

## RESEARCH ARTICLE

## Toxicity of Plant Derived Molluscicides in Attractant Food Pellets against Snail, *Lymnaea Acuminata*

FARINDRA TIWARI and DINESH KUMAR SINGH

For author affiliations, see end of text.

Received December 6, 2006; Accepted June 30, 2007

This paper is available online at <http://ijpt.iuims.ac.ir>

## ABSTRACT

Use of molluscicides in the attractant food pellet (AFP) is one of the effective methods of snail control. Attractant food pellets containing starch and agar plus different concentrations of these molluscicides (Azadirachta indica bark powder, Allium sativum bulb powder, Polianthes tuberosa bulb powder, Annona squamosa seed powder, their active components azadirachtin, allicin, hecogenin, acetogenin; herbal molluscicide pestoban and a synthetic molluscicide, Snail Kill, were tested for molluscicidal activity for 144h against the snail, *Lymnaea acuminata*. Active components of all the plant derived molluscicides were highly toxic to *L. acuminata* compared with their crude forms. The stability of bait formulations was studied by storing the pellets up to 4 weeks. Storage of molluscicide baits caused higher reduction in their toxicity in comparison with synthetic molluscicides.

**Keywords:** Attractant food pellets, Bait formulation, *Fasciola*, *L. acuminata*, Molluscicides, Starch

Liver- flukes *Fasciola hepatica* Linnaeus and *Fasciola gigantica* Cobbold cause endemic fascioliasis in cattle population of eastern Uttar Pradesh [1-2]. The snail *Lymnaea* (*Radix*) *acuminata* Lamarck (*Lymnaei*-*daea*) is the vector of these flukes. One way to reduce the incidence of fascioliasis is to de-link the life cycle of fluke by destroying the intermediate hosts [3-8]. The development of a selective and safe molluscicide should always be a realistic goal. It must be effective at low concentrations and exert minimal adverse effect on the other biota sharing the same habitat with snail. Lack of contact between molluscicides and target snail population due to meshy vegetation, dilution in upwelling sewage water are two main causes of the failure of snail control programme. The snails use chemical signals for locating food sources. These signals are released from the dead and living aquatic organisms into the modular system of the snails [9-13]. Starch is the strongest attractant for *L. acuminata* [14]. Bait formulation containing attractant and a molluscicide is an expedient approach in order to lure the target snail population to the molluscicide. In the present study different plant derived molluscicides have been used along with starch in bait formulation against *L. acuminata*.

## MATERIALS AND METHODS

Agar, starch, different plant derived molluscicides such as *Allium sativum* and *Polianthes tuberosa* bulb powder, *Annona squamosa* seed powder and *Azadirachta indica* bark powder and their active components allicin, hecogenin, acetogenin and azadirachtin (Sigma Chemical Co. USA), Snail Kill (metaldehyde-Pesticide India) and herbal molluscicide, Pestoban (Liquid concentrate of *Cedrus deodara*, *Azadirachta indica* and seed powder of *Embelia ribes* in 90:2:1 ratio- Indian Herbs, Research and Supply Co. Pvt. Ltd., India) were used in bait formulation. Adult *L. acuminata* (2.25±0.20 cm in length) were collected locally from lakes and low lying submerged fields in Gorakhpur. The snails were acclimatized for 72 hours in dechlorinated tap water at 25±1° C. The pH of the water was 7.1-7.3 and dissolved oxygen, free carbon dioxide and bicarbonate alkalinity were set to 6.5-7.2 mg/l, 5.2-6.3 mg/l and 102.0-105.0 mg/l, respectively.

Attractant food pellets (AFP) were prepared according to previous method [15] as modified by us [16]. 10 grams of starch (10 mM) was added to 2% agar solution. After boiling, each of the selective molluscicides were added to the solution in different concentrations (Table1), the mixture was stirred constantly for 30 minutes and spread to a uniform thickness (5 mm). After

Table 1. Mean number of snail *L. acuminata* in zone three in contact with the attractant food pellets (AFP) that contain different molluscicides after two hours from beginning of experiment.

Molluscicides	Concentration of molluscicides				
	0.1%*	0.2%	0.5%	0.7%	1.0%
<i>A. squamosa</i> (SP)	1.16±0.16 (58.0) +	0.83±0.16 (43.0)	1.33±0.21 (53.4)	1.67±0.21 (45.6)	0.83±0.16 (50.0)
<i>A. sativum</i> (BP)	3.67±0.2 (78.0) +	3.5±0.96 (53.8)	3.5±0.22 (61.8)	3.0±0.44 (50.0)	2.67±0.42 (47.0)
<i>P. tuberosa</i> (BP)	3.0±0.25 (60.0) +	2.67±0.21 (57.2)	2.33±0.21 (53.8)	1.83±0.40 (52.2)	1.67±0.21 (45.3)
<i>A. indica</i> (Ba P)	3.5±0.34 (60.0) +	1.83±0.16 (37.8)	3.0±0.22 (55.6)	2.33±0.42 (53.8)	0.83±0.30 (31.2)
Acetogenin	3.0±0.36 (50.0) +	2.0±0.25 (50.0)	1.16±0.3 (27.8)	1.5±0.22 (42.8)	0.5±0.22 (20.0)
Allicin	1.4±0.35 (46.7) +	1.33±0.21 (46.9)	1.0±0.63 (33.3)	1.5±0.34 (42.8)	0.83±0.16 (27.6)
Hecogenin	0.67±0.21 (50.3) +	0.33±0.21 (22.0)	0.5±0.22 (33.3)	0.83±0.30 (27.6)	0.33±0.21 (13.2)
Azadirachtin	1.16±0.16 (46.4) +	1.0±0.25 (31.5)	1.0±0.44 (33.3)	0.83±0.30 (33.3)	0.67±0.42 (21.2)
Snail Kill	1.67±0.21 (45.5) +	1.5±0.34 (42.8)	1.33±0.49 (39.9)	1.16±0.40 (36.7)	0.67±0.21 (40.2)
Pestoban	2.5±0.42 (57.7) +	1.5±0.34 (33.3)	1.33±0.5 (39.9)	1.33±0.42 (30.7)	0.83±0.40 (31.2)
Control (Agar)	4.33±0.21 (76.36)	3.83±0.16 (72.47)	4.5±0.34 (81.81)	4.16±0.16 (71.23)	3.5±0.34 (74.84)

Values in parentheses are percentages of snails in zone 3 (in contact with attractant food pellet) compared with snails in zone 1 and 2.

Statistically significant ( $p < 0.05$ ) when two way ANOVA was applied in between different molluscicides (+) and their different concentrations (\*).

Abbreviations: SP- Seed powder, BP- Bulb powder, BaP- Bark powder

cooling, the pellets were cut out from the layer with a corer (5 mm diameter).

### Assay and Apparatus

The bioassay was performed as reported earlier [14, 16]. The bioassay chamber consists of a clean glass aquarium having a diameter of 30 cm. Each aquarium was divided into four concentric zones; Zone 3 (central zone), zones 2 and 1 (middle zone) and zone 0 (outer zone) had diameters of 13, 18, 24 and 30 cm, respectively. A small annular elevation of 9 mm height and 2.4 cm in diameter was made in the centre of aquarium (Zone 3). Zone 0 had an area of 254 cm<sup>2</sup> on the periphery of aquarium. The aquaria were then filled with 500 ml of dechlorinated tap water to a height of 8 mm and maintained at 25±1<sup>0</sup> C. At the start of the assay ten individually marked snails of uniform size were placed on the circumference of zone 0. The distance between two snails was 66 mm. Simultaneously, one of the prepared bait of different molluscicides was added on the small annular elevation in the centre (Zone 3). The location of

each snail was recorded every 15 min for two hours. Six sets of experiments were carried out with ten snails each for every molluscicide used in this study. The mortality of the snails was observed after the test with every 24h up to 144h. Lethal values (LC<sub>50</sub>), lower and upper confidence limits (LCL and UCL), slope values, t- ratio, 'g' value and heterogeneity factor were calculated using POLO computer programme [17]. One/two-way ANOVA and product moment correlation coefficient was applied between the different data obtained in Tables 1-4 [18]. These experiments were repeated in stored pellets kept for 7, 14, 21 and 28 days under laboratory conditions.

## RESULTS

Low attraction (45.5%) of the snails was observed by the Snail Kill compared to plant derived molluscicides in zone 3 at 0.1% concentration in AFP (Table 1). 0.1% AFP containing *A. squamosa* seed powder, *A. sativum*, *P. tuberosa* bulb powder, *A. indica* bark powder,

Table 2. Mean number of snail *L. acuminata* in zone three in contact with the stored attractant food pellets (AFP) containing 0.1% molluscicides.

Molluscicides	TIME OF STORAGE (IN DAYS)				
	0	7	14	21	28
<i>Pestoban</i>	2.5±0.42 (57.7) +	2.16±0.16 (50.0)	1.83±0.16 (61.1)	1.75±0.19 (43.2)	1.16±0.16 (41.2)
<i>Snail Kill</i>	1.67±0.21 (45.5) +	1.67±0.21 (44.2)	1.33±0.21 (36.3)	0.83±0.16 (38.2)	0.67±0.21 (34.5)
<i>A. indica</i> (Ba P)	3.5±0.34 (60.0) +	3.33±0.21 (55.5)	1.83±0.16 (47.7)	1.5±0.22 (40.9)	1.33±0.21 (34.5)
<i>A. sativum</i> (BP)	3.67±0.2 (78.0) +	4.0±0.36 (44.4)	3.16±0.47 (41.2)	2.72±0.51 (40.4)	2.16±0.16 (35.0)
<i>P. tuberosa</i> (BP)	3.0±0.25 (60.0) +	1.83±0.16 (31.3)	1.67±0.21 (35.7)	1.16±0.16 (27.8)	0.83±0.16 (31.2)
<i>A. squamosa</i> (SP)	1.16±0.16 (58.0) +	1.67±0.21 (35.7)	1.33±0.42 (30.7)	1.16±0.16 (27.8)	0.83±0.16 (31.2)
Acetogenin	3.0±0.36 (50.0) +	2.67±0.21 (47.0)	2.0±0.44 (40.0)	1.5±0.34 (33.3)	1.16±0.16 (27.8)
Azadirachtin	1.16±0.16 (46.4) +	0.83±0.16 (31.2)	0.83±0.16 (31.2)	0.67±0.42 (28.6)	0.5±0.22 (25.0)
Allicin	1.4±0.35 (46.7) +	1.33±0.42 (36.3)	1.16±0.16 (34.9)	0.83±0.3 (31.2)	0.83±0.3 (31.2)
Hecogenin	0.67±0.21 (50.3) +	0.67±0.21 (28.6)	0.67±0.21 (28.6)	0.5±0.22 (25.0)	0.33±0.21 (24.0)
Control (Agar)	4.5±0.34 (81.81)	4.66±0.21 (78.23)	5.5±0.16 (74.87)	4.33±0.21 (78.56)	5.33±0.47 (77.68)

Values in parentheses are percentages of snails in zone 3 (in contact with the stored attractant food pellet) compared with snails in zone 1 and 2.

+ Statistically significant ( $p < 0.05$ ) when one way ANOVA was applied in between the number of snails in different storage period of bait formulations.

Abbreviations as in table 1.

Table 3. Toxicity in different bait formulations of molluscicides against the snail *L. acuminata* at different time exposure.

Expo-sure Period	Molluscicides	LC <sub>50</sub> % in AFP	LCL	UCL	Slope value	t-ratio	g-value	Heterogeneity
24h	<i>A. sativum</i>	1.57	1.07	4.38	1.80±0.45	3.92	0.24	0.28
	<i>P. tuberosa</i>	2.07	1.5	5.0	2.09±0.54	3.87	0.25	0.17
	Allicin	1.35	0.84	4.1	1.45±0.33	4.38	0.20	0.32
	Hecogenin	1.54	1.04	6.0	1.9±0.57	3.34	0.34	0.13
	Snail Kill	1.36	1.04	2.56	2.52±0.57	4.38	0.19	0.30
48h	<i>A. sativum</i>	1.53	0.93	11.29	1.12±0.37	3.03	0.41	0.15
	<i>P. tuberosa</i>	1.19	1.00	1.60	2.41±0.49	4.84	0.16	0.15
	Allicin	0.92	0.59	2.59	1.14±0.27	4.15	0.22	0.16
	Hecogenin	0.90	0.74	1.32	2.34±0.51	4.52	0.19	0.16
	Snail Kill	1.30	0.97	2.68	2.07±0.50	4.08	0.23	0.22
72h	<i>A. sativum</i>	0.86	0.61	2.0	1.16±0.34	3.35	0.34	0.22
	<i>P. tuberosa</i>	1.01	0.85	1.33	2.12±0.48	4.36	0.20	0.27
	Allicin	0.32	0.24	0.45	1.34±0.25	5.21	0.14	0.28
	Hecogenin	0.70	0.58	0.93	2.0±0.48	4.33	0.20	0.15
	Snail Kill	0.94	0.76	1.43	2.08±0.46	4.48	0.19	0.16
96h	<i>A. sativum</i>	0.44	0.28	0.61	1.19±0.33	3.55	0.30	0.21
	<i>P. tuberosa</i>	0.76	0.64	0.88	2.61±0.50	5.22	0.14	0.29
	Allicin	0.20	0.14	0.27	1.36±0.25	5.30	0.13	0.21
	Hecogenin	0.55	0.45	0.67	2.15±0.47	4.53	0.18	0.20
	Snail Kill	0.68	0.55	0.91	1.84±0.44	4.19	0.21	0.16
120h	<i>A. sativum</i>	0.28	0.08	0.42	0.99±0.33	2.99	0.42	0.28
	<i>P. tuberosa</i>	0.57	0.46	0.66	3.26±0.56	5.80	0.11	0.36
	Allicin	0.12	0.07	0.15	1.68±0.28	5.99	0.10	0.20
	Hecogenin	0.39	0.27	0.46	2.11±0.47	4.43	0.19	0.20
	Snail Kill	0.41	0.29	0.51	1.89±0.44	4.28	0.20	0.18
144h	<i>A. sativum</i>	0.18	0.07	0.26	1.46±0.35	4.15	0.22	0.34
	<i>P. tuberosa</i>	0.48	0.38	0.55	3.92±0.70	5.55	0.12	0.44
	Allicin	0.09	0.05	0.12	2.03±0.33	6.11	0.10	0.42
	Hecogenin	0.27	0.17	0.34	2.63±0.53	4.95	0.15	0.53
	Snail Kill	0.33	0.25	0.40	2.90±0.50	5.82	0.11	0.31

Product moment correlation showed significant ( $p<0.05$ ); negative correlation in between the exposure period and LC<sub>50</sub> of different molluscicides.

Abbreviations as in table 1.

108der, their active components i.e. acetogenin, allicin, 1373 and 4). The crude preparations of plant derived mol-  
109hecogenin, azadirachtin and pestoban caused more at-138luscicides and AFP containing pestoban caused signifi-  
110traction (58.0%, 78.0%, 60.0%, 60.0% 50.0%, 46.7%, 139cant molluscicidal activity against *L. acuminata* (Table  
11150.3%, 46.4% and 57.7%, respectively) than the AFP1403 and 4).

112containing 0.2% to 1.0% of the same molluscicides. The141 The slope values given in Tables 3 and 4 were steep.  
113attraction of the snails was significantly ( $p<0.05$ ) re-142Separate estimate of LC<sub>50</sub> based on each of the six repli-  
114duced with increasing concentration of different mollus-143cates was found to be within 95% confidence limits.  
115cicides in AFP. Lowest attraction (13.2%) of snails was144The t- ratio was greater than 1.96 and the heterogeneity  
116observed for 1.0% hecogenin containing AFP. There145less than 1.0. The 'g' value was less than 0.5 at all prob-  
117was a significant ( $p<0.05$ ) decrease in the number of the146ability levels (90, 95, 99).

118snails attracted by all other 0.1% stored AFP for 7, 14,

11921 and 28 days except *A. sativum* containing AFP (Ta-

120ble2).

121 Molluscicidal activity of different AFP containing148 Higher attraction of the snails towards AFP contain-  
122products/compounds against *L. acuminata* followed a149ing 0.1% plant derived molluscicides compared with  
123time and dose dependence relationship (Table 3-4).150Snail Kill, appears to be due to the slower release of  
124There was a significantly ( $p<0.05$ ) negative correlation151molluscicidal compounds in comparison with synthetic  
125between exposure period and LC<sub>50</sub> in different mollus-152ones. Higher concentration of plant derived mollus-  
126cicides. AFP containing bioactive components of differ-153cicides and their active components in AFP caused less  
127ent plants were more toxic (acetogenin 24h LC<sub>50</sub>-1.02%154attraction than corresponding concentration of Snail  
128in AFP; 144h LC<sub>50</sub>-0.12% in AFP) than synthetic ones.155Kill. It indicates that when higher titer of active compo-  
129The molluscicidal activity of garlic crude bulb powder156nents of plant derived molluscicides was used in AFP,  
130(144h LC<sub>50</sub>-0.18% in AFP) was higher than Snail Kill157snails were less attracted. Higher concentration (1.0%)  
131(144h LC<sub>50</sub>-0.33% in AFP). Allicin was more toxic158of allicin, hecogenin and azadirachtin [19-21] attracted  
132(144h LC<sub>50</sub>-0.09% in AFP) than the crude bulb powder159less snails than Snail Kill. There was a significant de-  
133of *A. sativum* (144h LC<sub>50</sub>-0.18% in AFP). The bioactive160crease in the attraction of *L. acuminata* towards AFP  
134components hecogenin, acetogenin and azadirachtin161containing molluscicides compared with AFP alone  
135were more toxic (24h LC<sub>50</sub>- 1.54%, 1.35% and 1.10% in162with a significant variation in mean number of snails in  
136AFP, respectively) than their crude preparations (Table163zone 3 containing different concentrations of mollus-

## DISCUSSION

Table 4. Toxicity in different bait formulations of molluscicides against the snail *L. acuminata* at different time exposure.

Exposure Period	Molluscicides	LC <sub>50</sub> % in AFP	LCL	UCL	Slope value	t-ratio	g-value	Heterogeneity
24h	<i>A. indica</i> BaP	1.48	0.86	6.98	1.24±0.33	3.76	0.27	0.18
	<i>A. squamosa</i>	1.53	1.23	2.57	3.18±0.74	4.27	0.21	0.26
	Azadirachtin	1.10	0.86	1.99	2.26±0.54	4.15	0.22	0.12
	Acetogenin	1.02	0.72	2.16	1.68±0.36	4.62	0.18	0.29
	Pestoban	2.82	2.24	5.71	3.14±0.86	3.62	0.29	0.23
48h	<i>A. indica</i> BaP	1.01	0.62	3.90	1.03±0.28	3.61	0.29	0.17
	<i>A. squamosa</i>	1.25	1.08	1.88	2.75±0.65	4.24	0.21	0.14
	Azadirachtin	1.03	0.78	2.14	1.82±0.50	3.64	0.28	0.13
	Acetogenin	0.78	0.54	1.75	1.23±0.29	4.22	0.21	0.19
	Pestoban	2.46	1.98	4.94	2.43±0.71	3.40	0.33	0.23
72h	<i>A. indica</i> BaP	0.53	0.37	1.09	1.05±0.27	3.88	0.25	0.15
	<i>A. squamosa</i>	0.98	0.83	1.32	2.38±0.60	3.95	0.24	0.11
	Azadirachtin	0.73	0.59	1.11	1.78±0.47	3.75	0.27	0.13
	Acetogenin	0.39	0.29	0.58	1.23±0.27	4.57	0.18	0.21
	Pestoban	1.73	1.48	2.27	2.44±0.66	4.14	0.28	0.21
96h	<i>A. indica</i> BaP	0.25	0.17	0.34	1.23±0.26	4.66	0.17	0.22
	<i>A. squamosa</i>	0.63	0.50	0.73	2.71±0.61	4.45	0.19	0.11
	Azadirachtin	0.41	0.25	0.52	1.60±0.46	3.45	0.32	0.14
	Acetogenin	0.32	0.24	0.42	1.47±0.27	5.42	0.13	0.52
	Pestoban	1.33	0.99	1.60	2.07±0.63	3.26	0.36	0.28
120h	<i>A. indica</i> BaP	0.15	0.70	0.23	1.10±0.26	4.20	0.21	0.23
	<i>A. squamosa</i>	0.53	0.45	0.59	4.75±0.74	6.37	0.09	0.37
	Azadirachtin	-	-	-	-	-	-	-
	Acetogenin	0.19	0.10	0.27	1.09±0.26	4.18	0.22	0.49
	Pestoban	1.06	0.75	1.25	2.58±0.64	4.00	0.24	0.28
144h	<i>A. indica</i> BaP	0.09	0.03	0.14	1.27±0.27	4.57	0.84	0.36
	<i>A. squamosa</i>	0.48	0.40	0.54	5.32±0.88	6.04	0.10	0.37
	Azadirachtin	-	-	-	-	-	-	-
	Acetogenin	0.12	0.06	0.16	1.40±0.27	5.10	0.14	0.55
	Pestoban	0.96	0.75	1.10	3.65±0.68	5.32	0.13	0.86

Product moment correlation showed significant ( $p < 0.05$ ); negative correlation between the exposure period and LC<sub>50</sub> of different molluscicides.

Abbreviations as in table 1.

cicides after two hours of exposure. AFP containing from the seeds of *A. squamosa* is higher than other plant acetogenin attracted more snails at lower concentrations derived molluscicides and Snail Kill (24h LC<sub>50</sub>- 1.36% than *A. squamosa* seed powder. It indicates that *A. indica* in AFP). Seeds of *A. squamosa* were used to kill human *squamosa* seed powder, instead of acetogenin contains lice [22] and their organic extracts have been reported to some other compounds which reduce the attraction of snails towards AFP. In contrast AFP containing *A. sativa* activity of *A. indica* bark powder (24h LC<sub>50</sub> 1.48% in *vum* and *P. tuberosa* bulb powder and *A. indica* bark powder (24h LC<sub>50</sub> 1.10% in AFP) is lower than the Snail Kill. However, its active powder attracted more snails than their pure compounds component azadirachtin (24h LC<sub>50</sub> 1.10% in AFP) is viz. allicin, hecogenin and azadirachtin. It seems that more toxic than Snail Kill. Toxicity of AFP containing these plant derived molluscicides either contain some azadirachtin was effective only up to 96h. It indicates other compounds which attract the snails or the concentration that it is less stable in water or it is metabolized in snail preparations of active molluscicidal components are less in body [20]. AFP containing hecogenin in AFP is 1.5 time crude preparations. The storage of attractant food pellets more toxic than the crude bulb powder of *P. tuberosa*. It for up to 28 days caused significant decrease in the attraction of snails. Thus, it seems logical to assume that powder and hecogenin caused significant reduction in AFPs containing plant derived molluscicides are less the reproduction of the *L. acuminata* [20]. It has been effective in attracting snails, when stored up to 28 days. However, toxicity of these AFP containing molluscicides was time and dose dependent as evident from the negative correlation between LC<sub>50</sub> in different molluscicides and exposure period.

Treatment of bulb powder of *A. sativum* and *P. tuberosa* *Cedrus deodara*, *A. indica* and *Embelia ribes* in liquid *rosa*, seed powder of *A. squamosa*, bark powder of *A. indica* concentrate form [26]. The toxicity of Pestoban to the *indica* and their active components such as allicin, hecogenin, acetogenin and azadirachtin in aquatic environment are highly toxic to *L. acuminata* [19-21]. The steep slope values indicate that a small increase in the concentration in different molluscicides cause a

218 significant mortality in the snail. t- ratio value greater  
219 than 1.96 indicates that the regression is significant.  
220 Values of heterogeneity less than 1.0 denote that in the  
221 replicates the concentration response line would fall  
222 within 95% confidence limit and thus the model fit the  
223 data adequately. The value of 'g' is less than 0.5 indi-  
224 cates the index of significance of potency estimation. 274  
225 Use of plant derived molluscicides in aquatic envi-  
226 ronments requires large amounts of molluscicides for  
227 effective control of snails. Using attractant food pellets  
228 like this study will be beneficial since it requires small  
229 quantities of molluscicides while killing the target pest  
230 specifically. The present study shows that the use of  
231 AFPs containing plant derived molluscicides is very  
232 effective in killing the snail *L. acuminata*. Use of these  
233 plant derived molluscicides inside the baits (Attractant  
234 food pellets) are ecologically sound, target specific and  
235 economic.

### 236 REFERENCES

2371. Singh O, Agarwal RA. 1981. Toxicity of certain pesticides to  
238 two economic species of snails in northern India. *J Econ Ento-*  
239 *mol* 74:568-571. 268
2402. Agarwal RA, Singh DK. 1988. Harmful gastropods and their  
241 control. *Acta Hydrochim Hydrobiol* 16:113-138. 269
2423. Godan D. 1983. "Pests slugs and snails. Biology and control"  
243 (ed., Dora Godan) translated by Sheila Grouber, Springer Verlag,  
244 Berlin Heidelberg New York . 270
2454. Marston A, Hosttetmann K. 1985. Plant molluscicides. *Phyto-*  
246 *chemistry* 24:639-652. 271
2475. Marston A, Hosttetmann K. 1987. Antifungal, molluscicidal and  
248 cytotoxic compounds from plants used in traditional medicines.  
249 In: "Biologically Active Natural Products" (Ed. Hosttetmann, K  
250 and Lea, PJ). Clarendon Press Oxford 65-83. 272
2516. Ndamba J. 1995. Response of the molluscicidal berry plant  
252 *Phytolacca dodecandra* to different climatic and edaphic condi-  
253 tions. *Trop Agric* 72:135-140. 273
2547. Singh A, Singh DK, Mishra TN and Agarwal RA. 1996a. Mol-  
255 luscicides of plant origin. *Biol Agri Horti* 13:205-252. 274
2568. Singh K, Singh DK. 2000. Effect of different combinations of  
257 MGK-264 and piperonyl butoxide with plant derived mollus-  
258 cicides on snail reproduction. *Arch Environ Contam Toxicol*  
259 38:182-190. 275
2609. MacInnis AJ, Bethal WM, Cornford EM. 1974. Identification of  
261 chemicals of snail origin that attract *Schistosoma mansoni*  
262 miracidia. *Nature* 248:361-363. 276
26310. Sterry PR, Thomas JD, Patience, RL. 1985. Changes in the con-  
264 centrations of short-chain carboxylic acids and gases during de-  
265 composition of the aquatic macrophytes *Lemna paucicostata* and  
266 *Ceratophyllum demersum*. *Freshw Biol* 15:139-153. 277
26711. Thomas JD. 1982. Chemical ecology of the snail hosts of schis-  
268 tosomiasis: snail-snail and snail-plant interactions. *Malacol*  
269 33:81-91. 278
26912. Thomas JD, Kowalczyk C, Somsundaram B. 1989. The bio-  
270 chemical ecology of *Biomphalaria glabrata*, a snail host of  
271 *Schistosoma mansoni*; short chain carboxylic and amino acids as  
272 phagostimulants. *Comp Biochem Physiol* 93A:899-911. 279
27013. Kpikpi JE K, Thomas JD. 1992. A study of sugar chemorecep-  
271 tion niches of two bulinid snail hosts of schistosomiasis. *Ann*  
272 *Trop Med Parasitol* 86:181-198. 280
27114. Tiwari F, Singh DK. 2004a. Behavioural responses of the snail  
272 *Lymnaea acuminata* to carbohydrates in snail attractant pellets.  
273 *Naturewissenschaften* 91:378-380. 281
27215. Madsen H. 1992. A comparative study on the food locating  
273 ability of *Helisoma duryi*, *Biomphalaria camerunensis* and *Bu-*  
274 *linus truncatus* (Pulmonata:Planorbidae). *J Appl Ecol* 29:70-78. 282
27316. Tiwari F, Singh DK. 2004b. Attraction to amino acids by *Lym-*  
274 *naea acuminata*, the snail host of *Fasciola* species. *Braz J Med*  
275 *Biol Res* 37:587-590 . 283
27417. Russel RM, Robertson JL, Savin NE. 1977. POLO: A new com-  
275 puter programme for probit log analysis. *Bull Entomol Soc*  
276 *Amer* 23:209-213. 284
27518. Sokal RR, Rohlf FJ. 1973. Introduction to Biostatistics. W H  
276 Freeman, San Francisco, 368pp. 285
27619. Singh VK, Singh DK (1995) Characterization of allacin as a  
277 molluscicidal agent in *Allium sativum*. *Biol Agric Horti* 12:119-  
278 131. 286
27720. Singh K, Singh A, Singh DK. 1996b. Molluscicidal activity of  
278 neem (*Azadirachta indica* A. Juss). *J of Ethnopharmacol* 52:35-  
279 40. 287
27821. Singh K, Singh VK, Singh DK. 1999. Effect of *Polianthes tube-*  
279 *rosa* (Amarillidaceae) on the reproduction and biochemical pa-  
280 rameters in the ovotestis of the snail *Lymnaea acuminata* (Mol-  
281 lusca:Pulmonata). *Acta Hydrochim Hydrobiol* 27:32-37. 288
27922. Reyes FR, Santos AC. 1931. Isolation of Anonaine from *Annona*  
280 *squamosa* Linn. *Philippines J of Sci* 44:409-410. 289
28023. Chattoraj AN, Tiwari SC. 1965. A note on the insecticidal prop-  
281 erty of *Annona squamosa* (Annonaceae). *Natl Acad Sci India*  
282 *Proc Sec B (Biol Sci)* 35:351-353. 290
28124. Mukerja TD, Govind R. 1958. Indigenous insecticidal plants:II  
282 *Annona squamosa*. *J Indian Res (India)* 17C:9-15. 291
28225. Singh VK, Singh DK. 1996. Molluscicidal activity of pre- and  
283 post-harvest (garlic) *Allium sativum*. *Biol Agric Horti* 12:311-  
284 318. 292
28326. Singh K, Singh A, Singh DK. 1995. Molluscicidal activity of  
284 different combinations of the plant products used in the mollus-  
285 cicide Pestoban. *Biol Agri Horti* 12:253-261. 293

### 314 CURRENT AUTHOR ADDRESSES

- 315 Farindra Tiwari, D.D.U. Gorakhpur University, Gorakhpur, India.  
316 Dinesh Kumar Singh, D.D.U. Gorakhpur University, Gorakhpur,  
317 India. E-mail: dksing\_gpu@yahoo.co.in (Corresponding author)