International Journal of Ecology and Environmental Sciences 39 (3): 159-169, 2013
ISSN: 0377-015X (Print); 2320-5199 (Online)

Determination of Phytocomponents of *Jatropha curcas* Root by GC-MS Analysis and Their Termiticidal Activity

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ABSTRACT

Green technology based botanical pesticides are highly favoured and in-demand all over the world. The aim of this study was to evaluate the efficacy of solvent extracts of various parts of *Jatropha curcas* against termites (*Microtermes obesi)*. No choice bioassay was performed with butanol, ether, hexane and methanol extracts of *J. curcas* leaves, root and bark against termites under controlled conditions (28 °C temperature and 80% relative humidity) for 48 h. Methanolic root extract (0.5 and 0.25 g mL^{-1} concentration) was found to be most promising imparting 100% termite mortality in 48 h. Ether extract of leaf showed moderate toxicity (70%) followed by hexane extract of root and butanolic extract of leaf (66.6 % each) with 0.5 g mL^{-1} concentration after 48 h. The present study suggested that *J. curcas* and its parts have termiticidal potential and could prove to be an ecofriendly biopesticide. GC-MS analysis of methanolic extract of *J. curcas* root, which confirmed the presence of fatty acids and terpenes, responsible for the termiticidal activity, has been reported for the first time. The bioformulations could be prepared using active component present in jatropha roots and may be successfully utilized in termite management.

Key Words: *Jatropha curcas*; *Microtermes obesi;* Termiticidal; Methanolic Extract; Gas Chromatography Mass Spectrometry.

INTRODUCTION

Termites are the massive threat to plants, trees and wooden structures globally in tropic and sub-tropic climate zones. Besides destroying wooden structures, they also attack live agricultural plants. Economically, termites cause over 3 billion Dollars damage to wooden structures annually in United States (Lewis 1997). In India, they cause the yield loss of 15- 25% of maize and about 1,478 million Rupees (IFAD-CIMMYT 2001). To resolve the problem of termites and the economic loss occurring due to their infestation, various control measures (physical, chemical and biological) have been reported (Verma et al. 2009). Chemical control is most successful method of prevent-ing termite attack but concerning to the poisoning, persistence, resistance and re-entry, inappropriate disposal and the secondary effects of environmental degradation and surface and ground water contamination (Vasant and Narasimhacharya 2008), sustainable alter-natives like botanical pesticides are being explored. Botanical pesticides are now recognized as green technology under biological control because these are environment friendly, biodegradable and safe. Higher plants produce and store secondary compounds in their leaves, stems, bark and roots etc. which can either be used directly or indirectly in the form of extracts or any other modified product as botanical pesticides. Botanical pesticides are natural organo-chemicals of plant origin, to protect themselves from pathogen, insects, pests and herbivore or competitor through diverse modes of action such as growth retardation, feeding deterrent, oviposition deterrent, reduction in fertility, altering the behaviour and life cycle, change in metabolism, enzyme inhibition, and respiratory irritant. These are now highly recom-mended by United Nations Environment Program (UNEP) and Food and Agriculture Organization (FAO) and are replacing the harmful chemical pesticides because of their beneficial properties of biodegradation in months or days in presence of high light intensity.

These are readily recycled in ecosystem and do not have any toxic effect on humans and mammals even in their body; no resistance development or biomagnification effect occurs. The current trend in the society towards 'green consumerism' desiring fewer synthetic ingredients in food favours plant-based products, which are 'generally recognized as safe' (GRAS), in eco-friendly management of plant pests (Dubey et al. 2010).

Jatropha curcas is a tropical plant belonging to the family Euphorbiaceae. It is a multipurpose, drought resistant, perennial plant which is important source for the production of biodiesel (Kumar and Sharma 2008). Jatropha seeds have approximately 24.6% crude protein, 47.3% crude fat, and 5.54% moisture content (Akintayo 2004). Different parts of the plant have many therapeutic values and are useful for numerous purposes (Narayana et al. 1969). *J. curcas* seeds and leaves extracts possess insecticidal, molluscicidal and fungicidal properties (Nwosu and Okafor 1995, Liu 1997, Solsoloy and Solsoloy 1997). The seeds are also reported to have anti nutritional factors such as phorbol esters, saponin, phytate, trypsin inhibitor and cyanogenic glucosides (Makkar et al. 1997, Rakshit et al. 2008).

With the above facts, the present study was made to screen and evaluate the antitermitic potential of *Jatropha curcas* leaves, roots and stem bark.

MATERIALS AND METHODS

Plant Material

Leaves, roots and stem bark of *J. curcas* plant were collected from Micromodel complex, Indian Institute of Technology Delhi, India. The plant materials were cleaned and air-dried at room temperature. They were then pulverized in a grinder to obtain a fine powder.

Preparation of Solvent Extracts

The powdered plant parts (leaves, roots and stem bark, 50 g each) were added to 300 mL of various solvents (butanol, ether, hexane and methanol) and extracted in soxhlet extraction apparatus for 6-8 h. The extracts were filtered through Whatman No. 1 filter paper and concentrated to dryness *in vacuo* using rotary evaporator to remove the solvents. All the crude extracts were stored in amber bottles and kept in dark at -20 °C.

Characterization of Methanolic Root Extract

The methanolic root extract of *J. curcas* was analyzed using a Shimadzu GCMS-QP 2010 Plus mass spectrometer. The sample was diluted 25 times with chloroform and 1 µL was injected. The column Rtx 1MS (length: 30.0 m, 0.32 mm i.d., film thickness 0.25 μm) was used. Injector port temperature was 260 °C; detector temperature was 270 °C and oven temperature was maintained at 60 °C for 2 min and then increased to 230 °C at the rate of 2 °C min^{-1} at which temperature the column was maintained for 12 min. Column max temp was 330 °C, carrier gas was N2/Air and flow rate was 0.91 mL min^{-1}. Retention indices of all compounds were determined according to the Kovats method using *n*-alkanes standards (Jennings and Shibamoto 1980). The compounds were identified by comparison of Kovats indices and by matching with those of NIST-MS library and published mass spectra (Adams 1989, Davis 1990, Hiserodt et al. 1996).

Termites

Termites, *Microtermes obesi* were collected from various locations within Indian Institute of Technology, New Delhi, using polyethylene bags. Adult workers (4-5 weeks old) were separated and used for the various tests after 24 hours of acclimatization. Termites were kept in an incubator at 28 ± 2 °C and 80 ± 10% relative humidity (RH). The collections were made in the evenings or early in the mornings (Meikle et al. 2005).

No Choice Bioassay

No-choice bioassay test (Kang et al. 1990) was performed to evaluate the termiticidal activity of extracts. The tests were done in Petri dishes (inner diameter 4.8 cm) filled with 1 g sand. 0.5, 0.25 and 0.05 g mL^{-1} concentration of butanol, ether, hexane and methanol extracts of leaves, roots and bark of *J. curcas* were prepared by diluting each extract with their respective solvents. Filter paper discs (diameter 4.5 cm) were treated with one mL of each extract. Discs were air dried and kept in Petri dishes. Control set contains only solvent. Ten adult workers were then released into the center of the Petri dishes and kept in BOD incubator (28 ± 2 °C and 80 ± 10% RH). Each treatment was replicated thrice.

Mortality of termites was observed after regular time interval for 48 hours. Dead termites were removed after every counting to avoid fungi or other infestations. The data were analyzed for percent mortality.

Statistical Analysis

Analysis of variance (ANOVA) was performed on all experimental data and means were compared using Duncan's multirange test with SPSS 17.0 software. The significance level was $p<0.05$.

RESULTS

Toxicity of Solvent Extracts of *J. curcas*

The yields of crude extracts of *J. curcas* leaves, root and bark in butanol, ether, hexane and methanol solvents are shown in Table 1. Effects of butanol, ether, hexane and methanol extracts of *J. curcas* bark on termite are shown in Figures 1 to 4. After 48 h, bark extract of *J. curcas* in hexane showed maximum mortality (63.33 %) with 0.5 g mL^{-1} concentration. 0.25 g mL^{-1} and 0.05 g mL^{-1} concentrations of hexane extracts showed low mortality i.e. 40% and 30%. Furthermore, 40, 43.33 and 50% termite mortality were observed with 0.5 g mL^{-1} of ether, butanol and methanol extracts of stem bark. Moderate termiticidal activity was observed with butanol and methanol (33.33% each), ether (30%) at 0.25 g mL^{-1} concentration. Low mortality was observed with lowest concentration (0.05 g mL^{-1}) of methanol (26.67%), butanol and ether (23.33% each) extracts of bark. Butanol and methanol control gave 6.67% mortality each however, both ether and hexane controls showed 10% termite mortality.

Table 1. Percent yield of *Jatropha curcas* leaves, roots and bark extracts in different solvents.

Solvents	Yield (%)		
	Leaves	Roots	Bark
Ether	7.8	2.2	0.8
Methanol	8.2	14.2	4.2
Butanol	11.6	2.0	1.0
Hexane	14.7	1.8	1.8

Figures 5 to 8 depict the mortality (%) occurred with butanol, ether, hexane and methanol extracts of *J. curcas* leaf respectively. Ether extract of *J. curcas* leaf (0.5 g mL^{-1}) showed maximum termite mortality (70%) in 48 h while 63% and 50% mortality were observed with 0.25 g mL^{-1} and 0.05 g mL^{-1} concentration. 10% mortality was observed in ether control. 0.5 g mL^{-1}, 0.25 g mL^{-1} and 0.05 g mL^{-1} of butanolic leaf extract resulted in 66.67%, 46.67% and 43.3% mortality of termites in 48 h, respectively. Butanolic control caused 10% mortality. Hexane extract caused 60% mortality with 0.5 g mL^{-1} concentration and 53.33% and 46.67% with 0.25 g mL^{-1} and 0.05 g mL^{-1} respectively, after 48 h. The control imparted 13.33% termite mortality. Methanolic leaf extract was least effective, causing only 36% mortality at 0.5 g mL^{-1} and 20% and 16.6% with consecutive decreased concentrations. In case of methanolic control, 10% termite mortality was achieved in 48 h.

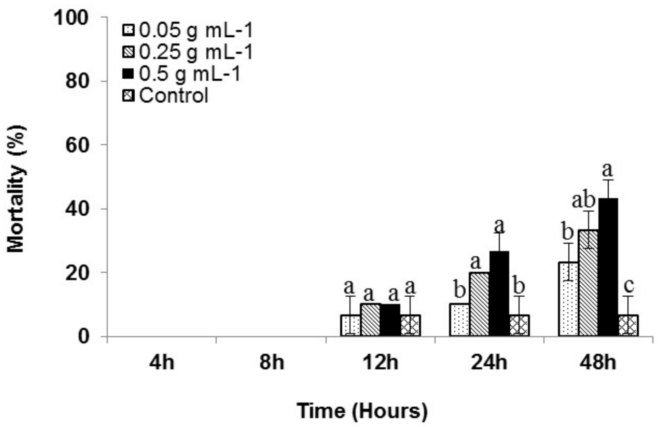

Figure 1. Effect of butanol extract of *Jatropha curcas* bark on termite mortality. Values (means of 3 replicates) in each bar not sharing a common letter differ significantly ($p<0.05$) from each other (Duncan's multirange test)

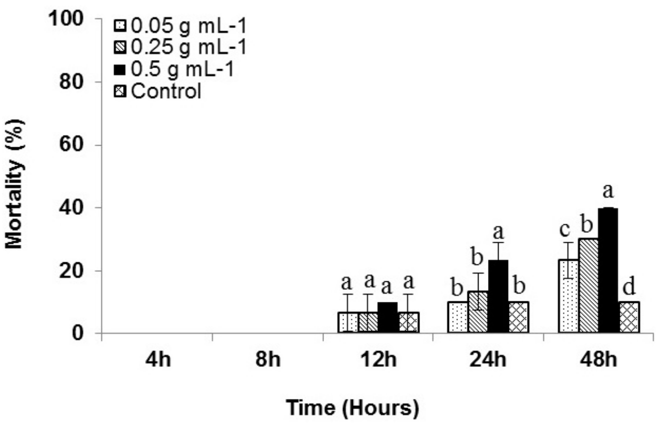

Figure 2. Effect of ether extract of *Jatropha curcas* bark on termite mortality. Values (means of 3 replicates) in each bar not sharing a common letter differ significantly ($p<0.05$) from each other (Duncan's multirange test)

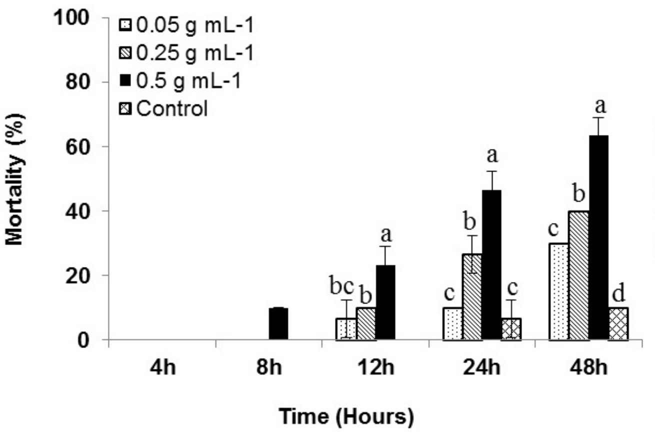

Figure 3. Effect of hexane extract of *Jatropha curcas* bark on termite mortality. Rest as in Figure 2.

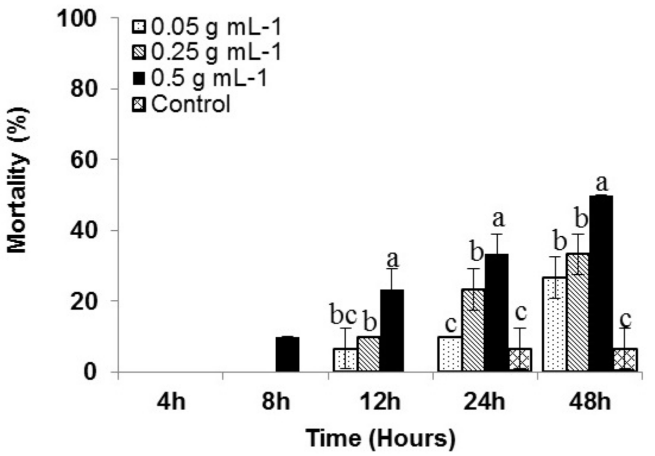

Figure 4. Effect of methanol extract of *Jatropha curcas* bark on termite mortality. Rest as in Figure 2.

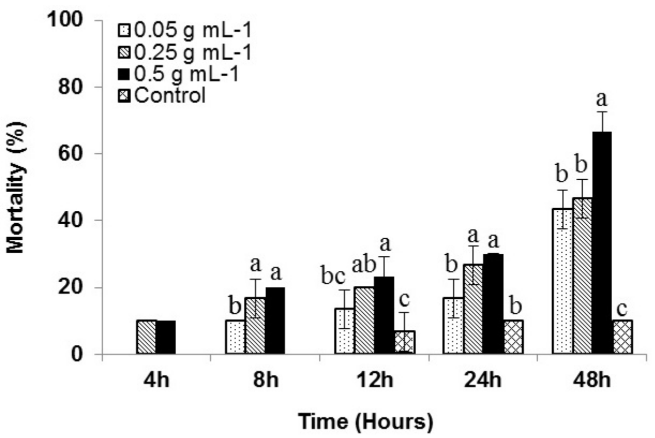

Figure 5. Effect of butanol extract of *Jatropha curcas* leaves on termite mortality. Rest as in Figure 2.

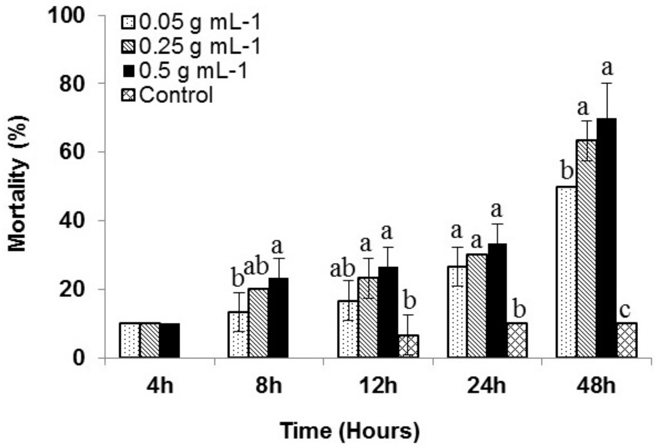

Figure 6. Effect of ether extract of *Jatropha curcas* leaves on termite mortality. Rest as in Figure 2.

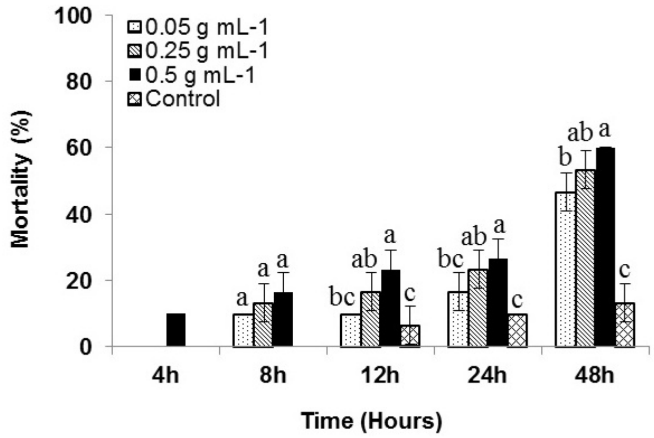

Figure 7. Effect of hexane extract of *Jatropha curcas* leaves on termite mortality. Rest as in Figure 2.

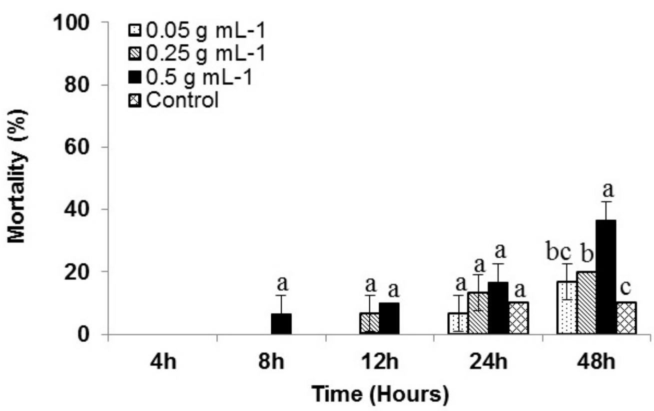

Figure 8. Effect of methanol extract of *Jatropha curcas* leaves on termite mortality. Rest as in Figure 2.

Table 2. Mortality (%) of termites by *Jatropha curcas* root extracts in methanol, hexane, ether and butanol

Treatments	Treatment Period				
	4 h	8 h	12 h	24 h	48 h
Methanol					
0.05 g mL^{-1}	0 ± 0	10 ± 0b	20 ± 0c	30 ± 0c	46.66 ± 5.77b
0.25 g mL^{-1}	10 ± 0	16.66 ± 5.77ab	33.33 ± 5.77b	56.66 ± 5.77b	100 ± 0a
0.5 g mL^{-1}	10 ± 0	23.33 ± 5.77a	40 ± 0a	66.66 ± 5.77a	100 ± 0a
Control	0 ± 0	0 ± 0c	0 ± 0d	10 ± 0d	10 ± 0c
Hexane					
0.05 g mL^{-1}	0 ± 0	0 ± 0b	10 ± 0b	16.66 ± 5.77bc	30 ± 0c
0.25 g mL^{-1}	0 ± 0	6.66 ± 5.77ab	13.33 ± 5.77b	23.33 ± 5.77b	43.33 ± 5.77b
0.5 g mL^{-1}	10 ± 0	13.33 ± 5.77a	26.66 ± 5.77a	43.33 ± 5.77a	66.66 ± 5.77a
Control	0 ± 0	0 ± 0b	0 ± 0c	6.66 ± 5.77c	10 ± 0d
Ether					
0.05 g mL^{-1}	0 ± 0b	0 ± 0b	10 ± 0b	13.33 ± 5.77bc	26.66 ± 5.77c
0.25 g mL^{-1}	0 ± 0b	6.66 ± 5.77a	13.33 ± 5.77b	20 ± 0b	40 ± 0b
0.5 g mL^{-1}	6.66 ± 5.77a	10 ± 0a	23.33 ± 5.77a	43.33 ± 5.77a	60 ± 0a
Control	0 ± 0b	0 ± 0b	6.66 ± 5.77b	6.66 ± 5.77c	10 ± 0d
Butanol					
0.05 g mL^{-1}	0 ± 0	0 ± 0b	6.66 ± 5.77bc	10 ± 0c	23.33 ± 5.77c
0.25 g mL^{-1}	0 ± 0	0 ± 0b	13.33 ± 5.77ab	20 ± 0b	36.66 ± 5.77b
0.5 g mL^{-1}	0 ± 0	6.66 ± 5.77a	16.66 ± 5.77a	30 ± 0a	46.66 ± 5.77a
Control	0 ± 0	0 ± 0b	0 ± 0c	6.66 ± 5.77c	10 ± 0d

Values (means of 3 replicates) in each column not sharing a common letter differ significantly ($p<0.05$) from each other (Duncan's multirange test)

Table 2 shows the data on termite mortality with butanol, ether, hexane and methanol extracts of *J. curcas* root. Methanolic root extract was found to be the most effective against termites. 100% termite mortality was observed with 0.5 g mL^{-1} and 0.25 g mL^{-1} of methanolic root extract of *J. curcas* in 48 h. 0.05 g mL^{-1} was moderately effective and showed 46.6% mortality with same extract. Hexane and ether extracts of root showed almost equal potency. They conferred 66.6 and 60% of termite mortality with 0.5 g mL^{-1} of hexane and ether extracts of root respectively. However, with 0.25 g mL^{-1} of hexane and ether extracts of jatropha root, 43.3 and 40% mortality was observed. Only 30 and 26.6% termite mortality was observed with 0.05 g mL^{-1} of hexane and ether extracts. Butanolic root extract killed 46.6, 36.6 and 23.3% termites with 0.5, 0.25 and 0.05 g mL^{-1} concentration respectively. In all the solvent controls, 10% mortality occurred in 48 h.

GC-MS Characterization of Methanolic Root Extract

Out of all the solvent extracts (leaves, roots and stem bark of various solvents butanol, ether, hexane and methanol), methanolic root extract was found to be most potent and showed excellent bioactivity against termites. Consequently, it has become important to find out the active components present in methanolic root extract which might be responsible for this activity. GC-MS was performed to identify the unknown compounds present in the extract. The GC-MS chromatogram of methanolic root extract of *Jatropha curcas* is shown in Figure 9. According to the increasing order of retention time, 23 compounds were identified (Table 3). The total content of 23 identified compounds was 87.98%. Fatty acids and terpenes were found to be present in high percentage i.e. 45.77, 25.82% respectively (Table 4). These fatty acids were: Brassidic acid (23.77%), Hexadecanoic acid (19.58%), Hystrene S-97 (1.36%), Elaidic acid (1.06%) and fatty acid esters like Myristic acid methyl ester (1.56%) and Phthalic acid, butyl 8-methylnonyl ester (1.54%). The other components were terpenes mainly diterpene such as Podocarpic acid (3.50%), Abieta-8(14), 9(11),12-triene (2.56%), Cryptotanshinone (1.83%), Retinol, acetate (1.61%) and 18-Oxokauran-17-yl acetate

(1.40%); sesquiterpenes namely (-)-Globulol (4.37%), Eudesma-4(14),11-diene (3.35%), Viridiflorol (1.99%), Diepicedrene-1-oxide (1.13%) and cis-Z-.alpha.-Bisabolene epoxide (2.07%) and monoterpene like 3-Benzylidene isoborneol (2.01%). Steroids such as Estra-1,3,5(10),9(11)-tetraen-17-one, 3-methoxy-1-methyl-(2.42%), Equilin (1.72%), Beta.-Sitosterol (1.48%); C15 Acetogenin (cyclic enyne) - Isomaneonene-B (1.70%), Cis-maneonene-A (1.27%) and hydrocarbon -Dimethyl (neopentyl) amine oxide (4.70%) were also present in the extract.

DISCUSSION

Toxicological Analysis of *J. curcas*

The present work revealed the termiticidal activity of *J. curcas* leaf, bark and root extracts in different solvents (butanol, ether, hexane and methanol). In this study, significant toxicity against termites was observed with methanolic root extract. The insecticidal activity of different parts of jatropha was also studied by other workers. Bullangpoti et al. (2012) reported the toxicity

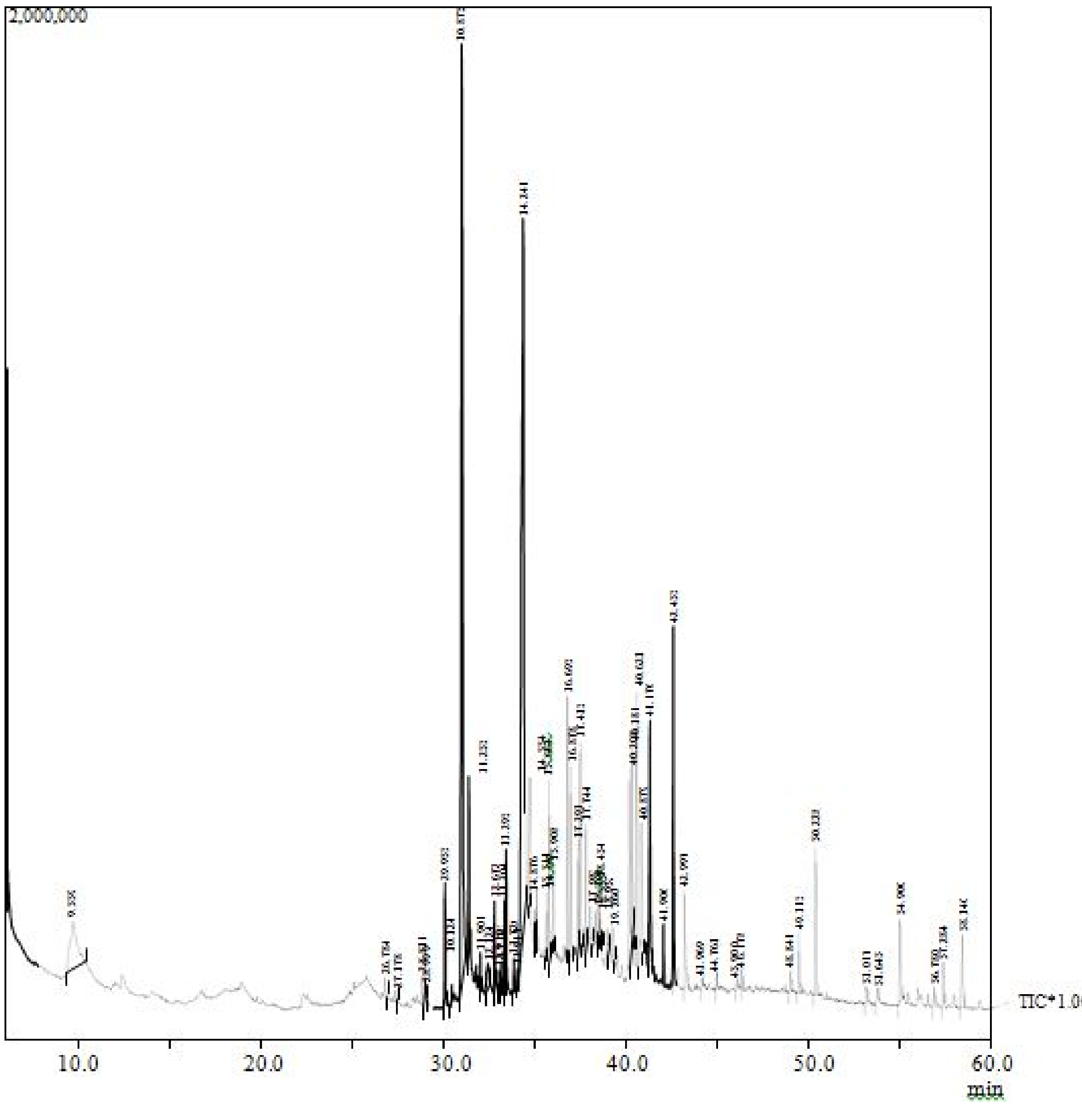

Figure 9. GC-MS chromatogram of methanolic root extract of *Jatropha curcas.*

Table 3. GC-MS profile of methanol extract of *Jatropha curcas* root

Name	Retention time	Area %
Dimethyl (neopentyl) amine oxide	9.559	4.70
Myristic acid methyl ester	29.955	1.56
Hexadecanoic acid	30.875	19.58
Phthalic acid, butyl 8-methylnonyl ester	31.255	1.54
Elaidic acid	33.295	1.06
Docosenoic acid	34.241	23.77
Hystrene S-97	34.554	1.36
Isomaneonene-B	35.664	1.70
Abieta-8(14),9(11),12-triene	36.695	2.56
3-Benzylidene isoborneol	36.878	2.01
Cis-maneonene-A	37.293	1.27
Cis-Z-.alpha.-Bisabolene epoxide	37.435	2.07
Diepicedrene-1-oxide	37.744	1.13
Cryptotanshinone	40.208	1.83
Estra-1,3,5(10),9(11)-tetraen-17-one, 3-methoxy-1-methyl	40.381	2.42
Eudesma-4(14),11-diene	40.623	3.35
Viridiflorol	40.879	1.99
Podocarpic acid	41.176	3.50
(-)-Globulol	42.455	4.37
Equilin	42.997	1.72
Retinol, acetate	50.225	1.61
Beta.-sitosterol	54.900	1.48
18-Oxokauran-17-yl acetate	58.340	1.40

of ethanolic senescent leaf extracts (SLEs) of *J. gossypifolia* and *Melia azedarach* on larvae of the noctuid pest *Spodoptera frugiperda*. Jide-Ojoa and Ojo (2011) examined antifeedant, insecticidal and oviposition deterrent activities of *Jatropha curcas* plant extract against maize weevil, *Sitophilus zeamis*. The efficacy of leaf extract of *J. gossypifolia* against second instar of *Spodoptera exigua* was studied by Khumrungsee et al. (2009). Peta and Pathipati (2008) studied the antifeedant effects of *J. curcas* on two Lepidopteran pests, *Spodoptera litura* and *Achaea janata*. Phowichit et al. (2008) also reported the insecticidal activity of *J. gossypifolia* L. against *S. litura*. Mahfuz and Khanam (2007) reported the toxicity of petroleum ether extract of *J. curcas* against *T. confusum* adults. The oil of *J. curcas* seed also showed insecticidal activity. The presence of a toxic component, phorbol esters is responsible for this bioactivity. The phorbol ester fraction of *J. curcas* gave 100% termite mortality in 12 h (Verma et al. 2011). Another study by Acda et al. (2009) reported that *J. curcas* oil showed an antifeedant effect, reduced tunneling activity, repellent activity and increased mortality against Philippine milk termites (*Coptotermes vastator* Light). The toxic effects of *J. curcas* oil and phorbol esters were also reported by Solsoloy (1993) and Solsoloy and Solsoloy (1997) on cotton insect pests; the emulsifiable concentrate formulation of crude oil was toxic against corn weevil (*Callosubruchus chinensis*),

Table 4. The major components of methanolic extract of *Jatropha curcas* root

Nature of compound	Compounds	Total (%)
Fatty acids	Brassidic acid, Hexadecanoic acid, Hystrene S-97, Elaidic acid	45.77
Fatty acid esters	Myristic acid methyl ester, Phthalic acid, butyl 8-methylnonyl ester	3.10
Diterpene*	Podocarpic acid, Abieta-8(14),9(11),12-triene, Cryptotanshinone, Retinol, acetate, 18-Oxokauran-17-yl acetate	10.90
Sesquiterpenes*	(-)-Globulol, Eudesma-4(14),11-diene, Viridiflorol, Diepicedrene-1-oxide, Cis-Z-.alpha.-Bisabolene epoxide	12.91
Monoterpene*	3-Benzylidene isoborneol	2.01
Steroids	Estra-1,3,5(10),9(11)-tetraen-17-one, 3-methoxy-1-methyl, Equilin, Beta.-Sitosterol	5.62
C15 Acetogenin (cyclic enyne)	Isomaneonene-B, Cis-maneonene-A	2.97
Hydrocarbon	Dimethyl (neopentyl) amine oxide	4.70

* Terpenes- Diterpene, Sesquiterpenes and Monoterpene - 25.82%

Table 5. Nature and activity of phyto-components identified in the methanolic root extract of *Jatropha curcas* by GC-MS analysis

Name	Nature	Activity	Reference
Dimethyl (neopentyl) amine oxide	Hydrocarbon	Agrichemical and pheromone	http://en.wikipedia.org/wiki/Dimethylamine
Hexadecanoic acid	Fatty acids	Termiticidal, insecticidal, mosquito larvicidal, maggoticidal, antipathogenic, antibacterial, insectistatic, antifungal and antiviral	Scheffrahn and Rust 1983, Rahuman et al. 2000, Sogabe et al. 2000, Falodun et al. 2009, Sayeda et al. 2009, Ogunlesi et al. 2010, Manilal et al. 2011
Phthalic acid, butyl 8-methylnonyl ester	Fatty acid esters	Antibacterial, antifungal, anti-inflammatory and antiviral	Ogunlesi et al. 2010
Docosenoic acid	Fatty acids	Insecticidal, antibacterial and antifungal	Ghazala et al. 2004, Pérez-Gutiérrez et al. 2011
Isomaneonene-B	C15 acetogenin (cyclic enyne)	Antibacterial	Dembitsky et al. 2003
Abieta-8(14),9(11),12-triene	Diterpene	Termiticidal, antifeedant, antimicrobial, antibacterial, antimycobacterial, antihelminth, leishmanicidal and antifungal	Fukushima et al. 2002, Fraga et al. 2005, Topçu and Gören 2007, Kusumoto et al. 2009, Tanaka et al. 2010
3-Benzylidene isoborneol	Monoterpene	Termiticidal repellent	Bläske et al. 2003
Cis-maneonene-A	C15 acetogenin (cyclic enyne)	Insecticidal, B-DNA fragmentation, apoptosis regulation, anthelminitic, antimalarial,anti-microbial, antiprotozoal and pesticidal	Alali et al. 1999, Abou-Elnaga et al. 2011, Ayyad et al. 2011
Cis-Z-.alpha.-Bisabolene epoxide	Sesquiterpenes	Semiochemical, insect repellent, toxicity and antimicrobial	Chavan et al. 2006, Mann et al. 2010
Diepicedrene-1-oxide	Oxygenated sesquiterpenes	Antimicrobial, antiseptic, antitumor, antibacterial, anticoagulant and nerve protection	Al-Rehaily, 2006, Li et al. 2008
Cryptotanshinone	Diterpene	Antibacterial, antidermatophytic, antioxidant, leishmanicidal, antimalarial/antiplasmodial (3D7 stain of *Plasmodium falciparum*), anticancer (STAT3 Tyr705 phosphorylation inhibitor), anti-inflammatory, cytotoxic and bacteriostatic activity	Baricevic and Bartol, 2000, Sairafianpour et al. 2001, Wu et al. 2003, Shin et al. 2009, www.nopr.niscair.res.in/bitstream/.../12244/1 /NPR%202(1)%2030-37.pdf
Eudesma-4(14),11-diene	Sesquiterpenes	Antitumor, Sedative, Anti-bacterial, Antiinflammatory and fungicide	Uma et al. 2011
Viridiflorol	Oxygenated sesquiterpenes	Insecticidal	Aboua et al. 2010
Podocarpic acid	Diterpene	Insect toxicity, antifungal, fungistatic and antitumor	Parish et al. 1987
(-)-Globulol	Oxygenated sesquiterpenes	Antimicrobial (antifungal and antibacterial)	Wells et al. 1993, Tan et al. 2008
Retinol, acetate	Diterpene	Antioxidant and antimutagenic	Bakkali et al. 2008, Waseem et al. 2009
18-Oxokauran-17-yl acetate	Diterpene	Antitumor, anti-HIV, trypanocidal, antifungal, antimicrobial, analgesic	Fujita et al. 1979, Batista et al. 2007

bean weevil (*Sitophilus zeamays*) and housefly (*Musca domestica*). Researchers suggested that a significant increase in anti-termitic activity may be achieved by enhancing the toxic components of jatropha through extraction using organic solvents (Acda 2009, Liu et al. 1997, Rug et al. 1997).

GC-MS of Methanolic Root Extract

The nature and activity of phytocomponents present in the methanolic root extract of *J. curcas*, by GCMS analysis (Table 5) reveal that high termiticidal activity may be attributed to the presence of a number of terpenes and fatty acids. Many components of the methanolic root extract of jatropha have been reported to be termiticidal and insecticidal. Sogabe et al. (2000), Sayeda et al. (2009), Falodun et al. (2009) and Rahuman et al. (2000) reported the termiticidal and insecticidal activity of hexadecanoic acid, present in methanolic root extract of *J. curcas*. In addition, erucic acid (Pérez-Gutiérrez et al. 2011), abietane (Kusumoto et al. 2009), isoborneol (Bläske et al. 2003), maneonene (Abou-Elnaga et al. 2011), cryptotanshinone (Jaroszewski et al. 2001) and viridifloral (Aboua et al. 2010) etc. are shown to have their insecticidal, termiticidal, termite repellent, antimicrobial, antifeedant and antioxidant activities.

CONCLUSIONS

The present study indicates that different parts of *Jatropha curcas* possess antitermite activity. Methanolic root extract of jatropha showed maximum mortality of termites followed by ether extract of leaves. GC-MS analysis of methanolic extract of jatropha root revealed high percentage of terpenes and fatty acids. These components have bioactivity against termites and other insects. Ecofriendly termiticidal formulations can be developed using jatropha root extract as green pesticide which could be low cost and safe to human health and environment. They could be formulated and further investigations are required at field conditions to establish them as commercial termiticides.

ACKNOWLEDGEMENT

We gratefully acknowledge financial support provided by the KVIC, India, for carrying out the research.

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Received 30 April 2013;
Accepted 3 July 2013