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Insecticidal and oviposition inhibition efficacy of *Capparis decidua* to *Sitophilus oryzae* Linn. (Coleoptera: Curculionidae)

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Abstract

In the present investigation insecticidal potential and oviposition inhibition efficacy of stem, root and flower extracts of *Capparis decidua* was evaluated against the rice weevil *Sitophilous oryzae*. For this purpose different bioassays were conducted and adult insects were exposed with varying doses of each extract. In bioassays on an average 90-95% mortality was obtained in various solvent extracts which found to be dose dependent. Further each extract has significantly repelled lar**g**e no. of insects at a very low dose. It is due to volatile action of diverse chemicals present in *Capparis decidua* having different functional groups. When female insects of *Sitophilous oryzae* were exposed with sub-lethal doses of above extracts it also significantly inhibited oviposition in susceptible females and disallow emergence of F_1 individuals by blocking the development. However, % ODI (oviposition deterrence index) obtained was very high i.e. 40.51 to 81.83%. Therefore, it can be concluded that above plant species can be used for isolation of bio-pesticides to control pulse weevil population. For this purpose, constituent's level study along with structure activity relationships of natural products is to be required for finding wider insecticidal performance and efficacy of *C. decidua*s not only against *Sitophilous oryzae* but also against all other stored grain insect pests.

Key words: *Capparis deciduas, Sitophilus oryzae, Oviposition inhibition, Bioinsecticides, Stored grain pests*

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1. Introduction

The Rice weevil, *Sitophilus oryzae* Linn. (Curculionidae: Coleoptera) is a pest of rice, paddy, wheat, barley, maize, jowar and other cereal grains. It is a major pest of stored grains which occurs worldwide. It is commonly known as Ghun in Hindi. Both adult and larval stages of insect attack the grain and voraciously feed upon it. Its population surge due to humid climatic conditions in the sub-tropical regions. The adult weevils hibernate during winter in cracks and crevices and other shelters in storage rooms. Its attack always counted to be sudden and irregular and increase with the humidity. Its population increase in geometrical ratio starting from initial egg laying by female adults as many as 250 eggs on an average basis. Its progeny production is so high that once food grains deposited with eggs, in next cycle control of weevil become very hard due to uncontrolled movements made by newly emerged adults. During rainy season their fourth instar larvae become highly active and cause very high infestation to rice. Both adult and larvae attack the grain upon which they feed voraciously so much that the grain rendered unfit for human consumption. In heavy infestation weevil larvae and adults seriously destroy the nutritive part of rice and the grain becomes a mass broken rice husky material of very low weight and does not remain usable for sowing in the field. For control of *S. oryzae* many synthetic insecticides have been tried so far, but insects have acquired resistance against most of them [1, 2]. To replace these synthetic chemicals, biocontrol agents such as parasitoids [3] and predators of insect pests of stored products were also employed to control stored grain pests. In addition micro-organisms such as bacteria [5], fungi [6,7] and viruses were used to kill insect pests in store houses [8]. Hence, new safe alternatives of synthetic pesticides were searched in form of bio-organic pesticides mainly plant extracts and potential compounds which have shown very high insecticidal activity against different insect pests mainly to kill its infective stages.

Capparis decidua (CD) is a xerophytic shrub that widely grows in the western parts of India. It is an indigenous medicinal plant commonly known as 'Kureel' in Hindi, belongs to family Capparidaceae. It is a dominating shrub found in desert region of Rajasthan having strong climatic adaptations. Plant is bushy densely branched, thorny shrub possesses smaller scanty and caduceus leaves, pink to red flowers and green berry fruits in pre-monsoon period. *Capparis decidua* is a multipurpose plant that is used as vegetable, fruits, fire wood and aesthetic purposes by ethnic groups of Rajshthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat and Maharashtra. Plant is used in traditional folk medicine as ailments to relieve variety of pains or aches such as toothache, cough and asthma healer. It is also used pain an anti-rheumatic and anti-diabitic anti-rheumatic, anti-arthritis and anti-gout agents. *C. decidua* contains chemical constituents which include the saccharides, glycosides, flavonoids, alkaloids, terpenoids and volatile oils, fatty acids and steroids which possess enormous pharmacological potential. Plant contains generous quantities of alkaloids, fatty acids, terpenes, sterols, fibre and oils [9] and has greater medicinal and nutritive values [10]. It shows both insecticidal [11-15] and antimicrobial activity [16, 17]. In the present study various extracts from stem, root and flowers of *C. decidua* were prepared and tested against adults of *Sitophilous oryzae*. For this purpose, various bioassays were conducted to assess insecticidal, repellent and oviposition inhibitory action of *C. decidua* at different serial doses and exposure periods in stored product weevil *S oryzae.*

2. Materials and methods

2.1. Insect culture

Adult insects of Rice Weevil, *Sitophilus oryzae* (Linn.) were collected from the food grain store houses available in local market in Gorakhpur. The weevils were reared on healthy, clean and un-infested wheat seeds in glass jars and capped with muslin cloth for ventilation. Culture was maintained in laboratory under controlled temperature (28 ± 2°C), relative humidity (75 ± 5% RH) and a photoperiod of 12: 12 (L:D) h in B.O.D. Insects were reared in glass jars on gram seeds and each time early age beetles were used for the experiments.

2.2. Collection of plant material

Stems of *Capparis decidua* were collected from different places of western part of India especially from state of Rajasthan. Specimens were identified by applying standard taxonomic key specially by observing inflorescence and family formula with the help of a taxonomic expert. Fresh plant material was used to prepare extracts. Plant material was dried, chopped, grounded and milled to make powder in domestic grinder.

2.3. Preparation of extracts

Stem of *C. decidua* was collected and chopped in to small pieces, dried and pulverized to make fine powder in an electric grinder. The powdered stem (200 gm) was then extracted with various solvents according to their polarity. Extracts were allowed to evaporate in a Speedvac to get residue. It was dried and weighed and re-dissolved in known volume of different solvents. Dissolved residues were stored in cold at 4˚C temperatures for experimental purpose.

2.4. Dose- response determination:

Adults of Rice Weevil, *Sitophilus oryzae* (Linn.) were exposed with various increasing concentrations of each plant extracts separately. For this purpose, separate filter paper strips (1 cm^2) were coated with different concentrations of plant extracts were placed in the glass culture tubes and open ends were plugged with cotton balls. The coated filter paper strips were air-dried before application. Only solvent treated filter papers were strips used to set control. Ten adult insects were released culture in glass culture tubes (10 cm Height × 4 cm diameter). For each extract, five different concentrations were used and for each concentration six replicates were set. Mortality in adults of *Sitophilus oryzae* was recorded after 24 hr in presence and absence of various plants extracts separately. LD_{50} values were determined by Probit method [10]. LD_{50} values were calculated in μg/gm body weight of the insect.

Plant extracts were applied in a tri-arm repellency apparatus. Known volume of plant extract was kept on a Whatman filter paper strips (1 cm^2) in the centre from open side of one arm. Ten adult weevils *Sitophilus oryzae* (Linn.) were placed in this arm with the help of aspirator tube and plugged with cotton. Remaining open sides of the two arms received 2 g of gram seeds. Number of repelled insects for each plant extracts was noted after 30 min and five different concentrations ranging from 0.010-2.0 μg/ μl of each plant were used.

Adults of *Sitophilus oryzae* were exposed with various increasing concentrations of each plant extracts separately. For this purpose, separate filter paper strips (1 cm^2) were coated with different concentrations of plant extracts and placed in the glass culture tubes and open ends were plugged with cotton balls. The coated filter paper strips were air-dried before application. Only solvent treated filter paper strips were used to set control. Ten adult insects were released in glass tubes (10 cm Height × 4 cm diameter). For each extract, five different concentrations were used and for each concentration six replicates were set. Mortality in *Sitophilus oryzae* was recorded after 24 hr in presence and absence of various plants extracts separately.

For observation of feeding inhibition responses in insects known volume of each plant extract was coated on Whatman filter paper strips (42 μ micron, 1 cm^2), and placed in a tri-arm repellency apparatus in the centre from open side of one arm. Ten adult weevils were released inside this arm with the help of aspirator tube and plugged with cotton. Gram seeds (20 in number) were kept inside from remaining open sides of the two arms. Number of repelled insects in presence of each plant extract was counted after 30 min and five different concentrations ranging from 0.010-0.770 of each plant were used.

For determination of oviposition deterrence in *S. oryzae* sub lethal concentrations (20, 40 and 60% of LD_{50}) of each plant extract were coated separately on filter paper strips (1 × 1 cm) and provided to insects. Six replicates were set for each plant extract. The number of eggs laid recorded after 96 hrs and %ODI (Oviposition Deterrence Index) was calculated. For each extract stimulus, three sub-lethal concentrations of each plant extract were coated on filter paper strips (1 × 1 cm). Rests of the concentrations were same as in toxicity bio- assays. Six replicates were set to determine oviposition inhibition responses in Rice Weevil, *Sitophilus oryzae* (Linn.) in presence of each plant extract. The number of eggs laid was recorded after 96 hrs.

2.5 Statistical analysis:

LD_{50} values of each solvent and aqueous extracts were calculated by applying POLO programme [18]. The efficacy of the test stimuli was compared with control on the basis of oviposition deterrence index (ODI). The %ODI of females was calculated as 100 (A- B)/ (A+ B), A and B being the number of eggs in the control and test, respectively. Repellency in various plant extracts was calculated on the basis of insects repelled in presence of each extract. Data was analyzed to have mean ± SE of each concentration used to deter feeding in beetles.

3. Results

In the present study all the solvent and aqueous extracts prepared from stem, root and flowers of *C decidua* have shown very high insecticidal activity. Extracts prepared from stem have shown very low LD_{50} values obtained i.e. 1.58, 0.839, 0.053, 0.916, 0.418 and 1.421µg/mg in acetone, chloroform, petroleum ether, methanol, hexane and water extracts respectively in *C. decicua*. The upper and lower confidence limit found 1.299-1.803, 0.390-1.168, 0.028-0.071, 0.820-1.024, 0.353-0.483 and 1.164-1.669 for acetone, chloroform, petroleum ether, methanol, hexane and water extracts respectively in *C. decidua* (Table 1). Contrary to this, solvent and aqueous extracts prepared from root of *C. decidua* found more toxic as they have shown lower LD_{50} values in comparison to*stem* extract. These have shown LD_{50} values obtained were 1.467, 0.414, 0.051, 0.918, 0.306 and 1.60 µg for acetone, chloroform, petroleum ether, methanol, hexane and water extracts respectively. Among all these fractions petroleum ether fraction has shown high toxicity to *Sitophilus oryzae*. In root extracts upper and lower confidence limits were found in the range of 1.224-1.736, 0.302-0.509, 0.031-0.066, 1.044-1.344, 0.240-0.378, 1.352-1.852 µg/mg for acetone, chloroform, petroleum ether, methanol, hexane and water extracts in *C. decicua* (Table 1). Similarly flower extracts have shown LD_{50} 1.655, 0.414, 0.010, 0.813, 0.071 and 0.326852 µg/mg in all the above fractions (Table 1). The upper and lower confidence limits were found in range of 1.404-1.941, 0.267-0.531, 0.005-0.017, 0.706-0.937, 0.062-0.079 and 0.278-0.74, respectively. Here both petroleum ether and hexane extracts have shown maximum toxicity and very low LD_{50} (Table 1). Similarly *Capparis decidua* aqueous extracts from flower has shown LD_{50} value 0.326 µg/gm body weight and seems to be more toxic (Table 1).

All the fractions obtained from *Capparis decidua* stem, flower and root have shown very low ED_{50} value in *S. oryzae* (Table- 2). Stem solvent and aqueous extracts of *C decidua* exhibited good oviposition inhibitory activity (Table 2). *S. oryzae,* ED_{50} values in solvent and aqueous extract of *C decidua* obtained were very low and obtained in a range i.e. 0.018-0.443. Here petroleum ether fraction has shown very low ED_{50} value and was highly toxic. Similarly root extracts have shown ED_{50} value in range of 0.020-0.190, and were lower. All there extracts have shown higher toxicity than obtained in flower extracts. Flower extracts have shown ED_{50} values 0.114, 0.108, 0.013, 0.093, and 0.071 in acetone, chloroform, petroleum ether, methanol, hexane and water, respectively (Table 2).

Similarly, oviposition inhibition bioassays, various solvent and aqueous extracts of *Capparis decidua* stem, root and flower have oviposition inhibitory activities in *Sitiphilous oryzae* famales.. When female adults of *Sitiphilous oryzae* were exposed to sub-lethal doses (20%-60% of LC 50) of these extracts insects have laid lesser number of eggs, compared to control. However, 60% of LD_{50} of acetone, chloroform, petroleum ether, hexane and water extract of *C deciduas* have shown 69.78, 56.31, 78.50, 81.83, 69.16 and 63.34 %ODI respectively. Highest % ODI 81.83 was obtained in methanol extract.

Similarly in root at 60% of LD_{50} of acetone, chloroform, petroleum ether % ODI obtained was 64.83, 77.16 and 67.28 % in S. *oryzae* (Table 2). The maximum oviposition deterrence index was found for water extract i.e. 80.72 in decreasing order by methanol and hexane. Similarly flower extracts of *C decidua* have shown very high %ODI (Oviposition Inhibition Index) i.e. 58.33, 69.38, 72.75, 57.57, 53.84 and 61.40 in acetone, chloroform, petroleum ether, methanol, hexane and water (Table 3c). More specially was also found that the toxicity, repellency and oviposition inhibition were was dose and time dependent (Table 1-3c).

4. Discussion

In the present investigation both solvent and aqueous extracts of *C decidua* have shown very high insecticidal activity and it is proved by very LD_{50} values obtained in each of them. Maximum toxicity was obtained in petroleum ether extract of stem, root and flower i.e. 0.053, 0.051, 0.010 µg/gm followed by hexane extract of root that showed LD_{50} value extract of i.e. 0.71µg/mg. Contrary to this, solvent and aqueous extracts prepared from root of *C. decidua* found more toxic as they have shown lower LD_{50} values in comparison to stem extract. These have shown LD_{50} values obtained were 1.467, 0.414, 0.051, 0.918, 0.306 and 1.60 µg for acetone, chloroform, petroleum ether, methanol, hexane and water extracts, respectively. Among all fractions petroleum ether fraction has shown high toxicity to *Sitophilus oryzae*. Similarly *Capparis decidua* aqueous extracts from flower has shown LD_{50} value 0.326 µg/gm and seems to be more toxic (Table- 1). Similar trends of toxic potential were obtained in *C. decidua* as all the solvent extracts have shown LD_{50} value in the range of 0.071-1.655 (Table 1).

Similar insecticidal and repellent activity was observed in *Artemisia princepi* and *Cinnamomum camphora* (L) against *Sitophilus oryzae* and *Bruchus rugimanus*[19] and *Melia dubia* against *Spodoptera litura* and *Helicoverpa armigera* larvae [20]. Similarly chemical constituents occur in *Foeniculum vulgare*[21], Japanese mint (*Mentha arvensis*) [22], *Azadirachta indica* against adults of *S. oryzae, T. castenum* and *Rhizopertha dominica* (F) [23]. Similar contact and fumigant activities were also found in *Piper nigrum* [24], *Curcuma longa* [25], *Artemisia anuua* [26] and in corn leaf essential oil against stored grain insects [27]. Similarly few essential oil constituents such as allyl acetate [28-29], d-limonene [30], linolool [31], phenylbutanoid [32] , methyl salicylate [33], diallyl disulphides have shown very high insecticidal activity against stored grain pests [34,35] and field crop insects [36,37] mainly against *S. oryzae* (L) and *Tribolium castenum* (Herbst) [38]. This insecticidal activity may be due to presence of volatile chemicals present in *Capparis decidua* having different functional groups which persist for longer time if used against stored grain insects in closed chambers [39].

Table 1. LD_{50} of values of different fractions of *C. decidua* stem against Rice Weevil, *Sitophilus oryzae* (Linn.)

Extracts	hr	LD_{50} Values (µg/gm) (p<0.05)	LCL	UCL	t-ratio	Slope Value	Heterogeneity	Chi-test
	Stem							
Acetone	24	1.538	1.299	1.803	3.488	6.548	3.333	0.555
Chloroform	24	0.839	0.390	1.168	3.777	5.710	1.8016	9.0078
Petroleum ether	24	0.053	0.028	0.071	6.051	6.064	1.7349	8.674
Methanol	24	0.916	0.820	1.024	1.318	5.913	0.953	5.715
Hexane	24	0.418	0.353	0.483	6.293	6.421	0.742	3.711
Water	24	1.421	1.164	1.669	2.557	6.226	0.293	1.757
	Root							
Acetone	24	1.467	1.224	1.736	3.066	6.495	0.897	5.383
Chloroform	24	0.414	0.302	0.509	2.973	6.687	0.220	1.318
Petroleum ether	24	0.051	0.031	0.066	6.276	6.308	8.3847	1.6769
Methanol	24	0.918	0.807	1.044	1.344	5.934	1.0073	6.0438
Hexane	24	0.306	0.240	0.378	4.544	4.690	0.353	1.766
Water	24	1.600	1.352	1.852	3.568	6.559	0.897	5.379
	Flower							
Acetone	24	1.655	1.404	1.941	3.976	6.441	0.700	4.202
Chloroform	24	0.412	0.267	0.531	2.143	6.384	1.0235	6.1411
Petroleum ether	24	0.010	0.005	0.017	6.225	6.610	0.828	4.140
Methanol	24	0.813	0.706	0.937	2.319	6.245	0.857	5.998
Hexane	24	0.071	0.062	0.079	6.528	6.377	0.347	1.737
Water	24	0.326	0.278	0.74	6.803	6.700	0.499	2.944

[a] LD50 values represents lethal dose that cause 50% mortality in the test insects. [b]LCL and UCL mean lower confidence limit and upper confidence limit respectively. [c] t- ratio, slope-value and heterogeneity were significant at all probability levels (90, 95 & 99%). t-ratio, difference in degree of freedom at 0.5, 0.05 and 0.005 levels; slope-value shows the average between LD_{50} and LD_{80}, from which LD_{50} value is calculated; and heterogeneity value, shows the effect of active fraction on both susceptible and tolerant insects among all of the treated insects.

TABLE 2: Percent repellency obtained in solvent extracts and pure compounds isolated from *Capparis decidua* against Rice Weevil, *Sitophilus oryzae* (Linn.).

Extracts Single fractions	**Concentration In mg**	**Mean no. of Insects repelled**	**Expected no. of Insect repelled**	**χ 2 Value**	**ED_{50}**
Stem					
Acetone	0.030-0.210	10.16	10	0.262	0.125
Chloroform	0.110-0.770	10.50	10	3.454	0.443
Petroleum ether	0.05-0.035	10.43	10	3.680	0.018
Methanol	0.011-0.099	10.28	10	3.300	0.195
Hexane	0.040-0.280	12.33	10	3.094	0.136
Water	0.070-0.490	11.50	10	2.237	0.258
Root					
Acetone	0.060-0.420	11.33	10	0.835	0.228
Chloroform	0.040-0.280	11.66	10	0.859	0.418
Petroleum ether	0.010-0.035	11.16	10	5.079	0.020
Methanol	0.050-0.400	10.25	10	5.307	0.245
Hexane	0.050-0.350	12.33	10	1.182	0.172
Water	0.100-0.700	11.66	10	1.698	0.368
Flower					
Acetone	0.020-0.240	10.66	10	5.412	0.114
Chloroform	0.030-0.210	11.16	10	1.022	0.108
Petroleum ether	0.010-0.040	11.16	10	4.885	0.023
Methanol	0.020-0.160	10.00	10	1.446	0.093
Hexane	0.020-0.140	12.00	10	1.737	0.071
Water	0.050-0.350	11.33	10	1.145	0.190

a. Not significant as the calculated values of χ^2 were less than the table values at all probability levels (90%, 95% and 99%) b. Significant at all probability levels (90%, 95% and 99%). The data responses lines would fall wit in 95% confidence limits and thus the model fits the data adequately. UCL-LCL
* Upper confidence limit and lower confidence limit.

Table-3a. Efficacy of solvent extracts of stem of *Capparis decidua* on oviposition behavior of Rice Weevil, *Sitophilus oryzae* (Linn.).

Fraction used	Dose applied	Mean no. of eggs laid per insect Mean ± SE	% eggs laid per insect Mean ± SE	%ODI [B]	F-value [C] At df 2 & 6
Acetone	20% of LD_{50}	18.16±0.477	44.67	40.51	5.539 S
	40% of LD_{50}	14.16 ±0.307	34.83	53.35	
	60% of LD_{50}	4.33± 0.421	10.65	69.78	
Chloroform	20% of LD_{50}	15.16±0.477	37.29	43.83	3.449 NS*
	40% of LD_{50}	7.33± 0.421	18.03	46.87	
	60% of LD_{50}	2.83± 0.307	6.90	56.31	
Petroleum ether	20% of LD_{50}	13.33±0.421	32.78	63.12	7.556 S**
	40% of LD_{50}	8.50± 0.428	20.49	71.57	
	60% of LD_{50}	4.50±0.423	11.06	78.50	
Methanol	20% of LD_{50}	16.83±0.654	41.39	37.88	11.124 VS***
	40% of LD_{50}	12.66±0.495	31.14	58.03	
	60% of LD_{50}	6.83± 0.307	16.80	81.83	
Hexane	20% of LD_{50}	21.66±0.477	50.04	42.73	4.582 NS
	40% of LD_{50}	16.33±0.421	40.16	58.30	
	60% of LD_{50}	3.83± 0.308	9.40	69.16	
Water	20% of LD_{50}	23.66±0.494	68.44	16.43	5.148 S
	40% of LD_{50}	14.50±0.428	35.65	53.06	
	60% of LD_{50}	7.33± 0.421	18.03	63.34	

[A]The chemical stimulus was coated on the Whatmann filter paper stripes (1 cm^2) in the oviposition inhibition test. [B] the ODI% was calculated as 100(A-B)/ A+B, where A and B represent the number of eggs laid in the control and in the test respectively. [C] F-values were significant at all probability levels (90, 95 and 99%). *NS= Non significant, S**=significant VS*** Very significant.

Table 3b. Efficacy of various solvent root extracts of *Capparis decidua* on oviposition behavior of Rice Weevil, *Sitophilus oryzae* (Linn.)

Extract used	Dose applied	Mean no. of eggs laid per insect Mean ± SE	% eggs laid per insect Mean ± SE	%ODI B	F-value C At df 2 and 6
Acetone	20% of LD_{50}	20.83±0.60	54.66	29.31	10.781 S
	40% of LD_{50}	17.16±0.447	45.77	37.19	
	60% of LD_{50}	8.0±0.365	21.33	64.83	
Chloroform	20% of LD_{50}	15.83±0.307	42.22	40.62	5.178 S
	40% of LD_{50}	7.33±0.494	19.55	67.28	
	60% of LD_{50}	4.83±0.477	12.80	77.16	
Petroleum ether	20% of LD_{50}	17.5±0.619	46.66	36.36	8.983 S
	40% of LD_{50}	9.3±0.493	24.88	60.14	
	60% of LD_{50}	7.3±0.421	19.55	67.28	
Methanol	20% of LD_{50}	23.5±0.619	62.66	22.95	9.627 S
	40% of LD_{50}	17.0±0.447	45.33	37.67	
	60% of LD_{50}	8.6±0.421	23.11	44.40	
Hexane	20% of LD_{50}	26±0.365	69.33	18.11	41.900 ES*
	40% of LD_{50}	21.33±0.333	56.88	27.47	
	60% of LD_{50}	16.66±0.421	44.44	38.46	
Water	20% of LD_{50}	12.66±0.421	39.55	43.31	5.230 S
	40% of LD_{50}	7.66±0.334	20.44	66.05	
	60% of LD_{50}	4.0±0.365	10.66	80.72	

[A]The chemical stimulus was coated on the Whatmann filter paper stripes (1 cm^2) in the oviposition inhibition test. [B] the ODI% was calculated as 100(A-B)/ A+B, where A and B represent the number of eggs laid in the control and in the test respectively. [C] F-values were significant at all probability levels (90, 95 and 99%). * S*=significant , ES*=extremely significant

Table 3c. Efficacy of various solvent extracts of flower of *Capparis decidua* on oviposition behavior of Rice Weevil, *Sitophilus oryzae* (Linn.)

Extract used	Dose applied	Mean no. of eggs laid per insect Mean ± SE	% eggs laid per insect Mean ± SE	%ODI B	F-value C At df 2 and 6
Acetone	20% of LD_{50}	25.833±0.307	59.61	25.30	12.370 VS*
	40% of LD_{50}	19.166±0.477	44.20	38.66	
	60% of LD_{50}	11.33±0.421	26.14	58.53	
Chloroform	20% of LD_{50}	24.33±0.494	56.15	28.07	7.676 S
	40% of LD_{50}	18.33±0.333	42.30	40.54	
	60% of LD_{50}	7.83±0.477	18.07	69.38	
Petroleum ether	20% of LD_{50}	20.50±0.763	47.31	35.77	6.784 S
	40% of LD_{50}	11.833±0.401	27.30	57.09	
	60% of LD_{50}	6.83±0.307	15.76	72.75	
Methanol	20% of LD_{50}	23.16±0.325	53.45	30.32	16.971 VS*
	40% of LD_{50}	17.33±0.421	39.49	42.87	
	60% of LD_{50}	11.66±0.333	26.90	57.57	
Hexane	20% of LD_{50}	27.833±0.477	64.23	21.77	15.492 VS*
	40% of LD_{50}	23.5±0.223	54.23	26.97	
	60% of LD_{50}	13.166±0.477	30.38	53.84	
Water	20% of LD_{50}	24.5±0.223	56.54	27.76	8.602 S
	40% of LD_{50}	16.00±0.365	36.92	46.06	
	60% of LD_{50}	8.833±0.307	20.38	61.40	

[A]The chemical stimulus was coated on the Whatmann filter paper stripes (1 cm^2) in the oviposition inhibition test. [B] the ODI% was calculated as 100(A-B)/ A+B, where A and B represent the number of eggs laid in the control and in the test respectively. [C] F-values were significant at all probability levels (90, 95 and 99%). S*=significant, VS*** Very significant

Similarly, in repellency bio-assays when adults of *Sitophilus oryzae* were exposed to sub-lethal (20%-60% of LD_{50}) doses of different extracts they have significantly repelled large number of insects in comparison to control (Table 2). It is clearly confirmed by very low ED_{50} values ob obtained in solvent and aqueous extracts of *C deciduas*. ED_{50} values were found in a range of 0.018-0.443(Table 2). On an average each extract has shown 60-75% repellency. Petroleum ether extract has shown very high repellency in comparison to other extracts. Similarly root extracts have shown ED_{50} value in range of 0.020-0.190 which was lower than the stem extracts. Flower extracts have shown ED_{50} values 0.114, 0.108 0.013, 0.093, 0.071 in acetone, chloroform, petroleum ether, methanol, hexane and water respectively (Table 2). From the results the steep slope values obtained in mortality indicated that a small dose of plant extracts can kill large population of *Sitophilus oryzae.* These values fall within 95.0% confidence limit and thus the model fits the data adequately. Besides this, number of insects repelled and F- values calculated indicate that dose responses were worked well to repel significantly more number of insects at a very small dose. This high toxicity and repellency in *Capparis decidua* was due to presence of volatile components in essential oils available in leaves and buds. From these oils few minor components such as benzyl alcohol (20.4%), furfural (7.4%), ethanal methyl pentyl acetal (5.9%), 4-vinyl guaiacol (5.3%), thymol (5.1%), octanoic acid (4.8%) and methyl isothiocyanate (4.5%) were identified. In addition few major volatile compounds also occur in caper leaves which are identified as methyl isothiocyanate (20.0%), thymol (15.5%), 4-vinyl guaiacol (4.3%), hexyl acetate (3.6%) and *trans*-theaspirane (2.6%). *Capparis decidua* seeds oil contains of 68.6% unsaturated fatty acids and 31.4% saturated fatty acids. Due to presence of above active components *C decidua* also showed very larval mortality in yellow fever mosquito, *Aedes aegypti* L [40].

Similarly, when adult weevils were exposed to sub-lethal (20%-60% of LD_{50}) dose of *C. decidua* extracts; these have shown significantly oviposition inhibition in female insects and block the emergence of F_1 individuals from exposed eggs. Effect of solvent extracts *C. decidua* on oviposition behavior on *S. oryzae* is given in the Table-3a-3c. From the result it was found that toxicity, repellent and oviposition inhibition in *S. oryzae* were dose and time dependent. A slight increase in concentration of natural extract increased the percent mortality and oviposition inhibition in adult weevils. Similarly active ingredients isolated from certain botanicals have shown very high toxicity [41-43] and adversely affect fecundity, egg to adult survival and progeny production in *C. chinensis* [20, 26, 44]. *Curcuma longa* and *Lippia alba* essential oils have shown similar oviposition inhibition and egg hatching suppression activity against *C. maculates*, *C. chinensis* and *T. castenum* [25]. The treatments with bio-insecticides also significantly cut down the grain damage, seed weight loss [45] show wider repellent responses in beetles to deter them from feeding [46,47,48,49] and inhibit oviposition in them [25]. Besides this, ethyl formate was also found effective against stored grain insects when combines with carbon dioxide [50]. Similarly few pesticides such as (S)-hydroprene and cyfluthrin [51], acrolein vapors [52] and allyl acetate used as fumigants [28] and were found effective against stored grain insects. Similarly heat treatment and high temperature exposure also showed high mortality in pupae and adults of *Tribolium castaneum* [53]. Similar ovicidal and adulticidal activity was also found in *Eugenia caryophyllata* bud and leaf against *Pediculus capitis* [54] and *Sesamia nonagrioides* [27]. Similarly triacontanol (C1), 2-carboxy-1,1-dimethylpyrrolidine (C2) chemical compounds isolated from *C deciduas* stem and 6-(1-hydroxy-non-3-enyl) tetrahydropyran-2-one from flower have shown insecticidal and oviposition inhibitory activities against *B. chinensis* at very low concentrations [11, 24].

Similar antifeedant and fecundity reduction was also observed in ethanol, ethyl acetate, diethyl ether and chloroform extracts of *Capparis aegyptia* plant leaves against black cutworm, *Agrotis ipsilon* [55]. It was due to presence of alkaloid, polyphenols and flavonoids in *Capparis* extracts [56, 57]. Similarly, various solvent (*n*-hexane, diethyl ether, ethyl acetate and ethanol) extracts of *Capparis aegyptia*, leaves and fruits have shown very high toxicity against adult females of the two-spotted spider mite, *Tetranychus urticae* Koch. Treated females have shown a reduction in the total number of eggs lay during 15 days with fruit extracts than that with leaf extract [58]. Leaf discs treated with LC_{50} concentration of various extracts showed a high percentage of repellency in case of Ethanol extract prepared from leaves and fruits of *C decidua* have shown 86.67 and 96.42% repellency. Similarly, *Capparis spinosa* (C. spinosa) showed molluscicidal activity in snails [59] and to the lesser grain borer, *Rhizopertha dominica* (Bostrichidae: Coleoptera) [60].

5. Conclusion

In the present investigation various solvent and aqueous extracts of *C. decidua* have shown very high toxicity, repellency and oviposition inhibition in *Sitophilous oryzae*. This anti-insect activity may be due to presence of certain chemical constituents in each fraction. No doubt these chemicals exerted chemical stimuli that have influenced the survival of adult weevils .These extracts have not only killed the adult insects but also inhibited oviposition in susceptible female *Sitophilous oryzae* and disallow emergence of F_1 individuals by blocking the development. Diverse chemical constituents occur in *C. decidua* stem, root and flower have certain volatile action on insects and acted like a good repellent or fumigant that is much enough to poison the stored grain pests in store houses. Further, toxic, repellent and oviposition inhibition responses were found to be dose and time dependent. It was also proved by F- ratio obtained between dose and oviposition responses. Therefore, it can be concluded that above plant species can be used for isolation of bio-pesticides to control pulse weevils. For this purpose, constituent's level study along with structure activity relationships of natural products is to be required for wider insecticidal performance and efficacy not only against *Sitophilous oryzae* but also against all other stored grain insect pests.

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