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Toxicity, antifeedant, egg hatchability and adult emergence effect of *Piper nigrum* L. and *Jatropha curcas* L. extracts against rice moth, *Corcyra cephalonica* (Stainton)

Mousa Khani[1,2], Rita Muhamad Awang[2*], Dzolkhifli Omar[2] and Mawardi Rahmani[3]

[1]Cultivation and Development Department of Medicinal Plants Research Center, Institute of Medicinal Plants, ACECR, Karaj, Iran.
[2]Department of Plant Protection, Faculty of Agriculture, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[3]Department of Chemistry, Faculty of Science, University Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

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Petroleum ether extract of black pepper, *Piper nigrum* and physic nut, *Jatropha curcas* were shown to have insecticidal efficacies against rice moth, *Corcyra cephalonica* (Stainton). The *C. cephalonica* 3rd instar larvae were shown to have similarities susceptibility to petroleum ether extract of *Piper nigrum* and *J. curcas* with LC_{50} values of 12.52 and 13.22 µL/ml, respectively. In a bioassay using no-choice tests, the parameters used to evaluate antifeedant activity were relative growth rate (RGR), relative consumption rate (RCR), efficiency on conversion of ingested food (ECI) and grain protection or feeding deterrence indices (FDI). Both extracts showed high bioactivity at all doses against *C. cephalonica* larvae and antifeedant action was increased with increasing plant extract concentrations. The petroleum ether extract of *P. nigrum* and *J. curcas* showed strong inhibition on egg hatchabilities and adult emergence of *C. cephalonica* at the lowest concentration. Based on the results of this study, petroleum ether extracts of *P. nigrum* and *J. curcas* could be used in IPM program for rice moth.

Key words: Antifeedant, feeding deterrence, *Jatropha curcas*, *Piper nigrum*, *Corcyra cephalonica*, egg hatchability, adult emergence.

INTRODUCTION

The rice moth, *Corcyra cephalonica* (St.) is the major pests of stored commodities in the tropics (Lucas and Riudavets, 2002), Asia, South America and Africa (Allotey and Azalekor, 2000; Huang and Subramanyam, 2004). The larvae feed on rice, corn, cocoa, chocolate, dried fruit, biscuits, coffee and other seeds. The rice moth is a worldwide pest of stored foodstuffs. Control of these insects generally requires the use of chemical insecticides that are toxic to humans and domestic animals, and and also harmful to the environment (Coelho et al., 2007). In addition, the larvae while feeding, leaves silken threads and contaminate the grain by producing dense webbing containing their fecal material and cast skins. The webbing formed is noticeably dense and tough, adding to the damage caused (Ayyar, 1934; Allotey and Azalekor, 2000).

For the control of stored produced insects, it is frequently safer to use plant materials with insecticidal,

*Corresponding author. E-mail: rita@agri.upm.edu.my.

antifeedant or repellent properties than the use synthetic insecticides (Prakash and Rao, 1997; Allotey and Azalekor, 2000) and several plant species have been noted for these purposes in pest management. However, no similar work has been carried out with rice moth, *C. cephalonica.* Moreover, black pepper (*Piper nigrum*) and physic nut (*Jatropha curcas*) are some of these plants that may possess insecticidal or antifeedant properties (Hayes et al., 2006; Salimon and Abdullah, 2008; Scott et al., 2008). In this study was evaluated the efficacy of petroleum ether extract of *P. nigrum* and *J.* curcas against rice moth, *C. cephalonica* larvae.

MATERIALS AND METHODS

Insects rearing

The rice moth (*C. cephalonica*) larvae were obtained from an entomology laboratory stock culture of the University Putra Malaysia (UPM) and reared on a medium including finely ground rice and maize flour in the ratio 1:1 (w/w) at 27 ± 1°C, 75 ± 5% RH with a 12:12 h light : dark cycle as described by Allotey and Azalekor, (2000) with some modifications. The food media were sterilized in an autoclave before experimentation. The subcultures and the tests were set up under the same conditions. *C. cephalonica* larvae (16 ± 1-day old) was used in the experiments. All the cultures in plastic containers (28×18×18 cm) were held in trays with guards submerged in water to prevent insects from crawling into them (Allotey and Azalekor, 2000).

Plant materials

Fruits of *P. nigrum* were supplied from Sarawak State in the North-East of Malaysia, and seeds of *J. curcas* were prepared from the botanical garden in University campus. Plant extracts of *P. nigrum* and *J. curcas* were prepared by the percolation method described by Sarker et al. (2006). Fruits of *P. nigrum* and seeds of *J. curcas* were ground to powder using a grinder prior to oil extraction. The powders (300 g) were soaked in methanol (95%) for 48 h, filtered and the residues were extracted afterwards. An equal volume of water was added to the crude extract, and then extraction was done by petroleum ether (Khani et al., 2011). The prepared extracts were concentrated by rotary evaporator (40°C) and stored at 4°C (Negahban et al., 2006) for further use.

Toxicity of plant extracts

Laboratory bioassays were conducted to evaluate toxicity of petroleum ether extracts of *P. nigrum* and *J. curcas* against *C. cephalonica*. To prepare stock solutions (w/v) of each extract, 10 g of crude extract was dissolved in 100 ml of respective solvent. Solutions were diluted using the formula: $C1V1 = C2V2$ (Gupta et al., 2011), where C1 and C2 are concentrations of the 1st and 2nd solution, V1 and V2 are volume of 1st and 2nd solution, respectively. For evaluating efficacy of plant extracts, rice kernels were treated with 2, 4, 6, 8, and 10% of prepared dilutions with n-hexane, and were then shaken to ensure uniform coverage of extracts on rice kernels.

After shaking, the treated rice in conical flask was placed on filter paper to evaporate the solvent. Subsequently, the rice kernels were divided five parts by electric balance (each part 5 g), after which each part was placed in the Petri dishes and 20 third instar larvae of *C. cephalonica* were introduced into each Petri dish. Infested Petri dishes were incubated at 27 ± 1°C, 75 ± 5% RH with a 12:12 h light: dark cycle. Petri dishes were checked out after 72 h to count the number of dead larvae for evaluating toxicity and followed 7 days to evaluate total mortality of *C. cephalonica* larvae. The Polo-Plus software was used (LeOra, 2003) to evaluate LC_{50} values, while percentage larvae mortality was calculated by probit analysis (Finney 1971).

Evaluation of antifeedant

No-choice test was carried out as described by Huang et al. (2002) and Gomah (2011) to determine antifeedant activity of plant extracts with some modifications. In brief, 1 ml of prepared concentrations of 1, 2, 3, 4 and 5% (or 2, 4, 6, 8 and 10 µL of plant extracts) or 1 ml solvent alone as control were applied on to 5 g rice kernels against 3rd instar larvae of *C. cephalonica*. After evaporating the solvent, the rice kernels were placed back in Petri dishes (5 cm diameter). Then 10 group-weighted larvae of *C. cephalonica* (starved for 24 h) were transferred to each pre-weighed rice kernels in Petri dishes. After 3 days of feeding under laboratory conditions (27 ± 1°C, 75 ± 5% RH with a 12:12 h light: dark cycle), the rice kernels and live insects were re-weighed, and mortality of insects, if any, was recorded. Five replicates of each treatment were prepared, including the control. Weight loss and nutritional indices were calculated as described by Mahdi and Rahman, (2008) and Huang et al. (2002). The following parameters were calculated:

Weight loss (%WL) = (IW - FW) × 100/ IW, where the IW is the initial weight and FW is the final weight;

Relative Growth Rate (RGR) = (A – B) / (B × day), where A is weight of live larvae on the third day (mg) / no. of live larvae on the third day, B is original weight of live larvae (mg) / original no. of larvae;

Relative Consumption Rate (RCR) = D / (B × day), where D is biomass ingested (mg) / no. of live larvae on the third day;

Efficiency of conversion of ingested food (ECI) (%) = (RGR / RCR) × 100.

The grain protection or loss protection due to application of plant extracts was evaluated by calculating the Feeding Deterrence Index (FDI) using the formula,

FDI (%) = (C – T) / C × 100, where C is the consumption of control rice kernels, and T is the consumption of treated rice kernels (Isman et al., 1990; Hung Ho et al., 2003).

The mortality data were adjusted for mortality in the control using Abbott's formula and expressed as percentages (Abbott 1925). Results of nutritional studies were expressed as means ± SEM and the significance of mean difference between treatments and control was assessed using the analysis of variance procedure at 5% probability level with individual pair wise comparisons with Tukey's test using the SAS v. 9.1.3 software package in Microsoft Windows 7 (SAS 2006).

Effect of plant extracts on egg hatchability

In brief, 5 g treated rice with petroleum ether extracts of *P. nigrum* and *J. curcas* at the 1, 2, 3, 4 and 5% dose level were placed in plastic Petri dishes (5 cm diameter) and twenty un-collapsed eggs (0 -24 h old) of *C. cephalonica* were introduced into each Petri dish using a fine brush. Five replicates of each treatment and untreated

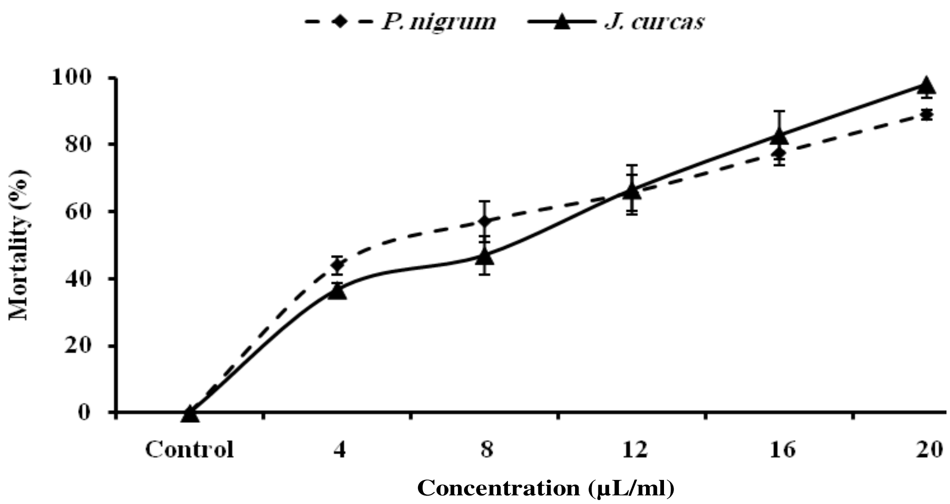

Figure 1. Mean mortality of *Corcyra cephalonica* 3rd instar larvae at 72 h after commencement of exposure to extracts.

Table 1. LC_{50} value of petroleum ether extracts of *Piper nigrum* and *Jatropha curcas* against *Corcyra cephalonica* larvae at 72 h after commencement of exposure.

Treatment	Slope ± SEM	(x^2)	Df	LC_{50} (µL/ml) (min - max)
P. nigrum (fruits)	2.26 ± 0.35	2.19	3	12.52 (11.23 - 16.08)
J. curcas (seeds)	2.26 ± 0.35	2.19	3	13.22 (11.23 - 16.08)

Df = Degree of freedom; 95% lower and upper fiducial limits are shown in parenthesis.

rice kernel were set up. After one week, Petri dishes were checked for eggs that failed to hatch (Huang and Subramanyam, 2004) and percentage egg hatch was calculated. Results were analyzed by analysis of variance (ANOVA) and mean values were adjusted by Tukey's comparison test.

Evaluation adult emergence

Rice kernels (5 g) were treated with plant extracts at 1, 2, 3, 4 and 5% and solvent only as a control. Then impregnated rice were placed in 25 ml Petri dishes and 20 larvae (3rd instar) of *C. cephalonica* were allowed to feed on to produce adults. The number of adults that emerged (Allotey and Azalekor, 2000) was recorded at the end of the experiment. Five replicates of each treatment and untreated rice kernel were set up. Data were statistically analyzed using the analysis of variance procedure in the SAS software (SAS 2006). For mortality tests, the original data were corrected using Abbotts (1925) formula. Means comparison were performed using Tukey's multiple comparison test at the $P<0.05$ level of probability.

RESULTS

Efficacy of plant materials against *Corcyra cephalonica*

Experiments were carried out to evaluate insecticidal activities of plant extracts from fruits of *P. nigrum* and seeds of *J. curcas* against *C. cephalonica* larvae. The medium lethal concentration (LC_{50}) of plant extracts on the *C. cephalonica* larvae 72 h from commencement of exposure are presented in Table 1. The results showed that the petroleum ether extracts from fruits of *P. nigrum* and seeds of *J. curcas* had LC_{50} values of 12.5 and 13.2 µL/ml against *C. cephalonica* larvae, respectively. Overlapping of the 95% fiducial limits showed that differences between the applied extracts against *C. cephalonica* larvae were non-significant. Petroleum ether extracts of *P. nigrum* and *J. curcas* at 12 µL/ml dose level caused mortality against *C. cephalonica* larvae with values of 65.6 and 66.5%, respectively, while high mortality was observed at 20 µL/ml dose level with values of 88.9 and 98.0%, respectively (Figure 1).

Evaluation of antifeedant efficacy of plant materials against *C. cephalonica*

Feeding deterrence indices (FDI) showed that the plant extracts had antifeedant action against *C. cephalonica* larvae at all concentrations. Also, petroleum ether extracts of *P. nigrum* and *J. curcas* showed antifeedant action against *C. cephalonica* larvae at a concentration of 6 µL/g rice kernels, with 55.87 and 48.08% reduction in feeding, respectively (Table 2). The results also showed

Table 2. Nutritional and feeding deterrence indices of *Corcyra cephalonica* larvae fed on rice kernels treated with petroleum ether extracts of *P. nigrum* and *J. curcas* at sublethal concentrations.

Extract	Concentration (µL/g rice kernels)	FDI (mean ± SEM) (%)	RGR (mean ± SEM) (mg/mg/day)	RCR (mean ± SEM) (mg/mg/day)	ECI (mean ± SEM) (%)	Mortality (%)
Petroleum ether extract of *P. nigrum*	0	-	0.071 ± 0.004[a]	0.448 ± 0.037[a]	16.41 ± 2.01[a]	0
	2	13.90 ± 9.98[c]	0.041 ± 0.003[bc]	0.429 ± 0.057[a]	10.45 ± 1.92[b]	2
	4	39.30 ± 20.44[b]	0.030 ± 0.008[c]	0.318 ± 0.103[ab]	11.36 ± 1.61[ab]	4
	6	55.87 ± 5.61[ab]	0.028 ± 0.003[c]	0.256 ± 0.043[b]	11.74 ± 1.26[ab]	14
	8	67.70 ± 16.82[a]	0.016 ± 0.007[cd]	0.196 ± 0.106[bc]	9.30 ± 3.95[b]	16
	10	60.21 ± 32.53[a]	0.013 ± 0.014[cd]	0.192 ± 0.045[bc]	6.72 ± 6.10[bc]	18
Petroleum ether extract of *J. curcas*	0	-	0.078 ± 0.007[a]	0.482 ± 0.019[a]	16.24 ± 1.48[a]	0
	2	24.78 ± 12.23[bc]	0.043 ± 0.009[bc]	0.367 ± 0.073[ab]	12.49 ± 2.14[ab]	4
	4	39.77 ± 11.94[b]	0.034 ± 0.001[c]	0.302 ± 0.036[b]	11.83 ± 1.24[ab]	8
	6	48.08 ± 9.14[ab]	0.032 ± 0.011[c]	0.290 ± 0.058[b]	10.66 ± 2.26[ab]	8
	8	64.70 ± 7.71[a]	0.007 ± 0.002[d]	0.183 ± 0.037[bc]	3.95 ± 1.33[bc]	8
	10	74.96 ± 7.63[a]	0.002 ± 0.002[d]	0.148 ± 0.054[bc]	0.88 ± 1.32[c]	14

Each datum represents the mean of five replicates. RGR, Relative growth rate; RCR, relative consumption rate; ECI, efficiency of conversion of ingested food; FDI, feeding deterrence index (Huang and Ho 1998). Means within columns followed by the same letters are not significantly different (P<0.05; Tukey's comparison test).

reduction in RGR, RCR and ECI of *C. cephalonica* larvae when the rice kernels were treated with *P. nigrum* and *J. curcas* extracts and significantly reduced RGR of *C. cephalonica* larvae at the lowest concentration dose level of 2 µL/g rice kernels (Table 2). Petroleum ether extract of *P. nigrum* and *J. curcas* were the most effective treatment.

This was in agreement with Senguttuvan et al. (1995) who showed that neem leaf powder, nochi leaf powder and neem oil are effective in controlling the rice moth, *C. cephalonica*, in groundnut kernels and pods. Aggarwal et al. (2001) also showed that *Acorus calamus* essential oils are effective on *C. cephalonica* larvae. In another study, Pathak and Krishna (1991) evaluated the effect of neem oil volatiles by confining the adults and larvae of *C. cephalonica* in a chamber containing neem oil. They recorded a marked decline in the reproductive potential and egg hatchability.

Effect of plant materials on egg hatchability

The results in Table 3 showed that egg hatchability was reduced by petroleum ether extract of *P. nigrum* and *J. curcas* at the lowest dose level (2 µL/ml) with values of 59 and 58%, respectively. Significant reductions in egg hatchability revealed the harmful effects of petroleum ether extracts of *P. nigrum* and *J. curcas* towards *C. cephalonica* eggs. This observation is in agreement with that of Khanam et al. (2008) who reported that food treated with *Jatropha gossypifolia* seed extract strongly inhibits the fecundity of *Tribolium castaneum* compared with *Tribolium confusum* at doses of 8000 and 16000 ppm. Bhardwaj et al. (2002) determined the effect of vegetable oils on the eggs of *C. cephalonica*. The treatments were castor bean (*Ricinus communis*), coconut (*Cocos nucifera*), groundnut (*Arachis hypogaea*), Indian mustard (*Brassica juncea*), sesame (*Sesamum indicum*), and sunflower (*Helianthus annuus*) oils at 0.5, 1.0, 2.0, 3.0 and 5.0%. All the vegetable oil concentrations were significantly superior to the control in reducing egg hatchability. In this study, the percentage of egg hatch inhibition in all the treatments increased with an increase in concentration.

Effect of plant materials on adult produce

The number of adults of *C. cephalonica* that emerged from the treated rice kernels decreased with increasing concentration of plant extracts. All the treatments strongly suppressed adult emergence of *C. cephalonica* larvae at the lowest concentrations with 2 µL/ml dosage (Table 4). The mean percent of F1 adults of *C. cephalonica* emerged

Table 3. Effect of petroleum ether extracts of *Piper nigrum* and *Jatropha curcas* on egg hatchability in *Corcyra cephalonica*.

Extract	Dosage (µL/ml)	Egg hatching % (mean ± SEM)*
Petroleum ether extract o f *P. nigrum*	Control	93 ± 2.55[a]
	2	59 ± 4.00[b]
	4	49 ± 1.87[bc]
	6	27 ± 2.55[e]
	8	22 ± 7.00[ef]
	10	9 ± 2.92[f]
Petroleum ether extract of *J. curcas*	Control	91 ± 2.92[a]
	2	58 ± 2.55[bc]
	4	48 ± 3.39[bc]
	6	32 ± 2.55[de]
	8	20 ± 2.24[ef]
	10	8 ± 1.22[f]

*Data are average of 5 replicates. Means within columns followed by the same letters are not significantly different (P<0.05; Tukey's multiple comparison test).

that emerged from the treated rice kernels strongly decreased even at the lowest concentrations of petroleum ether extracts from *P. nigrum* and *J. curcas*. These observation are in agreement with Adebowale and Adedire, (2006) who showed that the *J. curcas* oil at the lowest concentration of 0.5% suppressed adult emergence in *Callosobruchus maculatus*, also indicating that the oil had ovicidal activity.

The adults of *C. cephalonica* that emerged from rice kernels treated with petroleum ether extract of *P. nigrum* and *J. curcas* at the lowest concentration (2 µL/ml) were 3 and 8% compare with untreated rice kernels with 86 and 85%, respectively. In this regards, Senguttuvan et al. (1995) reported on the efficacy of a range of plant products, including neem leaf powder and edible oil in protecting stored groundnuts against the rice moth, *C. cephalonica* and noted that even though all the plant products and edible oils afforded protection, neem leaf powder and neem oil were most effective. Allotey and Azalekor, (2000) studied on groundnut kernels treated with *Citrus sinensis* at dosage of 0.5 and 2.0 g per 40 g of legume seeds, but differences between botanicals were not significant when all the dose levels were considered. They reported that *Eichhornia crassipes* suppressed the emergence of *C. cephalonica* to a greater extent at dosage of 0.5, 1.0 and 2.0 g than *C. sinensis* and *Chromolaena odorata.*

DISCUSSION

The Piperaceae family has been reported to have insecticidal activities due to presence of many potential phyto-chemicals. The *P. nigrum* extracts offer a unique and beneficial source of bio-pesticide material for the control of insect pests on a small scale (Chieng et al., 2008; Scott et al., 2008). The major components of *P. nigrum* fruit extracts such as piperine, caryophyllene and limonene are reported as having insecticidal properties. Many insecticidal components of plant extracts are mainly monoterpenes, such as limonene which have been shown to be toxic to *T. castaneum* (Awoyinka et al., 2006; Silva et al., 2008). Early studies on extracts of *P. nigrum* seeds had indicated that piperine and other active piperamides were responsible for the toxicity of the extracts to the adzuki bean weevil, *Callosobruchus chinensis* L. (Miyakado et al., 1979; Miyakado et al., 1980; Scott et al., 2005). *P. nigrum* seed oil formulations were found to be effective for protecting stored wheat from both stored grain pests, *Sitophilus oryzae* (L.) and *Rhyzopertha dominica* (F.) for more than 30 days at concentrations of 100 mg/L and higher (Sighamony et al., 1986).

Ethyl acetate extracts of *P. nigrum* seeds were also reported to be toxic to lepidopteran and hymenopteran herbivorous insects such as eastern tent caterpillar (*Malacosoma americanum* F.), forest tent caterpillar (*Malacosoma disstria* Hubner), pine sawfly (*Diprion similis* Hartig), gypsy moth (*Lymantria dispar* L.), spruce budworm (*Choristoneura fumiferana* Clemens), European pine sawfly (*Neodiprion sertifer* Geoffroy) and spindle ermine moth larvae (*Yponomeuta cagnagella* Hubner) (Scott et al., 2004, 2007). The toxic effect of *P. nigrum* was also reported against some test insects. *P. nigrum* was shown to be most toxic to *C. chinensis*, *Acanthoscelides obtectus*, *C. cephalonica*, *Ephestia cautella* Hubn., followed by *Oryzaephilus surinamensis* (L.), *Sitophilus zeamais* Mosteh, *Rhyzopertha dominica* (Fab.) and *T. castaneum* Herbst (Ponce de Leon 1983). The high toxicity effects of *P. nigrum* extracts against *C.*

Table 4. *Corcyra cephalonica* adult emergence from rice kernels treated with petroleum ether extracts of *Piper nigrum* and *Jatropha curcas*.

Extract	Dosage (µL/ml)	Adult emergence % (mean ± SEM)*
Petroleum ether extract of *P. nigrum*	Control	86 ± 1.87[a]
	2	3 ± 1.22[bc]
	4	1 ± 1.00[bc]
	6	0 ± 0.00[c]
	8	0 ± 0.00[c]
	10	0 ± 0.00[c]
Petroleum ether extract of *J. curcas*	Control	85 ± 2.74[a]
	2	8 ± 1.22[b]
	4	5 ± 1.58[bc]
	6	3 ± 2.00[bc]
	8	2 ± 1.22[bc]
	10	0 ± 0.00[c]

*Data are average of 5 replicates. Means within columns followed by the same letters are not significantly different (P<0.05; Tukey's multiple comparison test).

cephalonica larvae are attributed to the presence of high concentrations of well-known toxic components such as caryophyllene and piperine.

In the case of *J. curcas*, it is a multipurpose plant with many properties and considerable insecticidal potential (Openshaw 2000). Different parts of *J. curcas* contain the curcin and phorbol ester which are toxic alkaloids that inhibit animals from feeding on it (Igbinosa et al., 2009). The insecticidal and inhibition of progeny emergence activities of oil extracted from seeds of *J. curcas* has been reported by earlier researchers against several insect pests (Gübitz et al., 1999; Shah et al., 2005; Adebowale and Adedire, 2006; Li et al., 2006; Adabie-Gomez et al., 2007; Sirisomboon et al., 2007; Boateng and Kusi, 2008; Kumar and Sharma, 2008; Dowlathabad et al., 2010; Kshirsagar, 2010; Zahir et al., 2010; Kovendan et al., 2011; Tomass et al., 2011). This study is agreement with earlier studies; the petroleum ether extract of *J. curcas* seeds showed insecticidal activity against *C. cephalonica* larvae. These effects are attributed to the presence of oleic and linoleic acids which are well known toxic components.

The LC_{50} values of petroleum ether extract of *J. curcas* seeds at 72 h after exposure against *C. cephalonica* larvae were 13.2 µL/m. Li et al. (2006) investigated the toxicity of petroleum ether extracts of three different sources of *J. curcas* seeds and noted LC_{50} values of 8.0, 3.1 and 24.4 g/L against *S. oryzae*, respectively. Tomass et al. (2011) studied larvicidal activity of crude methanol leaf extracts from *J. curcas* and noted LC_{50} of 92.1 ppm against 3[rd] instar larvae of *Anopheles arabiensis*. In a similar study, Kovendan et al. (2011) reported high toxic activity of methanol leaf extracts of *J. curcas* against *Culex quinquefasciatus* Say from first to fourth instar larvae at dose levels of 1.2, 1.3, 1.4 and 1.5%. Rahuman et al. (2008) also reported the toxic effects of petroleum ether extracts of *J. curcas* against larvae of *C. quinquefasciatus* Say (LC_{50}=11.3 ppm) and *Aedes aegypti* (LC_{50} = 8.8 ppm). The petroleum ether extracts of *J. curcas* were reported to be more efficient than other tested plant extracts. Mortality percent also was highly significant for petroleum ether extract of *P. nigrum* and *J. curcas*. According to Chauhan *et al*., (1987) the extracts of *Croton sparsiflorus* (LC_{50}=0.073), *Annona squamosa* (LC_{50}=0.278) and *A. calamus* (LC_{50}=1.072) showed potential as safe insecticide. Moreover, Pathak and Tiwari (2010) reported 17±1.78% neem leaf larval mortality at 0.25% dose level, while 100% mortality was reported at 3.5% dose level of neem leaf. In addition, Jadhav (2009) reported LC_{50} values of *Annona squamosa* (14.36), *Tephrosia purpurea* (38.05) and *A. calamus* (33.11) after 72 h. Some possible reasons for these differences are insect strains, test conditions or test material. It was observed that the larval mortality increased with the increase of plant extracts concentrations. These effects are attributed to some well known toxic compounds such as piperine, caryophyllene, limonene, α-pinene, and β-pinene in *P. nigrum*, and oleic acid and linoleic acid in *J. curcas*

According to previous reports, any substance that reduces food consumption by an insect can be considered as an antifeedant. Isman (2002) defined antifeedant as a behavior-modifying substance that deter through a direct action on taste organs in insects. This definition excludes chemicals that suppress feeding by acting on the central nervous system, or a substance that has sublethal toxicity to the insect. Feeding inhibition in insect pests is the most important in the search for new and safer methods for pest control in stored grains. The high antifeedant effects of *P. nigrum* powder against *C. maculatus* at 25 and 30 g/kg on black gram were reported by Mahdi and Rahman, (2008). They attributed the antifeedant properties of *P. nigrum* to the piperine that killed the beetles earlier. Pepper seed extracts had also been shown to deterred Lily leaf beetles (*Lilioceris lilii* Scopoli) and *Acalymma vittatum* from damaging leaves of lily and cucumber plants respectively at concentrations in the 0.1 - 0.5 range (Scott et al., 2008). The finding of the present study are also is in agreement with that of Boateng and Kusi (2008) who reported good protection of cowpea seeds from *C. maculatus* damage in storage due to the use of *J. curcas* seed oil as a repellent and antifeedant. They also reported that doses of 1.0 ml/150 g grains and above gave superior mortality of the pest in cowpea. The mosquitocidal assay against fourth instar *A. aegypti* larvae showed that both linoleic and oleic acids had an LD_{50} of 100 µg/ml. In caterpillar bioassays, linoleic and oleic acids reduced the growth of *Helicoverpa zea* by 88 and 85%, *Lymantria dispar* by 93 and 91%, *Orgyia leucostigma* by 81 and 80% and *Malacosoma disstria* by 77 and 75%, respectively (Ramsewak et al., 2001). The petroleum ether extract of *P. nigrum* and *J. curcas* showed a positive dose dependent antifeedant activity. The reduced consumption of rice kernels treated with both plant extract by *C. cephalonica* larvae are likely to be the main cause of growth inhibition (Table 2). Both plant extract showed harmful effect on *C. cephalonica* larvae growth and development.

Significant reductions in egg hatchability revealed the harmful effects of petroleum ether extract of *P. nigrum* and *J. curcas* towards *C. cephalonica* eggs. This observation is in agreement with that of Khanam et al. (2008) who reported that food treated with *J. gossypifolia* seed extract strongly inhibited the fecundity of *T. castaneum* compared with *T. confusum* at doses of 8000 and 16000 ppm. These results are attributed to the physico-chemical action of the compounds, including piperine, caryophyllene, limonene, oleic acid, linoleic acid, menthone, menthol, α-pinene and β-pinene. Inhibition in egg hatching of the pulse beetle, *C. chinensis* with *P. nigrum* essential oils were reported by Chaubey (2008) who observed that egg hatching was inhibited significantly when fumigated with sublethal concentration of the essential oil. Inhibition in adult emergence with *P. nigrum* was reported by Mahdi and Rahman, (2008) who observed lesser number of *C. maculatus* adults emerging in black gram seeds treated with *P. nigrum* powder at doses of 25 and 30 g/kg. In treatments with *P. nigrum* oils, regression analysis showed a dose-dependent significant correlation with adult emergence (F=160.15), with the number of adults emerging from the fumigated larvae decreasing in a concentration-dependent manner (Chaubey, 2008). High efficacy of the hexane extract of *P. nigrum* on 2^{nd} instar larvae of *Spodoptera litura* was obtained with adult emergence of 19.79% for treatments of up to 40 mg/ml compared to the control (83.12%) (Fan et al., 2011). Additionally, inhibition of progeny emergence with *J. curcas* extracts were studied by Adabie-Gomez et al. (2007). It was shown that water ex-tracts of dried ground seeds of *J. curcas* at a dose of 5% (w/w) significantly reduced *S. zeamais* progeny emergence in treated grains of maize and cowpea.

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