Isolation and Identification of Insect Antifeedant Compound from Ethanol Extract of *Hemidesmus indicus* Root

Maya G. Pillai¹, Susha Dayanandan², Beena Joy³

**Abstract**

Phytochemicals with insect antifeedant potential can be used as a safer alternative to harmful chemicals that are used as grain protectants. The insect antifeedant effect of the extracts and fractions of *Hemidesmus indicus* root were tested against the stored grain insect pest *Corcyra cephalonica* Stainton. Bioactivity-guided study of ethanol extract of *Hemidesmus indicus* root led to isolation and identification of a triterpenoid, Lupeol with insect antifeedant potential. Although Lupeol showed insect antifeedant potential the ethanol extract was found to be more effective as an antifeedant. This implies that the synergistic action of compounds present in the ethanol extract of *H. indicus* root is responsible for the higher antifeedant potential.

**Keywords:** Antifeedant, Biopesticide, *Corcyra cephalonica*, Integrated Pest Management (IPM) Strategies, Lupeol, Post-harvest storage, Stored grain pest.

**Introduction**

Post-harvest storage of agricultural products is a matter of concern to farmers. Insect pests are a major challenge to stored grains and other food commodities. *Corcyra cephalonica* is a destructive insect pest of almost all stored food products and damage it by spinning web and converting it into a webbed mass; ultimately rendering unfit for human consumption. The insect pest management system often relied upon toxic broad-spectrum synthetic chemical insecticides. Controlling them with chemical pesticides is a serious concern as it leads to adverse environmental impact and health hazards.

Phytochemicals with insect antifeedant potential can be used as a safer alternative to harmful chemical pesticides. The identification of deterrent factors present in plants that could be isolated in sufficient quantities or synthesized for use as crop protectants should be considered for controlling insect pests.

*Hemidesmus indicus* commonly known as Anantamool or Indian Sarsaparilla is a slender laticiferous twining shrub distributed all over South East Asia, India, Sri Lanka, Malaysia, etc. It is widely used in various traditional medicines as tonic, demulcent, diaphoretic, blood purifier and diuretic. The present study is the first of its kind to analyse the antifeedant potential of *H. indicus* root ethanol extract against stored grain insect pest. The study was undertaken to isolate and characterise the bioactive compound present in ethanol extract of *Hemidesmus indicus* root against *C. cephalonica* larvae.

**Materials and Methods**

*Hemidesmus indicus* (Anantamool or Indian Sarsaparilla) root were washed, shade dried and powdered. The powder was subjected to fractional extraction on Soxhlet apparatus, using acetone, ethanol and water as solvents. As our earlier studies showed that ethanol extract is effective in controlling

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*Corcyra cephalonica*, the ethanol fraction was used for the study. The solvent from the extract was completely evaporated using rotary evaporator followed by vacuum evaporation and stored for further use.

**Fractionation by column chromatography**

The ethanol fraction was subjected to fractionation by column chromatography and the elution was monitored by TLC (Silica gel G; visualization: methanol-sulphuric acid reagent heated at 110°C and identical elutes (TLC monitored) were combined and concentrated and kept in a refrigerator. The fractionation by column chromatography resulted in the isolation of two compounds which were identified by spectral studies like IR, NMR and Mass Spectrometry.

**HPLC analysis**

**Preparation of sample solutions:** Accurately weighed 6mg of powdered ethanol extract of *H. indicus* root was taken in a 10 ml volumetric flask. The extract
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was dissolved in 7 ml of the HPLC grade acetonitrile. The volume was made up to 10 ml and the sample solution was sonicated using ultrasonicator for 10 min. Standard protocols were followed for HPLC analysis.

The ethanol extract was weighed and dissolved in ethanol. The extract (20 µl) in ethanol was injected onto the HPLC column at a temperature 30°C. The peaks were recorded at a wavelength 200nm using DAD detector. HPLC of different known concentrations of the standards α-amyrin and lupeol were also performed. The results obtained from the ethanol extract were compared with the standard. The quantification of the compounds present was done by plotting standard curve against known concentrations of α-amyrin and lupeol on X-axis and Peak area on the Y-axis.

Bioactivity-guided identification of antifeedant compound

Insect Rearing

The eggs of *Corcyra cephalonica*, (National Accession No: NBAII-MP-PYR-01) was obtained from the ICAR-National Bureau of Agricultural Insect Resource (NBAIR), Bangalore, Karnataka were reared in the laboratory conditions in standard rearing medium.

Ten pre-starved fourth instar larvae were introduced into the treated rice at different dosages of the fractions, subfractions and compounds. The minimum amount of acetone was used to dissolve all fractions, subfractions and compound along with water. Doses of fractions, subfractions and compounds were determined by the ratio of their presence in the ethanol extract of the corresponding doses. All the treatments were serially diluted to apply on rice at required doses. After 72 hours, changes in food consumed (weight change in rearing medium) and the difference in larval body mass were noticed. Two experimental sets having larval body mass were noticed. Two experimental sets having

Calculations

Nutritional indices and weight loss were calculated using (Ho et al., 2003; Isman et al., 1990) with some modifications. The following parameters were calculated using standard formulae

\[
\text{Mean weight gain WL} = \frac{(FW-IN)}{N}.
\]

FW - Weight after 3 days,

IN = Initial weight,

N = Initial number of larvae

Antifeedant activity or the grain protection or loss of protection due to the application of plant extracts was evaluated by calculating the Feeding Deterrence Index (FDI %)

\[
\text{FDI%} = \frac{(C - T)}{C} \times 100
\]

C is the consumption of control rice kernels and T is the consumption of treated rice kernels.

Percentage of starvation was calculated according to the formula (Abdel-Rahman and Al-Mozini, 2007)

\[
\% \text{Starvation} = \frac{(C-E)}{(C-S)} \times 100
\]

Where: C = Mean weight gain of control larvae after three days

E = Mean weight gain of treated larvae at each tested concentration after three days

S = Mean weight gain of starved control larvae after three days.

The EC_{50} dose which induced 50% starvation was calculated using probit analysis.

Data analysis

The data were tested for normality using the Shapiro–Wilk test and homogeneity of variance using the Levene test. Since the data were normally distributed with homogeneous variances, a significant treatment effect was determined using the one-way ANOVA followed by Duncan post hoc test at P < 0.05 using IBM SPSS statistics 20 software for windows and tables and the graphs were produced accordingly.

RESULTS AND DISCUSSION

Isolation of compounds by column chromatography

The fractionation of the ethanol extract of *H. indicus* root lead to the isolation of two compounds. NMR and IR studies of the isolated compounds revealed that the compounds were α-amyrin and lupeol.

HPLC analysis

From the HPLC-Chromatogram of the ethanol extract of *H. indicus* root, the peaks were seen at Rt-value 3.134 min and 3.42 min by using solvent system acetonitrile: water using gradient elution and the ratio of the solvents as given above. The peaks which could be identified from the graph were lupeol and α-amyrin respectively. A standard graph was drawn by taking the concentration of standard for each compound on the X-axis and peak area on Y-axis. From the graph, the concentration of compounds in the extract was calculated. From the calculations, it was found that α-amyrin was present at a concentration of 740µg/g and lupeol at a concentration of 4mg/g (Fig 1).

Bioactivity-guided fractionation studies

Isolation of ethanol extract initially yielded two fractions, hexane fraction 275mg and ethyl acetate fraction 4g and residual aqueous fraction 3.65g (Fig 1). The ethyl acetate fraction was the active fraction among the three. There was 15, 25.69, 44.47 and 62.13% feeding deterrence at the doses corresponding to 1, 2, 4 and 6% ethanol extract. The FDI for ethanol extract was 15.54, 26.15, 47.64 and 65.3% respectively for the dose tested (Table1).

Further isolation of ethyl acetate fraction gave five fractions (Fractions1-5). These fractions were concentrated and weighed and studied for antifeedant potential. Fraction 3 showed the highest antifeedant activity at the doses studied. There was a dose-dependent increase in feeding deterrent index (FDI) also. Fraction 3 gave FDI% of 13.96, 25.53, 49.15 and 61.66% respectively for the doses corresponding to 1, 2, 4 and 6% of ethanol extract (Table2).
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Fraction 3 was further isolated to subfractions A and B. The subfraction B showed the highest level of activity. The FDI% for the most active subfraction (SubFrB) was 13.2, 24.16, 46.13 and 60.38% respectively (Table 3) for the doses corresponding to the dose used in ethanol extract.

Lupeol was more active than alpha-amyrin as an antifeedant. The bioactivity of the compound was not at par but was close matching with that of ethanol extract. The FDI% was 12.32, 22.68, 43.57 and 59.08% for the doses studied (Table 3). Percentage Starvation was calculated for each of the test group. The percentage of starvation for ethyl acetate, Fraction 3, subfraction B lupeol and amyrin were 80.69%, 78.74%, 74.55%, 72.58% and 3.9% respectively. Amyrin-lupeol combination showed 75.08% starvation and for ethanol fraction, it was 95.89%. The EC50 for lupeol, which is the major component responsible for the antifeedant activity, was calculated as 3.45% (Probit analysis). The combination of amyrin and lupeol showed a small increase in indices when compared to lupeol alone.

The antifeedant effect of the non-volatile fractions isolated showed that the fraction 3 of ethyl acetate fraction of ethanol extract was most effective in inducing feeding deterrence. Further fractionation of fraction 3 yielded two subfractions (A and B). The subfraction B was found to be most effective and further isolation and characterization led to the identification of two triterpene compound, lupeol and α-amyrin. The compound lupeol has also shown antifeedant potential against fourth instar larvae of *Corcyra cephalonica*, while α-amyrin was less effective.

Numerous secondary products are generated by various metabolic pathways of plants. These plant secondary metabolites such as polyphenols and steroids have gained utmost attention in recent years due to their diverse pharmacological potential and benefits rendered to different industries (Atanasov, 2015). These natural compounds have shown to be effective in agricultural pest management, as they function as antifeedant, growth inhibitors, toxic, repellent, fumigant, attractant etc. and also causes moulting disruption, respiratory inhibition, pheromone-based behavioural adaptations, oviposition deterrence and fecundity reduction against target pest populations (Ajabri et al., 2017; Koul, 2008; Nawaz et al., 2017). Majority of plant secondary metabolites are untouched and are of particular interest in insecticide development (Isman, 2006; Miresmailli and Isman, 2014).

The pharmacological activities of natural triterpenoids and their therapeutic potentials are well documented (Dzubak et al., 2005, 2006a, 2006b; Mahato et al., 1992; Shanmugam et al., 2012; Zhou et al., 2017). Triterpenes are part of the terpenoid family, an extensive group of natural products, which are abundant in the plant kingdom. Triterpenes are reported having anti-inflammatory activity. Similarly, these compounds are reported to be antioxidant (Fiorentino et al., 2007), antiparasitic (Danelli et al., 2009), antiviral (Kuo et al., 2009; Zhu et al., 2014), antifungal (Yuan et al., 2009), antibacterial (Yuan et al., 2009), antitumor,

### Table 1: Mean percentage feeding deterrent index of fourth instar larvae of *C. cephalonica* after 72 hours of feeding on Hexane, ethyl acetate and aqueous fractions of *H. indicus* root ethanol extract treated diet. The result is expressed as mean ± SD followed by the same letter in each drug group do not differ significantly using Tukey’s test.

| Hexane | Ethyl acetate | Aqueous | Ethanol (Dose %w/w) |
|--------|---------------|---------|---------------------|
| (Dose mg/10g rice) | (Dose mg/10g rice) | (Dose mg/10g rice) | (Dose mg/10g rice) |
| 2.60 ± 0.94* (acetone control) | 2.60 ± 0.94* (acetone control) | 2.60 ± 0.94* (acetone control) | 2.60 ± 0.94 a (acetone control) |
| 7.91 ± 1.64*(2.75) | 15.00 ± 1.4* (40) | 7.08 ± 1.2* (36.55) | 15.54 ± 2.32 (1%) (100) |
| 10.84 ± 1.23*(5.5) | 25.69 ± 1.56* (80) | 10.66 ± 0.34* (73) | 26.15 ± 3.9 (2%)(200) |
| 16.98 ± 1.43*(11) | 44.47 ± 2.37* (160) | 15.98 ± 1.5* (146) | 47.64 ± 3.17 (4%) (400) |
| 17.72 ± 1.89*(16.5) | 62.13 ± 1.75* (240) | 17.05 ± 1.5* (219) | 65.30 ± 2.9 (6%)(600) |

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Fig 1: HPLC chromatogram of ethanol extract of *H. indicus* root.
Table 2: Mean percentage Feeding deterrent index of fourth instar larvae of C. cephalonica after 72 hours of feeding on fractions of ethyl acetate fractions of H. indicus root ethanol extract treated diet. The result is expressed as mean ± SD followed by the same letter in each drug group do not differ significantly using Tukey’s test.

| F1 (Dose in mg /10g rice) | F2 (Dose in mg /10g rice) | F3 (Dose in mg /10g rice) | F4 (Dose in mg /10g rice) | F5 (Dose in mg /10g rice) |
|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) |
| 7.78 ± 1.8* (0.96) | 10.92 ± 2.21* (2.2) | 13.96 ± 1.7* (11.7) | 6.81 ± 2.28* (0.83) | 6.56 ± 2.74* (14) |
| 10.55 ± 1.24* (0.192) | 15.95 ± 3.76* (4.4) | 25.53 ± 4.07* (22.34) | 8.32 ± 1.68* (1.66) | 7.87 ± 2.25* (28) |
| 16.57 ± 1.73* (0.384) | 26.39 ± 3.8* (8.8) | 49.15 ± 1.06* (44.68) | 10.90 ± 1.28* (3.32) | 8.72 ± 1.18* (56) |
| 17.1 ± 1.47* (0.558) | 31.31 ± 4.15* (3.2) | 61.66 ± 2.28* (67.02) | 16.77 ± 1.58* (4.98) | 12.62 ± 1.91* (84) |

Table 3: Mean percentage Feeding deterrent index of fourth instar larvae of C. cephalonica after 72 hours of feeding on subfractions of fraction 3 of H. indicus root Lupoel, α-amyrin and ethanol extract treated diet. The result is expressed as mean ± SD followed by the same letter in each drug group do not differ significantly using Tukey’s test.

| SubFrA (Dose mg/10g) | SubFrB (Dose mg/10g) | Lupeol (Dose mg/10g) | α-amyrin (Dose mg/10g) | α-Amlyn + lupeol (Dose mg/10g) |
|-----------------------|----------------------|----------------------|------------------------|--------------------------------|
| 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) | 2.60 ± 0.94* (Acetone control) |
| 5.70 ± 1.6* (2.19) | 13.20 ± 1.68* (63.4) | 12.32 ± 0.94* (0.4) | 4.45 ± 1.1* (0.074) | 13.96 ± 1.7* (0.474) |
| 8.90 ± 1.72* (4.38) | 24.16 ± 4.87* (126.8) | 22.68 ± 2.1* (0.8) | 7.52 ± 1.4* (0.148) | 24.99 ± 4.5* (0.848) |
| 10.75 ± 1.61* (8.76) | 46.13 ± 3.97* (253.6) | 43.57 ± 2.62* (1.6) | 13.35 ± 1.8* (0.296) | 47.87 ± 5.3* (1.896) |
| 12.72 ± 2.25* (13.14) | 60.38 ± 4.31* (380.4) | 59.08 ± 1.39* (2.4) | 19.35 ± 2.9* (0.444) | 62.7 ± 2.5* (2.844) |
In this regard, you may please reply to the reviewer comments mail. Isolation and Identification of Insect Antifeedant Compound from Ethanol Extract of *Hemidesmus indicus* Root

Anticarcinogenic (Chen *et al.*, 2010; Gordaliza, 2010; Kuo *et al.*, 2009), antidiabetic (Castellano *et al.*, 2013; Nazaruk and Borzym-Kluczyk, 2015; Patil *et al.*, 2011), antiulcerogenic (de Andrade *et al.*, 2008), hepatoprotective (Li *et al.*, 2017; H. Wu *et al.*, 2016), neuroprotective (Koneri *et al.*, 2014), analgesic (Nieto *et al.*, 2013; C.-R. Wu *et al.*, 2010) etc.

The antifeedant activity of ethanol extract of *Hemidesmus indicus* root on the fourth instar larvae of *Corcyra cephalonica* could be mainly due to the triterpenoid compound lupeol. Triterpenes have been reported to be active against the leaf miners *Ctenopseustis obliquana* (Walker) (Lepidoptera: Tortricidae) in feeding deterrence bioassays (Thoison *et al.*, 2004). Insect antifeedant and phytotoxic effects of several pentacyclic triterpenes of plant origin on *Spodoptera littoralis*, *Leptinotarsa decemlineata* have been reported by (Caballero *et al.*, 2001; Pavela, 2010).

Even though lupeol showed antifeedant effect, the ethanol extract was found to be the most effective when compared to fractions and compound isolated. This could be due to the synergistic effect of some other compound present in the ethanol extract. Most of the well-documented plant-derived insect antifeedants are triterpenoids. These compounds have a 30-carbon skeleton and are often highly oxygenated. The limonoids from the neem (*Azadirachta indica*) and chinaberry (*Melia azedarach*), trees, contains azadirachtin and toosendanin respectively and limonin from *Citrus* species are very well documented as insect antifeedants. Other antifeedants belonging to the triterpenoids include cardenolides, steroidal saponins and withanolides (Isman, 2002).

Thus along with the identified compound, one or more factors present in ethanol extract of *H. indicus* root are involved in the induction of feeding deterrence in the fourth instar larvae of *C. cephalonica*. Combinations of the two were also tested against the larvae. The results reveal that lupeol is the major bioactive component responsible for the antifeedant potential of the ethanol extract of *H. indicus* root.

From the chemical studies, it is evident that the volatile, as well as the non-volatile components of the *Hemidesmis indicus*, have contributed to the antifeedant effect of the plant against the rice pest *Corcyra cephalonica*. Since ethanol extract is more effective as a grain protectant than lupeol further ecotoxicological studies were carried out in the ethanol extract to ensure its safety.

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**REFERENCES**

Abdel-Rahman, H. R. and Al-Mozini, R. N. (2007). Antifeedant and toxic activity of some plant extracts against larvae of cotton leafworm Spodoptera littoralis (Lepidoptera: Noctuidae). Pakistan Journal of Biological Sciences, 10 (24): 4467–4472. http://www.docsdrive.com/pdfs/ansinet/pjbs/2007/4467-4472.pdf

AlJabr, A.M., Hussain, A., Rizwan-ul-Haq, M. and Al-Ayedh, H. (2017). Toxicity of plant secondary metabolites modulating detoxification genes expression for natural red Palm Weevil Pesticide development. Molecules. 22(1).

Atanasov, A.G. (2015, December). Discovery and resupply of pharmacologically active plant-derived natural products: A review 33: 1582–1614. https://doi.org/10.1016/j.biotechadv.2015.08.001

Caballero, C., Castaera, P., Ortego, F., Fontana, G., Pierro, P.,...
Goh, S. H. (2003). Meliternatin: A feeding deterrent. Phytochemistry. 58(2): 249–256. https://doi.org/10.1016/S0031-9422(01)00253-9.

Castellano, J. M., Guinda, A., Delgado, T., Rada, M. and Cayuela, J. A. (2013). Biochemical basis of the antidiabetic activity of oleandric acid and related pentacyclic Triterpenes. Diabetes. 62(6): 1791 LP – 1799. Retrieved from http://diabetes.diabetesjournals.org/content/62/6/1791.abstract

Chen, C.-C., Wu, J.-H., Yang, N.-S., Chang, J.-Y., Kuo, C.-C., Wang, S.-Y. and Kuo, Y.-H. (2010). Cytotoxic C(35) terpenoid cryptotironene from the bark of Cryptomeria japonica. Organic Letters. 12(12): 2786–2789. https://doi.org/10.1021/ol1009027

Danelli, M.G.M., Soares, D.C., Abreu, H.S., Pe?anha, L.M.T. and Saraiva, E.M. (2009). Leishmanicidal effect of LLD-3 (1), a nor-triterpene isolated from Lophanthera lactescens. Phytochemistry. 70(5): 608–614. https://doi.org/10.1016/j.phytochem.2009.03.009

de Andrade, S.F., Comunello, E., Noldin, V.F., Monache, F.D., Cechin Filho, V. and Niero, R. (2008). Anticancerogenic activity of fractions and 3,15-dioxo-21alpha-hydroxy friedelane isolated from Maytenus robusta (Celastraceae). Archives of Pharmacal Research. 31(1): 41–46.

Dzubak, P., Hajduck, M., Vydra, D., Hustova, A., Kvasnica, M., Biedermann, D., ... Sarek, J. (2005). Pharmacological activities of natural triterpenoids and their therapeutic implications. Nat. Prod. Rep. 2: 1990–2005. https://doi.org/10.1039/b515312n

Dzubak, P., Hajduck, M., Vydra, D., Hustova, A., Kvasnica, M., Biedermann, D., ... Sarek, J. (2006a). Pharmacological activities of natural triterpenoids and their therapeutic implications. Natural Product Reports. 23(3): 394–411. https://doi.org/10.1039/b515312n

Fiorentino, A., D’Abrasca, B., Pacifico, S., Mastellone, C., Piccolella, S. and Monaco, P. (2007). isolation, structure elucidation and antioxidant evaluation of cydondiosine A, an unusual terpenoid from the fruits of Cydonia vulgaris. Chemistry and Biodiversity. 4(5): 973–979. https://doi.org/10.1002/cbdv.200790090

Gordaliza, M. (2010). Cytotoxic terpene quinones from marine sponges. Marine Drugs. 8(12): 2849–2870. https://doi.org/10.3390/md8122849

Ho, S. H., Wang, J., Sim, K. Y., Ee, G. C. L., Imiyabir, Z., Yap, K. F., ... Goh, S. H. (2003). Melittin: A feeding deterrent and larvicidal polyoxgenated flavone from Melicope subumnifoliate. Phytochemistry. 62(7): 1121–1124. https://doi.org/10.1016/S0031-9422(02)00632-5

Isman, M. (2002). Insect antifeedants. Pesticide Outlook. 13(4): 152–157. https://doi.org/10.1039/b206507

Isman, M. B. (2006). Botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology. 51(1): 45–66. https://doi.org/10.1146/annurev.ento.51.110104.151146

Isman, M. B., Koul, O., Luczynski, A. and Kaminski, J. (1990). Insecticidal and antifeedant bioactivities of neem oils and their relationship to azadirachtin content. Journal of Agricultural and Food Chemistry. 38(6): 1406–1411. https://doi.org/10.1021/jf00096a024

Koneri, R. B., Samaddar, S., Simi, S. M. and Rao, S. T. (2014). Neuroprotective effect of a triterpenoid saponin isolated from Momordica cymbalaria Fenzl in diabetic peripheral neuropathy. Indian Journal of Pharmacology. 46(1): 76–81. https://doi.org/10.4103/0253-7613.125179

Koul, O. (2008). Phytochemicals and insect control: An antifeedant approach. Critical Reviews in Plant Sciences. 27(1): 1–24. https://doi.org/10.1080/07352680802053908

Kuo, R.-Y., Qian, K., Morris-Natschke, S. L. and Lee, K.-H. (2009, October). Plant-derived triterpenoids and analogues as antitumor and anti-HIV agents. Natural Product Reports. 26: 1321–1344. https://doi.org/10.1039/b810774m

Li, Z.-W., Huang, Y., Tang, S.-N., Li, K., Huang, Y., Qiao, X., ... Ye, M. (2017). Hepatoprotective activities of Antrodia camphorata and its triterpenoid compounds against CCI4-induced liver injury in mice. Journal of Ethnopharmacology. 206: 31–39. https://doi.org/10.1016/j.jep.2017.05.020

Mahato, S. B., Nandy, A. K. and Roy, G. (1992). Triterpenoids. Phytochemistry. 31: 2199–2249. https://doi.org/10.1016/0031-9422(92)83257-Y

Miresmailli, S. and Isman, M. B. (2014). Botanical insecticides inspired by plant-herbivore chemical interactions. Trends in Plant Science. 19. https://doi.org/10.1016/j.tplants.2013.10.002

Nawaz, M., Cai, W., Jing, Z., Zhou, X., Mabubu, J. I. and Hua, H. (2017). Toxicity and sublethal effects of chlorantraniliprole on the development and fecundity of a non-specific predator, the multicolored Asian lady beetle, Harmonia axyridis (Pallas), Chernosphere. 178: 496–503. https://doi.org/10.1016/j.chemosphere.2017.03.082

Nazaruk, J. and Borzym-Kluczyk, M. (2015). The role of triterpenes in the management of diabetes mellitus and its complications. Phytochemistry Reviews. 14: 675–690. https://doi.org/10.1007/s11101-014-9369-x

Nieto, F.R., Cobos, E.J., Entrena, J. M., Parra, A., Garcia-Granados, A. and Baeyens, J. M. (2013). Antialdolymic and analgesic effects of maslinic acid, a pentacyclic triterpenoid from Olea europaea. Journal of Natural Products. 76(4): 737–740. https://doi.org/10.1021/np300783a

Patil, R., Patil, R., Ahirwar, B. and Ahirwar, D. (2011). Isolation and characterization of anti-diabetic component (bioactivity—guided fractionation) from Ocimum sanctum L. (Lamiaceae) aerial part. Asian Pacific Journal of Tropical Medicine. 4(4): 278–282. https://doi.org/10.1016/j.2013.10.002

Pavela, R. (2010). Antifeedant activity of plant extracts on Leptinotarsa decemlineata Say. and Spodoptera littoralis Bois. larvae. Industrial Crops and Products. 32(3): 213–219. https://doi.org/10.1016/j.indcrop.2010.04.010

Shanmugam, M.K., Nguyen, A.H., Kumar, A.P., Tan, B.K.H. and Sethi, G. (2012). Targeted inhibition of tumor proliferation, survival and metastasis by pentacyclic triterpenoids: Potential role in prevention and therapy of cancer. Cancer Letters. 320: 158–170. https://doi.org/10.1016/j.canlet.2012.02.037

Thoison, O., Sévenet, T., Niemeyer, H. M. and Russell, G. B. (2004). Insect antifeedant compounds from Notholagus dombeyi

Savona, G. and Rodríguez, B. (2001). Effects of ajugarins and related neoclerodane diterpenoids on feeding behaviour of Leptinotarsa decemlineata and Spodoptera exigua larvae. Phytochemistry. 58(2): 249–256. https://doi.org/10.1016/S0031-9422(01)00253-9.

Isman, M. B. (2006). Botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology. 51(1): 45–66. https://doi.org/10.1146/annurev.ento.51.110104.151146

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6
and N. pumilio. Phytochemistry. 65(14): 2173–2176. https://doi.org/10.1016/j.phytochem.2004.04.002

Wu, C.R., Hseu, Y.C., Lien, J.C., Lin, L.W., Lin, Y.T. and Ching, H. (2010). Triterpenoid contents and anti-inflammatory properties of the methanol extracts of ligustrum species leaves. Molecules (Basel, Switzerland). 16(1): 1–15. https://doi.org/10.3390/molecules16010001

Wu, H., Tang, S., Huang, Z., Zhou, Q., Zhang, P. and Chen, Z. (2016). Hepatoprotective Effects and Mechanisms of Action of Triterpenoids from Lingzhi or Reishi Medicinal Mushroom Ganoderma lucidum (Agaricomycetes) on alpha-Amanitin-Induced Liver Injury in Mice. International Journal of Medicinal Mushrooms. 18(9): 841–850. https://doi.org/10.1615/IntJMedMushrooms.v18.i9.80

Yuan, W.H., Yi, Y., Tang, H.F., Liu, B.-S., Wang, Z.L., Sun, G.Q., ... Sun, P. (2009). Antifungal Triterpene Glycosides from the Sea Cucumber Bohadschia marmorata. Planta Med. 75(02): 168–173. https://doi.org/10.1055/s-0028-1088348

Zhou, M., Zhang, R. H., Wang, M., Xu, G. B. and Liao, S. G. (2017). Prodrugs of triterpenoids and their derivatives. European Journal of Medicinal Chemistry. 131: 222–236. https://doi.org/10.1016/j.ejmech.2017.03.005

Zhu, J., Zhang, Y., Ghosh, A., Cuevas, R.A., Forero, A., Dhar, J., Sarkar, S.N. (2014). Antiviral activity of human OASL protein is mediated by enhancing signaling of the RIG-I RNA sensor. Immunity. 40(6): 936–948. https://doi.org/10.1016/j.immuni.2014.05.007