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CHEMICAL COMPONENTS AND INSECTICIDAL PROPERTIES OF *BAKAIN* (*MELIA AZEDARACH* L.) - A REVIEW

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ABSTRACT

Melia azedarach L., a deciduous tree of moderate size, grown throughout warm countries, possesses various uses in our day-to-day life. The extract of plant parts (leaves, fruits or root bark) in different solvent systems (methanol, benzene, hexane, acetone) when applied to insect-pests of field plantation crops, acts as phagorepellent, ovipositional deterrent and antifeedant and also causes morphogenetic defects. In this review, the work done by different workers on insecticidal properties of the tree has been described and discussed alongwith the LC_{50}\$AFC_{50}$\$LC_{95}$. of extracts from different parts of the plant against the different pests of agricultural importance.

Indiscriminate use of synthetic insecticides over four decades has caused enormous damage to agroecosystems and human habitant by way of contaminating foodstuffs, killing non-target organisms, resurgence of insects of secondary importance, increasing insecticide resistant pest populations and posing a number of health hazards. As a result, there is a growing demand and awareness for the use of eco-friendly insecticides to manage pests of agricultural importance globally. Natural plant products are more desirable as they are safer to non-target organisms, less persistent in the environment and are compatible with other methods of control in an integrated pest management system.

Bakain, *Melia azedarach* L., a close relative of neem, from the family Meliaceae which occurs in India and other tropical and subtropical countries, contains chemical constituents which makes it a candidate in pest control. It has been reported to possess antimicrobial, insecticidal and nematicidal properties. It is also known for its anti-inflammatory, antipyretic, antimycotic, antiulcer, spermacidal and antifertility activity. It has been reported that all the species of *Melia* are avoided by locusts (Carlothays, 1910). *M. azedarach* is avoided by locusts during a plague in Kathiawar Sind (Mann and Burns, 1927). Attempts on pesticidal properties of *M. azedarach* as repellent and phagorepellent, ovipositional deterrent, antifeedant, disturbances in metamorphosis, larval mortality and adverse effect on reproductive potential, have been discussed in detail under this review.

TAXONOMY

There are five poorly defined species of *Melia* from tropical Asia and Africa. Mabberley (1984), stated that all species/forms/variations/cultivars of *Melia* complex in Asia and Pacific regions are *Melia azedarach*. Consequently *Melia dubia* CAV, *M. australasia* A Juss, *M. toosendan* Sub and Zucc, *M. conchinchinesis* M.J. Roem, *M. superba* Roxb, *M. floribunda* Carr, *M. azedarach* var. sempervirens L. and numerous other species are synonymous with *M. azedarach*. *M. azedarach* cv. umbraculifera, the Texas umbrella tree, which grows in the southern USA, is considered a mutation of *M. azedarach*. In contrast to all other species, *M. azedarach* variations/forms have a flattened crown of branches.

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Melia azedarach is a deciduous tree of moderate size with a height of 6-10 m and cylindrical trunk (3.5 m long 1.62 m girth). The tree is drought resistant and is found growing wild in the sub-Himalayan tract up to 2000 m above sea level with an annual precipetation of 600-1000 mm. It is resistant to frost and a fast growing tree.

The bark of the tree is dark grey with shallow longitudinal furrows with bi - or occasionally tripinnate leaves with serrated leaflets either ovate or lanceolate; flowers are lilac with a fragrance exuded from axillary panicles. The fruit is an ellipsoidglabose drupe with 4-5 seeds.

The origin of *M. azedarach* is West Asia and now it is grown throughout the tropics. In the plains of India, it is grown as an ornamental avenue tree and sometimes as a shade tree in coffee and tea plantations. It bears a spreading crown and withstands a colder climate than the neem tree (*Azadirachta indica*). It flowers during the hot season and fruits ripen during the cold weather and well suited for the afforestation purposes.

The plant regenerates freely from seeds during rains under natural conditions. Artificially it can be propagated by direct sowing, transplanting seedlings from nursery or by cuttings and root suckers. With annual girth increment of 3.75-5.00 cm the plant grows fast in early stages. It grows well upto girth of 1 m. The tree which is prone to attack of *Formica* spp. does not live long and needs to be replaced after 20 years. The common names for *M. azedarach* have been placed in Table 1. The number of chromosomes is the same as in the neem tree, *Azadirachta indica* (n=14, 2n=28).

Table 1. Common names* for *Melia azedarach* L.

Name		Country
Bakain	(Hindi)	India
Drek	(Punjabi)	
Limbado	(Gujarati)	
Taruka vepa	(Telugu)	
Malai vemba	(Tamil)	
Karin vembu	(Malyalam)	
Sema veppu	(Malyalam)	
Arbevu	(Kannada)	
Hutchu	(Kannada)	
Persian lilac		England
Lilac		
Chinaberry		
Paradise tree		
White cedar		
Umbrella tree		
Bead tree		
Syringa		
Hoop tree		
China tree		
Pride of India		
Lilas des indes		France
Lilas de chine		
Lilas de perse		
Paraiso		
Margoiser		
Lelaila		Singapore
Aleli		
Pasilla		
Violeta		
Mindi kechil		Malayasia
Persischer zedrachbaum		Germany
Chiwesischer holunder		
Poteronosterbaum		
Paradiesbaum		
Persischer fleider		
Cinamomo		Brazil
Ku lian		China

* Maheswari (1963)

PHYTOCHEMISTRY

The plant is known to contain a number of organic molecules i.e. terpenoids (1 - 96, Table 2), flavonoids (97 - 101, Table 3), steroids (102 - 115, Table 4), acids (116 - 122, Table 5) and anthraquinones (123 - 125, Table 6).

Triterpenoids, meliantriol (60, Table 2), melianone (58, Table 2) and melianol (55, Table 2) have been isolated from the fruits of *M. azedarach* L. Of these, meliantriol (60, Table 2) shows very strong growth disrupting (antifeedant) properties against the desert

Table 2. Terpenoids and Limonoids from *Melia azedarach*

Compound	Structure	Plant part	Reference
6-Acetoxy-7α-hydroxy-3-oxo-14β, 15β-epoxymeliac-1,5-diene	1	Roots	Srivastava and Gupta (1985)
6-Acetoxy-3β-hydroxy-7-oxo-14β, 15β-epoxymeliac-1, 5-diene-3-O-β-D-glucopyranoside	2	Roots	Srivastava and Gupta (1985)
6-Acetoxy-14,15-epoxy-3, 11-dihydroxymeliaca-1,5-diene-7-one	3	Fruits	Srivastava (1986)
7α-Acetoxy-14β, 15β-epoxygedunan-1-ene-3-O-β-D-glucopyranoside	4	Stem bark	Saxena and Srivastava (1986)
12-Acetoxy amoorastatin	5	Stem bark	Ahn *et al.* (1994)
12-O-Acetyl azedarachin-A	6	Root bark	Huang *et al.* (1995)
12-O-Acetyl azedarachin-B	7	Root bark	Huang *et al.* (1995)
1-Acetyl-3-tigloyl-11-methoxy meliacarpinin	8	Root bark	Itokawa *et al.* (1995)
12-O-Acetyl trichilin-B	9	Root bark	Nakatani *et al.* (1994)
2α-Acetyl-29-deacetyl-29-isobutyryl sendanin	10	Root bark	Oelrichs *et al.* (1983)
Amoorastatin	11	Stem bark and Fruits	Polonskiy *et al.* (1978)
Amorastatone	12	Fruits	Polonsky *et al.* (1979)
Azecin-1	13	Roots	Srivastava and Srivastava (1996a and b)
Azecin-2	14	Roots	Srivastava and Srivastava (1996 a and b)
Azecin-3	15	Roots	Srivastava and Srivastava (1996 a and b)
Azecin-4	35	Roots	Srivastava and Srivastava (1996 a and b)
Azedarachin-A	16	Root bark	Huang *et al.* (1995)
Azedirachtin-A	17	Fruits	Kraus *et al.* (1985)
Azedarachin-C	18	Root bark	Huang *et al.* (1995)
1-Cinnamoyl-3-acetyl-11-hydroxy meliacarpin	19	Leaves	Bohnenstengel *et al.* (1999)
1-Cinnamoyl-3-acetyl-11-methoxy meliacarpinin	20	Root bark	Takeya *et al.* (1996)
1-Cinnamoyl-3,11-dihydroxy- meliacarpinin	21	Fruits	Lee *et al.* (1991)
1-Cinnamoyl-3-hydroxy-11-methoxy meliacarpinin	22	Root bark	Takaya *et al.* (1996)
1-Cinnamoyl-3-methacrylyl-11-hydroxy meliacarpin	23	Leaves	Bohnenstengel *et al.* (1999)
1-Cinnamoyl melianolone	24	Fruits	Lee and Klocke (1987)
1-Cinnamoyl melianone	25	Fruits	Lee *et al.* (1991)
Compositin	26	Fruits	Purushothaman *et al.* (1985)
Compositolide	27	Fruits	Purushothaman *et al.* (1985)
1-O-Deacetyl ohchinolide-B	28	Fruits	Ochi *et al.* (1978)
1-Deoxy-3-methacrylyl-11-methoxy meliacarpinin	29	Root bark	Takeya *et al.* (1996)
Deacetyl salannin	30	Leaves	Huang *et al.* (1996)
29-Deacetyl sendanin	31	Fruits	Itokawa *et al.* (1995)
1-Deacetyl nimbolinin-A	32	Fruits	Kraus *et al.* (1981)
1-Deacetyl nimbolinin-B	33	Root bark	Kraus *et al.* (1981)
3-Deoxymelianone	34	Fruits	Schulte *et al.* (1979)
1,12-Diacetyl trichilin-B	35	Root bark	Nakatani *et al.*(1994)
7,12-Diacetyl trichilin-B	36	Root bark	Nakatani *et al.* (1994)
21,23: 24,25-Diepoxy-tirucall-7-ene-21-ol	37	Fruits	Schulte *et al.* (1979)
1,3-Dicinnamoyl-11-hydroxy-meliacarpin	38	Leaves	Bohnenstengel *et al.* (1999)
3ß, 7α-Dihydroxy-21,23-epoxy-apotirucalla-14, 24-diene-21-one	39	Seeds	Lavie and Levy (1971)
3-Epimelianol	40	Fruits	Lyons and Taylor (1975)
3-Epimeliantriol	41	Fruits	Lyons and Taylor (1975)

(Contd.

Compound	Structure	Plant part	Reference
Fraxinellone	42	Stem bark	Ekong *et al.* (1969)
Gedunin	43	Fruits	Akisanya *et al.* (1960)
12-α-Hydroxyamoorastatin	44	Fruits	Itokawa *et al.* (1995)
12-Hydroxyamoorastatone	45	Stem bark	Ahn *et al.* (1994)
3-Hydroxy eupha-7, 24-diene-21,16-olide	46	Stem bark	Chiang and Chang (1973)
29-Isobutyl sendanin	47	Root bark	Itokawa *et al.*(1995)
Kulactone	48	Stem bark	Chang and Chiang (1969)
Kulinone	49	Stem bark	Chang and Chiang (1969)
Kulolactone	50	Stem bark	Chang and Chiang (1969)
Meldenin	51	Seeds	Srivastava (1986)
Meliacarpinin-E	52	Root bark	Huang *et al.* (1996)
Meliandiol	53	Fruits	Dilawari *et al.* (1994)
Melianin-A	54	Stem wood	Okagun *et al.* (1975)
Melianin-B	55	Stem wood	Okogun *et al.* (1975) Suhag *et al.* (2000)
Melianol	56	Fruits	Wang *et al.* (1994)
Melianolone	57	Fruits	Lee and Klocke (1987)
Melianone	58	Fruits	Lyons and Taylor (1975)
Melianoninol	59	Fruits	Wang *et al.* (1994)
Meliantriol	60	Fruits	Wang *et al.* (1994)
Meliatoxin-A1	61	Fruits	Oelrichs *et al.* (1983)
Meliatoxin-A2	62	Fruits	Oelrichs *et al.* (1983)
Meliatoxin-B1	63	Fruits	Oelrichs *et al.* (1983)
Meliatoxin-B2	64	Fruits	Oelrichs *et al.* (1983)
Methylkulonate	65	Stem bark	Chiang and Chang (197
Nimbolidin-A	66	Fruits	Huang *et al.* (1996)
Nimbolidin-B	67	Fruit Root bark	Huang *et al.* (1996)
Nimbolin-A	68	Wood	Ekong *et al.* (1969)
Nimbolin-B	69	Wood	Ekong *et al.* (1969)
Nimbolinin-A	70	Fruits	Kraus *et al.* (1981)
Nimbolinin-B	71	Fruits	Huang *et al.* (1996)
Ohchinal	72	Fruits	Ochi *et al.* (1978)
Ohchinin	73	Fruits	Fakuyama *et al.* (1983)
Ohchinin acetate	74	Fruits	Ochi *et al.* (1978)
Ohchinolal	75	Fruits	Fakuyama *et al.* (1983)
Ohchinolide-A	76	Fruits	Kraus *et al.* (1981)
Ohchinolide-B	77	Fruits	Kraus *et al.* (1981)
α-Pinene	78	Stem bark Leaves	Cao-Bing *et al.*(1997)
β-Pinene	79	Stem bark Leaves	Cao-Bing *et al.* (1997)
Salannal	80	Root bark	Huang *et al.* (1996)
Salannin	81	Root bark Seeds	Huang *et al.* (1996)
Sendanal	82	Fruits	Ochi *et al.* (1978)
Sendandal	83	Fruits	Ochi *et al.* (1978)
Sendanin	84	Fruits	Itokawa *et al.* (1995)
Sendanolactone	85	Stems	Suhag *et al.* (2000)
Surianol	86	Stems	Suhag *et al.* (2000)
1-Tigloyl-3-acetyl-11-methoxy meliacarpinin	87	Root bark	Itokawa *et al.* (1995)
1-Tigloyl-3,20-diacetyl-11-methoxymeliacarpinin	88	Root bark	Takeya *et al.* (1996)
3-Tigloyl-1,20-diacetyl-11-methoxymeliacarpinin	89	Root bark	Takeya *et al.* (1996)
3-O-Tigloyl ohchinin	90	Fruits	Fakuyama *et al.* (1983)
Trichilin-B	91	Root bark	Nakatani *et al.* (1994)
Trichilin-D	92	Root bark	Nakatani *et al.* (1994)
Trichilin-H	93	Root bark	Nakatani *et al.* (1994)
α-Terpinene	94	Stem bark Leaves	Cao-Bing *et al.* (1997)
α-Terpineol	95	Stem bark Leaves	Cao-Bing *et al.* (1997)
Vilasinin	96	Fruits	Purushothasman *et al.* (1985)

Table 3. Flavonoids from *Melia azedarach*

Compound	Structure	Plant part	Reference
4', 5-Dihydroxy flavone-7-O-α-L-rhamnopyranosyl-(1→4)-β-D-glucopyranoside	97	Stem bark	Mishra and Srivastava (1984)
Apigenin-5-O-β-D-galactopyranoside	98	Roots	Gupta and Srivastava (1985)
Kaempferol-3-O-β-rutinoside	99	Leaves	Marco *et al.* (1986)
Kaempferol-3-L-rhamno-D-glucoside	100	Leaves	Aritomi *et al.* (1964)
Rutin	101	Leaves	Marco *et al.* (1986)

Table 4. Steroids from *Melia azedarach*

Compound	Structure	Plant part	Reference
24-Methylenecycloartanol	102	Roots	Schulte *et al.* (1979)
24-Methylenecycloartanone	103	Roots	Schulte *et al.* (1979)
4-Stigmastanen-3-one	104	Roots	Schulte *et al.* (1979)
4-Campestene-3-one	105	Roots	Schulte *et al.* (1979)
6β-Hydroxy-4-canpesten-3-one	106	Root bark	Nair and Chang (1973)
6β -Hydroxy-4-Stigmasten-3-one	107	Root bark	Nair and Chang (1973)
Azedarachol	108	Root bark	Nakatani *et al.* (1985)
Campesterol	109	Seeds	Cabral *et al.* (1995)
Cholesterol	110	Seeds	Cabral *et al.* (1995)
Cycloeucalenol	111	Roots	Schulte *et al.* (1979)
Cycloeucalenone	112	Roots	Schulte *et al.* (1979)
Stigmasterol	113	Seeds	Cabral *et al.* (1995)
β-Sitosterol	114	Roots	Schulte *et al.*(1979)
β -Sitosterol-ß-D-glucoside	115	Roots	Schulte *et al.* (1979)

Table 5. Acids from *Melia azedarach*

Compound	Structure	Plant part	Reference
Linoleic acid	116	Seeds	Bashyal and Poudell (1991)
Linolenic acid	117	Seeds	Bashyal and Poudell (1991)
Oleic acid (9-octadecenoic acid)	118	Seeds	Bashyal and Poudell (1991)
Palmitic acid (hexadecanoic acid)	119	Leaves	Bashyal and Poudell (1991)
Stearic acid (octadecanoic acid)	120	Fruits	Bashyal and Poudell (1991)
Trans-cinnamic acid	121	Roots, fruits	Schulte *et al.* (1979)
Vanillic acid (4-Hydroxy-3-methoxy benzoic acid)	122	Roots	Schulte *et al.* (1979)

Table 6. Anthraquinone from *Melia azedarach*

Compound	Structure	Plant part	Reference
1,3,5,8-Tetrahydroxy-2-methyl anthraquinone; 8-Me ether, 3-O-α-L-rhamnopyranoside	123	Stem bark	Srivastava and Mishra (1985)
1,5-dihydroxy-8-methoxy-2-methyl-anthraquinone-3-O-α-L-rhamnopyranoside	124	Stem bark	Srivastava and Mishra (1985)
1,8-dihydroxy-2-methyl anthraquinone-3-O-β-D-galactopyranoside	125	Stem bark	Srivastava and Mishra (1985)

locust, *Schistocerca gregaria*. Some of the compounds isolated from other parts of Chinaberry tree during 1980s, showed antifeedant properties in a bioassay while others did not have any antifeedant activity and show strong growth disrupting properties. The latter applies to the azadirachtin analogues.

Three derivatives of vilasinine (96, Table 2) isolated from *M. azedarach*, have considerably less antifeedant effect than related

compounds isolated from *A. indica* (Kraus *et al.*, 1987). Pohnl (1985) found a strong antifeedant effect of 1-O-deacetyl ohchinolide-B (28, Table 2) at 0.05 % against *Epilancha varivestis*. Other compounds with antifeedant activity are 2-α-acetyl-29-deacetyl-29-isobutyryl-sendanin (10, Table 2) and deacetyl-nimbolin-A (deacetylated 68, Table 2). Recent researchers have shown that azadirachtin exists only in *Azadirachta spp.* (Morgan and Thornton, 1973; Warthen and Morgan, 1990). The methanolic extract of green Chinaberry fruits have yielded two very potential insecticide tetranortriterpenoids, a novel meliacin termed as 1-cinnamoyl melianone (25, Table 2) and a new derivative of meliacarpin i.e. 1-cinnamoyl-3, 11-dihydroxymeliacarpin (20, Table 2). Various tetranortriterpenes, the meliatoxins A_1, A_2 and B_2 (56, 57 and 59, Table 2), which have been isolated in Australia from *M. azedarach* var australica, may be responsible for the established high toxicity in Chinaberry fruits to mammals, such as pigs (Sinniah and Baskaran, 1981). However, in children, fruits (6 - 8) can cause nausea and spasms followed by death if swallowed by mistake. Leaves seem to be much less toxic as they are used as fodder for goats in India. The leaves of *M. azedarach* are occassionally fed forcely to sheep and goats to free them of parasitic worms in their digestive systems (Bhandari and Govil, 1978).

MELIA AZEDARACH AS REPELLENT: Repellent activity of *Melia azedarach* has been summarised in Table 7. Extracts of leaves, kernels, seeds/fruits/drupes were found to be effective repellent to more than 20 crop pests under field and laboratory conditions.

Table 7. *Melia azedarach* L. extracts as repellents

Plant part	Test insect	Test material	Lab/Field	Reference
Leaves	Termite	Wheat	Field	Hussain (1929)
Leaves	*Schistoceca gregaria* *Locusta migratoria migratorioides* *Acridium aegiptium* *Calliplanus italicers* *Diciostaurus macrocanus*	Vineyard	Field	Volkonsy (1937 a & b)
Leaves	Grasshopper	Vegetable	Field	Sergent (1944)
Leaves Pulp Kernels	Locust	-	Lab	Lavie and Jain (1967 a & b)
Leaves and Seeds	*Spodoptera littoralis*	-	Lab	Ahmed *et al.* (1978)
Leaves	Gastrimargus transversus	-	Lab	Mazeed and Aziz (1981)
Seeds	*Otheris fullonica*	-	-	Baptist (1945)
Fruits	*Tribolium casteneum*	Grain	Lab	Atwal and Sandhu (1970)
Drupes	*Sitophillus oryzae*	Rice	Lab	Teotia and Pandey (1978)
Leaves	*Raphidopalpa faveicollis*	Cucurbit plants	Lab	Bodhade and Borle (1979)
Drupes	*Sitotroga cerealella*	Rice	Lab	Teotia and Tiwari (1977)
Seeds	*Callosobruchus chinensis*	Mungbean	Lab	Saxena (1987)
	Diacrisia obliqua	Jute	Lab	
Seeds	*Panoynchus citri* *Aleurocanthus spiniferous*	Citrus	Field	Chiu (1987)
Kernels	*Mythimna separata*	-	-	Chiu (1987)
Seeds	*Triatoma infestans*	-	-	Rojas and Hirschmann (1988)
Seeds	*Aphis gossyii*	-	Lab	Matter *et al.* (1993)

MELIA AZEDARACH AS ANTIFEEDANT: Antifeedant activity of *M. azedarach* was observed against 68 insect pests of different crops on the basis of 93 experiments conducted in laboratory and field conditions (Table 8) and it is evident that the seed has strong antifeedant activity.

Table 8. *Melia azedarach* L. extracts as antifeedants

Plant part	Test insect	Test material	Lab/ Field	Reference
Leaves	Locust	-	-	Leepage *et al.* (1946)
Leaves	*Helicoverpa zea*	-	-	McMillian *et al.* (1969)
Fruits	*Helicoverpa armigera*			
	Spodoptera litura			
Leaves	*Epilachna varivestis*	Bean	Lab field	Steets (1975)
Leaves	*Spodoptera littoralis*	Castor bean	-	Khadr *et al.* (1986)
Leaves	*Pieris rapae*	Cabbage	Lab	Zhu (1991)
	Pieris brassicae			
	Plutella xylostella			
	Mamestra brassicae			
Leaves	*Epilachna varivestis*	-	Lab	Zhu and Ermel (1991)
Leaves	Cystidia couaggaria	-	Lab	Liu *et al.* (1992)
Fruits	*Brevicoryne brassicae*	Cabbage	Lab	Astrakhantzev *et al.* (1936)
Seeds	*Pieris brassicae*	Cabbage	Lab	Atwal and Pajni (1964)
Seeds	*Schistocera gregaria*	-	Lab	Lavie *et al.*(1967)
Seeds	*Sitotroga cerealella*	Rice	Lab	Teotia and Tiwari (1971)
Drupes	*Agrotis segetum*	-	Lab	Gupta *et al.* (1973)
Kernels	*Pieris brassicae*	Cabbage	Lab	Sandhu and Singh (1975)
Kernels	*Athalia proxima*	Mustard	Lab	Pandey *et al.* (1977)
	Athalia calamus			
Fruits	*Epilachna varivestis*	-	Lab	Kraus *et al.* (1981)
Timber	*Coptotermes formosanus*	-	Field	Huang and Chen (1981)
Seeds	*Thaumetopoea pityocampa*	Pine	-	Yelecki *et al.* (1981)
Kernels	*Scirpophaga incertulus*	Rice	Lab	Chiu and Zhang (1982)
Seeds	*Panonychus citri*	Citrus	Field	Chiu *et al.* (1982)
Seeds	*Ariathisa abyssina*	-	Lab	Zhang and Chiu (1983)
	Leucania compta			
Seeds	Stomoxys	Guinea pig wheat	Lab	Omollo (1983)
	Glossina			
	Aedes			
	Locusts			
Seeds	*Scirpophaga incertulus*	Rice	Lab field	Jianzhang *et al.* (1983)
	Sogatella fructifera			
	Nilaparvata lugens			
Leaves	*Nilaparvata lugens*			
Seeds	*Dicladispa armigera*	-	Lab	Islam (1984)
	Nephotettix nigropictus			
Seeds	*Nilaparvata lugens*	Rice citrus	Lab field	Chiu (1984)
	Pieris rapae			
	Ariathsia abyssina			
	Diaphorna citri			
	Panonycus citri			
	Phyllocnistis citrella			
	Spodoptera litura			
	Anomala cupripes			

(Contd.

Plant part	Test insect	Test material	Lab/ Field	Reference
Kernels	*Orseolia oryzae*	Rice	Lab	Chiu *et al.* (1984)
Seeds	*Nilaparvata lugens, Sogetella frucifera*	Rice	Lab	Saxena *et al.* (1984)
	Nephotettix virescens			
	Spodoptera frugiperda			
Seeds	*Epilachana varivestis*	-	Lab	Schwinger *et al.* (1984)
Seeds	*Dysdercus koenigii*	-	Lab	Jaipal and Singh (1985)
Drupes	*Henosepilachna vigintioctopunctata*	-	-	Tewari and Moorthy (1985)
Kernels	*Pieris rapae*	Cabbage	Lab	Zhang and Chiu (1985)
Seeds	*Aphis citricola*	Citrus	Lab	Chiu and Zeng (1986)
Seeds	*Scirpophaga incertulus*	Rice	Field	Tu (1986)
Leaves	-	-	-	Ascher (1987)
Fruits				
Seeds				
Seeds	*Phyllocnistis citri*	Citrus	Lab	Chiu (1987)
	Aleurocanthus spiniferous			
	Mythimna separata			
Leaves	*Dicladispa armigera*	Rice	Lab	Islam (1987)
Seeds	*Callosobruchus chinensis*			
Seeds	*Acalymma vittatum*	Bean	Lab	Mikolajczek and Reed (1987)
Seeds	*Nephotettix nigropictus*	Rice	Lab	Haque and Islam (1988)
Fruits	*Phyllocopturata oleivora*	Citrus	Lab	Zhang and Xu (1988)
Kernels	Lychee stink bugs	-	Lab	Chiu (1989)
Seeds	*Pieris brassicae*	Leaf disc cabbage	Lab	Zhu (1989)
	Pieris rapae			
	Pluttela xylostella			
	Mamestra brassicae			
Fruits	*Scirtothrips aurantii*	-	-	Nasseh and Mughai (1990)
Drupes	*Thaumetopea pityocampa*	*Pinus mungo*		Bruer and Devkota (1990)
Drupes	*Spodoptera frugiperda*	*Lettuce leaves*	Lab	Breur and Schmidt (1990)
Seeds	*Spodoptera litura*	-	Lab	Macleod *et al.* (1990)
Bakain	*Anoplophora glabrippenis*	Poplar	Field	Sun *et al.* (1990)
Seeds	*Aphis fabae*	*Vicia faba*	Lab	Dimetry and Schmidt (1991)
Fruits	*Locusta migratoria migratoriodes*	-	Lab	Wen and Schmutterer (1991)
Fruits	*Helicoverpa armigera*	-	Lab	Anwar *et al.* (1992)
Fruits	*Phthormaea operculella*	-	Lab	Nasseh and Alfurassy (1992)
Seeds	*Empoasca sp.*	*Saliva officinallis*	-	Alessandro and Sletta (1993)
	Eupteryx sp.			
Fruits	*Schistocera gregaria*	-	-	Doumbia (1994)
Seeds	*Pieris brassicae*	*Cabbage*	Lab	Dilawari *et al.* (1994 a, b)
	Plutella xylostella			
Fruits	*Aphis gossypii*	-	-	Hashem *et al.* (1994)
	Myzus persicae			
	Spodoptera littorallis			
Fruits	*Spodoptera littorallis*		Lab	Kheirallah *et al.* (1994)
Fruits	*Rhizopertha dominica*			
	Callosobruchus chinensis			
	Tribolium casteneum			
	Sitophillus oryzae	-	-	El-Lakwah *et al.* (1994,a,b,c and 1995)
Seeds	*Spodoptera litura*	-	-	Lee and Shih (1995)
Seeds	*Rhodnius prolixus*	Blood	Lab	Cabral *et al.* (1996)
Seeds	*Sesamia nonagrioides*	-	-	Riba *et al.* (1996)
Bakain + Tithonia	Termite	Fruits	Field	Adoyo *et al.* (1997)

(Contd.

Plant part	Test insect	Test material	Lab/ Field	Reference
Seeds	*Agrotis ipsilon*	Artificial diet	Lab	Ahmed *et al.* 1997)
Seeds	*Spodoptera frugipeerda*	Artificial diet	Lab	Hernatidez and Vendramin (1997)
Stems				
Seeds				
Stems	*Manduca sexata*	Potato	Pot Exp.	Hu *et al.* (1997)
	Leptinotarsa decemlineata	Tomato		
		Sorghum		
Fruits	*Tetranychus urticae*	-	Lab	Ismail (1997)
	Stethorus gilvifrons			
Seeds	*Callosobruchus chinensis*	Chickpea	Storage	Javid and Mpotokwane (1997)
Seeds	*Anthonomus eugenii*	Sweet pepper	Lab	Palma and Serrano (1997)
Seeds	*Phthorimaea operculella*	-	Lab	Sharma *et al.* (1997)
Seeds	*Spodoptera littoralis*	Artificial diet	Lab	Salam and Ahmed (1997)
Fruits	*Spodoptera littoralis*	-	Lab	Schmidt *et al.* (1997)
	Agrotis ipsilon			
Fruits	*Xanthogalanca luteola*	-	Lab	Valladares *et al.* (1997)
Seeds	*Spodoptera frugiperda*	Corn	Lab	Vendramim and Scampini (1997)
Fruits	*Thaumetopoea processionea*	Quercus robr	Lab	Breuer and Loaf (1998)
		Quercus rubra		
Seeds	*Helpopeltis theivora*	-	Lab	Deka *et al.* (1998)
Seeds	*Spodoptera littoralis*	-	Lab	Harshem *et al.* (1998)
Fruits	*Spodoptera littoralis*	-	Lab	Schmidt *et al.* (1998)
	Agrotis ipsilon			
Fruits	*Helicoverpa armigera*	-	-	Singh *et al.* (1998)
Seeds	*Helopeltis theivora*	-	-	Deka *et al.* (1999)
Fruits	*Busseola fusca*	Maize	Field	Gebre-Amlaki and Azerefegne (1999)
Root	*Agrotis ipsilon*	-	Lab	Nakatani *et al.* (1985)
Bark				
Fruits	Termite	-	Field	Lin and Wang (1988)
Leaves				
Bark				
Seeds				
Bark	*Pieris rapae*	-	Lab	Zhang *et al.* (1988)
Bark	*Epilachna varivestis*	-	-	Schmutterer (1989)
Bark	*Pieris rapae*	-	-	Wang *et al.* (1992)
Fruits	*Otheris furnacalis*			
Bark	*Pieris rapae*	-	Lab	Zhang and Chiu (1992)
Leaves	*Epilachna varivestis*	Bean leaves	Lab	Zhu and Schmutterer (1993)
Fruits				
Bark	*Spodoptera exigua*	-	Lab	Nakatani *et al.* (1994)
Bakain	*Rhodnius prolixus*	-	Lab	Cabral et al. (1995)
Bakain	*Spodoptera eridania*	-	Lab	Huang *et al.* (1995)
Leaves	*Spodoptera frugiperda*	-	Lab	Rodriguez and Vendramim (1996)
Stems				
Roots	-	-	-	Srivastava and Srivastava (1996)
Bark	*Anoplofora nobilis*	-	Lab	Caobring *et al.* (1997)
Leaves				
Bark	*Spodoptera littoralis*	-	Lab	Nakatani *et al.* (1998)
Bark	*Spodoptera littoralis*	-	Lab	Zhou *et al.* (1998)
Leaves	*Spodoptera littoralis*	-	Lab	Bohnenstengel *et al.* (1999)

The toxic effects of the seeds/fruits extracts of bakain in terms of insect mortality have been reported by the several workers under the laboratory conditions (Astrakhantzev *et al.*, 1936; Atwal and Pajini, 1964; Gupta *et al.*, 1973; Teotia and Tiwari, 1971 and 1977; Huang and Chen, 1981; Yelecki *et al.*, 1981; Saxena *et al.*,1984; Khadr *et al.*, 1986; Saxena, 1987; Dimetry and Schmidt, 1991; Wern and Schmutterer, 1991; Nasseh and AlFurassy, 1992; Doumbia, 1994; Dilawari *et al.* 1994 a and b; Hernatidez and Vendramim, 1997; Palma and Serrano, 1997; Salam and Ahmed, 1997; Singh *et al.*, 1998; CaoBing *et al.*, 1997).

Seeds fruits extracts have also been observed to cause growth inhibition and morphogenetic defects in immatue stages of insects (Steets, 1975; Omollo, 1983; Chiu, 1987; Zhu, 1989 and 1991; Zhu and Ermel, 1991; Liu *et al.*, 1992; Breuer and schmidt, 1990; Anwar *et al.* 1992; Hashem *et al.*, 1994; Riba *et al.*, 1996; Bohnenstengel *et al.*, 1999).

Several workers (Omollo, 1983; Chiu *et al.*, 1984; Islam, 1984; Jaipal and Singh, 1985; Islam, 1987; Zhu, 1989; Zhu and Schumutterer, 1993; Dilawari *et al.*, 1994 a and b; Ahmed *et al.*, 1997; Sharma *et al.*, 1997; Deka *et al.*, 1998) have recorded ovipositional deterrent activity of the seed extracts of the plant under the laboratory conditions. The effective concentrations of bakain extracts ranged from 0.0027 to 7.542 % depending upon pests (Table 9).

Table 9. Toxicity of *Melia azedarach.* extract or its compounds against various crop pests

Extract/Solution	Pest (Order)	Toxicity	Reference
Sendanin	*Pectinophora gossypiella* (Lepidoptera)	200 ppm [1](LC_{95}) 60 ppm [2](AFC_5)	Kubo and Klocke (1982)
	Helicoverpa virescens (Lepidoptera)	11 ppm (AFC_{50})	
	Helicoverpa zea (Lepidoptera)	9 ppm (AFC_{50})	
Sendanol	*Spodoptera frugiperda* (Lepidoptera)	70 ppm (AFC_{50})	
	Pectinophora gossypiella (Lepidoptera)		
	Pectinophora gossypiella (Lepidoptera)		
Toosendanin	*Nilaparvata lungens* (Homoptera)	0.52 % (II instar) 1.20 % (III instar)	Chiu *et al.* (1983)
Methanolic extract	*Spodoptera litura* (Lepidoptera)	0.0027 % (Choice, AFC_{50})	Chiu and Zhang (1984)
Methanolic extract		0.26 % (No-choice, AFC_{50})	
Toosendanin		0.12 % (Choice, AFC_{50})	
		1.27 % (No-choice, AFC_{50})	
		0.0027 % (Choice, AFC_{50})	
		0.09 % (No-choice, AFC_{50})	
Meliandiol	*Papillo japonica* (Coleptera)	0.012 % (AFC_{50})	Schwinger (1985)
Petroleum ether extract	*Corcyra cephalonica* (Lepidoptera)	7.542 % (LC_{50})	Chauhan *et al.* (1987)
Seeds extract	*Panonychus citri* (Acarina)	0.27 % (LC_{50}) 1.65 % (LC_{50})	Wei *et al.* (1989)
	Amblyseius neusami (Acarina)		

(Contd.

Extract/Solution	Pest (Order)	Toxicity	Reference
Melianone	*Helicoverpa virescens* (Lepidoptera)	0.12 ppm [3](EC_{50})	Lee *et al.* (1991)
Seeds	*Spodoptera littorallis* (Lepidoptera)	1.65 % (LC_{50})	Hashem *et al.* (1988)
Meliacarpins	*Spodoptera littorallis* (Lepidoptera)	0.27 ppm (EC_{50}) 0.48 ppm (LC_{50})	Bohnenstengel *et al.* (1999)

Melia toosendanin
[1]LC: Lethal concentration
[2]AFC: Antifeedant concentration
[3]EC: Effective concentration

BAKAIN VIS-À-VIS NEEM

Numerous plant species have been reported to possess the pest control properties but only a few seem to be ideally suited for the practical utilization. Amongst these, neem (*Azadirachta indica* A. Juss) and *bakain* (*Melia azedarach* L.) are the most promising plants from the insecticidal perspective (Schmutterer, 1990 and 1995). Neem seed kernel extracts and its commercial formulations have been found to be effective insecticide against several insect pests (Schmutterer, 1990 and 1995) and fit in integrated pest management (Schmutterer, 1988; Gupta and Sharma, 1997). *Melia azedarach* has been evaluated against several pests (Tables 7 - 9) but its comparative efficacy in relation to neem has been tested only in four cases. Steets (1975) has shown that cabbage leaves which have been sprayed with the crude extracts of neem and *bakain* at concentrations of 2 to 5 % are effective to the larvae of *Plutella xylostella* L. and the former exhibited higher antifeedant activity than the latter. Hashem *et al.*(1998) have claimed neem to be the most potent botanical pesticide followed by *bakain* when tested against different instars of *Spodoptera littoralis*. Gajmer (2000) has tested the methanolic seed extracts of *bakain* and neem against different stages of *Earias vittella* and it has been found that 4 to 5 % neem extract is as effective as 8 to 10 % *bakain* extract concentration. Similar conclusions have been drawn by Kraus *et al.* (1981); Schwinger *et al.* (1984) and Chari *et al.* (1999).

ECONOMIC IMPORTANCE

The heartwood of *bakain* is tough and durable; and it is used for making boxes, sportswares, agricultural implements and for the roofing material. Fruits of the plant are used for the production of alcohol because these contain glucose and starch. Goats and birds have been observed to eat the fruit without any ill effect. The stones of the fruits are used in making necklaces and rosaries. Its oil is used for preparing the candle wax, for pest control and lice killing etc.

The various parts of the tree are used for curing diseases (Dastur, 1968; and Oelrichs *et al.*, 1983). Its flowers are used to relieve the nervous headache, for killing lice, for eruptic skin diseases, as antilithic and diuretic agent. Its fruits have been prescribed for relieving pain, stiffness and inflammation in the midguts. Its gum is used in spleen enlargement. Leaves of the plant are known to increase haemoglobin and are also antithelmithic. Its bark is also effective as antithelmithic. Bark is used for the treatment of leprosy, eczema and asthamatic attacks (Oelrichs *et al.*, 1983).

CONCLUSIONS AND FUTURE RESEARCH

Bakain is widely grown as ornamental tree in the tropical and the subtropical countries. It has great potential in the pest control because of its repellent, deterrent, antifeedant, morphogenetic defects and toxic

properties against a vast range of crop pests. However, it is imperative to study the variation of active ingredients of *bakain* in different locations to identify the compounds, which hold promise against the insect pests. It is also desirable to study the effects of active constituents of bakain on non-target species including natural enemies.

This plant is known to contain 96 terpenoids and limonoids (1-96, Table 2); 5 flavonoids (97-101, Table 3); 14 steroids (102-115, Table 4); 7 carboxylic acids (116-122, Table 5) and 3 antraquinones (123-125, Table 6).

The biological activity of most of these compounds are yet to be tested. Thus, there is scope for further research related to agricultural use of this plant.

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