic stirrer for six hours. This EC formulation was tested against snails (Kose and Bayraktar 2016). The treatments were applied as per given in treatment details. The preparation of EC formulation was done in different

treatment combination such as 3ml to 10ml. One separate control was maintained to observe natural mortality. The treatments were given in glass bottles with three replications.

List 1. Treatment details EC

Pr. No.	Solvent type	Solid–liquid ratio	Emulsifying agent	Concentration
I.	Water	1:10	Tween 20	3ml to 10 ml
II.	Boil water	1:10	Tween 20	3ml to 10 ml
III.	Water - Ethanol	1:10	Tween 20	3ml to 10 ml
IV.	Ethanol	1:10	Tween 20	3ml to 10 ml
V.	Acetone	1:10	Tween 20	3ml to 10 ml
VI.	Water – Acetone	1:10	Tween 20	3ml to 10 ml

Observations recorded

The observations of the dead snails were recorded at 12, 24 and 48 h from each treatment and each replication. Disruption of mucous membrane and water loss through integument of snails were treated as dead. The per cent mortality in each treatment was worked by counting dead snails.

Results and discussion

I. Topical application EC formulation–

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

Tr. No.	Conc. (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	8.33 (16.76)	20.00 (26.53)	28.33 (32.12)
T_2	4	10.00 (18.41)	23.33 (28.85)	30.00 (33.17)
T_3	5	15.00 (22.76)	35.00 (36.23)	46.66 (43.04)
T_4	6	18.33 (25.32)	38.33 (38.21)	51.66 (45.90)
T_5	7	21.66 (27.71)	50.00 (44.95)	60.00 (50.71)
T_6	8	25.00 (29.96)	56.66 (48.77)	70.00 (56.72)
T_7	9	31.66	65.00	80.00

		(34.20)	(53.67)	(63.36)
T_8	**10**	**45.00 (42.08)**	**76.66 (61.04)**	**95.00 (76.99)**
SE ±		**0.52**	**0.56**	**0.61**
CD at 1%		**2.12**	**2.26**	**2.48**

*Figures in parentheses indicate arcsine transformed values.

The experiment was conducted to study the efficacy of EC Product -I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment. The data presented in Table 1 indicated that all the treatments were significantly superior over control. The per cent mortality was recorded in the range of 8.33 to 95.00 per cent. The observations recorded at 12 h post-treatment resulted ~~in significantly superior per cent~~ mortality in treatment T_8 (45.00 %). The next best treatments were T_7 with 31.66 per cent, T_6 with 25.00 per cent, T_5 with 21.66 per cent and T_4 with 18.33 per cent, respectively. In the control treatment (T_0) 0.00 per cent mortality was observed. Results obtained 24 h post-treatment indicated ~~that significantly superior~~ mortality percentage was recorded at T_8 (76.66 %) and T_7 (65.00 %). The next best treatment was T_6 (56.66 %) followed by treatment T_5 (50.00 %), T_4 (38.33%) and which was at par with T_3 (35.00%). The minimum per cent mortality was observed at T_1 (20.00 %). The data recorded 48 h post-treatment showed ~~significantly superior~~ mortality percentage at T_8 (95.00 %) gave highest per cent mortality as compared to 12 h and 24 h. The best results were obtained in these treatments such as T_7 (80.00%), T_6 (70.00 %), T_5 (60.00%), T_4 (51.66%), T_3 (46.66%), T_2 (30.00 %) and T_1 (28.33 %) mortality. In the control treatment zero per cent mortality was observed.

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

Sr. No.	Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
			12h	24h	48h
1.	T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
2.	T_1	3	6.66 (14.94)	11.66 (19.95)	20.00 (26.53)
3.	T_2	4	11.66 (19.95)	16.66 (24.06)	25.00 (29.96)
4.	T_3	5	13.33 (21.39)	18.33 (25.32)	28.33 (32.12)
5.	T_4	6	15.00 (22.76)	20.00 (26.53)	31.66 (34.20)
6.	T_5	7	18.33 (25.32)	25.00 (29.96)	38.33 (38.21)
7.	T_6	8	26.66 (31.05)	41.66 (40.15)	55.00 (47.81)
8.	T_7	9	35.00 (36.23)	58.33 (49.74)	70.00 (56.72)

9.	**T_8**	**10**	**40.00 (39.18)**	**71.66 (57.77)**	**91.66 (73.14)**
SE ±			**0.42**	**0.54**	**0.59**
CD at 1%			**1.69**	**2.22**	**2.39**

*Figures in parentheses indicate arcsine transformed values.

The result investigated the efficacy of EC Product - II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality after 12, 24 and 48 h post-treatment were presented in Table 2. The results indicated that all the treatments ~~were significantly superior over~~ control 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 6.66 per cent to 91.66 per cent. Results obtained 12 h after treatment indicated that the treatment was T_8 with 40.00 per cent mortality. The further data revealed that the treatments T_7, T_6, T_5, T_4, T_3 and T_2 were 35.00 per cent, 26.66 per cent, 18.33 per cent, 15.00 per cent and 13.33 per cent, respectively. While treatment T_1 with 6.66 per cent mortality was the least effective treatment as compared to other treatments. Observations recorded 24 h post-treatment showed that the treatment was T_8 (71.66%) gave per cent mortality ~~that was significantly superior~~ to other treatments, followed by T_7 with 58.33 per cent, T_6 with 41.66 per cent, T_5 with 25.00 per cent, T_4 with 20.00 per cent and T_3 with 18.33 per cent which was at par with T_2 (16.66 %). Treatment T_1 caused minimum percent mortality (11.66 %). Results obtained 48 h post-treatment indicated that treatment T_8 which gave the highest per cent mortality with 91.66 per cent was most effective ~~and was significantly superior over~~ ~~all~~ other treatments. The next best results T_7 (70.00 %) and T_6 (55.00 %) were obtained. The other treatments were T_5 (38.33%), T_4 (31.66%) and T_3 (28.33%) which was at par with T_2 (25.00%). In the control treatment zero per cent mortality was observed.

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Table 3 Efficacy of EC Product III [Water- Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	**24h**	**48h**
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	11.66 (19.95)	16.66 (24.06)	25.00 (29.96)
T_2	4	13.33 (21.39)	21.66 (27.71)	30.00 (33.17)
T_3	5	20.00 (26.53)	26.66 (31.05)	38.33 (38.21)
T_4	6	23.33 (28.85)	33.33 (35.22)	46.66 (43.04)
T_5	7	25.00 (29.96)	38.33 (38.21)	56.66 (48.77)
T_6	8	40.00 (39.18)	48.33 (43.99)	70.00 (56.72)
T_7	9	41.66 (40.15)	55.00 (47.81)	75.00 (59.93)
T_8	**10**	**48.33**	**70.00**	**88.33**

		(43.99)	**(56.72)**	**(69.95)**
SE ±		**0.50**	**0.54**	**0.56**
CD at 1%		**2.02**	**2.22**	**2.26**

*Figures in parentheses indicate arcsine transformed values.

The result showed the efficacy of EC Product-III [Water- Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment were presented in Table 3. The results indicated that all the treatments ~~were significantly superior~~ to control at 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 11.66 per cent to 88.33 per cent. Results obtained 12 h after treatment revealed that the treatments were T_8 (48.33%), T_7 (41.66 %) and which was at par with T_6 (40.00 %). The other treatments were T_5 (25.00 %) which was at par with T_4 (23.33 %), T_3 (20.00%) and T_2 (13.33 %) at par with T_1 (11.66%) mortality. Data recorded 24 h post-treatment indicated that T_8 (70.00 %), T_7 (55.00 %) and T_6 (48.33 %) were relatively more effective than other treatments. Observations recorded 48 h post-treatment showed that T_8 gave the highest per cent mortality which was 88.33 per cent and significantly superior over all the other treatments. The next best treatments were T_7 (75.00 %) and T_6 (70.00 %).

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

Sr. No.	Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
			12h	**24h**	**48h**
1.	T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
2.	T_1	3	11.66 (19.95)	18.33 (25.32)	25.00 (29.96)
3.	T_2	4	13.33 (21.39)	20.00 (26.53)	28.33 (32.12)
4.	T_3	5	18.33 (25.32)	25.00 (29.96)	36.66 (37.22)
5.	T_4	6	20.00 (26.53)	30.00 (33.17)	45.00 (42.08)
6.	T_5	7	31.66 (34.20)	35.00 (36.23)	48.33 (43.99)
7.	T_6	8	41.66 (40.15)	55.00 (47.81)	80.00 (63.36)
8.	T_7	9	50.00 (44.95)	66.66 (54.67)	95.00 (76.99)
9.	**T_8**	**10**	**55.00 (47.81)**	**75.00 (59.93)**	**100 (89.90)**
SE ±			**0.53**	**0.57**	**0.64**
CD at 1%			**2.17**	**2.31**	**2.6**

*Figures in parentheses indicate arcsine transformed values.

The experiment aimed to examine the efficacy of EC Product - IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The

data recorded on per cent mortality at 12, 24 and 48 h post-treatment were presented in Table 4. The results indicated that all the treatments ~~were significantly superior~~ to control at 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 11.66 per cent to 100 per cent. Results obtained 12 h post-treatment revealed that the treatments were T_8 with 55.00 per cent mortality, T_7 with 50.00 per cent mortality, T_6 with 41.66 per cent mortality, T_5 with 31.66 per cent mortality and T_4 (20.00 %) which was at par with T_3 (18.33%). Next treatment T_2 (13.33 %) was at par with T_1 (11.66%). Observations recorded 24 h post-treatment revealed that treatments T_8, T_7 and T_6 were 75.00 per cent, 66.66 per cent and 55.00 per cent, respectively. The other treatment T_5 (35.00%) was at par with T_4 (30.00%), T_3 with 25.00 per cent mortality and T_2 (20.00%) which was at par with T_1 (18.33%). Data obtained 48 h after treatment were gave the best results T_8 (100 %), T_7 (95.00 %) and T_6 (80.00 %) being most effective. The other treatments were followed by T_5 (48.33 %) which was at par with T_4 (45.00%), T_3 (36.66 %) and T_2 (28.33%) which was at par with T_1 (25.00 %). In the control treatment zero per cent mortality was observed.

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	8.33 (16.76)	15.00 (22.76)	20.00 (26.53)
T_2	4	11.66 (19.95)	20.00 (26.53)	26.66 (31.05)
T_3	5	15.00 (22.76)	25.00 (29.96)	35.00 (36.23)
T_4	6	20.00 (26.53)	28.33 (32.12)	40.00 (39.18)
T_5	7	30.00 (33.17)	35.00 (36.23)	45.00 (42.08)
T_6	8	45.00 (42.08)	50.00 (44.95)	55.00 (47.81)
T_7	9	50.00 (44.95)	55.00 (47.81)	61.66 (51.69)
T_8	**10**	**53.33 (46.86)**	**65.00 (53.67)**	**76.66 (61.04)**
SE ±		**0.47**	**0.52**	**0.58**
CD at 1%		**1.92**	**2.12**	**2.35**

*Figures in parentheses indicate arcsine transformed values.

The experiment aimed to investigate the efficacy of EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality after 12, 24 and 48 h post-treatment were presented in Table 5. The results indicated that all the treatments were significantly superior to control 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 8.33 per cent to 76.66 per

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cent. The result recorded at 12 h post-treatment revealed that significantly superior mortality percentage recorded at T_8 (53.33 %) which was at par with T_7 (50.00 %). The other treatments were followed by T_6 (45.00 %), T_5 (30.00 %), T_4 (20.00 %), T_3 (15.00 %), T_2 (11.66 %) and T_1 with 8.33 per cent mortality.The observations recorded after 24 h treatment significantly superior mortality percentage was recorded at T_8 (65.00%). The next treatments were T_7, T_6, T_5, T_4, T_3, T_2 and T_1 with 55.00 per cent, 50.00 per cent, 35.00 per cent, 28.33 per cent, 25.00 per cent, 20.00 per cent and 15.00 per cent mortality, respectively. In the control treatment zero per cent mortality was observed. The data recorded 48 h post-treatment revealed that T_8 (76.66 %), T_7 (61.66 %) and T_6 (55.00 %) were relatively more effective than other treatments.

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	6.66 (14.94)	11.66 (19.95)	16.66 (24.06)
T_2	4	11.66 (19.95)	16.66 (24.06)	21.66 (27.71)
T_3	5	13.33 (21.39)	20.00 (26.53)	25.00 (29.96)
T_4	6	15.00 (22.76)	21.66 (27.71)	28.33 (32.12)
T_5	7	18.33 (25.32)	23.33 (28.85)	30.00 (33.17)
T_6	8	25.00 (29.96)	30.00 (33.17)	36.66 (37.22)
T_7	9	26.66 (31.05)	40.00 (39.18)	53.33 (46.86)
T_8	**10**	**35.00 (36.23)**	**48.33 (43.99)**	**61.66 (51.69)**
SE±		**0.42**	**0.50**	**0.61**
CD at 1%		**1.69**	**2.02**	**2.48**

*Figures in parentheses indicate arcsine transformed values.

The research investigated the efficacy of EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality after 12, 24 and 48 h post-treatment were presented in Table 6. The results indicated that all the treatments were significantly superior over control 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 6.66 per cent to 61.66 per cent. Results obtained 12 hours post-treatment showed varying levels of mortality among the treatments. The treatment T_8 (35.00%), T_7 (26.66 %) which was at par with T_6 (25.00%), T_5 (18.33%), T_4 (15.00 %) which was at par with T_3 (13.33 %), T_2 (11.66 %). The treatment T_1 (6.66%) was least effective as compared to all other treatments. These findings illustrate the different

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effectiveness levels of each treatment in reducing snail populations within the initial period. Data recorded 24 h post-treatment revealed that the treatments were T_8, T_7, T_6 and T_5 with 48.33 per cent, 40.00 per cent, 30.00 per cent and 23.33 per cent mortality, respectively. The next treatment was T_4 (21.66%) at par with T_3 (20.00%), T_2 (16.66%) and T_1 (11.66%) mortality. Observations recorded 48 h post-treatment indicated that treatments were T_8 with 61.66 per cent mortality. The treatments T_7 (53.33%), T_6 (36.66%) and T_5 (30.00%) which was at par with T_4 (28.33%) mortality.

II. Leaf dipping method EC formulation–

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	5.00 (12.90)	15.00 (22.76)	23.33 (28.85)
T_2	4	6.66 (14.94)	18.33 (25.32)	25.00 (29.96)
T_3	5	11.66 (19.95)	30.00 (33.17)	41.66 (40.15)
T_4	6	15.00 (22.76)	33.33 (35.22)	46.66 (43.04)
T_5	7	16.66 (24.06)	45.00 (42.08)	53.33 (46.86)
T_6	8	20.00 (26.53)	51.66 (45.90)	60.00 (50.71)
T_7	9	26.66 (31.05)	60.00 (50.71)	66.66 (54.67)
T_8	**10**	**40.00 (39.18)**	**70.00 (56.72)**	**71.66 (57.77)**
SE ±		**0.44**	**0.51**	**0.61**
CD at 1%		**1.81**	**2.07**	**2.48**

*Figures in parentheses indicate arcsine transformed values.

The experiment was conducted to study the efficacy of EC Product -I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment. The data presented in Table 7 indicated that all the treatments were significantly superior over control by recording per cent mortality was in the range of 5.00 to 71.66 per cent. The Results obtained 12 h post-treatment resulted in significantly superior per cent mortality in treatment T_8 (40.00 %). The next treatments were T_7 (26.66 %), T_6 (20.00%) and T_5 (16.66%) which was at par with T_4 (15.00%). The treatments were T_3 (11.66%), T_2 (6.66 %) and T_1 (5.00%). In the control treatment zero per cent mortality was observed. The data recorded 24 h after treatment indicated that T_8 had 70.00 per cent mortality. Further data revealed that the treatments were T_7, T_6, T_5, T_4, T_2 and T_1 with 60.00 per cent, 51.66 per cent, 45.00 per cent, 33.33 per cent, 30.00 per cent, 18.33 per cent and 15.00 per cent, respectively. The observations recorded 48 h post-treatment revealed that significantly

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superior mortality percentage was recorded at T_8 (71.66 %). The next best treatments were T_7 (66.66 %), T_6 (60.00 %), T_5 (53.33 %), T_4 (46.66%), T_3 (41.66%) and T_2 (25.00%) which was at par with T_1 (23.33%).

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	5.00 (12.90)	6.66 (14.94)	15.00 (22.76)
T_2	4	6.66 (14.94)	11.66 (19.95)	20.00 (26.53)
T_3	5	8.33 (16.76)	13.33 (21.39)	23.33 (28.85)
T_4	6	10.00 (18.41)	15.00 (22.76)	25.00 (29.96)
T_5	7	13.33 (21.39)	20.00 (26.53)	38.33 (38.21)
T_6	8	26.66 (31.05)	36.66 (37.22)	50.00 (44.95)
T_7	9	33.33 (35.22)	53.33 (46.86)	65.00 (53.67)
T_8	**10**	**40.00 (39.18)**	**65.00 (53.67)**	**68.33 (55.69)**
SE ±		**0.46**	**0.50**	**0.58**
CD at 1%		**1.86**	**2.02**	**2.35**

*Figures in parentheses indicate arcsine transformed values.

The present study recorded the efficacy of EC Product II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment were presented in Table 7. The results indicated that all the treatments were significantly superior over control at 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 10.00 per cent to 53.33 per cent. The result showed that after 12 h of treatment that significantly superior mortality percentage was recorded at T_8 with 40.00 per cent mortality. The next treatment was T_7 (33.33%), and which was at par with T_6 (26.66 %), T_5 (13.33 %) and T_4 (10.00 %) which was at par with T_3 (8.33%). The treatment T_2 with 6.66 per cent mortality and T_1 observed minimum mortality percentage (5.00%). The data indicated 24 h post-treatment that the significantly superior mortality percentage was recorded at T_8 (65.00%). The other treatments were followed by T_7, T_6 and T_5 with 53.33 per cent, 36.66 per cent and 20.00 per cent mortality, respectively. The treatment T_4 (15.00 %) which was at par with T_3 (13.33 %) and at par with T_2 (11.66 %). The treatment T_1 with (6.66%) and in the control treatment zero per cent mortality was observed. The result indicated that all treatments were significantly superior to control at 12, 24 and 48 h post treatment. The

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observations recorded after 48 h of treatment revealed T_8 (68.33%) mortality. Other next best treatments were followed by T_7 with 65.00 per cent, T_6 with 50.00 per cent , T_5 with 38.33 percent, T_4 with 25.00 per cent which was at par with T_3 (23.33 %) and which was at par with T_2 (20.00%). The treatment T_1 with 15.00 per cent mortality.

Table 9 Efficacy of EC Product III [Water- Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	6.66 (14.94)	11.66 (19.95)	20.00 (26.53)
T_2	4	10.00 (18.41)	16.66 (24.06)	25.00 (29.96)
T_3	5	15.00 (22.76)	21.66 (27.71)	33.33 (35.22)
T_4	6	18.33 (25.32)	26.66 (31.05)	40.00 (39.18)
T_5	7	20.00 (26.53)	31.66 (34.20)	51.66 (45.90)
T_6	8	33.33 (35.22)	43.33 (41.12)	60.00 (50.71)
T_7	9	35.00 (36.23)	50.00 (44.95)	63.33 (52.67)
T_8	**10**	**38.33 (38.21)**	**60.00 (50.71)**	**65.00 (53.67)**
SE ±		**0.40**	**0.47**	**0.58**
CD at 1%		**1.63**	**1.92**	**2.35**

*Figures in parentheses indicate arcsine transformed values.

The experiment was conducted to investigate the efficacy of EC Product III [Water-Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality after 12, 24 and 48 h post-treatment were presented in Table 9. The results indicated that all the treatments were significantly superior to control 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 6.66 per cent to 65.00 per cent. After 12 h of treatment that significantly superior mortality percentage was recorded at T_8 (38.33 %). The next treatments were T_7 (35.00%) at par with T_6 (33.33%) and T_5 (20.00%) at par with T_4 (18.33%). The next treatments were T_3, T_2 and T_1 with 15.00 per cent, 10.00 per cent and 6.66 per cent, respectively. The result obtained 24 h post-treatment significantly superior mortality percentage was recorded at T_8 with 60.00 per cent mortality. The other treatments were T_7 (50.00 %), T_6 (43.33 %) and T_5 (31.66%). The result indicated that 48 h post treatment significantly superior mortality percentage was recorded for T_8 (65.00%) at par with T_7 (63.33%) relatively more effective than other treatments. The next best treatments were T_7, T_6 and T_5 with 63.33 per cent, 60.00 per cent and 51.66 per cent mortality, respectively. In the control treatment zero per cent mortality was observed.

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	6.66 (14.94)	13.33 (21.39)	20.00 (26.53)
T_2	4	8.33 (16.76)	15.00 (22.76)	23.33 (28.85)
T_3	5	13.33 (21.39)	20.00 (26.53)	31.66 (34.20)
T_4	6	15.00 (22.76)	26.66 (31.05)	40.00 (39.18)
T_5	7	23.33 (28.85)	35.00 (36.23)	43.33 (41.12)
T_6	8	35.00 (36.23)	48.33 (43.99)	56.66 (48.77)
T_7	9	43.33 (41.12)	55.00 (47.81)	61.66 (51.69)
T_8	**10**	**46.66 (43.04)**	**65.00 (53.67)**	**75.00 (59.93)**
SE ±		**0.47**	**0.54**	**0.63**
CD at 1%		**1.92**	**2.22**	**2.56**

*Figures in parentheses indicate arcsine transformed values.

The experiment aimed to study the efficacy of EC Product IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment were presented in Table 10. The results indicated that all the treatments were significantly superior to control at 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 6.66 per cent to 75.00 per cent. The further data revealed that the treatments with low concentrations were less effective as compared to other treatments. Results obtained 12 h after treatment indicated that the treatment was T_8 with 46.66 per cent mortality which was at par with T_7 (43.33%). The further data revealed that the treatments T_6 and T_5 were 35.00 per cent and 23.33 per cent, respectively. The treatment T_4 (15.00%) was at par with T_3 (13.33%) and T_2 (8.33%) which was at par with T_1 (6.66%). Observations recorded 24 hours post-treatment indicated that treatment T_8 achieved the highest mortality rate at (65.00 %), which was significantly superior to all other treatments. Followed by T_7 resulted in 55.00 per cent mortality, while treatment T_6 showed 48.33 per cent mortality. Results obtained 48 h post-treatment indicated that treatment T_8 which gave the highest per cent mortality with 75.00 per cent was most effective and significantly superior over all other treatments. The next best results T_7 (61.66%) and T_6 (56.66%) were obtained. The treatment T_5 (43.33%) at par with T_4 (40.00%), T_3 (31.66%), T_2 (23.33%) which was at par with T_1 (20.00%). In the control treatment zero per cent mortality was observed.

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	**24h**	**48h**
T_0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*
T_1	3	5.00 (12.90)	10.00 (8.41)	15.00 (22.76)
T_2	4	8.33 (16.76)	15.00 (22.76)	21.66 (27.71)
T_3	5	13.33 (21.39)	18.33 (25.32)	30.00 (33.17)
T_4	6	16.66 (24.06)	23.33 (28.85)	35.00 (36.23)
T_5	7	25.00 (29.96)	30.00 (33.17)	38.33 (38.21)
T_6	8	38.33 (38.21)	43.33 (41.12)	45.00 (42.08)
T_7	9	40.00 (39.18)	45.00 (42.08)	50.00 (44.95)
T_8	**10**	**43.33 (41.12)**	**50.00 (44.95)**	**61.66 (51.69)**
SE ±		**0.42**	**0.51**	**0.54**
CD at 1%		**1.69**	**2.07**	**2.22**

*Figures in parentheses indicate arcsine transformed values.

The experiment aimed to investigate the efficacy of EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality at 12, 24 and 48 h post-treatment were presented in Table 11. The results indicated that all the treatments were significantly superior to control at 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 5.00 per cent to 61.66 per cent. Results obtained 12 h post-treatment T_8 (43.33 %), T_7 (40.00%) which was at par with T_6 (38.33%), T_5 (25.00 %), T_4 (16.66%), T_3 (13.33 %), T_2 (8.33%) and T_1 (5.00 %) were the least effective as compared to all other treatments. These treatments were less effective compared to the other treatments in reducing snail populations. Data recorded 24 h post-treatment revealed that the treatments were T_8 (50.00%) and T_7 (45.00%) at par with T_6 (43.33%). The next treatments were T_5, T_4, T_3, T_2 and T_1 such as 30.00 per cent, 23.33 per cent, 18.33 per cent, 15.00 per cent and 10.00 per cent mortality, respectively. Observations recorded 48 h post-treatment indicated that treatment T_8 with 61.66 per cent mortality was significantly superior over control.

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

Tr. No.	Concentration (ml/l)	Per cent Mortality (%)		
		12h	24h	48h
T0	0	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)*

T_1	3	6.66 (14.94)	11.66 (19.95)	13.33 (21.39)
T_2	4	11.66 (19.95)	16.66 (24.06)	20.00 (26.53)
T_3	5	13.33 (21.39)	18.33 (25.32)	21.66 (27.71)
T_4	6	15.00 (22.76)	21.66 (27.71)	28.33 (32.12)
T_5	7	18.33 (25.32)	23.33 (28.85)	30.00 (33.17)
T_6	8	23.33 (28.85)	23.33 (28.85)	31.66 (34.20)
T_7	9	23.33 (28.85)	36.66 (37.22)	45.00 (42.08)
T_8	**10**	**33.33 (35.22)**	**43.33 (41.12)**	**55.00 (47.81)**
SE ±		**0.40**	**0.50**	**0.52**
CD at 1%		**1.63**	**2.02**	**2.12**

*Figures in parentheses indicate arcsine transformed values.

The research investigated the efficacy of EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)] against snails under laboratory conditions. The data recorded on per cent mortality after 12, 24 and 48 h post-treatment were presented in Table 12. The results indicated that all the treatments were significantly superior over control 12, 24 and 48 h post-treatment. The per cent mortality was recorded in the range of 6.66 per cent to 55.00 per cent. Results obtained 12 hours post-treatment showed varying levels of mortality among the treatments. The treatment T_8 (33.33 %). The results were obtained in these treatments with T_7 and T_6 both giving 23.33 per cent mortality each. The treatment T_5 (18.33%), T_4 (15.00%) which was at par with T_3 (13.33%). Data recorded 24 h post-treatment revealed that the treatments were T_8, T_7, T_6 and T_5 with 43.33 per cent, 36.66 per cent, 23.33 per cent, 23.33 per cent mortality, respectively. The next treatment was T_4 (21.66%) at par with T_3 (18.33 %), T_2 (16.66%) and T_1(11.66%) mortality. Observations recorded 48 h post-treatment indicated that treatment T_8 with 55.00 per cent mortality.

Phytotoxic effect for emulsifiable concentrates formulations

The data have been presented in table 13 regarding the phytotoxic effect of EC Product I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)], EC Product II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)], EC Product III [Water-Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)], EC Product IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)], EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)], EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20

(Emulsifying agent)] and uuntreated control tested on tomato, okra, groundnut, cow pea and wal plant. The observations recorded for symptoms like leaf injury on tips/surface, wilting, vein clearing, necrosis, epinasty, hyponasty and chlorosis/ scorching showed that there was no phytotoxic effect of the emulsifiable concentrates formulation on the tested plant for 3-10 ml/l of the doses evaluated in the experiment. This indicated that there was no any phytotoxic effect observed after application of soapnut based formulations at the evaluated doses.

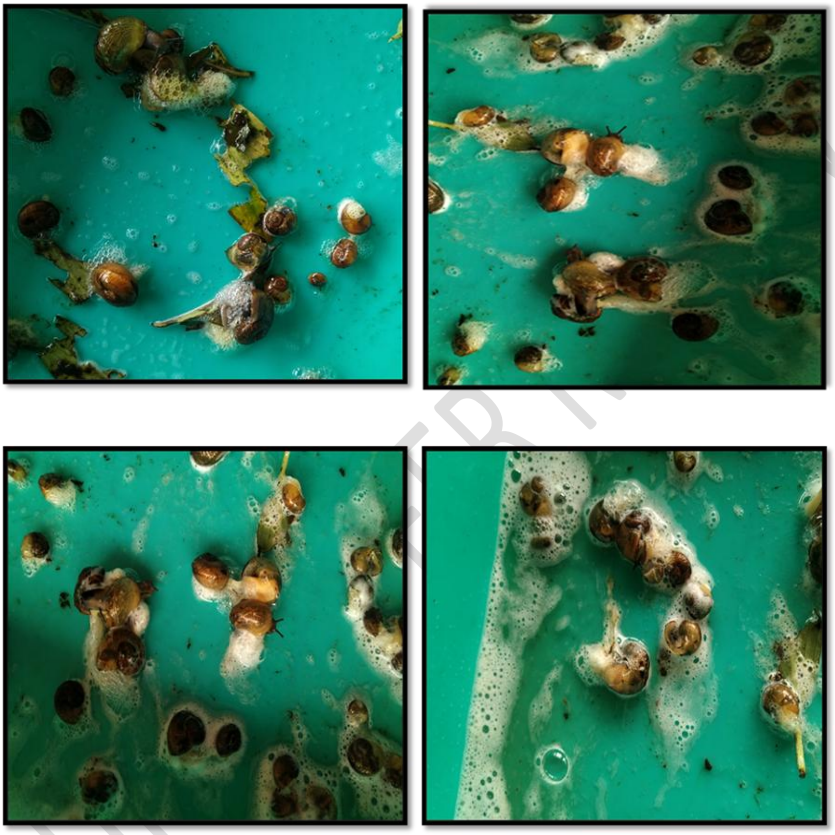

Plate 1. Snails mortality caused by EC product

Plate 2. No phytotoxic effect of EC formulations on the tested plant

Table 13 : Phytotoxic effect for emulsifiable concentrates formulation during 2023-2024

Product name	Concentration (ml/l)	Phytotoxicity parameters observed* (mean observations recorded after 1, 3, 5, 7 and 10 days spray application)						
		Leaf injury on tips/surface	Wilting	Vein Clearing	Necrosis	Epinasty	Hyponasty	Chlorosis / Scorching
EC Product I [Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
EC Product II [Boil Water + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
EC Product III [Water-Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
EC Product IV [Ethanol + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
EC Product V [Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
EC Product VI [Water-Acetone + Soapnut Powder (1:10) + Tween 20 (Emulsifying agent)]	3-10 ml/l	0	0	0	0	0	0	0
Untreated control	3-10 ml/l	0	0	0	0	0	0	0

*Based on 0-10 Scale where: 0 = 00%, 1 = 1-10%, 2 = 11-20%, 3 = 31-30%, 4 = 41-50%, 5 = 51-60%, 6 = 61-70%, 7 = 71-80%, 8 = 81-90%, 9 = 91-100%

Conclusions

In the EC formulations, optimal results were achieved with Ethanol, Water, Boiled Water, Water - Ethanol, Acetone, and Acetone-Water. Ethanol demonstrated the greatest efficacy, likely due to its potent solvent properties and ability to disrupt cellular membranes. Water provided a notable level of snail mortality, which was further enhanced by boiling, possibly due to thermal effects in addition to its solvent properties. Consequently, the topical application methods targeted approach and higher contact efficacy make it a more reliable and effective choice for managing snail populations. None of the formulations demonstrated phytotoxic effects on the evaluated crops, indicating their safety and suitability for agricultural applications. The research will provide a foundation for further exploration into the efficacy and safety of soapnut-based formulations, promoting sustainable agricultural practices and enhancing pest management strategies while preserving ecological balance.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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