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Chemical composition, nematicidal, insecticidal and herbicidal activities of *Hedychium coronarium* J. Koenig rhizome oleoresin

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Abstract
The aim of the present study was to evaluate nematicidal, herbicidal and insecticidal activity of rhizome chloroform oleoresin of *Hedychium coronarium* J. Koenig. The GC-MS analysis led to identification of fifteen constituents comprising of 87.9% of total oleoresin composition. The major component found to be was Coronarin *E* (20.1%). The oleoresin exhibited the significant nematicidal activity against the *Meloidogyne incognita* nematode and effective herbicidal activity against the *R. raphanistrum* subsp. *sativus* seeds on the basis of three distinct parameters that was percent inhibition of seed germination, inhibition of root length, and inhibition of shoot length respectively. Oleoresin also showed potent insecticidal activity by using no choice leaf dip method in a sequentially dose and time dependent manner against *Spodoptera litura.*

Keywords: *Hedychium coronarium*, oleoresin, coronarin E, insecticidal activity, nematicidal activity

Introduction
The Zingiberaceae is one of the largest family in the plant kingdom includes 56 genera and 1300 species, and found throughout tropical Asia, especially in the Indo-Malayan region [1, 2]. The genus *Hedychium* is prominent medicinal plants owing their biological and pharmacological properties and reported to be used medicinally to treat a variety of diseases [3, 4]. It can be found throughout India, China, Japan, and Southeast Asia [5]. The species *H. coronarium* is a monocotyledon perennial, tall (1-2.5m) herb with attractive and fragrant flowers [6]. It is widely grown in India, Southeast Asian countries, China, Japan and Brazil [7]. It is used in the field of traditional medicine and found to possess various biological properties such as anti-tumor, antiallergic, anti-malarial, leishmanicidal, cytotoxic, anti-cancer, antioxidant, anti-hypertensive, diuretic, anti-malarial, cercuricidal, molluscicidal, antibacterial, analgesic activities etc. [8, 9, 10]. Considering its biological importance, the present investigation on phytochemical analysis and screening of nematicidal, herbicidal and insecticidal activity of rhizome chloroform oleoresin of *H. coronarium* collected from Kumaun region, Uttarakhand was carried out.

Materials and Methods
Collection of Plant material
H. coronarium rhizome was collected from Pithoragarh (Altitude-1627m, Latitude 29°34'31.2"N, and Longitude 80°14'55.0"E), Uttarakhand, India in the month of November, 2020 and was identified (voucher number GBPUH-1034) by the taxonomist, Dr. D.S. Rawat of the Department of Biological Sciences, C.B.S.H., G.B.P.U.A.T., Pantnagar, Uttarakhand, India.

Oleoresin preparation
H. coronarium fresh rhizomes were cut into small pieces, dried and pulverized into a coarse powder. The pulverized rhizome powders were extracted in chloroform using cold percolation method. The obtained extract was filtered and condensed by using rotary evaporator. Mean yield of oleoresin was found to be 1.90% (w/w). The sample was stored at 4 ^{0}C for further chemical analysis and determination of biological activities [11].

GC-MS analysis

The phytochemical analysis of the *Hedychium coronarium* rhizome chloroform oleoresin was analysed by gas chromatography-mass spectrometry (GC-MS) by using Perkin Elmer GCMS-SQ8 equipment. The GC capillary column PE-5 column (30 m × 0.25 mm, i.d. 0.25 µm) was used. The injector temperature was adjusted to 280 °C with a split ratio of 50.1, and the carrier gas was helium at a flow rate of 1 mL/min. The constituents of oleoresin were identified by analysing their mass spectral fragmentation pattern and their RI values with MS library (NIST14.lib.) as well as comparing the spectra with literature data [12].

Evaluation of nematicidal activity

Nematode population collection

Eggs of *Meloidogyne incognita* were collected from nematode infected roots of tomato (*Solanum lycopersicum*) from Crop Research Center, G. B. Pant University of Agriculture and Technology, Pantnagar in a glasshouse maintained at 25±2 °C. The sample was collected on the basis of the visual symptoms of root-knots or galls formed in the tomato plant. Hand-picked mature egg masses from infected roots were cultured in distilled water in a growth chamber at 25 °C. Emerged juveniles were collected and stored at 5 °C for further uses [13, 14].

In vitro* mortality assay on second stage larvae of *M. Incognita

For *in vitro* mortality assay, second stage juveniles (100-200 in number) collected from hatched eggs within 48 hrs were placed on gridded petri dishes with stock solution and 1.0mL distilled water. There were three varied doses i.e., 0.25, 0.5, and 1µl/mL of oleoresin in 1.0% Tween-20 water solution. The treatments were performed in triplicates and arranged in randomized order. The juveniles immersed in water were used as a control group. The numbers of dead nematodes were counted using a stereo-binocular microscope throughout time periods of 24, 48, 72, and 96hrs.Totally motionless (dead larvae) nematodes were picked out of the Petri dish and placed in distilled water. Abbott's formula was used to estimate percent mortality [15].

Percent Mortality = (Nt-Nc/100% -Nc)×100

Where, Nt =Mortality in treatment; Nc = Mortality in control.

Effect of oleoresin on egg hatchability of *M. Incognita*

Two egg masses of *M. incognita* were suspended in 0.25, 0.5, and 1µl/mL concentrations of chloroform rhizome oleoresin of *H. coronarium* in gridded petri dishes. The egg masses suspended in Tween-20(1%) water solution were used as a control. All of the treatments were set up in triplicates and in a completely random order in the BOD incubator at a constant temperature of 27±1^{O}C. Observations on egg hatchability were made at time intervals of 24, 48, 72, and 96hrs. Counting of the number of eggs hatched was made under a microscope at a magnification of 40x. Percent reduction in egg hatchability was computed using Abbott's formula mentioned above.

Evaluation of herbicidal activity

Herbicidal activity of chloroform oleoresin from *H. coronarium* rhizome was evaluated by using various parameters such as seed germination, root length inhibition and shoot length inhibition.

Bioassay

The herbicidal activity of chloroform oleoresin from *H. coronarium* rhizome at different concentrations(250-1000ppm) were assessed against *R. raphanistrum* subsp. *sativus* (Wild radish). Seeds of *R. raphanistrum* were obtained from the VRC (Vegetable Research Centre), G.B.P.U.A. &T., Pantnagar. For evaluating the seed germination inhibition, root and shoot length inhibition, different concentrations of chloroform oleoresin (250-1000ppm) were prepared in 1% Tween-20 aqueous solution, respectively. The seed against which herbicidal activity was performed were firstly surface sterilized for 15min. in a 5% sodium hypochlorite solution. Ten sterilized seeds of *R. raphanistrum* were placed in each petri plates, which were coated with filter papers at the bottom in order to maintain sufficient moisture for the germination of the seeds. Then 2 mL of various concentrations of the tested sample were put onto the plates and seeds were left to germinate at 25±1 ºC for 12hrs in an incubator. The experiment was stopped after all the seeds were germinated in the control and root and shoot length was measured. The activity was assessed in comparison to control and the standard pendimethalin. The formula used for determination of inhibition of seed germination, inhibition of root and shoot lengths were as follows:

Inhibition of seed germination

% Inhibition =100 × (1- Gt/Gc)

Where

Gt – no. of seeds germination in treatment,

Gc – no. of seeds germination in control.

Inhibition of shoot length

% Inhibition =100 × (1- Ct/Cc)

Where

Ct –shoot length in treatment,

Cc – shoot length in control.

Inhibition of root length

% Inhibition =100 × (1- Rt/Rc)

Where

Rt –root length in treatment,

Rc – root length in control.

Evaluation of insecticidal activity

The insecticidal activity of chloroform oleoresin of *H. coronarium* rhizome was estimated against cotton cut worm (*Spodoptera litura* belongs to family: Noctuidae and order: Lapidoptera)**,** by using leaf dip method [16]. Its third instar and later stages inflict the most injury and damage to crops because to leaf defoliation [17, 18]. *S. litura* egg mass were collected from wild castor (*Ricinus communis*) plant from CRC (Crop Research Centre), G.B.P.U.A&T., Pantnagar, Uttarakhand, India. The rearing of test insect was carried out in a plastic container closed with muslin cloth at a temperature of 27 °C and a humidity of 75-80%. Castor leaf

was first cleaned and washed with distilled water and air dried for an hour. Each caster leaf was cut into an area of 25sq.cm and then dipped in the solution of oleoresin made in Tween-20 (1.0%) and chloroform to smooth the progress of uniform treatment of active ingredient for few seconds. The obtained leaf discs were kept slanting for 2-3 min on a blotting paper and placed in the tray to drain out excess solution for 2hrs at room temperature. Fourth instar adult larvae, which were starved for 12-24hrs, released on each petri dish in individual petri plate. At the bottom of each plate, blotting paper was placed. These petri plates were taken under observation for 72hrs to watch any insecticidal action. This activity was held under fine laboratory conditions, maintaining temperature at 27°C and relative humidity at 75-80%. The percent mortality was calculated after 24, 48 and 72hrs of the treatment using Abbott's formula [15]. The LC_{50} values were analysed by Probit analysis [19].

Statistical analysis

The triplicated results of the experiments was statistically analyzed as mean ± SD using two way ANOVA at 5% level of significance ($p< 0.05$). R Studio 2021.09.2 was used to conduct all statistical analyses. Regression line method was used to calculate IC_{50} and Probit analysis was used to calculate LC_{50}.

Results

Chemical composition of extract

GC-MS analysis of the chloroform rhizome oleoresin of *H. coronarium* revealed the presence of fifteen components that contributed to 87.9% of total extract composition. Coronarin *E* (20.1%) was found to be major constituent of the chloroform oleoresin followed by 1,8- cineole (12.6%), α-terpineol (9.5%), isopulegol (8.2%), dodecane (7.3%), α-pinene (6.2%) and α-fenchene (5.9%). Other major constituents investigated from oleoresin were isobornyl acetate (3.4%), α-2-adamantanone (2.9%), bisabolene (2.8%) and pentadecane (2.6%). However, the minor constituents in the chloroform rhizome oleoresin contributing less than 2.0% to the total oleoresin were (3-*Z*)-hexenyl methyl carbonate (1.3%), β-atlantol (1.2%) and hexadecane (1.7%). The chemical composition of chloroform rhizome oleoresin of *H. coronarium* is represented in (Table 1).

Table 1: Chemical composition of chloroform rhizome oleoresin of *Hedychium coronarium*

S. No.	Compound	KI value	% contribution	Molecular formula	Method of identification m/z
1.	α-pinene (MH)	939	6.2	$C_{10}H_{16}$	M^+=136 m/z; 136,121,105, 93(100%),77,53,39,27
2.	α-fenchene (MH)	952	5.9	$C_{10}H_{16}$	M^+=136 m/z;136,121,107,93(100%),91,79,67,53,41
3.	1,8 cineole (OM)	1031	12.6	$C_{10}H_{18}O$	M^+=154 m/z;154,139,111,108,93,81,71,43(100%)
4.	(3-*Z*)-hexenyl methyl carbonate	1091	1.3	$C_8H_{14}O_3$	M^+=82 m/z; 82,67(100%),55,41
5.	Isopulegol (OM)	1149	8.2	$C_{10}H_{18}O$	M^+=154 m/z;154,136,121,54,81,68,67,55,41(100%),27
6.	α- terpineol (OM)	1188	9.5	$C_{10}H_{18}O$	M^+=136 m/z;136,121,93,81,59(100%),43,41
7.	Dodecane (MH)	1200	7.3	$C_{12}H_{26}$	M^+=170 m/z;170,141,127,98,85,71,57(100%),43
8.	isobornyl acetate (OM)	1285	3.4	$C_{12}H_{20}O_2$	M^+=196 m/z;196,136,121,108,95(100%),93,43,41
9.	Hexadecane (MH)	1286	1.7	$C_{12}H_{20}O_2$	M^+=196 m/z;196,136,121,108,95(100%),93,43,41
10.	2- adamantanone (OM)	1311	2.9	$C_{10}H_{14}O$	M^+=150 m/z;150(100%),132,117, 104,91,67,53,41
11.	Pentadecane (SH)	1500	2.6	$C_{15}H_{32}$	M^+=112 m/z;112,183,169,155,141,127,99,85,71, 57(100%),43
12.	α-bisabolene (SH)	1507	2.8	$C_{15}H_{24}$	M^+=204 m/z;204,161,133, 121, 105,93(100%),79,67,55,41
13.	β-atlantol (OS)	1608	1.2	$C_{15}H_{24}O$	M^+=136 m/z;136,94,92,91,80,70,69(100%),67,42
14.	coronarin *E* (OS)	2166	20.1	$C_{20}H_{28}O$	M^+=286 m/z;286,284,160,147(100%),115,91,81,55,41
15.	1-heptatriacotanol (OS)	3942	2.2	$C_{19}H_{30}O_2$	M^+=286 m/z;286,284,160,147(100%),115,91,81,55,41
Class composition			% Composition		
Monoterpene hydrocarbons(MH)			21.1		
Oxygenated monoterpenes(OM)			36.6		
Sesquiterpenes hydrocarbons(SH)			5.4		
Oxygenated sesquiterpenes (OS)			23.5		
Others			1.3		
Total(%)			87.9		

Note: *KI value=Kovats index value on a DB-5MS column in reference [12].

Nematicidal activity

Effect on mortality of second stage larvae of *M. Incognita*

The nematicidal activity of chloroform oleoresin was carried out against second stage juvenile larvae of *M. incognita* (root knot nematode) for the duration of 24, 48, 72 and 96hrs. A dose dependent and time dependent immobility of second stage larvae of *M. incognita* was observed in the oleoresin with respect to negative control as percent mortality was found to increase with increase in concentration as well as time duration of theexposure of nematodes to oleoresin. After 96hrs, oleoresin was found to be most effective at dose level 1µL/mL with 53.33% inhibition in mobility of larvae, followed by 0.5µL/mL with 45.33% inhibition. The LC_{50} values of the chloroform oleoresin of *H. coronarium* at 24, 48, 72 and 96hrs after treatment are 0.14, 0.03, 0.01 and 0.003% respectively. The detailed experimental observation of percentage mortality and LC_{50} has been represented in (Table 2 and Table 3).

Table 2: Nematicidal activity of chloroform rhizome oleoresin of *Hedychium coronarium* on the mortality of second stage juveniles of *M. incognita*

Concentration (µL/mL)	Percent mortality (Mean±SD) and exposure time (hrs.)			
	24hrs	48hrs	72hrs	96hrs
0.25	18.33±2.51	25.66±2.08	29.00±1.00	35.66±2.08
0.5	31.00±1.00	37.00±1.73	41.10±1.00	45.33±0.57
1	42.33±2.51	45.66±1.15	49.33±1.15	53.33±1.52
Control	1.11±0.19	3.50±0.50	5.40±0.10	6.9±0.10

Table 3: LC_{50} values of chloroform rhizome oleoresin of *H. coronarium* for nematicidal activity against of second stage juveniles of *M. incognita*

Duration (Hrs.)	*LC_{50} (%)	Reg. eq.
24	0.14	y = 0.01x +3.92
48	0.03	y = 0.008x +4.21
72	0.01	y = 0.008x+ 4.32
96	0.003	y = 0.007x+ 4.50

*LC_{50}= Lethal concentration

Effect on egg hatchability of *M. Incognita*

Oleoresin showed a strong inhibitory effect on egg hatching in a concentration and time dependent manner. The rate of egg hatching was found to be directly proportional to exposure time period and inversely proportional to sample concentration. After 96hrs, the maximum rate of egg hatching in oleoresin was observed at a dose level of 0.25µL/mL (57.66%) while the minimum rate of egg hatching was observed at 1 µL/mL (17%). It was observed that increasing the concentration of oleoresin delayed the starting of egg hatching. The LC_{50} values of the chloroform oleoresin of *H. coronarium* at 24, 48, 72and 96hrs after treatment are 0.02% respectively. The percentage hatching and LC_{50} value of *M. incognita* shows in (Table 4 and Table 5), respectively.

Table 4: Nematicidal activity of chloroform rhizome oleoresin of *Hedychium coronarium* on the egg hatching of *Meloidogyne incognita*

Concentration (µL/mL)	Percent egg hatching of nematodes and exposure time (hrs.)			
	24hrs	48hrs	72hrs	96hrs
0.25	41.10±1.00	42.00±1.00	51.33 ±1.15	57.66±0.57
0.5	31.66±0.57	38.33 ±0.57	40.66±0.57	42.66±1.15
1	11.66±0.57	13.66±0.57	15.66±0.57	17.00±1.00
Control	57.66±0.57	62.66±1.15	77.00±1.00	87.66±0.57

Table 5: LC_{50} values of chloroform rhizome oleoresin of *H. coronarium* for nematicidal activity against of second stage juveniles of *M. incognita.*

Duration (hrs)	*LC_{50}(%)	Reg. eq.
24	0.02	y = 0.01x +3.59
48	0.02	y = 0.01x + 3.75
72	0.02	y = 0.01x + 3.77
96	0.02	y = 0.01x + 3.82

*LC_{50}= Lethal concentration

Herbicidal activity

Inhibition of seed germination

The chloroform oleoresin possesses good to moderate herbicidal activity in a dose dependent manner. The percent inhibition of seed germination of chloroform oleoresin of *H. coronarium* was recorded as 24.81%, 60.00%, 84.44% and 98.88% from lowest to highest concentration of oleoresin (250, 500, 750 and 1000ppm) respectively. IC_{50} value of *H. coronarium* rhizome chloroform oleoresin was found as 105.38±7.62 ppm which was calculated at the time when 100% germination is achieved in the control and used to compare the relative herbicidal activity in term of inhibition of seed germination at various concentrations range of 250, 500, 750, 1000 ppm. The percent inhibition of seed germination and IC_{50} value of chloroform rhizome oleoresin of *H. coronarium* are presented in (Table 6 and Table 9).

Table 6: Percent inhibition of seed germination of chloroform rhizome oleoresin of *H. coronarium*

S. No.	Sample	% Inhibition of germination (Mean±SD)			
		250 ppm	500 ppm	750 ppm	1000 ppm
1	HCCRO	24.81±0.64	60.00±2.22	84.44±1.92	98.88±1.11
2	Pendimethalin*	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00

*Standard herbicide; HCCRO=*Hedychium coronarium* chloroform rhizome oleoresin

Inhibition of root length

The percent inhibition of root length was calculated at the time when 100% germination was achieved at various concentrations range of 250, 500, 750, 1000 ppm. The percent inhibition of root length was recorded as 19.62%, 27.77%, 75.18% and 92.62% from lowest to highest concentrations, respectively. IC_{50} value of chloroform rhizome oleoresin of *H. coronarium* was 194.58±2.57 ppm which was calculated at the time when 100% germination was achieved in the control and was used to compare the relative herbicidal activities in terms of inhibition of root growth of the samples. The percent inhibition of root length and IC_{50} value of chloroform rhizome oleoresin of *H. coronarium* represent in (Table 7 and Table 9).

Table 7: Percent inhibition of root length of chloroform rhizome oleoresin of *H. coronarium*

S. No.	Sample	% Inhibition of root length (Mean±SD)			
		250 ppm	500 ppm	750 ppm	1000 ppm
1	HCCRO	19.62±0.64	27.77±1.11	75.18±2.79	99.62±0.64
2	Pendimethalin*	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00

*= Standard herbicide; HCCRO=*Hedychium coronarium* chloroform rhizome oleoresin

Inhibition of shoot length

The percent inhibition of shoot length was calculated at the time when 100% germination is achieved at various concentrations range of 250, 500, 750, 1000ppm. The percent inhibition of root length of *H. coronarium* chloroform oleoresin was recorded as 16.29%, 30.37%, 73.33% and 99.62% from lowest to highest concentrations. IC_{50} value was 194.58±2.57 ppm which was calculated at the time when 100% germination was achieved in the control and was used to compare the relative herbicidal activities in terms of inhibition of root growth of the samples as lower is the herbicidal activity higher will be its IC_{50} values. The percent inhibition of shoot length and IC_{50} value of chloroform rhizome oleoresin of *H. coronarium* are present in (Table 8 and Table 9).

Table 8: Percent inhibition of shoot length of chloroform rhizome oleoresin of *H. coronarium*

S. No.	Sample	% Inhibition of shoot length (Mean±SD)			
		250 ppm	500 ppm	750 ppm	1000 ppm
1	HCCRO	16.29±3.39	30.37±1.69	73.33±1.11	99.62±0.64
2	Pendimethalin*	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00	100.00 ±0.00

*= Standard herbicide; HCCRO=*Hedychium coronarium* chloroform rhizome oleoresin

Table 9: IC_{50} values of seed germination, root length and shoot length inhibiion of chloroform rhizome oleoresin of *H. coronarium*

IC_{50} values in ppm (Mean±SD)		
Seed germination inhibition	**Root length inhibition**	**Shoot length inhibition**
105.38±7.62	194.58±2.57	198.19±9.51

Insecticidal activity

The insecticidal activity of the chloroform rhizome oleoresin of *H. coronarium* was evaluated against *S. litura* insect by using leaf dip method. Five, third instar larvae of *S. litura* were used for each concentration of oleoresin to test the activity. The experiment was performed in triplicates and total number of test insects per petri plate was five. After 72hrs, the maximum rate of mortality in oleoresin was observed as 6.66%, 20.00%, 33.33% and 60.00% at 10, 25, 50 and 100 ppm concentration, respectively. The insecticidal activity of the oleoresin was found to be the highest at 100ppm and sequentially decreased with concentration in concentration dependent manner. During the experiment there is no mortality was observed after 72hrs.Tween-20(1%) water solution was taken as control. The Mortality percentage of *S. litura* insect, treated with the chloroform rhizome oleoresin of *H. coronarium* is presented in (Table 10). The LC_{50} values of the chloroform oleoresin of *H. coronarium* at 24, 48 and 72hrs after treatment were 0.07, 0.06, and 0.04% respectively. The LC_{50} value of chloroform oleoresin from rhizome part of *H. coronarium* is present in (Table 11).

Table 10: Mortality percentage of *Spodoptera litura* insect, treated with chloroform rhizome oleoresin of *H. coronarium*

Concentration(ppm)	No. of insect used	No. of insect dead			Average % mortality			Mean% mortality
		24hrs	48hrs	72hrs	24hrs	48hrs	72hrs	
10	5	0	0	1	0.00	0.00	20.00	6.66±11.54
25	5	1	1	2	20.00	20.00	40.00	26.66±11.54
50	5	2	2	3	40.00	40.00	60.00	46.66±11.54
100	5	2	3	3	40.00	60.00	60.00	53.33±11.54
control	5	0	0	0	0.00	0.00	0.00	0.00±0.00

Table 11: Chi square values, regression equation and (LC_{50}, LC_{30}, LC_{90}) values of chloroform rhizome oleoresin of *H. coronarium*

Duration (hrs)	LC_{30}(%)	LC_{50}(%)	LC_{90}(%)	chi sq.	Reg. eq.
24	0.005	0.007	0.013	0.76	y = 0.059x +0.44
48	0.005	0.006	0.011	0.82	y = 0.06x +0.27
72	0.001	0.004	0.057	0.91	y = 0.01x+ 4.09

*LC_{50}= Lethal concentration

Discussion

The results showed that the oxygenated monoterpenes (36.6%) followed by oxygenated sesquiterpenes (23.5%) contributed largely to the chloroform rhizome oleoresin of *H. coronarium* with 1,8-cineole (12.6%) and Coronarin *E* (20.0%) as a major components. Dodecane (7.3%) was identifies as major constituent along with the other minor constituents of monoterpenes hydrocarbons in chloroform rhizome oleoresin of *H. coronarium*. While the sesquiterpenes hydrocarbons contributed a lesser amount (5.4%) to the total oleoresin with α-bisabolene (2.8%) as a major component. 1,8-Cineol is a commonly occurring biologically active compound and has previously been found as the major constituent in the essential oil of *Hedychium* species [7, 20]. β-Sitosterol, daucosterol and stigmasterol, sesquiterpenes have been reported major component in the rhizome methanolic extract of *H. coronarium* There constituents were totaly absent in present investigation [21].

The nematicidal activity of chloroform rhizome oleoresin of *H. coronarium* might be associated with its main constituents such as α-terpineol (7.7%), α-pinene (7.3%), limonene (5.2%) and *p*-cymene (4.9%) [20]. α-Pinene, α-fenchene, 1,8 cineole, dodecane and isobornyl acetate were found as main components of chloroform rhizome oleoresin of *H. coronarium* might be responsible for its insecticidal activity [21]. Insecticidal activity of 9 different *Hedychium* essential oils could be associated with its main constituents such as α-bisabolene, α-terpineol, 1,8 cineol and β-pinene as some of which were evaluated for their insecticidal activity against azelaea lace bug (*S. pyrioides*), the yellow fever mosquito (*Ae. aegypti*), and the red imported fire ant (*S. invicta*) [20]. While, herbicidal activity of oleoresin may be due to the presence of the main compounds such as 1,8-cineole, dodecane, pentadecane, coronarin *E*, 1-heptatriacotanol and β-atlantol, or to a possible allelophatic effect of the minor or other major compounds present in the chloroform rhizome oleoresin of *H. coronarium*.

Conclusion

Based on the present study, it can be concluded that the significant nematicidal activity, herbicidal activity and a moderate insecticidal activity of the rhizome oleoresin of *H. coronarium* in a tested concentrations, supporting their used for designing a potent botanical pesticide. The potential herbicidal activity of the rhizome chloroform oleoresin of *H. coronarium* showed the possibility of this plant as a source of natural and organic botanical herbicides for weed management. Nematicidal activity of the oleoresin might be good source of a more selective, biodegradable, naturally produced and environmental friendly natural nematicides acting as a substitute to synthetic nematicides. In addition, chloroform rhizome oleoresin of *H. coronarium* consists various bioactive constituents that may be exploited for management of various lepidopterous pests in many crops and it may be utilized as Integrated pest management programme (IPM).

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