BIOLOGICAL ACTIVITY OF DIFFERENT PLANT EXTRACTS WITH PARTICULAR REFERENCE TO THEIR INSECTICIDAL, HORMONAL AND ANTIFEEDING ACTIONS

BY
K. SARADAMMA

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DECLARATION

I hereby declare that this thesis entitled "Biological activity of plant extracts with particular reference to their insecticidal, hormonal and antifeeding actions" is a bonafide record of research work done by me during the course of research and that this has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar titles of any other University or Society.

K. SARADAMMA.

Vellayani,
24-4-1989

CERTIFICATE

Certified that the thesis entitled "Biological activity of different plant extracts with particular reference to the insecticidal, hormonal and antifeeding actions" is a record research work done independently by Smt. K. SARADAMMA under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

25.4.89

N. Mohan Das.

Chairman
Advisory Committee

Professor & Head,
Dept. of Entomology,
College of Agriculture,
Vellayani.

Vellayani,
25.4.89.

Approved by:

CHAIRMAN

Dr. N. Mohan Das.

MEMBERS

Dr. M.M. Koshy. 22/11/90

Dr. V.G. Nair.

Dr. K.P. Vasudevan Nair.

Dr. P.B. Gopinathan.

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INTRODUCTION

Antifeedants or feeding deterrents have been recognized as a very potential group of allelochemicals for pest control since they protect the crop right from the time of application (Jermy, 1966; Chapman, 1974; Munakata, 1977 and Jacobson, 1980). A large number of such chemicals have been identified during the last two decades (Mc Millan et al., 1969; Jacobson et al., 1975; Pandey et al., 1977; Rao and Mehrotra, 1977; Sudhakar et al., 1978; and Raman and Ananthakrishnan, 1986). The active compounds isolated and identified ranged from a simple compound like ethane (Sumimoto et al., 1975) to acids, phenols, terpenes, alcohols, lactones, alkaloids and other nitrogen containing compounds quinones, diterpenoides and sesquiterpenoid molecules (Koul, 1982)

The classic example of a plant containing feeding deterrency is the neem tree, Azadirachta indica Juss. which shows activity against a broad spectrum of pest species. The effectiveness of the components of neem has been studied in detail by several workers (Pradhan et al., 1963; Mc Millan et al., 1969; Rembold and Schmatterer, 1980; Jacobson et al., 1983; Joshi et al., 1984; and Schmatterer and Ascher, 1984). Potent antifeedants from a number of East African plants have also been isolated (Kubo et al., 1977; Kubo and Nakanishi, 1977). Antifeedant substances from the leaves of Ipomoea batatas L., Cocculus trilobus DC., Parabenzoin trilobum N., Orixa Japonica T, Clerodendron tricotamum T. and Caryopteris divaricata M. have been isolated (Munakata, 1977). Gossypium sp. (Raman and

Ananthakrishnan, 1986), Iberis amara (Mitchell, 1988), leaves and roots of Catharanthus sp., Lantana camara Linn. and Nerium odorum L. (Kumuda Sukumar, 1988). Tropical flora are reported to have efficient built in defence mechanisms, including substances with considerable feeding inhibitors. Plants under extreme arid conditions are known to have evolved protective mechanism against competitors. Many more plants are likely to be found as rich sources for antifeedant materials when properly investigated.

Though feeding inhibitors by themselves may not contain pest problems completely, they are promising to be included in an integrated pest control system.

Chopra et al. (1949) have listed 700 plant species reportedly used for pest control in different parts of the world. From published revies and survey reports (Jacobson, 1958; Jacobson et al., 1975; Secoy and Smith, 1983; Ahmed et al., 1984) 1840 plants were listed to have pesticide properties. Apart from neem (A. indica) extracts of other plants like Annona squamosa L. (Tattersfield and Potter, 1940; Puttarudriah and Bhatta, 1955), Acorus calamus L. (Trehan, 1956), N. odorum and Calotropis procera (Puttarudriah and Bhatta, 1955), Ocimum basilicum (Deshpande and Tipnis, 1977; Pandey et al., 1982), Thevetia spp. (Gattefossae, 1949; Atal and Kapur, 1977 and Freedman, 1979) and Clerodendron sp. (El Ghar and El Sheikh, 1987) were also reported to be toxic to different species of insects. Available informations on the insecticides of plant origin

(nicotine, rotenone, pyrethrins) taught us to believe that the insecticide principles identified in plants would be much safer in the human environment than the synthetic insecticides. If there are simple techniques for the extraction of these principles using the common tools accessible to a farmer, the technology will prove to be a boon for them, especially the small farmers all over the world.

Yet another method of exploiting plant constituents for pest control will be the possibility of using JH analogues as potential insect control agents included under third generation pesticides. This was first recognised by Carrol Williams (1956, 1967). He also reported the occurrence of JH like substances in plants for the first time (Slama and Williams, 1966) and was later isolated and characterised as juvabione (Bowers et al., 1966). Subsequent investigations showed that many plants possess substances which behaved like JH in bioassay tests. Other juvenile hormone analogues also were traced in balsam fir (Cerny et al., 1967), wood of douglas fir (Rogers and Mauville, 1972) and Ocimum basilicum L.(Nishida et al., 1984). Juvenile hormone activity was attributed to chemicals isolated from some plants from India also (Saxena and Srivatsava, 1972; Prabhu et al., 1973; Prabhu and John, 1975a, b; Deshpande et al., 1974; Gopakumar et al., 1977; Saxena et al., 1986; Saxena and Tikku, 1988).

Ecdysone analogues were reported from rhizomes of ferns (Nakanishi et al., 1966). Antijuvenile hormones which counteract the effect of insect hormones were isolated from Ageratum spp. (Bowers, 1976 and Bowers et al., 1976). Since these substances of plant origin affected the morphogenesis and physiology of the insects in various ways affecting derangement of insect population, attempts are under way to use them as a new generation of pesticides (Retnakaran et al., 1985). Insect growth regulators can surely control receptive phytophagous insects. Hence the possibility of incorporating these defensive allelochemics in insect control has to be explored with emphasis.

Even though many active principles have been isolated and identified from plants, synthesis of these compounds for commercial purposes have not yet been realised even in developed countries. Economics of the process is one of the practical difficulties regarding synthesis of these compounds. Chemical characterisation and purification of the active principle involve a series of complex steps which are expensive. Even when synthesised these products may prove too luxurious for the developing countries on cost basis. As opined by Radwanski (1980), two distinct approaches may be desirable in this area of research. One, he identifies as the 'western approach' wherein intensive research leading to the development of materials for production on large scale, industrial scale suited for advanced

3. Assessment of the persistent antifeedant activity of the extracts of selected plants under field conditions.

4. Screening essential oils for their antifeedant activity.

5. Screening of locally available plants for insecticidal action.

6. Bioassay of the extracts of selected plants for the contact toxicity.

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8. Screening available essential oils for their insecticidal effect.

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11. Screening essential oils showing juvenilising activity.

12. Control of pests of vegetables using plant extracts under field conditions.

REVIEW OF LITERATURE

1. REVIEW OF LITERATURE

A comprehensive review of the work done on the plant products and their utilization as pest control agents by virtue of their antifeedant, insecticidal and juvenile hormone activities has been done here.

1.1. Antifeedant action

1.1.1. Neem leaves

The earliest report of the deterrency of neem leaves was that of Volkonsky (1937) who observed that extracts of the leaves of Melia azedarach L. (the Persian lilac) when sprinkled on the leaves of other plants gave protection against locusts. Sergent (1944) found that the extract of fresh or dry leaves either by maceration or by decoction, was effective in preventing the feeding of desert locust Schistocerca gregaria Forsk. Chauvin (1946) reported that a chloroform extract of the leaves of M. azedarach possessed antifeeding action against locusts. Repellency of neem leaves against insects in stored grains was reported by Krishnamurti and Rao (1950). Bhatia and Sikka (1957) reported that desert locust S. gregaria feeding on a wide range of plants did not feed on neem leaves. Leaf extracts of M. azedarach when incorporated into food media or applied to corn seedlings acted as feeding deterrent and growth retardant for the larvae of corn earworm, Heliothis zea (Boisd.) and fall army worm Spodoptera frugiperda (J.E.Smith

(Mc Millan and Starks, 1966; Mc Millan et al., 1969). Chari and Muraleedharan (1983) found 10% extract of neem leaves to be effective feeding deterrent against castor semilooper Achoea janata Linn. while Singh & Sharma (1986) observed strong repellent and antifeedant action of water extracts of neem leaves at 1 and 5% concentrations against the aphid Brevicornye brassicae Linn. when applied at 15 days intervals on cabbage and cauliflower, in the pots and under field conditions.

1.1.2. Neem seed kernel powder

Use of neem seed kernel powder as a protectant of stored grains was demonstrated (Jotwani and Sircar, 1965 and 1967; Deshpande, 1967; Saradamma et al., 1977; Teotia and Pandey, 1978). Powdered neem seed kernel mixed with wheat/paddy grains @ 1 to 2 parts per 100 parts of seeds gave protection for 10 to 12 months from Rhizopertha dominica Fabr., Sitophilus oryzae Linn. and Trogoderma granarium Everts. Similarly different species of pulses were protected from the damage of pulse beetle Callosobruchus maculatus L. for 8 to 9 months.

Girish and Jain (1974) observed that neem seed kernel powder was effective as a grain protectant in the case of external feeders like Trogoderma granarium E. while in the case of internal feeders it did not have any significant effect. The antifeedant property of dried drupes and seed powders of neem and dharek against the larvae of Pieris brassicae (L.) was demonstrated by Gurmela Singh and Darshan Singh (1975).

A mixture of the neem seed kernel powder and urea (1:10) when applied to the root zone of rice plants caused marked reduction of BPH feeding. There was reduction in the number of first instar nymphs of BPH becoming adults and the life span of the hopper was also affected (Chiu, 1985).

1.1.3. Neem oil

Siddique (1942) isolated three neutral and water soluble bitter principles from neem oil, but they were quite ineffective as antifeedants. Cherian and Menon (1944) observed that neem oil emulsion was more toxic than the extract prepared from neem seeds against Aphis gossypii G., Urentius echnius D. and Saissetia nigra N. Kadam (1976) reported the effectiveness of neem oil against Plutella xylostella (L.). Atri and Prasad (1979) tested neem oil extracts against S. gregaria and found that it was about 40 times less effective than water extracts of neem kernel powder in causing feeding inhibition. Narayanan et al. (1978) reported that neem oil fractions with cold aqueous alcohol at 1% concentration deterred the feeding of S. gregaria effectively on treated cabbage foliage. Saxena et al. (1980, a, b and 1983) found that crude neem oil (12%) controlled brown plant hopper Nilaparvata lugens (Stal) and rice leaf roller Cnaphalocrocis medinalis Guen. They also observed that neem oil repelled the hopper and caused disorientation and the restless behaviour of the hopper and significantly reduced the duration of feeding and quantity of food ingested.

Potentialities of neem oil as a feeding deterrent was indicated against brown plant hopper, white backed plant hopper, green leaf hopper (Heyde et al., 1983) and gall midge (Chiu, 1984) infesting rice. Saxena and Khan (1986) monitered the effect of neem oil on the feeding behaviour of Nephotettix virescens Dist. and observed that the garlicky odour of the oil disrupted the normal feeding behaviour of the hopper. Feeding was significantly reduced on rice plants kept in an arena permeated with odour of 6, 12 and 23% neem oil. Rajasekharan et al. (1987) reported the disruption of feeding behaviour of rice leaf roller larvae.

Neem oil was found slightly active against Spodoptera littoralis (Boisd.) at 1% in the laboratory and completely inactive at 2% in the field (Meisner et al., 1980). Saxena et al. (1980) observed that neem oil was effective only at higher concentrations and its antifeedant property was rapidly degraded by sunlight. Topical application of neem oil to the fifth instar nymphs of S. gregaria did not affect the feeding behaviour of the insect (Gujar and Mehrotra, 1985).

Field trials conducted by Singh et al (1985) revealed that neem oil was effective against Melanagromyza obtusa Mall. whereas the pod borers of pigeon pea Heliothes armigera Hb. and Maruca testulalis Gey. were not controlled. Shelke et al. (1987) reported that even at 10% concentration neem oil did not reduce the feeding of Phthorimoea operculella Zell. on potato.

1.1.4. Neem seed kernel suspension

Pradhan et al. (1962) observed that 0.05 per cent aqueous suspension of neem seed kernel gave absolute deterrence to Locusta migratoria (Linn.) and even at 0.01 per cent the feeding of S. gregaria F. was completely inhibited. The superiority of crude extracts over refined products was reported by Pradhan et al. (1963) and Pradhan and Jotwani (1968 and 1971). Mane (1968) reported the repellent action of gaseous seed suspension against Euproctis lunata Walk., Prodenia litura F., Utethesia pulchella L., Acrida exaltata L. and Aulocophora foevicollis L. The deterrency of neem seed paste suspension against the hairy caterpillar Amsacta moori Butl. was reported by Patel et al. (1968). Pradhan and Jotwani (1971a) showed that L. migratoria (Linn.) and S. gregaria showed complete feeding inhibition at very low concentrations of neem seed paste suspension (0.005 per cent and 0.001 per cent respectively). S. littoralis F. on lucerne showed significant feeding inhibition only when 0.4 to 1% was used (Meisner et al., 1980).

Significant protection of brinjal against the aphid and leaf hoppers (Asari and Nair, 1972), against Chrotogonus brachypterus Blanch. (Sandhu and Verma, 1975), pulse crops against pod borers (Abdul Kareem et al., 1978, Siddapaji, 1978), sugar beet against S. littoralis F. (Meisner et al., 1980), cucumber against Podagrica uniforme, P. sjostedli and

Epilachna chrysomelinae (Redknap, 1980), citrus against Papilio demoleus L. (Redknap, 1980), tobacco nurseries against S.litura Fe. (Joshi et al., 1984; Ramaprasad, et al 1987) were reported using neem seed suspension.

1.1.5. Neem seed kernel extract

Babu and Beri (1969) found that extracts of neem seed kernel using alcohol had maximum deterrent principles against E. lunata Walk. 'Thionemone' a compound extracted from neem seed kernel was reported as a repellent against A. foevicollis (Lucas) in cucurbits (Chakrawarthy et al., 1970).

Hexane extracts of neem kernels significantly deterred the feeding of scale insects Aoniediella aurantii (Markell), A. citrine (Coquillet) and Phenacoccus citri (Risso.); the wool white fly Aleurothrias floceasus (Maskell) and the citrus red mite Panonychus citri (Mc Gregor) (Jacobson et al., 1978).

Chiu et al. (1983) reported that petroleum ether extracts of seed kernels of Melia toosandan and M. azadirachta had stron feeding deterrent activity on the nymphs of BPH.

Antifeeding activity of crude ethanol/methanol extract of neem seeds was reported against Diaphoria hyalinata L. (melon worm) at 1%, second instar larvae of Heliothis virescens (F.) (tobacco budworm) at 0.001% and H. zea (corn ear worm) at 0.2%, larval and adult Leptinotarsa decemlineata Say. (colorado

potato beetle) at 0.2 to 1%, larvae of Liriomyza sativa Meig. and L. trifoli (vegetable leaf miners) at 0.1%, larvae of Manduca sexta (tobacco horn worm) at 0.2%, adult of Rhizopertha dominica (lesser grain borer) at 1%, adults of Sitophilus granaria L. (granery weevil) at 1% and adults of Tribolium castaneum Hebst. (red flour beetle) at 1% (Jacobson et al., 1983); larvae of Mythimna separata (Wlk.) on sorgham and perl millet (Sharma et al., 1983), Euproctis fraterna M. on castor and Nephantis serinopa Meyr. on coconut (Abdul Kareem et al., 1975), Popillio japonica Newman on soyabean (Ladd et al., 1976 and 1978), Spodoptera littoralis F. on cotton (Meisner et al., 1981), N. lugens (Stal.), Sogotella furcifera Horv., N. virescens and Leptocorisa acuta Thumb. on rice (Heyde et al., 1983), Podagrica spp. and Sylepta derogata F. on bhindi (Adhikary, 1981).

Ascher et al. (1980) found that methanol was a good solvent for preparing neem seed kernel extract (NSKE) and showed that 0.05% emulsion of methanol extract had antifeedant activity against Epilachna varivestis Mostant. both in the laboratory and on potted plants. Fagoonee (1980) investigated the behavioural response of cabbage webworm Crocidolomia binotalis Z. to neem extracts and found that the extract masked the inherent phagostimulatory property of cabbage towards its pest. Ladd (1980) found host plant specific feeding inhibition of neem for the Japanese beetle P. japonica. Aqueous emultions of alcohol

extract of neem seed protected sessafras and soyabean from P. japonica in the laboratory and in field, while the two favourite host plants of the beetle, the rose (Rosa sp.) and grapes Vitis labrusca could not be protected by the treatment. The volatile attractants produced by these plants which included geraniol, eugenol and phenethyl butyrate probably overcame the deterrent qualities of neem extracts. Meisner et al. (1981) found that neem suspension applied on sugar been and lucerne had good toxicity against S. littoralis F. while no protection was noted on cotton. The neem seed extract remained active for 21 days against S. frugiperda on corn (Jacobson et al., 1983). Efficacy of ethanolic extracts in field trials against M.obtusa, H. armigera and M. testulalis was reported by Singh et al.(1985).

Margosan-O (a commercial formulation of neem seed extract) when applied as a systamic soil drench reduced the development of L. trifoli and the effect persisted in the soil up to 21 days (Knobei et al., 1986). Foliar spray at 0.4% also could reduce the population of insects. Phadke et al. (1988) reported the efficacy and superiority of another commercial neem product 'Neemark' over insecticides in controlling white fly on cotton.

1.1.6. Neem cake

Water extracts of neem cake reduced the incidence of citrus leaf miner Phillocnistis citrella S. (Ramachandran et al., 1962).

Sinha and Gulati (1963) found that alcohol extracts of the seed cake (after extraction of neem oil) showed repellent action against the migratory locust, L. migratoria and the desert locust, S. gregaria. Similar repellent action of alcohol extract of the cake was reported against aphids (Sinha and Gulati, 1964) and against Rhopalosiphum nymphae Fitsch. and S. gregaria (Goyal et al., 1971). Saxena et al. (1983) observed that the food intake by newly emerged females of BPH was significantly reduced when confined on plants treated with neem cake and urea (3 : 10). Neem cake applied at 150 kg/ha in rice soil came on par with carbofuran 0.75 kg ai/ha in controlling the green leaf hopper N. virescens which was the only known vector of 'tungro virus' and this was attributed to the change in the feeding behaviour of the insect from the virus-infected phloem vessels to virus-free xylem vessels from which it does not normally feed.

1.1.7. Plants other than neem as sources of insect antifeedants

Ailanthus excelsa

Acetone extracts of A. excelsa gave 89.7% protection against D. obliqua (Spilosoma obliqua) (Tripathi and Rizvi, 1985).

Aloe spp.

Undiluted leaf extracts of Aloe vera Tourn. could protect raddish leaves from mustard saw fly (Pandey et al., 1977).

Another species, A. barbadensis M. also exhibited good antifeedant property against A. proxima in the laboratory, the PC_{90} value being 55.34 per cent (Sudhakar et al., 1978).

Amoora ruhituka Wright & Arn

Hexane and acetone extracts of A. ruhituka acted as feeding deterrent to adults of rice hispa (Islam,1983).

Annona spp.

Antifeedant activity was reported on the acetone and ethanol extracts of seeds and leaves of Annona reticulata Linn. against rice hispa, rice weevil, lady bird beetle, adults of pulse beetle and early instars of jute hairy caterpillars (Islam, 1983). Feeding deterrency of oil of Annona sp. (custard apple) against rice hoppers, BPH, GLH and WBPH was reported by Saxena et al.(1983).

Calotropis gigantea Linn.

Husain et al. (1946) observed that C. gigantea deterred S. gregaria and Mehrotra and Rao (1966) suggested the presence of some feeding deterrents in the plant. Rao and Mehrotra (1977) found that benzene and water extracts and also alkaloid fractions of the leaves of C. gigantea were deterring S. gregaria. Rao (1982) found that methanol extract of leaves, flowers and latex of C. gigantea contained phagostimulants while the extract of fruits and root bark possessed feeding deterrents.

Chloroform extracts of all parts of the plant contained antifeedants. Methanol extract of root bark was a potent antifeedant which showed deterrency even at one g dried powder/100 ml solvent.

Caryopteris divaricata Linn.

Benzene extract (1%) of C. divaricata had feeding inhibitory activity against S. litura (Hasozava et al., 1974).

Cellicarpa japonica

When fed on leaf discs treated with one per cent benzene extract of C. japonica feeding inhibition was observed in S. litura (Hosozava et al., 1974).

Chloroxylon swietenia DC

Leaf extracts of C. swietenia in p
form and methanol exhibited high antifeedant activity (98 to 99%) against S. litura (Srimannarayana et al., 1988).

Clerodendron sp.

One per cent ether extracts of the leaves of Clerodendron frajan, C. calamilosum and C. cryptophyllum could inhibit the feeding of S. litura (Hosozava et al., 1974). Similar antifeedant potency of C. incerne Linn. was reported against

Diacrisia obliqua Walk. (Tripathi and Rizvi, 1985) and against Callosobruchus chinensis L. (El Ghar and El Sheikh, 1987).

Crinum spp.

The antifeeding effect of Crinum bulbispermum Burm. has been reported by Singh (1974) against locust on cabbage and Pandey et al. (1977) against A. proxima (Klug.) on raddish. Sudhakar et al. (1978) reported the feeding inhibitory activity of C. defixum Ker Gawl against A. proxima which had a PC_{90} value of 43.75 per cent.

Euphorbea royleans Boisd.

Crude extracts of E. royleans leaves were reported to be antifeedant against leaves of mustard saw fly with a PC_{90} value of 45.71 per cent under laboratory conditions.(Pandey et al., 1977 and Sudhakar et al., 1978).

Ficus carica Linn.

Hosazava et al. (1974) reported the antifeedant potency of benzene extracts of F. carica at 1% concentration against S. litura.

Lantana camara L.

Fresh green leaf extracts of L. camara L. var. aculeata (L showed potent antifeeding property against mustard saw fly

Athalia proxima Klug. with PC_{90} value of 44.67 per cent. Pandey et al., 1977; Sudhakar et al., 1978).

Medicago sativa Linn.

A crude extract of M. sativa root contained a strong feeding deterrent against the larvae of Costelytra zealandica (White) (Sutherland et al., 1975).

Mimordica charantia Linn.

An emulsion of bittergourd seed oil could deter the feeding of mustard saw fly A. proxima (Arunkumar et al., 1979).

Osmunda japonica L.

Numata et al. (1984) isolated three antifeedant compounds from the plant O. japonica which was active against the larvae of yellow butterfly Furematerabe mandarina.

Pongamia glabra Vent.

Cakes of karanja (P. glabra) was reported to be very effective in keeping the white grubs (Holotrichia consanguinea Blanch.) population low (Nigam, 1978). Karanjin and extractives isolated from the seeds of P. glabra (petrol extractive oil), methanol extractive and residual oil (after removing karanjin) exhibited antifeedant activity ranging from 73.33 to 86.68% against S. litura (Srimannarayana et al., 1988).

Miscellaneous sources

Oils of mahua, maravatty and punnai were found as effective as neem oil for the control of C. medinalis on rice (Rajasekharan et al., 1987).

1.1.8. Isolation and chemical characterization of active principles showing antifeedant action

Neem

In 1967, Lavie and coworkers in Israel isolated 'meliantriol' a triterpenoid alcohol, as the active principle in M. azedarach which gave 100 per cent antifeedance to the locusts @ 8/ug/cm^2. Simultaneously in England 'azadirachtin' was isolated and identified from neem seeds (Butterworth and Morgan, 1968, 1971) and from the fruits of M. azedarach (Morgan and Thornton, 1973). The structural geometry was confirmed by Butterworth et al. (1972), Nakanishi (1975) and Zanno et al. (1975). This substance gave complete inhibition of the feeding of desert locust at 1 x 10^{-6} per cent concentration (Haskell and Luntz, 1969). Subsequently azadirachtin was shown as potent antifeedant for Plutella xylostella (L.) and H. virescens (Ruscoe, 1972), P. brassicae (Butterworth and Morgan, 1971), S. gregaria F. (Warthen et al., 1978; Redfern et al., 1980; Rao and Subramaniam, 1986), Acheta domesticus (Warthen and Uebl, 1980), S. littoralis and

tomatin and demmissine from solanaceous plants which acted as strong antifeedants against Colorado potato beetle L.dicemlineata.

Jugalone (5-hydroxy 1,4, napthoquinone) obtained from the bark of Carya ovata Koch. acted as a feeding deterrent for scolytid bark beetles (Gilbert et al., 1967; Gilbert and Norris, 1968). Wada and Munakata (1968) isolated and identified five antifeedant compounds active against S. litura from three plant leaves - isoboldine from Cocculus trilobus DC, 'clerodendrin' A and B from Clerodendron tricotomum Thumb., 'shiromodiol-diacetate' and 'shiromodiol-monoacetate from Parabenzoin trilobum Nakai. Gymneonic acid from leaves of a vine, Gymneonia sylvestia R. showed feeding deterrence in Spodoptera eridania (Cramer) (Granich et al., 1974).

A transaconitic acid isolated from barn yard grass Echinochloe crussgalli Link. had powerful antifeedant potency against brown plant hopper N. lugens (Kim et al., 1976).

Warburganal and muzidadial extracted from the bark of an East African tree Warburgia ugandensis Sprague. acted as feeding deterrents to the African army worm S. littoralis and S. exempta (Kubo et al., 1977). These sesquiterpenes exhibited very potent activity, the effective dose being 0.1ppm against army worms. But the antifeedant action was nonsignificant against M. sexta and S. voga (Nakanishi, 1977).

Cucurbitacin E and I isolated from green parts of Iberis amara Linn. inhibited feeding on Phyllotreta memarum Zimm. (Nielson et al., 1977). From the leaves of Orixa japonica Yogjima et al. (1977) isolated and identified six feeding deterrent principles - isopimpenellin, beryapectin, xantheloxin kokusogin, evoxine and japonine against S. litura.

The two active principles isolated from the leaves of Toona ciliata M.Roem (meliaceae) viz. toonacilin and 6 acetoxy toonacelin exhibited strong antifeeding activity against Hypsipyla grandelia and E. varivestis (Kraus et al., 1978).

Picman et al. (1978) reported that alantolactone occurring in a number of compositae plants, were insect feeding deterrent; for coleopeterans. Similarly Dahlman et al. (1979) reported that a number of leguminaceous plants contained an amino acid -canavannin which prevents feeding by several insects.

Xylomolin isolated from the unripened fruits of Xylocarpus mollascensis M.Roem (meliaceae) acted as antifeedant against S. exempta (Kubo et al., 1976; Kubo and Nakanishi, 1978). Limonoids extracted from Trichlia roka (meliaceae) exhibited insect feeding deterrent activity (Nakatani et al., 1981). They isolated the compounds trichlin A, B, C and D from the root barks of the plant which were effective antifeedants for S. eridania and E. varivestis. These findings gave further support to the fact that plants of the family meliaceae are

most resistant to insect attack. Kaul (1983) isolated two limonoids from Cedrella toona R. and grape fruits (cedrelone and limonin) which induced feeding deterrent activity in the larvae of S. litura.

Kalmotoxin I to V isolated from Kalmea latifolia (ericaceae) deter the feeding of gypsy moth larvae. Out of them Kalmotoxin I was the most effective compound showing 77% deterrent effect (El Naggar et al., 1980). Plumbagin from Plumbago capensis Thumb. (plumbagenaceae) acted as an effective antifeedant for Spodoptera exempta (W.) (Kubo et al., 1980).

Feeding deterrent activity of fractions from the foliage of Western red cidar Tuja plicata D. (coniferae) has been studied against white pine weevil Pissodes strobi Peck. and the most active fractions found on volatile leaf oil contained monoterpene hydrocarbon thujone (Alfaro et al., 1981).

The feeding deterrents isolated from sorgham leaves, p-hydroxy benzaldehyde (ED-50 = 0.08%) (Dreyer et al., 1981) were active against the major green bug Schizaphis graminum R.

Reed et al. (1982) reported the antifeedant activity of nerifolin against codling moth, striped cucumber beetle and japanese beetle. The glycoside protected cantaloupe plants from feeding by Acalymma vittata Fabr. for 7 days and soyabean plants from P. japonica for five days. Application through roots indicated systemic action also. Ascher (1983) reported the antifeedant activity of ooithanolides obtained from solanaceae.

Among the eight natural sesquiterpenoid lactones isolated from umbelliferae Laserpitilam siler Linn., L. archangelica Jacq. and L. trilobum S. greatest feeding deterrent activity was recorded for trilobolidae (Naw Rot et al., 1983). Oil of tansy (Tanocetum vulgare Linn.) and also the commercial tansy oil could strongly repel the Colorado potato beetle L. decemlineata (Schrarer, 1984).

The alkaloids vasicine, vasicinol, deoxyvasicine, vasicinone and deoxy vasicinone extracted from Adathoda vesica Nees. deterred the feeding of epilachna and aulocophora beetles at 0.05 and 0.1 per cent concentrations (Saxena et al., 1986). Thappa et al. (1988) reported the feeding deterrency of 'canessine' a compound from Holarrhena antidysenterica Wall. against the larvae of S. litura and P. brassicae at 0.2 per cent foliar spray.

1.2. Insecticidal action of plant products

Chopra et al. (1949) listed 700 spp. of plants having poisonous effect on man, livestock and insects, out of which 74 plants showed insecticidal and insect repellent properties. Feinstein (1952) reported that 2000 species of plants belonging to 170 families had insecticidal effect though many did not show sufficient toxicity for commercial exploitation.

1.2.1. Crude and solvent extracts

1.2.1.1. Neem and neem products

Neem leaves

Insecticidal property of neem leaves was first explored by Chopra (1928) on the larvae of lucerne weevil Hypera postica Gyll. and he recorded 25 per cent mortality of larvae; soil treatement of neem leaves to wheat at 7 tonnes per acre reduced the termite damage to 0.7 per cent as compared to 8 per cent in untreated plot. Fry and Sons (1938) observed neem leaves as an effective insecticide against Ephestia cautella Walker. infesting cocoa leaves. Steets (1975) reported that neem leaf extract at concentrations of 2 and 5 per cent killed the larvae of E. verivestis and P. xylostella fed on treated beans and cabbage foliage respectively. Petroleum ether extracts of dried neem leaves showed promising larvicidal activity against mosquitoes (Chavan and Nikam, 1988).

Neem seed kernel extracts

First report of the insecticidal property of neem seed kernel was by Cherian and Menon (1944) who found that cold extracts of neem seed kernel was efficient as an insecticide and their toxicity increased by addition of soap when tried against A. gossypii, U. echinus and S. nigra. Water extracts of neem seed kernel at 0.075 to 1 per cent concentration gave

80 to 90 per cent mortality of larvae of E. insulana (Meisner et al., 1978). Systemic action of water soluble neem extract caused high mortality of all hopper nymphs of rice (Heyde et al., 1983, Saxena et al., 1983). Neem kernel suspensions at 0.1, 0.2 and 0.4 per cent, when applied at 15 day intervals on cauliflower and cabbage, could reduce the population of aphids B. brassicae both in pot and field trials (Singh and Sharma, 1986).

Neem oil

Cherian and Menon (1944) observed that neem oil emulsion had higher toxicity than the extract prepared from seed against A. gossypii, U. echinus and S. nigra. But Christudas et al. (1981) and Saxena et al. (1983) observed that neem oil was ineffective against pulse beetle and N. lugens respectively. Neem oil gave a significant reduction in the population of rice grass hopper Oxya chinensis Walker. (Chiu, 1985). Aphicidal activity of neem oil at 0.2 to 0.8 per cent emulsions on B. brassicae (Singh and Sharma, 1986) and at 0.5 per cent on A. gossypii (Srivastava et al., 1986) was reported. Jhansi and Babu (1987) showed high larval mortality (32 per cent) of spotted pod borer M. testulalis on the third day after spraying which decreased subsequently due to photodegradation as reported by Meisner et al. (1983). Neem oil at 2 per cent was found to be insecticidal against rice thrips Stenchaetothrips biformis (Bagnall) in the nurseries and early transplanted crop (Pillai

and Ponnaiah, 1988). Reghuraman *et al.* (1988) reported 74 per cent nymphal mortality of BPH by the application of three per cent neem oil.

Neem cake

Sachan and Pal (1976) reported the effectiveness of neem cake for the control of white grubs, *H. insularis*.

1.2.1.2. *Acorus calamus* L. (Sweet flag)

Insecticidal effect of powdered rhizomes of sweet flag, *A. calamus* was recognized against mosquitoes, houseflies, pulse beetles, bird lice, bed bugs etc. since long (Subramanian, 1942; Mukerji and Govind, 1959). But Purnamma and Mammen (1984) found that cowpea seeds treated with bits of sweet flag rhizome suffered higher damage than control after six months and the treatments did not cause any reduction in egg laying of the pulse beetle.

Trehan (1956) reported that 50 per cent aqueous suspensions of *A. calamus* was toxic to *Empoasca devastens* Dist. and *A. foevicolis*.

Dixit *et al.* (1956) found that solvent extracts and essential oils of the rhizomes were toxic to housefly (*Musca nebulo* Wied.), mosquito (*Culex fatigens* Wied.) and carpet beetle (*Anthrenus vorax* Waterhouse). Insecticidal properties of

essential oil of A. calamus was reported agáist various storage pests (Agarwal et al., 1973; Yadava, 1974). Ether extract of rhizomes of A. calamus was toxic to A. proxima (Pandey et al., 1976; Sudhakar et al., 1978). Pandey et al.(1982) reported that 2 per cent extract of rhizomes killed fifth instar larvae of potato tuber moth P. operculella. Rhizome extract was effective against storage pests Oryzaephilus surinamensis Linn. and Tribolium castaneum Herbst. (Prakash and Rao, 1985) and against the land leach Haemedispa sylvestis (SaLeela et al., 1988).

1.2.1.3. Ageratum conyzoides L.

Leaf extract of A. conyzoides at two per cent concentration could kill 40.74 per cent of fifth instar larvae of P. operculella (Pandey et al., 1982).

1.2.1.4. Allium sativum L. (Garlic)

Although the medicinal and bactericidal properties of garlic have been extensively studied, the toxicity of its oil to mosquito larvae was found by Amonkar and Reeves in 1970 only. Efficiency of garlic oil for the control of aphids, cabbage white fly, caterpillars and Colorado potato beetle (Greenstock, 1970) and red cotton bug D. cingulatus (Sundaramurthy, 1979) also have been reported subsequently. Barakat et al. (1986) found that acetone extract of garlic bulbs when mixed with

insecticides showed potentiation against Tetranychus urticae Koch. on cotton.

1.2.1.5. Anacardium occidentale Linn.

Madhusudan (1979) found that A. occidentale has high insecticidal activity against D. cingulatus and S. litura.

1.2.1.6. Annona squamosa L. (Custard apple)

Puttarudraiah and Bhatta (1955) reported the insecticidal properties of A. squamosa. Deshmukh and Borle (1975) found that cold alcoholic extract of A. squamosa could give 70 per cent kill of Dactynotus carthami Hpl. Saxena et al. (1983) observed that oil of A. squamosa was effective against N. lugens and S. furcifera when topically applied. Though the treatment was toxic to the predator Cyrtorhinus lividipennis (Reuta), the spider Lycosa pseudoannulata (B & S) was not adversely affected even at higher doses. Mariappan and Saxena (1983) reported the efficacy of custard apple oil against N. virescens and consequent reduction in the incidence of rice tungro disease. Reguraman et al. (1988) reported high mortality of BPH when sprayed with a mixture of neem oil and custard apple oil (2:1).

1.2.1.7. Artemesia spp.

Ferolino-Calumpang and Podolino (1985) found that the chloroform extracts of the leaves of Artemesia vulgaris L.

was toxic to O. furnacalis, Drosophila melanogaster Meigen., T. castaneum and S. zeamais. Khan and Khan (1985) reported that the oil of Artemesia kurromensis Linn. was toxic to the fruit flies viz. Dacus dorsalis H., D. cucurbitae, D. zonatus and D.diversus.

1.2.1.8. Camphor

Camphor, an old insect repellent was reported as a safe fumigant against Musca domestica Linn., Plodia interpunctella Hubn., E. cautella, Galleria mellonella Linn., Cydia pomonella H, P. brassicae, R. dominica and Tenbrio moliter Linn. giving 100 per cent knock-down action within three hours when applied @ 40/ug/l in air tight containers (Abivardi and Benz, 1984).

1.2.1.9. Clerodendron spp.

Chopped leaves of C. infortunatum incorporated into the soil @ 5000 kg/ha one week prior to planting of sweet potato vines gave significant reduction in the infestation by Cylas formicarius Fab. (Rajamma, 1982). Petroleum ether extracts of C. incerme gave 93 per cent protection of cowpea seeds against pulse beetle C. chinensis (El Ghar and El Sheikh, 1987).

1.2.1.10. Coconut oil

Christudas et al. (1981) showed that treating cowpea seeds with coconut oil at 1 per cent level could protect them from pulse beetle for a period of seven months.

1.2.1.16. Ipomoea palmata Forsk.

Petroleum ether extract of I. palmata had contact toxicity to pulse beetle C. chinensis (El Ghar and El Sheikh, 1987) and it gave 97 per cent protection of stored pulses.

1.2.1.17. Lantana camara Linn.

Crude extracts of L. camara was found to be ineffective even in undiluted form against mustard saw fly A. proxima (Pandey et al., 1976). Flower extracts of L. camara was reported to be toxic to BPH (Fuentebella and Morallo-Rejesus, 1980).

1.2.1.18. Mentha spicata Linn.

Kashyap et al. (1974) reported M. spicata as a promising protectant of stored wheat against Sitophilus oryzae Linn.

1.2.1.19. Mimordica charantia Linn.

Insecticidal properties of bitter gourd seed oil emulsion against mustard saw fly A. proxima was reported by Arunkumar et al. (1979).

1.2.1.20. Nerium oleander L.

Biocidal activity of N. oleander against pulse beetle C. chinensis was reported by El Ghar and El Sheikh (1987).

1.2.1.21. Ocimum spp. (Tulsi)

Ocimum sanctum L. was reported to contain methyl eugenol and the extract was used to attract the fruit fly Dacus caritus Bez. (Shah and Patel, 1976). Insecticidal activity of O. basilicum Linn. (the sweet basil) was reported by Deshpande and Tipnis (1977). Two per cent extracts of seeds of C.basilicum could cause 44.07 per cent mortality of the fifth instar larvae of potato tuber moth P. operculella on exposure to dry films for 24 hours (Pandey et al., 1982).

1.2.1.22. Oligocheta ranosa

Saxena and Yadav (1983) observed a potent mosquito larvicide in the acetone extract of O. ranosa.

1.2.1.23. Pongamia glabra Vent.

The seed oil of P. glabra and its chemical constituents were known to possess insecticidal, nematicidal and bactericidal activities (Parmer et al., 1976). Karanj oil and karanj extract were reported to be active against housefly M.domestica Linn. and cockroach Periplanata americana Linn. (Parmer et al., 1976 and Vimal and Nephade, 1980) and karanjin cake was found toxic against white grubs H. insularis (Sachan and Pal, 1976). Ethanolic extracts of deoiled karanjin cake and defattened seeds and pure karanjin were toxic against mustard aphid,

Lipaphis erysimi Kalf. (Vimal and Naphade, 1980). Insecticidal action of seed oil of karanja was reported on cotton stainer D. koenigii, potato tuber moth P. operculella, housefly M. domestica and mosquitoes A. aegyptii, C. fatigens and A. stevensi (Tare and Sharma, 1984) on O. surinamensis and T. castaneum on stored rice (Prakash and Rao, 1985) and on potato tuber moth P. operculella (Singh et al., 1987).

1.2.1.24. Schinus terebinthifolius W & A

Alcohol extract of the leaf powder of S.terebinthifolius was toxic to fourth instar larvae of S. littoralis and was superior to carbaryl (Abbassy, 1982).

1.2.1.25. Spilanthus acemela Linn.

S. acemela extracts were also reported to be toxic against D. carthami (Deshmukh and Borle, 1975).

1.2.1.26. Tagetes spp.

Two toxic principles isolated from the seeds of marigold plants were found toxic to green leafhopper and brown plant-hopper of rice. The two fractions obtained from T. patala L. and T. erecta L. were equally toxic as the standard insecticide for GLH (Morallo-Rejesus and Eroles, 1978).

1.2.1.27. Thevatia spp. (Oleander)

The effectiveness as well as ineffectiveness of Thevatia powders and extracts against a variety of insect species was reported (Mc Indoo, 1945; Jacobson, 1958; Deshmukh and Borle, (1975). Gattefossae (1949) attributed the insecticidal activity of Thevatia neriifolia Juss. to the glycoside 'thevitin' and to another unidentified material of even greater toxicity.

In India extracts of Thevatia leaves were used as pediculicide (Atal and Kapur, 1977) and powdered seeds of Thevatia was reported to act as a protectant of stored seeds (Pandey et al., 1977).

Freedman et al. (1979) reported that ethanol extract of the seeds of Mexican yellow oleander (Thevatia thevetioides (HBK) K Schum.) was lethal producing 100 per cent larval mortality when incorporated into the diet of European corn borer Ostrinia nubilalis (Hubner).

1.2.1.28. Tinospora ramphii Boert.

Chopped stems of makabuhai T. ramphii applied in soil in potted rice plants showed toxicity to N. virescens, N. lugens and Chilo suppressalis Walker feeding on the plants (Silva D, 1979 and Morallo-Rejesus, 1984).

1.2.1.29. Tripterygium spp.

Acetone extracts of root bark of T. wilfordii Hook G. and T. forrestii Loes had systemic action against newly hatched larvae of the rice yellow stem borer Scirpophaga incertulas (Walker) (Chiu and Zhang, 1982).

1.2.1.30. Urtica parviflora Roxb.

Insecticidal property of acetone extract of a wild medicinal plant U. parviflora on B. brassicae at 0.1 to 0.5 per cent was reported by Lal (1976).

1.2.2. Isolation and identification of active principles

Wada and Munakata (1968) isolated an insecticidal alkaloid 'cocculolidine' from Cocculus trilobus DC. Amonkar and Banerji (1971) isolated and identified the larvicidal principles of garlic as diallyl disulfide and diallyl trisulfide which were toxic to Culex pipiens quinquifasciatus Kl. Banerji and coworkers (1979) identified 'allitin', a mixture of diallyl disulfide and diallyl trisulfide isolated from garlic as an insecticide with low persistence. Narayanan et al. (1984) found that allitin interfered in the growth and reproduction of D. cingulatus through the inhibition of gut microflora. The bacterial and fungal isolates from gut content showed marked reduction in growth at higher doses of allitin.

Garlic oil derivatives and their analogues were screened for insecticidal activity. Out of 21 compounds tested, only diallyl trisulfide and triallyl bisulfide had significant toxicity to mosquito larvae (Premlatha Thomas and Kokate, 1979).

'Nagilactone' and 'hallactone' obtained from the leaves of Podocarpus spp. (P. nivillis Hooker. and P. halli Kirk.) were reported to have insecticidal action (Russel et al., 1972,1973). Singh et al. (1973) tested five more neutral norditerpene dilactones obtained from Podocarpus sp. on housefly larvae and found that Podolactone E was the most active compound.

Deshpande et al. (1974) isolated the active components of two Indian medicinal plants Nigella sativa Linn. and Pogosternum heyneanum Benth. which were found toxic to the pulse beetle B. chinensis.

Mc Laughlin et al. (1980) crystalized the active insecticidal principles from the seeds of T. thevetioides and the cardiotonic glycosides obtained and identified as nerifolin and 2-acetyl nerifolin were found toxic to O. nubilalis. Reed et al. (1982) found that nerifolin protected cantaloupe plants from A. vittatum for seven days. The material had systemic and contact action on the insect.

Toxic components of Milletia ovalifolia Kurg. was isolated by Khan and Zaman (1974). Taylor and Vickory (1974)

reported the insecticidal properties of 'limonene', a constituent of citrus oil against Callosobruchus phaseoli Gyll.

Oda et al. (1977) identified the insecticidal constituents in heartwood of Juniperus recurva Buch-Ham as 'thujapone' and 8-cedron - 13-ol which were active against culex mosquitoes.

A non-alkaloid insecticide was isolated from the wild tomato Lycopersicon hirsutum Humb. var. glabratum Humb. and identified as 2-tridecanone. This compound was 72 times more abundant in wild tomato than in the cultivated tomato L. esculentum and was toxic to lepidopterous larvae M. sexta and H. zea and aphid A. gossypii (Williams et al., 1980).

Methyl cinnamate and methyl chevicol, the insecticidal principles obtained by steam distillation of O. basilicum, were toxic to T. castaneum, S. oryzae, S. paniceum and B. chinensis (Pandey et al., 1982).

Sesquiterpene lactones, the natural constituents of the asteraceae, were toxic to Melanoplus sp. when injected into the haemocael at doses greater than 0.25 µ mol per 300 mg insect. Compounds containing a cyclopentenone ring was equitoxic to both sexes whereas those lacking this functional group were four times more toxic to males than females (Isman, 1985).

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1.2.3. Effect on natural enemies

Applications of neem oil in rice fields did not harm natural enemies of plant hoppers and leaf hoppers (Saxena et al., 1980a). Neem oil augmented parasitization of leaf folder larvae as the ichneumonid, eucyrlid and braconid parasites of C. medinalis larvae since neem oil prevented the larvae from folding rice leaves (Saxena et al., 1980b). Later it was reported that topical application of high doses of neem oil caused mortality of the predatory mirid by Cyrtorhinus lividipennis (Reuter), but the predatory spider Lycosa pseudoannulata (B & S) was not affected even at a dose of 50/ug neem oil per spider (Saxena et al., 1983). Schmutterer et al. (1983) revealed that the growth and development of endoparasitic hymenopterans on C. medinalis larvae feeding on neem treated rice leaves were unaffected. This may be due to the lack of contact with neem extract and the parasites. Wu (1986) also reported that neem seed oil was safest to the natural enemies of BPH viz. L. pseudoannulata and Apanteles cypris. Effect of methanol, ethanol, acetone and pentane extracts of neem in the predatory phytoseid Phytoseilus persimilis A. and the tetranychid Tetranychus cinnabarinus Boisd. were compared by Mansour et al., 1987. Pentane extract was most toxic to P. persimilis (the predator).

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1.3. Insect hormonal activity of plant products

The possibility of using materials with insect juvenile hormone activity as pesticides was first reported by Slama and Williams (1966) who observed the inability of European linden bug Pyrrhocoris apterus to reproduce when kept in contact with paper made from the wood of balsam fir (Abies balsamea Mill.) which they called 'paper factor'.

Williams and Robbins (1968) listed 52 species of plants having JH activity on Tenebrio sp. among which six gave positive results.

Mansing et al. (1970) assayed the methanol dichloromethane extracts of wood and bark of A. balsamea, Thuja plicata D.Don., Picea sitchensis Carr., Thuja heterophylla L. and Pinus contesta S. on the pupae of the wax moth Galleria mellonella by topical application. The wood extracts were more active than bark extracts. Fruit extracts of Pesodari pubescens and seeds of Bixa orellans Linn. showed JH activity in T. moliter, and C. fatigens (Moussatche et al., 1970). Such activity has also been reported for Iris ensata Thumb. on D. koenigii (Saxena and Srivatsava, 1972).

Acetone extracts of some South Indian plants Tectona grandis L., Pteropus marsupiam Roth and Vertomia indicum Less. showed JH activity when applied topically to the last instar nymphs of D. cingulatus (Prabhu et al., 1973; Prabhu and John, 1975).

Essential oil of Tagetus minuta L. was found to have juvenile hormone like activity on D. koenigii (Saxena and Srivatsava, 1973). JH activity was shown against D. koenigii on the essential oil of some herbaceous plants of Western India viz. Elephantopus scaber Linn., Pogostemon laneanus S., Strobilanthus oxiocephalus B. and Bambusa arundinaceae W. (Deshpande et al., 1974).

Topical application of the extracts of Anthocephalus cadamba Miq., L. camara, T. grandis, Calophyllum Linn. sp. and Phyllanthus emblica L. to the fifth instar nymphs of D. cingulatus resulted in sixth instar retaining varying degrees of nymphal characters (Prabhu and John, 1975a). Juvenomimetic activity in 12 South Indian plants was reported by Gopakumar et al. (1977). Osmani et al. (1977) reported JH mimicking activity of citral oil in D. cingulatus.

1.3.2. Isolation of active principles

Bowers et al. (1966) isolated and identified the active component from A. balsamea as 'juvabione' which was sesquiterpenoid of todomatic acid. Cerny et al. (1967) isolated 'dehydrojuvabione' from the same source and it also had JH activity on insects.

Mansingh et al. (1970) reported the insect juvenile hormone activity of 'thujic acid' extracted from the Western Cidar tree Thuja plicata. When injected into fresh pupae of

T. moliter thujic acid showed juvenilizing effect (Barten et al., 1972). Rogers and Mauville (1972) isolated a JH analogue from the wood of a variety of douglas fir from British Columbia.

Nagilactone and halloctone obtained from the leaves of Podocarpus nivillis Hooker and P. halli Kirk. had JH effect on housefly (Russel et al., 1972,1973). Jacobson et al. (1975) identified a compound Echinotone from the roots of Echminocera angustifoliae which induced strong juvenilising effects in the yellow meal worm T. moliter.

Bowers et al. (1976) isolated and identified two natural antijuvenile hormones Precocene I and II from the extract of budding plant Ageratum houstonianum Mill. which induced precocious moulting in the nymphs of milk weed bug Oncopeltis fasciatus Dallas. and D. cingulatus. Joshi et al. (1980) reported the anti-JH effects of Precocene II obtained from Ageratum conizoides Linn. on red cotton bug.

Two extremely active JH analogues were isolated from Sweet basil O. baselicum. Juvocimene I and Juvocimene II the two JH mimics were later synthesised. The biological activities of the natural and synthetic juvocimene on fifth instar nymphs of O. fasciatus were found to be identical (Nishida et al., 1984).

1.3.3. Growth regulating activity of neem and its components

Mc Millan et al. (1969) reported that growth and development of S. frugiperda and H. zea were retarded by chloroform extracts of M. azedarach leaves although water extracts had no such activity. Ruscoe (1972) also reported the growth retarding effect of azadirachtin on the larvae of P.xylostella, P. brassicae and H. virescens and nymphs of Dysdercus foetidus. Later Leuschner (1972,1974) detected a growth regulating influence of crude methanolic extract of neem leaves on coffee bug Antestiopsis orbitalis bechuana. Leuschner (1972) concluded that the active principles in leaf extracts of A. indica may be related to ecdysoids. Crude extracts from leaves and seeds, oil and highly purified portions of seed extracts and pure azadirachtin were tested by Steets (1975) and a pronounced contact effect on larvae and pupae of E. varivestis was found. It also caused malformations and reduced fecundity (Steets and Schmutterer, 1975; Schmutterer and Rembold, 1980). Growth regulating activity of neem products was reported on C. medinalis and N. lugens (Saxena et al., 1980), L. migratoria (Rembold and Sieber, 1980), on E. varivestis (Schulz, 1980; Schluter, 1980), on H. zea, S. gragipuda, P. gossypiella and H. virescens (Kubo and Klocke, 1982), on S. littoralis (Meisner and Ascher, 1983), on Oncopeltus fasciatus Dullas. (Jacobson et al., 1983), on P. japonica (Ladd et al., 1978; Ladid et al., 1984), on M. separata (Schmutterer et al., 1983, Chiu, 1985), on

evoked specific and non-specific effects during the course of development. Prolonged developmental period, wing deformities, unplasticization of wing lobes, development of wingless adults and larval mortality were the characteristic features. Similar morphogenetic abnormalities were observed by the application of neem seed extracts on C. medinalis (Saxena et al., 1980b), M. separata (Schmutterer et al., 1983; Chiu, 1985) and S. littoralis (El Sayed, 1985).

1.3.5. Moulting inhibition caused by plant products

Helen et al., (1972) reported that citrus oil inhibited the emergence of C. maculosis. Non-emergence of adults from treated larvae were reported on C. fumiferana and S. littoralis (Outram, 1973), S. litura (Sundaramurthy and Balasubramoniam, 1978), on D. cingulatus (Abraham and Ambika, 1979) and on P. japonica (Jacobson et al., 1983).

Muthukrishnan et al. (1980) observed incomplete pupation and pupal mortality leading to inhibition of adult emergence on the adverse effect of caffeine and theophylline on D. chrysipus. Ecdysteroid production was delayed and erratic on the fifth instar larvae of O. fasciatus treated with azadirachtin, resulting in incomplete adult ecdysis (Jacobson et al., 1983). Various neem extracts caused ecdysis inhibition of the rice bug L. oratorius (Heyde et al., 1983).

1.3.6. Mating behaviour

Abnormalities in mating behaviour were noted in D. cingulatus treated with extracts of A. cadamba (Prabhu and John, 1975a). KumudaSukumar and Osmani (1981) observed abnormal protrusions of male genetalia of red cotton bug treated with catharanthus extract though there was no adverse effect on mating. Dangre and Rohlkar (1982) found that exposure of the adults of Earias vitella to vapours of oil obtained from the weed Blumea eriantha DC (compositae) could reduce the mating ability especially in males.

1.3.7. Ovarian development

Prabhu and John (1975) observed that crude extracts of A. cadamba at high doses inhibited the ovarian development resulting in sixth instar nymphs with nymphal type ovary. Bowers et al. (1976) and Joshi and Ramakrishnan (1979) reported the prevention of ovarian development in adult females of D. cingulatus and milk weed bug O. fasciatus by the application of Precocene I and II. Saxena and Mathur (1976) found that application of plant extracts induced sterility by the interference of regulatory functions rather than by the direct effect upon the ovarian tissues.

1.3.8. Fecundity

Slama and Williams (1966) discovered female sterility caused by juvenoids which was connected with ovicidal effects. Reduced fecundity caused by juvenoids on C. fumiferanae (Outram, 1973) and D. cingulatus (Prabhu and John, 1975b), Carpophilus hemipterus L. (Jacobson et al., 1978), Crocidolomia binotalis Zell. (Fagoonee, 1980), N. lugens (Saxena et al., 1980) and S. gregaria (Brajendra Singh, 1981) was reported. The leaf alkaloid of C. roseus gave better sterilant action than the root alkaloid and the males were more susceptible to leaf alkaloids while the root alkaloids showed some specificity to the females also (Kumuda Sukumar and Osmani, 1983). Narayanan et al. (1984) found that allitin caused total mortality of eggs of D. cingulatus. Chiu (1985) reported reduced oviposition in gall fly O. oryzae by neem oil application.

When newly emerged adults of lygeid O. fasciatus were treated with azadirachtin, the life span and fecundity of treated adults and hatchability of eggs resulting from the treated adults were greatly reduced depending upon the degree of concentration. Topical treatment of egg had no effect (Dorn, 1986).

Saxena et al. (1986) investigated the insect antifertility effect of allelochemics in Adathoda vesica and found considerable reduction in fecundity and fertility of the bugs D.koenigii

and the tenebrionid T. castaneum at 0.1 and 0.3 per cent concentrations.

El Ghar and El Sheikh (1987) reported reduction in fecundity of pulse beetle C. chinensis emerging from pulses treated with petroleum ether extracts of Clerodendron infortunatum, Nerium oleander, Ipomoea palmata and Artiplex s Reproductive fitness of males of N. virescens and N. lugens were reduced when caged on rice plants treated with neem seed extract and aqueous neem seed suspensions (Saxena and Bassiem 1987). They observed chromosomal and cellular dysfunctions during spermatogenesis leading to non-viability and senescenc of sperm cells. Velusamy et al. (1987) also reported similar effects on oviposition of fall army worm S. frugiperda and BPH, N. lugens.

Essential oils obtained from plants induced sterility among insects. Oil of Indian Calamus root (Acorus calamus L. caused sterility in male houseflies, female bean weevils, khapra beetles and red cotton stainer (Walker and Bowers, 1970). Lang and Treece (1971) found that oil of Sterculia faetida Linn. also contained one active component sterculic acid which acted as sterilent for females of Musca domestica and M. autumnalis. Similar activity was found against D. koenigii in the essential oil of T. minutus (Saxena and

Srivastsava, 1973) and in some herbaceous plants of Western India viz. E. scaber, P. laneanum, S. exocephalus and B. aurundinaceae (Deshpande et al., 1974).

1.3.9. Embryonic development

Williams and Slama (1966) and Williams (1967) observed that paper factor inhibited embryonic development in P. aphenus. Vapours of the oil of A. calamus affected embryonic development of E. varivestis (Walker and Bowers, 1970) and D. koenigii (Saxena and Srivastsva, 1972). Reduction in hatchability of eggs laid by the adultoids produced after the application of plant extracts was reported in D. cingulatus (Prabhu and John, 1975a), in S. littoralis (El Sayed, 1985), on O. fasciatus (Dorn, 1986) and on S. gregaria and P. operculella (Singh and Singh, 1987; Shelke et al., 1987). Neem oil did not affect the hatchability of the eggs of N. lugens whereas 50 to 75 per cent inhibition in hatchability was noted in C. medinalis (Saxena et al., 1980b).

MATERIALS AND METHODS

2. MATERIALS AND METHODS

2.1. Screening plants for feeding inhibitory activity

Extracts of twenty plants were tested against fourth instar larvae of Spodoptera litura (Fb.) and Pericallia ricini (Fb.) and third instar larvae of Henosepilachna vigintioctopunctata (Fb.) for their feeding inhibitory activity.

2.1.1. Selection of plants for screening

Locally available plants which were known to possess biocidal activity/medicinal property/poisonous effect on higher animals and/or those which harbour low levels of insect population were screened and 20 plants were selected. Plants selected were:

1. Neem - Azadiracta indica Juss. - Meliaceae
2. Clerodendron - Clerodendron infortunatum Linn. Verbinaceae
3. Eupatorium - Eupatorium odoratum Linn. (Cromolaena odorata) - Compositae
4. Tulsi - Ocimum sanctum L. - Labiatae
5. Oleander - Thevatia neriifolia Juss. - Apocynaceae
6. Champakam - Plumeria rubra Ait. - Apocynaceae
7. Calotropis - Calotropis gigantea R.Br. - Asclepiadaceae
8. Notchy - Vitex negundo Linn. - Verbinaceae
9. Nerium - Nerium oleander Linn. Apocynaceae
10. Panikoorka - Coleus aromaticus Benth. Labiatae
11. Chunda - Solanum indicum Linn. - Solanaceae

2.1.3. Rearing of test insects

The tobacco caterpillar S. litura, the hairy caterpillar P. ricini on castor and the epilachna beetle H. vigintioctopunctata on brinjal were reared in the laboratory starting from the eggs and larvae collected from their respective host plants in the college farm. The adults obtained from the rearing were confined in circular glass jars provided with the leaves of the host plant for feeding and egg laying. Eggs laid each day were collected separately and kept in glass troughs with the relevant food material (castor or brinjal). The food materials were changed on alternate days. This procedure facilitated the availability of life stages of the test insects in known age for different experiments.

2.1.4. Assessment of area/weight of treated leaves consumed by the insects

S. litura and P. ricini were exposed on treated castor leaves. Circular discs of 50 mm diameter were cut from the leaves of uniform age. The leaf discs were dipped in plant extracts and were air dried. Each leaf disc was placed on filter paper kept over wet padding of cotton in a petri dish. The leaf disc was then exposed to one pre-weighed fourth instar larva of the test insect. The larvae were preconditioned without food for four hours. Five replications were maintained

for each treatment. Leaf discs treated with water alone and exposed to larvae served as control. Starvation treatment in which no food was provided was also maintained. The larvae were allowed to feed for 48 hours. The leaf surface consumed by the larva during the above period was estimated by drawing the outline of the uneaten portion of the leaf discs over a graph paper and then counting the number of squares inside the line. The above area deducted from the original area of the leaf discs gave the area consumed by the insect. The insects released in different treatments were weighed at the end of 48 hours (Ascher and Rones, 1964).

In the case of epilachna, third instar grubs were exposed to treated brinjal leaves. Pre-weighed brinjal leaves of uniform age and size were dipped in leaf extracts and were dried. Ten third instar grubs of epilachna were collected from the culture, weighed and released in each dish over which a chimney was placed. Forty eight hours after exposure, the uneaten portions of the leaves were taken out, cleaned and weighed. The difference with the pretreatment weight gave the weights of leaves consumed. Pre-weighed leaves dipped in water and exposed to larvae in petri dishes served as control. The weight loss of leaf in similar set, kept without exposure to larvae, served to find the natural loss of leaf weight due to evaporation and to make adjustments in the weight of leaves

consumed by the grubs. Three replications were maintained for each treatment.

2.1.5. Estimation of percentage of leaf protection

The percentage of leaf area / weight protected by the extracts was estimated as = (A - B)/A x 100, where A = area / weight of leaf consumed in control, and B = area / weight of leaf consumed in treatment.

2.1.6. Estimation of percentage of larval starvation

The difference between the weight gain of larvae in control and the mean weight loss of starved larvae was treated as 100 per cent starvation. Percentage of larval starvation in treatments was calculated as (C-E)/(C-S) x 100 where C = mean weight gain of control larvae in 48 hours, E = mean weight gain of experimental larvae in 48 hours and S = mean weight gain of starved control larvae in 48 hours (the figure is negative). C - S = 100 per cent starvation.

2.1.7. Grading of plant extract for antifeedant property

Based on the percentage of leaf protection and percentage larval starvation the plant extracts were graded for their feeding inhibition as follows:

per cent protection	grade	degree of activity
80 - 100	+ + + +	very high
60 - 80	+ + +	high
40 - 60	+ +	low
20 - 40	+	very low
less than 20	-	no activity

2.2. Estimation of feeding inhibition of P. ricini caused by essential oils

Feeding inhibitory activity of eight essential oils on the third instar larvae of P. ricini was evaluated. The oils used in these studies were obtained from Medicinal and Essential Oil Factory, Naduvattom, Nilgiris (S. India) and were of high purity. The oils used were citronella oil, palmarosa oil, geranium oil, citrodora oil, camphor oil, oil of wintergreen, patcholi oil and eucalyptus oil. Each oil was tried in three concentrations of 10.0, 5.0 and 2.5 per cent.

Preweighed leaves of castor were sprayed with different dilutions of the essential oil using an atomizer ensuring uniform coverage of the leaves. The sprayed leaves were air-dried and kept in dishes over filter paper on wet cotton padding and the percentages of leaf protection and larval starvations were estimated as described in para 2.1.4.

2.3. Assessment of antifeedant potency of different types of plant extracts to H. vigintioctopunctata

Based on the data collected from the screening trials, A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia, which showed high feeding inhibition were selected for detailed studies. Benzene extracts of the plants were assayed in the laboratory for their relative antifeedant potency against third instar grubs of H. vigintioctopunctata.

2.3.1. Preparation of extracts

Twenty five g samples of the shade-dried powdered plant material was extracted in a Soxhlet apparatus for 24 hours using benzene as solvent. The extracts thus obtained were transferred to volumetric flasks and the volume was made up to 25 ml by adding appropriate quantities of the solvent. The extract was evaporated to dryness in a rotary vacuum evaporator at 40°C and redissolved in the solvent and diluted to different concentrations required for assay using water containing 1% teepol. The solvent concentrations in the final spray formulation was maintained at 5 per cent level.

2.3.2. Exposure of insects to plant extracts on larvae

Pre-weighed brinjal leaves of uniform age were dipped in emulsions of plant extracts in graded concentrations of

2, 1, 0.5, 0.25 and 0.125 per cent. The leaves were air-dried and fed to pre-weighed third instar grubs of epilachna beetle as described in para 2.1.4.

2.3.3. Evaluation of leaf protected

The percentage of leaf protection and larval starvation in different treatments were estimated as detailed in para 2.1.5 and 2.1.6. These data were subjected to probit analysis (Finney, 1952) and from the regression equation for leaf protection PC 50 and PC 95 values and from the equation for larval starvation SC 50 and SC 95 values were calculated (Ascher and Nissim, 1965).

2.4. Evaluation of persistent antifeedant activity of plant extracts under field conditions

The residual antifeedant activity of plant extracts was bioassayed using third instar grubs of H. vigintioctopunctata as test insect.

2.4.1. Raising of potted plants and applying plant extracts

The plants used for the experiment were raised in garden pots of size 30 x 30 cm. Forty day old seedlings of 'Pusa purple long' variety of brinjal were planted in each pot at the rate of one seedling per pot. Benzene extracts of A. indica, E. odoratum, C. infortunatum, T. neriifolia and N. oleander and

water extract of T. neriifolia were the treatments. When the plants attained sufficient growth, two per cent emulsion of the plant extracts were applied on them with a hand sprayer to the run off point. A control sprayed with water mixed with 0.625 per cent triton X 100 was also maintained.

2.4.2. Collection of samples and exposure of test insect

Leaves of uniform age and size were collected from the treated and control plants at different intervals after spraying (vide Table 7), weighed and offered to third instar grubs of epilachna beetle for feeding as described in para 2.1.4.

2.4.3. Assessment of results

The percentages of leaf (weight) protected over control when the grubs were exposed for 48 hours on leaves collected at different intervals after spraying, were determined as done in para 2.1.5. The bioassay was repeated at different intervals till the effect tailed out in all the treatments. The persistent antifeedant effects of the treatments were estimated in terms of PT indices following the method elaborated by Pradhan (1967).

2.5. Screening of different types of plant extracts for insecticidal activity

Extracts of twenty plants (vide para 2.1.1) in water, acetone, benzene and petroleum ether were screened for their

contact toxicity to third instar larvae of S. litura and H. vigintioctopunctata, and third, fourth and fifth instar nymphs of Dysdercus cingulatus (Fb.) and the adults of Aphis craccivora (Koch.)

2.5.1. Mass culture of test insects

D. cingulatus: Nymphs, collected from the field were fed on water soaked cotton seeds and maintained in the insectary at the temperature 27 ± 0.5°C. The adults emerging from the nymphs were transferred to cylindrical glass jars (30 x 15 cm) for mating and egg laying. Moist sand was placed at the bottom of the rearing jars to a height of 2 cm over which soaked cotton seeds were kept for the insects to feed. The jar was kept closed using a muslin cloth, kept in position using a rubber band. The moist sand prevented early drying of the soaked seeds and eggs laid by the insect. The eggs were collected from the jars every day and placed in separate containers for further development. The growth and moulting of the nymphs were recorded daily so that the age of the larval instars selected for each experiment did not vary beyond 24 hours.

2.5.2. Rearing of S. litura and H. vigintioctopunctata

The mass culture of S. litura was raised and maintained in the laboratory on castor leaves and H. vigintioctopunctata on brinjal leaves following the methods described in para 2.1.3.

2.5.3. Rearing of A. craccivora

Adults of A. craccivora were collected from cowpea plants in field and reared on tender twigs of cowpea kept in glass troughs. The turgidity of the twigs was maintained by keeping their cut ends dipped in water taken in small glass vials. At the end of 24 hours of exposure the twigs with first instar nymphs were removed to fresh glass troughs, and the twigs were subsequently changed on alternate days. The moulting of the nymphs was observed and recorded daily, so as to enable the selection of nymphs of different instars and age for the differer experiments.

2.5.4. Testing the toxic effect of plant extracts

Required larval stages (vide Table 8) of uniform age and size were collected from mass culture maintained in the laboratory. In the case of aphids 24 hour-old apterous adults were used. Acetone, benzene, petroleum ether and water extracts of twenty plants obtained as described in 2.3.1 were tested in the experiment each at three different concentrations (vide Table 8). The extracts were directly sprayed on the test insects, taken in clean petri dishes, under Potter's tower. One ml each of the extract was sprayed in one dish containing ten insects which formed one replication. Three replications were taken for each treatment. Controls were sprayed with the respective solvents only. The sprayed dishes were kept exposed under a

fan for the spray fluid to evaporate. The sprayed insects were then transferred to chimneys placed over a petri dish with fresh food material and the open end was closed with muslin cloth. Treated aphids were transferred to the tender twigs of pea kept in specimen tubes and the open end of the tubes was closed by muslin held in position by rubber band. Mortality counts were taken at the end of 24 and 48 hours. The percentage mortalities of the insects were calculated and the data were corrected for mortality in control using Abbot's formula (Abbot, 1925).

The extracts which gave more than 50 per cent mortality of pea aphid at 100 per cent concentration were applied at serial dilutions and the mortality data obtained were subjected to probit analysis and their LC 50 values were calculated.

2.6. Relative toxicity of the extracts of *A. indica*, *E. odoratum*, *C. infortunatum*, *N. oleander* and *T. neriifolia* to *D. cingulatus*

2.6.1. Preparation of the emulsions

Emulsions were prepared from plant extracts as described in para 2.3.1. Emulsions at concentrations of 2.0, 1.0, 0.5, 0.25 and 0.125 per cent were prepared maintaining the concentrations of benzene in the final spray fluid at 5 and of triton X 100 (emulsifier) at 0.625 per cent respectively.

2.7. Assessment of the insecticidal activity of essential oils

The eight essential oils listed in para 2.2 were evaluated for their insecticidal activity using third instar larvae of S. litura, last instar nymph of D. cingulatus and adults of A. craccivora as test insects. Four concentrations viz. 10.0, 5.0, 2.5 and 1.25 per cent emulsions were used for the evaluation Bioassay was done by direct spraying under Potter's tower as described in para 2.5.4. Mortality counts were taken 24 h after treatment and the corrected mortality percentages were compared for the assessment of the relative efficacy of treatments through analysis of variance and Duncan's multiple range test (DMRT).

2.8. Screening plants for juvenomimetic activity

2.8.1. Mass culture of the test insects

S. litura and D. cingulatus were reared in the laboratory as described in para 2.1.3 and 2.5.1 respectively.

2.8.2. Preparation of plant extracts

Extracts of twenty plants (vide Tables 12-15) in water, acetone, benzene and petroleum ether were screened for their juvenomimetic activity in insects.

These plant extracts were prepared as described in para 2.3.1. Twenty five g each of powdered plant material was

extracted and the volume was made up.to 100 ml using the respective solvents and this was treated as 100 per cent extract while preparing formulations for different experiments.

2.8.3. Application of plant extracts on the insects

The plant extracts were applied topically to the newly moulted fifth instar nymphs of D. cingulatus and sixth instar caterpillars of S. litura on the abdominal tergites using a Hamilton micro applicator prepared from 10 lamda microcapillaries. The microapplicator was designed to deliver fixed quantities of the extract at each operation. Groups of twenty insects each treated with two µl of the extract confined in petri dishes (9 cm dia) served as one replication and four such replications formed one treatment. Two µl each of the solvent applied on 20 insects served as one replication of the control and four replications were maintained for that too. The treated insects were fed on fresh untreated food material in petri dishes over which chimneys were placed and the upper ends of the chimneys were closed with muslin clothing held in position with rubber bands.

In the case of S. litura, 5 µl of the plant extract was used for the treatment of each insect and groups of twenty treated insects were kept in round glass troughs provided with fresh food materials and the troughs were kept covered with muslin clothing.

PLATE I

Screening of morphological changes in *D. cingulatus* treated with plant extracts

Category III - Adultoid Grade II

A - Control

B - Treated

PLATE I

B A

PLATE II

B A

B B B A

PLATE III

Screening of morphological changes in *D. cingulatus* treated with plant extracts

Category III - Adultoid Grade III

Unable to separate out from nymphal exuvium

PLATE III

PLATE IV

Screening of morphological changes in *D. cingulatus* treated with plant extracts

Category IV a. Incomplete ecdysis

b. Incomplete ecdysis

PLATE IV

PLATE V

Screening of morphological changes in *D. cingulatus* treated with plant extracts

a. Normal 5th instar nymph

b. Category IV - 6th instar nymph
(Supernumerary nymph)
Wing pads and abdominal spots retained

PLATE V

a

b

Grade II - where the forewings were highly reduced, membrane was not present, hindwings were reduced and mostly asymmetrical, wings covered half the length of the abdomen only and tarsi were three-segmented (Plate II a &

Grade III - where the body was completely crinkled, not active and unable to separate out from the nymphal exuvium. They died within a few hours after emergence, tarsi three-segmented (Plate III).

Category IV - Incomplete ecdysis: The adults formed in the nymphal skin, but die without eclosion at different periods after treatment (Plate IV a & b).

Category V - Supernumerary nymphs I: (sixth instar nymph) where wing pads were similar in shape to those of fifth instar nymphs, but proportionately longer and more rounded at the tip, abdominal spots were present, tarsi three-segmented (Plate V).

Category VI - Supernumerary nymphs II: Tarsi two-segmented, other characters similar to those of Category V.

2.8.4.1.2. Assessment of longevity of treated insects

The treated insects kept with fresh food were daily observed. The duration of next moult as adult/adultoid/ supernumerary instars was treated as last nymphal duration. The

adultoids/normal adults/supernumerary instars were transferred to separate glass chimneys and were supplied with soaked cotton seeds for feeding. They were maintained till death allowing adults/adultoids to mate and lay eggs. By noting the day of death of each insect the longevity of adults/adultoids/sixth instar nymphs could be assessed.

2.8.4.1.3. Assessment of fecundity of insects

The numbers of eggs laid by each isolated insect in experiment 2.8.4.1.1 were counted daily and from the data the fecundity of insects in different categories and grades could be calculated.

2.8.4.1.4. Assessment of hatchability of eggs

The eggs laid by insects in different categories and grades in experiment 2.8.4.1.1 were collected separately and kept in small vials over moist sand. The hatching of the eggs was observed daily. From the data the percentage of eggs hatched could be calculated for each category/grade of insect.

2.8.4.1.5. Assessment of sterility percentage

From the data relating to the fecundity of the insects and hatching percentages of eggs, the sterility percentage was worked out by using the formula suggested by Outram (1973). The sterility percentage (s) = 100 - (a x b) x 100/A x B, where

a = number of eggs laid/female in treatment

b = percentage of eggs hatching in treatment

A = number of eggs in control and

B = percentage of eggs hatching in control.

2.8.4.2. S. litura

All the treated larvae were observed daily for the morphological changes and moulting until they died or emerged as adults/adultoids. Observations were recorded daily on the larval mortality, pupation, nature of pupae, pupal mortality, pupal duration and the nature of adults emerged. The emerging adults from each treatment and control were individually examined and confined in glass troughs and maintained providing sugar solution as food source for mating and egg laying. The number of eggs laid was recorded. The eggs from each treatment were collected and maintained separately for recording hatching percentage.

From the data the sterility percentage was also worked out as detailed in para 2.8.4.1.5.

2.8.5. Assessment of juvenilising potency of different plant extracts on D. cingulatus

Based on the data collected from the screening trials, A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia, which showed high morphogeneitic activity were

selected for this experiment. Acetone and benzene extracts of the five plants selected were assayed in the laboratory for their biological activity on D. cingulatus.

Acetone and benzene extracts of A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia were prepared as described in para 2.8.3. From the stock of 100 per cent solution, 100, 50, 25, 12.5 per cent dilutions were prepared using the corresponding solvents. The method of application and assessment of results were done as described in para 2.8.3 and 2.8.4.

2.8.5.1. Juvenilisation rating

The effect of plant extract on metamorphosis of D. cingulatus was assessed in terms of the scores described in para 2.8.4.1.1. The scores were then converted into percentage of juvenilisation rating treating the categories I, II, III (Grade I), III (Grade II), III (Grade III), IV and V as having juvenilisation rating of 0, 10, 20, 40, 60, 80 and 100 per cent respectively. To compare the relative activity of plant extracts an activity index was derived by multiplying the number of emerging insects in each category/grade by its numerical rating, summing up the results and then dividing the sum by the total number of nymphs treated in the experiment.

2.8.5.2. Assessment of the effect of plant extracts on the mating behaviour of D. cingulatus

Insects emerging as adults/adultoids in the experiment 2.8.5.1 were kept in separate glass chimneys and were provided with food material. They were allowed to mate and the mating behaviour was observed in detail.

2.8.5.3. Assessment of the effect of plant extracts on the ovarian development in juvenilised adults of D. cingulatus

The ovarian development in malformed adults produced by benzene and acetone extracts of A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia, was studied. The emerging adults were dissected five days after moulting and the condition of the ovaries was observed in detail.

2.8.5.4. Assessment of the effect of plant extracts on the embryonic development (on the ovicidal action)

Effect on the embryonic development of plant extracts on D. cingulatus was studied by treating the eggs with different concentrations of benzene extracts of A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia. Eggs collected from the mass culture of D. cingulatus maintained in the laboratory were used for the experiment. Freshly laid eggs (0 to 15 old) were taken in a small piece of muslin cloth and kept

immersed in the graded concentration of the plant extract emulsions at 2.0, 1.0, 0.5, 0.25 and 0.125 per cent concentrations for five minutes. Groups of thirty eggs were taken in each replication. Eggs immersed in water mixed with emulsifier served as control. Treated eggs were then dried under a fan and transferred carefully to specimen tubes for further observations. The numbers of eggs hatching were counted and the hatching percentage of eggs in treatments and control were calculated. These data were corrected using Abbot's formula and were subejcted to probit analysis following the method of Finney (1952).

2.8.6. Assessment of the JH activity of essential oils on D. cingulatus

The eight essential oils listed in para 2.1.2 were evaluated for their juvenile hormone activity on last instar nymphs of D. cingulatus. Three concentrations viz. 10, 5 and 2.5 per cent of each essential oil were prepared in olive oil which was used as a solvent. Two µl of the essential oil was topically applied as described in para 2.8.3. Twenty insects were used for each replication. A control lot was kept, the insects of which were treated only with olive oil. Assessment of results was done as given in para 2.8.4.

2.8.7. Statistical analysis

The data on the nymphal/larval mortality, nymphal/pupal periods, pupal mortality, emergence of normal/malformed adults,

longevity and fecundity of adults and hatchability of eggs were subjected to analysis of variance and the treatments were compared using Duncans Multiple Range Test.

2.9.1. Field evaluation of plant extracts for the control of insect pests of vegetables

The experiment was laid in field adopting a randomised block design with plot of 2.25 x 1.8 m area. The seeds/seedlings of concerned crops were raised adopting recommended spacing. Application of fertilizers and other crop husbandary practices recommended in the package of practices (Kerala Agricultural University, 1982) were adopted excluding the plant protection measures. The treatments included benzene extracts of A. indica, E. odoratum, C. infortunatum, N. oleander and T. neriifolia, water extracts of T. neriifolia and carbaryl. An untreated control was also included. Each treatment was replicated thrice.

Two per cent emulsion of the plant extracts were sprayed on the plants using a knapsack sprayer ensuring a thorough coverage of the plant.

2.9.2. Assessment of results

Results were assessed by monitoring th
the crops before the application of plant extracts, two days after spraying and then at weekly intervals. The data were collected from the net plots and subjected to statistical analysis.

RESULTS

3. RESULTS

3.1. Effect of plant extracts on the extent of leaf fed by epilachna grubs and on the larval starvation

The data on the mean percentage weight of leaf protected over control and mean percentage of larval starvation are furnished in Table 1. The water extract of T. neriifolia gave 100 per cent protection of leaf against the feeding of epilachna grubs. This was followed by the extracts of E. odoratum, A. indica and M. viridis, the mean percentages of leaf protection in these treatments being 73.33, 62.22 and 61.53 respectively. Feeding inhibitory activity of C. infortunatus and A. conizoides were found to be low showing leaf protections of 57.11 and 42.59 per cent respectively. In the case of V. negundo and C. aromaticus the percentage protections were 29.63 and 28.18 respectively. Water extracts of the remaining plants did not have any inhibition on the feeding of epilachna grubs.

With reference to the larval starvation also water extract of T. neriifolia ranked first. The treatment showed 100 per cent larval starvation. This was closely followed by A. indica extract in which the starvation percentage was as high as 92.00. Extracts of M. viridis (76.92 per cent), C. infortunatum, P. odoratissimus (72.00 per cent), A. vesica (68.00 per cent), N. oleander (66.67 per cent), C. gigantea, M. esculenta, C. papaya (64 per cent), E.odoratum and S.indicum (60.00 per cent) also

showed high larval starvation. Extracts of remaining eight plants caused low levels of larval starvation or had no effect.

Acetone extract of E. odoratum gave the maximum protection of 60.00 per cent and it was closely followed by V. negundo (56.20), C. gigantea (52.80) and A. indica (48.33). C. papaya, C. infortunatum, O. sanctum and A. conizoides had very low activity, the percentages of leaf area protected being in the range of 1.92 to 35.24 only. Twelve plants did not show any feeding inhibition.

Acetone extract of C. infortunatum, A. indica, E. odoratum and C. aromaticus caused high percentage of larval starvation (89.00, 83.33, 83.25 and 81.82 per cent respectively) while in T. neriifolia and C. gigantea the larval starvations were 72.73 and 66.67 per cent respectively. In N. oleander, the larval starvation was low (35.71 per cent) and all the other extracts showed very low (4.55 to 31.58) activity and eight plants were totally ineffective.

Benzene extract of N. oleander gave 100 per cent leaf protection against epilachna grubs and it was closely followed by the extract of C. infortunatum (93.36 per cent). Extracts of A. indica, E. odoratum, T. neriifolia, P. odoratissimus and O. sanctum also had high feeding inhibitory activity the percentages of leaf protected by the treatments being 78.37, 75.51, 75.37, 62.22 and 60.81 respectively.

Table 1. Feeding inhibition of epilachna grubs exposed on brinjal leaves treated with extracts of different plants

plants extracted	water extract		acetone extract		benzene extract		ether extract	
	mean weight of leaf protected over control (%)	mean larval starvation (%)	mean weight of leaf protected over control (%)	mean larval starvation (%)	mean weight of leaf protected over control (%)	mean larval starvation (%)	mean weight of leaf protected over control (%)	mean larval starvation (%)
A. indica	62.22 +++	92.00 ++++	48.33 ++	83.33 ++++	78.37 +++	31.25 +	8.94 –	75.00 +++
C. infortunatum	57.77 ++	72.00 +++	27.78 +	89.00 ++++	93.36 ++++	87.50 ++++	10.88 –	77.78 +++
E. oderatum	73.33 +++	60.00 +++	60.00 +++	83.25 ++++	75.51 +++	90.63 ++++	16.22 –	111.11 ++++
O. sanctum	0.00 –	40.00 ++	27.73 +	0.00 –	60.81 +++	31.25 +	0.00 –	0.00 –
P. rubra	0.00 –	48.00 ++	14.81 –	0.00 –	53.81 ++	43.75 ++	42.72 ++	0.00 –
T. neriifolia	100.00 ++++	100.00 ++++	18.76 –	72.73 +++	75.37 +++	87.50 ++++	52.22 ++	27.27 +
C. gigantea	0.00 –	64.00 +++	52.80 ++	66.67 +++	22.85 +	54.55 ++	25.61 +	27.27 +
V. negundo	29.63 +	5.88 –	56.20 ++	0.00 –	20.00 +	18.18 –	0.00 –	6.67 –
N. oleander	0.00	66.67 +++	0.00 –	35.71 +	100.00 ++++	100.00 ++++	53.33 ++	45.45 ++
C. aromaticus	28.18 +	6.67 –	1.92 –	81.82 ++++	0.00 –	0.00 –	25.20 +	41.67 ++
S. indicum	0.00 –	60.00 +++	2.46 –	27.27 +	14.30 –	18.18 –	6.25 –	30.77 +
L. aspera	0.00 –	56.00 ++	0.00 –	31.58 +	37.14 +	78.18 +++	0.00 –	0.00 –
M. esculenta	0.00 –	64.00 +++	0.00 –	0.00 –	0.00 –	36.36 +	0.00 –	0.00 –
L. camara	0.00 –	40.00 ++	0.00 –	25.00 +	0.00 –	54.55 ++	47.96 ++	0.00 –
C. variegatum	0.00 –	48.00 ++	0.00 –	18.18 –	20.00 +	78.18 +++	13.41 –	25.00 +
A. vesica	0.00 –	68.00 +++	9.83 –	18.18 –	0.00 –	36.36 +	0.96 –	5.56 –
C. papaya	0.00 –	64.00 +++	35.24 +	4.55 –	0.00 –	54.55 ++	56.31 ++	18.18 –
P. odoratissimus	0.00 –	72.00 +++	0.00 –	20.00 +	62.22 +++	54.55 ++	36.36 +	11.11 –
A. conizoides	42.59 ++	6.80 –	23.57 +	0.00 –	0.00–	18.18 –	0.00 –	35.29 +
M. viridis	61.53 +++	76.92 +++	0.00 –	20.00 +	0.00 –	54.55 ++	0.00 –	0.00 –

Benzene extracts of N. oleander caused maximum larval starvation (100.00 per cent) also and it was followed by E. odoratum (90.63 per cent), C. infortunatum, T. neriifolia (87.50), L. aspera and C. variegatum (78.18). Extracts of C. gigantea, L. camara, C. papaya, P. odoratissimus and M. viridis caused 54.55 per cent larval starvation while P. rubra extract caused 43.75 per cent larval starvation. Extracts of A. indica, O. sanctum, M. esculenta and A. vesica caused very low larval starvation, the percentages being in the range of 31.25 to 36.36. V. negundo, C. aromaticus, S. indicum and A. conizoides did not cause any larval starvation.

Ether extracts of the plants caused relatively low feeding inhibition of epilachna grubs. Extracts of C. papaya (56.31 per cent), N. oleander (53.33 per cent), T. neriifolia (52.22 per cent), L. camara (47.96 per cent) and P. rubra (42.72 per cent) could be considered as significant when the extracts from the remaining plants gave very low or no protection at all. However, very high percentage of larval starvation was observed in E. odoratum extract (111.11) even though the percentage leaf protection was insignificant (16.22). Ether extracts of C. infortunatum and A. indica were also found to induce high percentage larval starvation (77.78 and 75.00). Extracts of N. oleander and C. aromaticus caused only low larval starvation i.e. 45.45 and 41.67 per cent respectively and the activity of other extracts were insignificant.

3.1.2. Effect of plant extracts on the extent of leaf fed by S. litura and on larval starvation of S. litura

Results relating to the studies are presented in Table 2. Water extract of A. indica caused high feeding inhibition in S. litura and 65.41 per cent of the leaf provided for feeding was protected from damage. C. infortunatum extract could give 54.17 per cent leaf protection. T. neriifolia, C. papaya, O. sanctum, A. vesica, M. esculenta, P. odoratissimus and E. odoratum gave protections ranging from 30.42 to 39.59 per cent. Eleven plants gave protection ranging from 0 to 18.75 per cent only.

A similar trend was observed in the case of larval starvation also. Extract of A. indica was the only treatment giving a high larval starvation of 78.25 per cent. Extracts of C. infortunatum, P. odoratissimus and A. vesica caused mean percentages of 59.21, 53.78 and 52.27 larval starvation respectively. Five plants viz. E. odoratum, V. negundo, O. sanctum, T. neriifolia and C. variegatum caused low larval starvation ranging from 23.56 per cent to 39.27 per cent. The remaining eleven plants were ineffective with reference to larval starvation.

Acetone extract of C. infortunatum and C. gigantea exhibited very high feeding inhibition resulting in 98.18 and

94.40 per cent leaf protection. Extracts of T. neriifolia, L. aspera, A. indica and A. vesica gave low percentage leaf protection (57.80, 57.80, 45.19 and 40.73). Extract of M. viridis gave a leaf protection of 33.18 per cent while all the remaining thirteen plants had no effect on the feeding of the insect.

The larval starvation caused by C. infortunatum (98.88 per cent) and C. gigantea (96.27 per cent) were also very high. Acetone extract of T. neriifolia induced a high larval starvation of 61.57 per cent while extracts of L. aspera, A. indica, A. vesica and P. odoratissimus resulted in the larval starvation ranging from 52.24 to 44.04 per cent.

Among the benzene extracts C. infortunatum could prevent the feeding of S. litura on castor leaves completely. Very high feeding inhibitions were observed in V. negundo (86.00) and E. odoratum (80.00). P. rubra and A. indica also gave high leaf protections, the mean percentages of leaf area protected being 72.00 and 63.77 respectively. Benzene extracts of A. vesica, C. variegatum, T. neriifolia, C. gigantea and M. esculenta protected the leaf to the extent of 55.30 to 40.00 per cent. Feeding inhibition in all the other plants tested were insignificant.

Table 2. Feeding inhibition of larvae of S. litura exposed on castor leaves treated with extracts of different plants

plants extracted	water extract		acetone extract		benzene extract		ether extract	
	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)
A. indica	65.41 +++	78.25 +++	45.19 ++	51.12 ++	63.77 +++	62.84 +++	58.83 ++	62.74 +++
C. infortunatum	54.17 ++	59.21 ++	98.18 ++++	98.88 ++++	100.00 ++++	92.72 ++++	90.22 ++++	96.58 ++++
E. oderatum	39.59 +	23.56 +	0.00 -	1.87 -	80.00 ++++	80.08 ++++	23.60 +	12.17 -
O. sanctum	34.59 +	29.61 +	8.50 -	7.46 -	0.00 -	3.83 -	39.60 +	28.14 +
P. rubra	0.00 -	0.91 -	8.50 -	14.93 -	72.00 +++	54.02 ++	61.80 +++	44.87 ++
T. neriifolia	30.42 +	34.14 +	57.80 ++	61.57 +++	48.00 ++	48.28 ++	40.00 ++	36.12 +
C. gigantea	0.00 -	0.00 -	94.40 ++++	96.27 ++++	48.00 ++	24.14 +	47.20 ++	27.38 +
V. negundo	2.09 -	25.08 +	0.00 -	13.81 -	86.00 ++++	62.45 +++	0.00 -	12.17 -
N. oleander	6.25 -	2.42 -	0.00 -	37.31 +	8.00 -	39.46 +	81.30 ++++	82.89 ++++
C. aromaticus	0.00 -	0.00 -	0.00 -	7.46 -	0.00 -	10.73 -	0.00 -	0.00 -
S. indicum	18.75 -	0.00 -	4.33 -	0.00 -	28.00 +	4.98 -	18.70 -	7.66 -
L. aspera	17.40 -	7.85 -	57.80 ++	52.24 ++	0.00 -	12.64 -	18.70 -	19.01 -
M. esculenta	36.50 +	9.97 -	0.00 -	7.46 -	40.00 ++	3.83 -	63.50 +++	50.19 ++
L. camara	0.00 -	0.00 -	5.76 -	13.06 -	1.99 -	11.49 -	17.53 -	6.84 -
C. variegatum	5.18 -	39.27 +	0.00 -	26.12 +	50.00 ++	43.30 ++	25.78 +	18.63 -
A. vesica	35.00 +	52.27 ++	40.73 ++	46.64 ++	55.30 ++	24.14 +	26.48 +	12.93 -
C. papaya	31.25 +	5.44 -	15.63 -	5.60 -	22.25 +	10.34 -	17.36 -	4.56 -
P. odoratissimus	37.50 +	53.78 ++	0.00 -	41.04 ++	5.50 -	16.48 -	22.65 +	20.91 +
A. conizoides	0.00 -	3.63 -	5.56 -	16.79 -	0.00 -	3.07 -	0.00 -	1.90 -
M. viridis	1.12 -	1.51 -	33.18 +	24.25 +	20.45 +	16.08 -	3.75 -	0.00 -

Percentage larval starvation was also very high in the benzene extracts of C. infortunatum and E. odoratum (92.72 and 80.08). A. indica and V. negundo induced high percentage larval starvation (62.84 and 62.45). P. rubra, T. neriifolia and A. vesica had low activity when C. gigantea, N. oleander and C. papaya had very low activity. Ten plants had no activity.

Very high feeding inhibitory activity was observed in ether extracts of C. infortunatum (90.22 per cent) and that of N. oleander (87.30 per cent). The percentage protection was high on leaves treated with ether extracts of M. esculenta (63.50) and P. rubra (61.80). Extract of A. indica protected 58.63 per cent leaf area when C. gigantea and T. neriifolia gave 47.20 and 40.00 per cent leaf protection respectively. All other ether extracts were either less effective or inactive.

Ether extracts of C. infortunatum and N. oleander caused very high larval starvation also in S. litura with mean percentages of 96.58 and 82.89 respectively. High level of starvation percentage was caused by extract of A. indica (62.74 per cent), M. esculenta (50.19 per cent) and P. rubra (44.87 per cent). The starvation effect was low. Only very low larval starvation was observed in T. neriifolia (36.12 per cent), O. sanctum (28.14 per cent), C. gigantea (27.38 per cent) and P. odoratissimus (20.91 per cent). The remaining eleven ether extracts had no activity in inducing larval starvation in S. litura.

Among the acetone extracts also only A. indica was found to be highly effective recording complete inhibition of feeding of P. ricini. Acetone extract of C. variegatum could protect 60.76 per cent leaf from feeding. A low level of leaf protection was seen in the case of L. camara (59.50 per cent), C. papaya (48.27 per cent), E. odoratum (47.95 per cent) and M. viridis (47.95 per cent). All the other twelve plant extracts were ineffective with respect to leaf protection from P. ricini.

Larval starvation induced by acetone extract of A. indica was very high (112.5 per cent). N. oleander also could induce a high larval starvation of 62.5 per cent. All the other acetone extracts could not influence the larval starvation significantly.

Relatively high feeding inhibition of P. ricini was observed in the case of benzene extracts of plants. Complete leaf protection was obtained with the extract of A. indica. O. sanctum, N. oleander and M. viridis also exhibited very high feeding inhibitory activity with mean leaf protection 92.95, 87.36 and 82.05 per cent respectively. L. camara, V. negundo and C. aromaticus also resulted in high feeding inhibition of P. ricini protecting 79.40, 74.75 and 74.75 per cent leaf area. A. conizoides and P. odoratissimus extracts could protect only 48.99 and 48.23 per cent leaf area respectively. A very low

Table 3. Feeding inhibition of larvae of *P. ricini* exposed on castor leaves treated with extracts of different plants

plants extracted	water extract		acetone extract		benzene extract		ether extract	
	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)	mean leaf area protected over control (%)	mean larval starvation (%)
A. indica	100.00 ++++	99.01 ++++	100.00 ++++	112.50 ++++	100.00 ++++	108.70 ++++	83.34 ++++	75.32 +++
C. infortunatum	5.95 -	16.83 -	0.00 -	0.00 -	5.20 -	8.70 -	0.00 -	5.19 -
E. odoratum	5.95 -	15.35 -	47.95 ++	0.00 -	5.00 -	0.00 -	0.00 -	0.00 -
O. sanctum	0.78 -	13.86 -	0.00 -	0.00 -	92.95 ++++	46.38 ++	5.95 -	0.00 -
P. rubra	0.00 -	22.77 +	33.62 +	8.75 -	1.00 -	0.00 -	40.64 ++	22.08 +
T. neriifolia	22.69 +	9.90 -	22.69 +	5.00 -	0.00 -	13.04 -	3.33 -	16.88 -
C. gigantea	0.00 -	0.00 -	39.13 +	12.50 -	0.00 -	0.00 -	13.09 -	5.19 -
V. negundo	69.33 +++	49.50 ++	31.94 +	0.00 -	74.75 +++	37.68 +	2.85 -	14.29 -
N. oleander	51.11 ++	43.56 ++	53.60 ++	62.50 +++	87.36 ++++	42.03 ++	0.00 -	5.19 -
C. aromaticus	32.99 +	26.73 +	55.64 ++	27.50 +	74.45 +++	31.88 +	16.17 -	0.00 -
S. indicum	13.84 -	17.82 -	4.00 -	1.25 -	0.00 -	0.00 -	8.33 -	0.00 -
L. aspera	0.00 -	23.76 +	26.88 +	7.50 -	27.97 +	0.00 -	70.82 +++	31.17 +
M. esculenta	7.69 -	42.57 ++	0.00 -	0.00 -	2.00 -	0.00 -	7.69 -	9.09 -
L. camara	41.15 ++	37.62 +	59.50 ++	37.50 +	79.40 +++	36.23 +	33.77 +	0.00 -
C. variegatum	32.50 +	28.71 +	60.76 +++	35.00 +	0.00 -	23.19 +	39.27 +	7.79 -
A. vesica	34.64 +	6.93 -	0.00 -	7.50 -	0.00 -	18.84 -	0.00 -	12.99 -
C. papaya	0.00 -	11.88 -	49.27 ++	25.00 -	0.00 -	0.00 -	18.00 -	0.00 -
P. odoratissimus	40.10 ++	43.56 ++	0.00 -	17.50 -	48.23 ++	19.56 -	5.00 -	18.18 -
A. conizoides	0.00 -	0.00 -	8.69 -	3.75 -	48.99 ++	12.32 -	74.07 +++	48.05 ++
M. viridis	50.00 ++	20.79 +	47.95 ++	13.75 -	82.05 ++++	23.19 +	82.07 ++++	50.65 ++

feeding inhibitory activity was observed in the case of benzene extract of L. aspera (27.97 per cent). Ten of the benzene extracts tested were totally ineffective against P. ricini.

Benzene extract of only A. indica was significantly effective in inducing larval starvation in P. ricini. Extracts of O. sanctum and N. oleander could cause 46.38 and 42.03 per cent larval starvation and the starvation induced by all the other benzene extracts were not much significant.

Ether extract of A. indica and M. viridis had very high antifeeding action protecting 83.34 and 82.07 per cent leaves respectively. A. conizoides and L. aspera extracts could give 74.07 and 70.82 per cent leaf protection. P. rubra gave 40.64 per cent protection and the extracts of C. variegatum and L. camara gave 39.27 and 33.77 per cent respectively. All the other extracts were completely inactive in inhibiting the feeding of P. ricini larvae.

Ether extracts of plants were comparatively less effective in inducing larval starvation. Larval starvation was high only in the case of A. indica extract (75.32 per cent). M. viridis and A. conizoides could cause starvation percentages of 50.05 and 48.05 respectively and L. aspera and P. rubra extracts induced very low larval starvation of 31.17 and 22.08 per cent respectively. Remaining fifteen ether extracts had no effect on the starvation of P. ricini larvae.

Table 4. Feeding inhibition of third instar larvae of P. ricini exposed to castor leaves treated with essential oils

treatments	mean weight of leaf protected over control (%)			mean % larval starvation		
	A	B	C	A	B	C
Citronella oil	66.55 bcd	31.84 ij	30.05 ijk	46.78 ab	11.11 jk	0.00 l
Palmarosa oil	36.13 hi	28.80 ijk	35.59 hi	20.47 fghij	15.00 hij	1.17 l
Geranium oil	76.12 a	49.29 fg	22.58 k	88.00 a	18.23 fghij	5.21 k
Eucalyptus oil	50.19 fg	24.77 jk	8.90 l	40.00 bcd	14.58 hij	13.54 ij
Oil of wintergreen	64.30 cde	55.53 ef	51.90 fg	48.00 ab	24.36 efgh	33.33 cde
Patcholi oil	63.60 cde	55.69 ef	57.25 def	21.50 fghij	28.21 def	26.28 efg
Citrodora oil	79.11 a	71.20 abc	43.35 gh	47.00 ab	29.00 def	21.79 efghi
Camphor oil	73.41 ab	63.29 cde	49.05 fg	46.00 bc	42.00 bc	16.67 hij

A - 10 per cent emulsion B - 5 per cent emulsion C - 2.5 per cent emulsion

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

3.2. Feeding inhibition of essential oils on P. ricini

The data on the mean weight of leaves protected in different treatments when compared to control and mean larval starvations are presented in Table 4. It was observed that all the essential oils tested had deterrent effect on the feeding of P. ricini. The mean leaf weight protected by geranium oil 10%, citronella oil 10% and 5% and camphor oil 10% (76.12, 79.11, 71.20 and 73.41 per cent respectively) were on par and significantly superior to all other treatments. Citronella oil 10 per cent (66.55 per cent leaf protection) ranked next to the above treatments and it was also on par with oil of wintergreen (64.30%) and patcholi oil (63.60%), camphor oil 5% (63.29%) and patcholi oil 2.5% (57.25%).

Patcholi oil 2.5% and 5%, oil of wintergreen 5%, geranium oil 5% and camphor oil 2.5% came on par next in rank. Remaining treatments which gave mean percentage protection of 43.35 to 8.90 per cent were found less effective.

Mean larval starvation also was at its maximum on leaves treated with geranium oil (88 per cent) and it was closely followed by oil of wintergreen (48%), citronella oil (46.78%) and camphor oil (46%). The treatments were on par also. It was followed by camphor oil 5% (42.0%) and eucalyptus oil 10% (40%). At all doses palmarosa oil caused low levels of larval starvation (1.17 to 20.47%). At 5 and 2.5 per cent concentrations all treatments (except camphor oil caused low larval starvation (1.17 to 33.33 per cent) only.

Table 5. Bioassay of the antifeedant effects of different plant extracts based on leaf protection using epilachna grub as test insect

benzene extracts of	heterogeneity	regression equation	PC_{50}	fiducial limits	PC_{95}	fiducial limits
A. indica	$X^2_{(3)} = 6.1102$	y = 2.62825x + 2.54693	0.8576	0.9366 0.7654	1.5608	1.669 1.430
E. odoratum	$X^2_{(2)} = 2.7493$	y = 3.04672x + 1.73278	1.1810	1.3230 1.0390	1.6123	1.9043 1.4288
C. infortunatum	$X^2_{(3)} = 6.5834$	y = 2.0683x + 3.4025	0.5921	0.6543 0.5358	1.5678	1.7423 1.4270
N. oleander	$X^2_{(3)} = 7.195$	y = 2.38066x + 3.9097	0.2871	0.3160 0.2608	1.1489	1.2650 1.0430
T. neriifolia	$X^2_{(3)} = 6.681$	y = 1.15868x + 3.76823	1.1560	1.2976 1.0144	2.4833	2.6696 2.0450

Fig. 1. Leaf protection against feeding by H. vigintioctopunctata in relation to concentrations of plant extracts

Fig. 2. Larval starvation of H. vigintioctopunctata in relation to concentrations of plant extracts

FIG. 1.

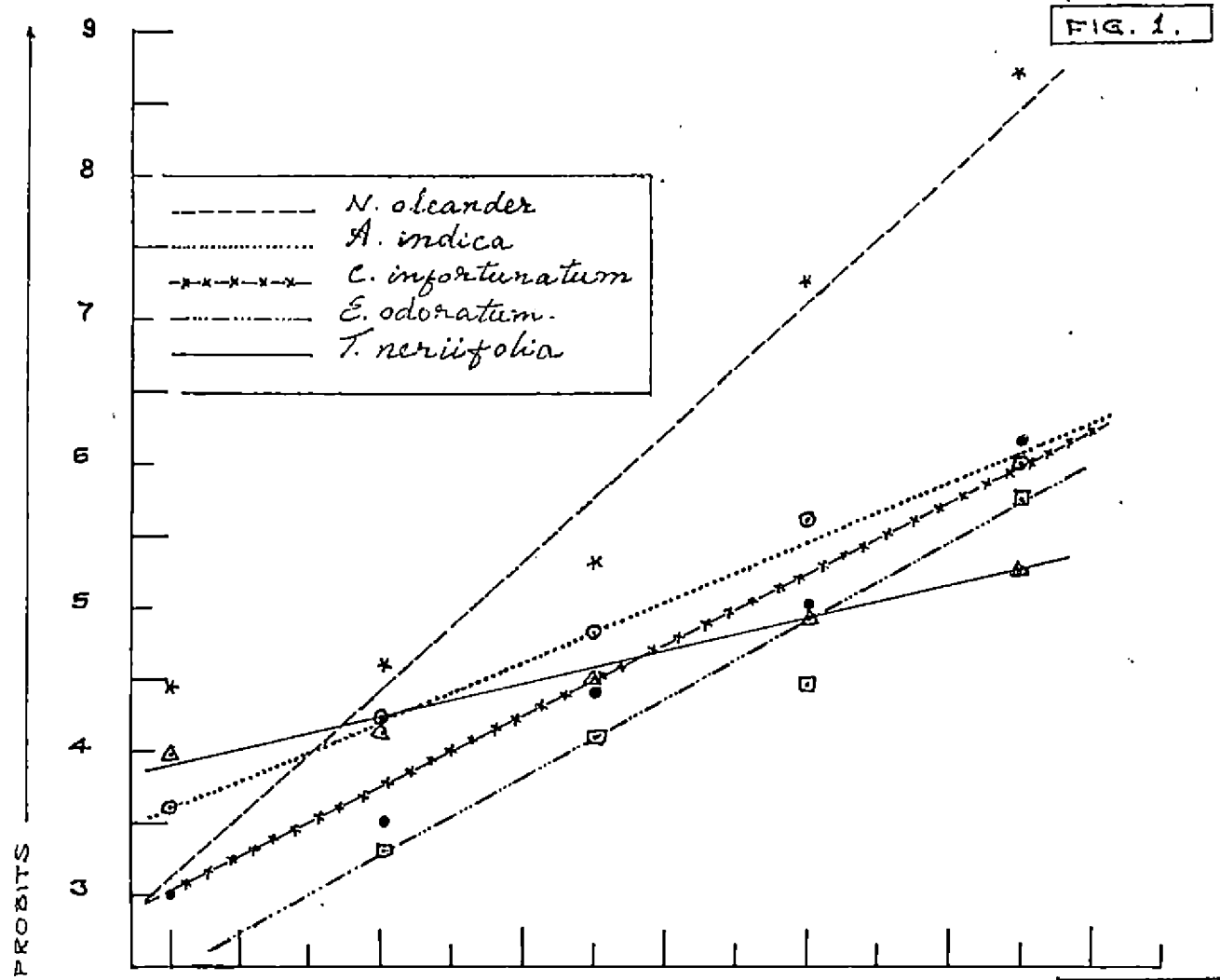
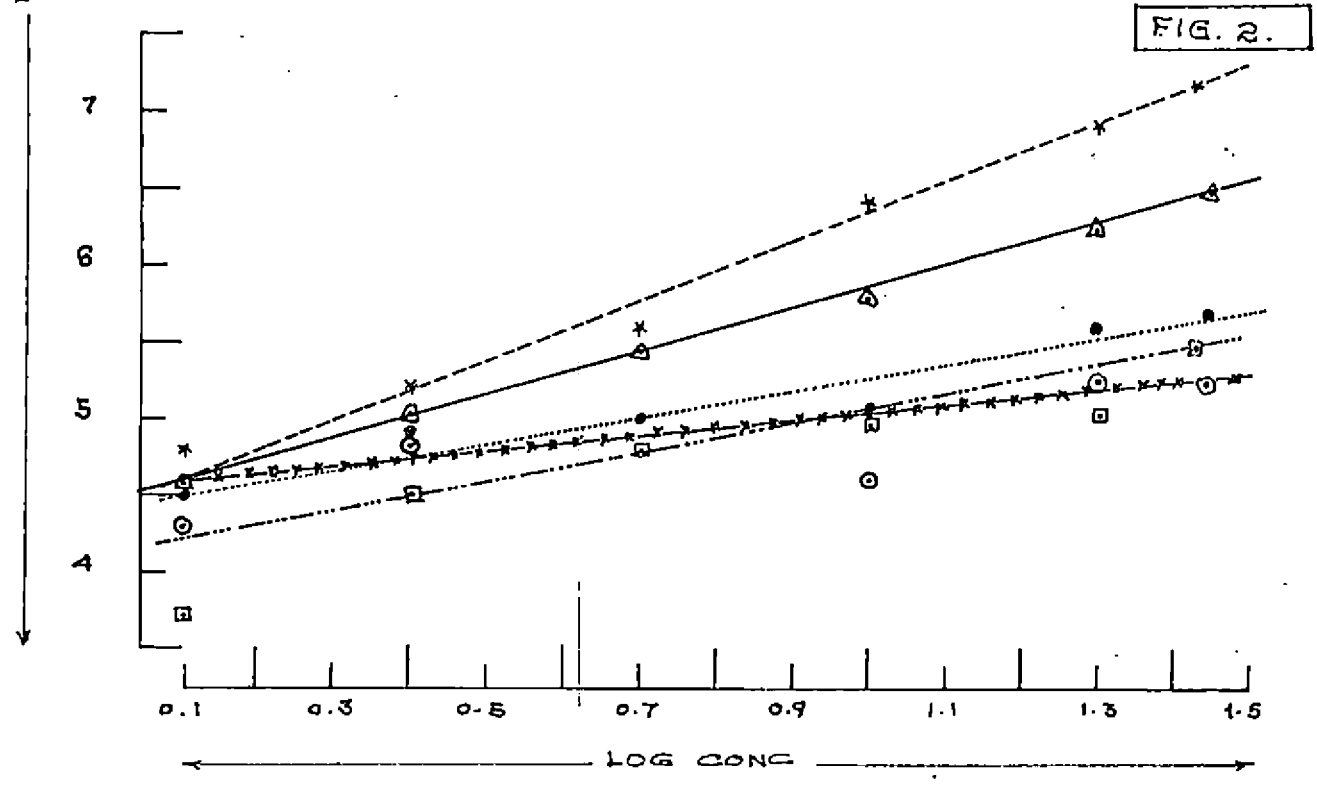

9
8
7
6
5
4
3
PROBITS
N. oleander
A. indica
C. inoportunatum
E. odoratum.
T. neriifolia

FIG. 2.


7
6
5
4
0.1
0.3
0.5
0.7
0.9
1.1
1.3
1.5
LOG CONC

3.3. Antifeedant effect of different plant extracts on epilachna beetle of brinjal

Five plants which ranked high in the screening trial were bioassayed for assessing their relative efficacy in terms of leaf protection and starvation percentage. The results of the statistical analysis of the data are presented in Table 5. The log dose-probit effect lines are presented in Fig. 1.

N. oleander was the most effective plant extract followed by C. infortunatum, A. indica, T. neriifolia and E. odoratum, the PC 50 values being 0.2871, 0.5921, 0.8576, 1.1560 and 1.1810 respectively. Based on PC 95 values N. oleander (1.1489) was ranked as the best plant extract which was followed by A. indica, C. infortunatum, E. odoratum and T. neriifolia (PC 95 values 1.5608, 1.5678, 1.6123 and 2.4833 respectively). From the graph it is seen that N. oleander has the steepest slope while the slope of T. neriifolia is very flat. The slopes of E. odoratum, A. indica and C. infortunatum do not vary much.

The results of the statistical analysis of data on larval starvation are presented in Table 6 and Fig. 2. N. oleander was the most effective treatment causing maximum larval starvation, the SC 50 value being 0.5116. It was followed by A. indica, T. neriifolia, C. infortunatum and E. odoratum, the SC 50 values being 1.161, 1.2350, 1.7850 and 1.7915 respectively. The relative efficacy varied when the comparison was done on the basis of SC 95 values. N. oleander was the best and it was

followed by C. infortunatum, E. odoratum, T. neriifolia and A. indica, the SC 95 values being 1.2520, 2.0140, 2.8844, 2.9247 and 4.1301 respectively. The regression lines for larval starvation reveals a uniform pattern without much variation in the slopes in different treatments. However, the steepest slope was seen in N. oleander while the slope of C. infortunatum was very flat.

3.4. Persistent antifeedant activity of extracts of some plants against grubs of epilachna beetle on brinjal under field conditions -

The results of the experiments and the results of the statistical analysis of the data are presented in Table 7. T. neriifolia and N. oleander extracts persisted up to 22 days after application on brinjal leaves, while that of C. infortunatum, E. odoratum and A. indica persisted up to 18 days only. From the 24th day onwards the effects were not detected in any of the treatments.

It was seen that water extract of T. neriifolia was superior over all the other treatments with an average leaf protection of 75.74 per cent. This was followed by benzene extract of N. oleander, the average leaf protection being 70.34 per cent. Benzene extract of C. infortunatum, E. odoratum, A. indica and T. neriifolia gave average leaf protection ranging from 18.93 to 43.82 per cent only.

Table 7. Persistence of antifeedant activity of plant extracts on brinjal, under field conditions, bioassayed using epilachna grub as test insect

benzene extracts of	per cent weight of leaves protected, when grubs were released on treated leaves - period of sampling (days after spraying)							mean leaf weight protected (%) T	period for cessation of antifeedant effect (day)	P T index	Order of relative efficacy
	2	4	6	10	14	18	22				
A. indica	58.54 (50.79)	44.99 (42.18)	40.24 (39.16)	10.87 (19.39)	5.35 (13.04)	6.41 (14.28)	0.00 (10.60)	27.73 (27.06)	18	499.14	5
E. odoratum	65.12 (54.59)	63.60 (52.75)	56.31 (46.83)	23.96 (29.61)	6.05 (13.43)	2.05 (7.02)	0.00 (3.98)	36.18 (29.74)	18	651.24	4
C. infortunatum	82.44 (65.26)	71.50 (57.52)	53.65 (46.96)	20.22 (26.90)	27.93 (31.21)	7.21 (14.82)	0.00 (4.01)	43.82 (35.20)	18	788.76	3
T. neriifolia	76.09 (60.92)	29.23 (31.79)	17.98 (23.44)	15.88 (23.07)	10.44 (18.73)	9.72 (18.14)	0.19 (3.52)	18.93 (25.66)	22	416.46	6
N. oleander	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	96.58 (78.96)	65.66 (53.45)	27.93 (31.93)	2.28 (8.50)	70.34 (63.26)	22	1547.48	2
T. neriifolia (water)	100.00) (90.00)	100.00 (90.00)	98.41 (82.20)	99.19 (87.00)	85.86 (70.03)	39.36 (37.99)	4.69 (10.31)	75.74 (66.79)	22	1666.28	1

(Figures in parentheses are transformed values : angles)

C.D. for comparing treatments : 3.34

C.D. for comparing periods : 3.61

The persistent antifeedant effect of the plant extracts against epilachna grubs was found to be highest (PT index 1666.29) for water extract of T. neriifolia and it was followed by the benzene extract of N. oleander (1547.48). This was followed by benzene extracts of C. infortunatum, E. odoratum, A. indica and T. neriifolia, the PT indices being 788.76, 651.24, 499.14 and 416.46 respectively.

Water extracts of T. neriifolia and benzene extract of N. oleander gave 100 per cent leaf protection when the treated plants were exposed for feeding at two days after treatments and the effect remained without significant reduction up to 10 days after treatment. In the case of T. neriifolia (benzene extract) a significant reduction in effect was observed on the fourth day and in all other treatments such a change was evident from the fourth day after treatment. Benzene extract of T. neriifolia which persisted for 22 days after treatment, was found inferior to C. infortunatum, E. odoratum and A. indica which persisted up to 18 days only, on the basis of PT indices. This was due to the faster rates of dissipation of the material. The area of leaf protected in the treatment fell from a high level of 76.09 per cent on the second day after treatment to a low level of 29.23 per cent on the very fourth day and to a negligible level of 17.98 per cent on the 6th day after treatment. Such drastic drop in leaf protection was not observed in any of the remaining treatments. Consequent to this benzene extract of T. neriifolia came best in the order of relative efficacy of the treatments.

3.5. Screening of different plant extracts for insecticidal activity

Water, benzene, acetone and petroleum ether extracts of 20 plants were tested for their contact toxicity to four test insects, D. cingulatus, H. vigintioctopunctata, A. craccivora and S. litura. Different larval instars of D. cingulatus and H. vigintioctopunctata even at concentrations as high as 100 per cent of the extract did not show any contact toxicity.

3.5.1. Contact toxicity of plant extracts to A. craccivora

Data relating to the study are presented in Table 8. Water extract of A. indica at 100% gave complete kill of A. craccivora and at the same concentration T. neriifolia also gave high kill of 88.08 per cent. The above two extracts gave 72.22 per cent kill of the insect each at 50 per cent concentration. Out of the remaining 56 treatments 28 treatments caused mortality ranging from 1.23 per cent to 38.88 per cent.

Among the acetone extracts of T. neriifolia (100%) gave 64.70 per cent kill of A. craccivora and it was the most effective treatment in the lot. A. indica, C. infortunatum and C. gigantea were toxic to the insect at the two higher concentrations of 100 and 50 per cent of the extract and in the above treatments the mortalities ranged between 3.53 to 26.47 per cent only. Acetone extracts of P. odoratissimus,

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A. conizoides and M. viridis showed toxicity at all the three concentrations of 100, 50 and 25 per cent, but in these treatments also the mortality ranged between 1.95 and 21.18 per cent only. Extracts of O. sanctum, P. rubra, V. negundo, C. aromaticus and S. indicum showed toxicity at a concentration of 100% only and even at this high concentration the mortality ranged from 1.95 to 13.72 per cent only.

Benzene extracts (100%) of A. indica, C. infortunatum and T. neriifolia gave 52.36, 64.18 and 68.66 per cent mortality respectively. Extract of P. rubra at 100% concentration gave 43.59 per cent mortality of A. craccivora. At 100% concentration benzene extract of C. gigantea, C. aromaticus, L. aspera and P. odoratissimus gave 37.32, 31.05, 37.32 and 37.32 per cent mortality respectively. In another twenty three treatments low mortality ranging from 1.49 to 27.92 per cent was observed and in 29 treatments no mortality was observed.

Petroleum ether extract of P. odoratissimus, P. rubra, C. gigantea and C. aromaticus at the concentration of 100% gave 100, 87.86, 86.50 and 59.52 per cent mortality respectively. P. odoratissimus and C. gigantea extracts at 50% concentration also gave 86.50 and 57.50% kill of A. craccivora respectively Extracts of A. indica 100%, C. infortunatum 100%, P. rubra 50% and C. aromaticus 50% gave significant kills of 39.29, 45.36, 45.36 and 33.22 per cent of A. craccivora respectively.

Table 8. Contact toxicity of solvent extracts of different plants to A. craccivora (apterous adults) and S. litura (third instar larvae)

plants extracted	concen-tration (%)	corrected per cent mortality of A. craccivora sprayed with				corrected per cent mortality of S. litura sprayed with			
		A	B	C	D	A	B	C	D
A. indica	100	100.00	26.47	52.36	39.29	0.00	10.00	0.00	0.00
	50	72.22	3.53	27.92	8.94	0.00	0.00	0.00	0.00
	25	11.11	0.00	8.83	0.00	0.00	0.00	0.00	0.00
E. odoratum	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I. infortunatum	100	19.44	21.36	64.18	45.36	0.00	0.00	5.00	0.00
	50	13.88	10.59	24.78	19.05	0.00	0.00	0.00	0.00
	25	7.22	0.00	1.49	0.00	0.00	0.00	0.00	0.00
O. sanctum	100	0.00	5.88	24.78	19.05	0.00	10.00	20.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P. rubra	100	0.00	5.88	43.59	87.86	0.00	10.00	0.00	0.00
	50	0.00	0.00	7.23	45.36	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	4.14	0.00	0.00	0.00	0.00
T. neriifolia	100	88.08	64.70	68.66	19.05	0.00	0.00	10.00	0.00
	50	72.22	38.82	16.42	10.15	0.00	0.00	0.00	0.00
	25	33.33	7.65	12.25	0.00	0.00	0.00	0.00	0.00
C. gigantea	100	33.33	23.53	37.32	86.50	0.00	0.00	20.00	0.00
	50	15.00	10.00	16.42	57.50	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	27.15	0.00	0.00	0.00	0.00
V. negundo	100	7.40	5.88	12.25	0.00	0.00	0.00	0.00	0.00
	50	5.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N. oleander	100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. aromaticus	100	21.56	13.72	31.05	59.52	0.00	0.00	0.00	0.00
	50	5.55	0.00	4.73	33.22	0.00	0.00	0.00	0.00
	25	5.55	0.00	0.00	0.44	0.00	0.00	0.00	0.00
I. indicum	100	11.11	0.00	12.25	10.96	0.00	0.00	10.00	0.00
	50	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L. aspera	100	0.00	0.00	37.32	25.94	0.00	0.00	10.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. esculenta	100	0.00	0.00	12.25	14.29	10.00	0.00	0.00	0.00
	50	0.00	0.00	0.00	8.94	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M. camara	100	0.00	1.95	0.00	0.00	0.00	10.00	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. variegatum	100	0.00	1.95	18.52	0.00	0.00	0.00	25.00	0.00
	50	0.00	0.00	7.23	0.00	0.00	0.00	10.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A. vesica	100	2.77	0.00	2.49	0.00	0.00	0.00	0.00	0.00
	50	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. papaya	100	38.88	1.95	16.42	27.15	20.00	0.00	0.00	0.00
	50	4.75	0.00	0.00	5.56	0.00	0.00	0.00	0.00
	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O. odoratissimus	100	38.88	21.18	37.32	100.00	0.00	0.00	10.00	0.00
	50	25.92	11.76	16.42	86.50	0.00	0.00	0.00	0.00
	25	16.06	17.04	5.98	21.08	0.00	0.00	0.00	0.00
A. conizoides	100	13.57	13.72	18.52	19.05	0.00	0.00	0.00	0.00
	50	16.06	3.74	0.00	10.95	0.00	0.00	0.00	0.00
	25	7.40	1.95	2.49	8.94	0.00	0.00	0.00	0.00
A. viridis	100	8.04	16.95	5.98	21.08	0.00	0.00	0.00	0.00
	50	1.23	11.76	16.42	2.86	0.00	0.00	0.00	0.00
	25	2.77	1.95	0.00	0.00	0.00	0.00	0.00	0.00

A - Water extract B - Acetone extract C - Benzene extract

D - Petroleum ether extract

In another 20 treatments the mortality ranged from 0.44 to 27.15 per cent, most of them being in the higher concentration levels. In 30 treatments no mortality was observed during the period of observation.

Insecticidal action observed on S. litura was also very negligible. Among the treatments water extract of M. esculenta and C. papaya caused 10 and 20 per cent mortality respectively and that too at 100% concentration only. Acetone extract of A. indica, O. sanctum, P. rubra and L. camara, all at 100% concentration caused ten per cent mortality of S. litura caterpillars. Regarding benzene extract C. infortunatum, O. sanctum, C. gigantea T. neriifolia, S. indicum, L. aspera, C. variegatum and P. odoratissimus showed low insecticidal activity since 100 per cent extracts of the plants caused mortalities ranging from 5 to 25% mortality of S. litura. The petroleum ether extract of N. oleander, 100% concentration, alone caused ten per cent kill of the insect. All other treatments were totally ineffective.

3.5.2. Relative toxicity of plant extracts against A. craccivora

The results presented in Table 9 showed that among the plant extracts which exerted contact toxicity, water extract of T. neriifolia was the most toxic with LC 50 of 34.14 per cent and it was closely followed by either extract of

Table 9. Relative toxicity of different plant extracts to the apterous adults of *A. craccivora*

plants extracted	extractants used	heterogeneity	regression equation	LC 50 (%)	fiducial limits	relative toxicity
A. indica	water	0.28661	y = 6.1394025x - 4.850635	40.23	47.51 34.05	1.0000
A. indica	benzene	0.01775	y = 2.2392647x + 0.582024	93.97	98.86 89.32	0.4281
C. infortunatum	benzene	0.05280	y = 3.9864133x - 1.802588	78.50	97.14 64.00	0.5125
C. aromaticus	ether	2.41574	y = 6.4388687x - 6.403824	59.03	73.24 47.57	0.6815
P. odoratissimus	ether	3.85691	y = 6.9511338x - 5.67519	34.34	44.50 26.45	1.1715
C. gigantea	ether	0.02440	y = 2.8909574x + 0.321418	41.54	43.71 39.46	0.9685
P. rubra	ether	0.13579	y = 4.818764x - 3.372604	54.63	63.48 47.06	0.7378
T. neriifolia	water	0.49137	y = 2.7277149x - 0.817574	34.14	36.13 32.44	1.1784
T. neriifolia	benzene	1.01216	y = 2.8812192x - 0.450667	71.96	81.20 74.82	0.5591
T. neriifolia	acetone	0.53483	y = 2.7508079x - 0.06754	69.53	89.21 54.20	0.5786

P. odoratissimus, the LC 50 of which was 34.34 per cent. Next in effectiveness was aqueous extract of A. indica its LC 50 being 40.23. Ether extract of C. gigantea with LC 50 value of 41.54 per cent ranked next to aqueous extract of A. indica. This was followed by ether extracts of P. rubra and C. aromaticus, their LC 50 values being 54.63 and 59.63 respectively. Acetone and benzene extracts of C. infortunatum were ranked next in the descending order of effectiveness with LC 50 values of 69.53, 71.96 and 78.50 respectively. Benzene extract of A. indica with 93.97 LC 50 value was the least toxic among the ten extracts.

The relative toxicity of the plant extracts were assessed taking the toxicity of aqueous extract of A.indica as 1. It will be seen that among the ten extracts aqueous extract of T. neriifolia and ether extract of P. odoratissimus were the best treatments and was approximately equitoxic being 1.1784 and 1.1715 times more toxic than aqueous extract of A. indica. All the other extracts were less toxic than aqueous extract of A. indica with toxicities ranging from 0.9685 to 0.4281 (Table 9).

3.6. Insecticidal activity of selected plant extracts to different larval instars of D. cingulatus

Data relating to the experiment and results of statistical analysis of the same are presented in Table 10. All plant

Table 10. Relative toxicity of plant extracts to different nymphal instars of D. cingulatus

benzene extract of	heterogeneity $\chi^2_{(3)}$	regression equation	LC 50 (%)	fiducial limits	relative toxicity
		second instar			
A. indica	4.4938	y = 1.7825x + 4.6335	0.1605	0.1892 0.1362	1.0000
E. odoratum	4.2092	y = 3.3527x + 2.7637	0.4645	0.5524 0.3906	0.3455
C. infortunatum	2.0474	y = 3.5832x + 2.8062	0.1250	0.1894 0.0806	1.2840
T. neriifolia	3.7855	y = 1.4238x + 4.1277	0.1785	0.2333 0.1237	0.8992
		third instar			
A. indica	1.4703	y = 7.5243x + 1.8804	0.2598	0.2961 0.2279	1.0000
E. odoratum	2.4254	y = 3.2725x + 3.07044	0.3887	0.4646 0.3260	0.6684
C. infortunatum	0.2541	y = 2.80306x + 4.5854	0.1406	0.1638 0.1217	1.8478
T. neriifolia	3.5108	y = 1.77602x + 4.238064	0.2685	0.2885 0.2495	0.9676
		fourth instar			
A. indica	5.6348	y = 4.33995x + 2.6989	0.3390	0.4108 0.2798	1.0000
E. odoratum	0.5575	y = 2.96955x + 1.6864	1.3060	1.6470 1.0350	0.2596
C. infortunatum	1.2198	y = 4.1731x + 2.6046	0.2523	0.4629 0.2037	1.3436
T. neriifolia	4.5379	y = 2.41215x + 3.3586	0.4792	0.7143 0.3466	0.7074
		fifth instar			
A. indica	2.3931	y = 3.928873x + 3.69426	0.2149	0.2714 0.1702	1.0000
E. odoratum	4.6229	y = 3.445694x + 2.30735	0.6045	0.7210 0.4999	0.3555
C. infortunatum	0.8699	y = 2.7448547x + 4.464405	0.1566	0.1714 0.1431	1.3723
T. neriifolia	0.0365	y =10.493465x + 0.5838223	0.2635	0.2904 0.2387	0.8156

extracts except that of N. oleander gave significant mortalities of second, third, fourth and fifth instar nymphs of D. cingulatus. The extracts of C. infortunatum was the most toxic to the second, third, fourth and fifth instar nymphs with LC 50 values of 0.1250, 0.1406, 0.2523 and 0.1566 per cent respectively. It was followed by A. indica, the LC 50 of which was 0.1605, 0.2598, 0.3390 and 0.2149 for the second, third, fourth and fifth instar nymphs respectively. T. neriifolia with LC 50 value of 0.1785, 0.2685, 0.4792 and 0.2635 respectively for the second, third, fourth and fifth instars ranked third in effectiveness. In all the nymphal instars E. odoratum was the least toxic with LC 50 value of 0.4645 per cent for the second instar, 0.3887 for the third instar, 0.3060 for the fourth instar and 0.6045 for the fifth instar nymphs. It is evident from the results that the order of relative efficacy is similar in all the instars. Comparing the LC 50 values of the four plant extracts for differnt nymphal instars, it will be observed that the fourth instar nymphs are more tolerant to the toxic effect of the plant extracts, their LC 50 values being more than that of third instar and fifth instar nymphs.

3.7. Assessment of insecticidal activity of essential oils

Data relating to the experiment and the results of statistical analysis of the same are presented in Table 11. The essential oils tested were found to possess low insecticidal

Table 14. Insecticidal action of essential oils on last instar nymphs of D. cingulatus, third instar larvae of S. litura and apterous adults of A. craccivora

treatments	corrected per cent mortality observed 24 h after treatment											
	D. cingulatus*				S. litura*				A. craccivora			
	A	B	C	D	A	B	C	D	A	B	C	D
Citronella oil	10.50	0.00	0.00	0.00	30.00	10.00	0.00	0.00	37.77 ghij	25.00 hijkl	15.00 klm	0.00 p
Palmarosa oil	16.66	0.00	0.00	0.00	5.00	0.00	0.00	0.00	40.00 fghi	22.22 ijkl	10.00 lmn	0.00 p
Geranium oil	10.00	5.00	5.00	0.00	20.00	10.00	0.00	0.00	100.00 a	100.00 a	78.00 bcd	45.00 efgh
Eucalyptus oil	27.37	12.50	0.00	0.00	20.00	10.00	0.00	0.00	46.66 efg	20.00 jklm	10.00 lm	0.00 op
Oil of wintergreen	16.66	8.33	0.00	0.00	50.00	0.00	0.00	0.00	100.00 a	100.00 a	80.00 bcd	45.66 efg
Patcholi oil	25.00	12.50	0.00	0.00	0.00	0.00	10.00	0.00	80.00 bcd	56.00 def	36.00 ghij	10.00 mno
Citrodora oil	12.50	10.00	5.00	0.00	20.00	0.00	0.00	0.00	80.00 bcd	30.00 ghijk	15.00 klm	0.00 nop
Camphor oil	8.33	8.33	0.00	0.00	20.00	0.00	0.00	0.00	65.00 cde	50.00 efg	42.66 fgh	20.00 lmn

* Data were not statistically analysed since the mortality percentage were low

A - 10 per cent emulsion B - 5 per cent emulsion C - 2.5 per cent emulsion
D - 1.25 per cent emulsion

activity on D. cingulatus and S. litura. At concentrations of 10.0, 5.0 and 2.5 per cents the mortalities of D.cingulatus were within the ranges of 8.33 to 27.27, 0 to 12.5 and 0 to 5 per cent respectively. At 1.25 per cent concentration no mortality was observed. Against S. litura, the oil of wintergreen and citronella oil at 10.0 per cent gave 50.00 and 30.00 per cent mortalities respectively. In the remaining treatments the per cent mortalities were at or below 20.00 per cent level. At 5% concentration, citronella oil, geranium oil and eucalyptus oil gave 10 per cent mortality each and at 2.5 per cent concentration, patcholi oil alone gave 10 per cent mortality while at 1.25 per cent concentrations none of the treatments showed toxicity to S. litura.

In the case of A. craccivora the essential oils caused high mortality. Geranium oil and oil of wintergreen at 10 and 5 per cent concentrations gave 100 per cent mortality of aphids and these treatments were significantly superior to all other treatments. The above treatments were followed by patcholi oil and citronella oil each at 10% concentration and geranium oil and oil of wintergreen at 2.5 per cent concentration which gave 78 to 80 per cent mortality and were on par. Camphor oil 10 per cent and 5 per cent, patcholi oil 1.25 per cent and eucalyptus oil 10 per cent, which gave mortalities ranging from 45 to 65 per cent were on par and came next in rank in relative

efficacy. Remaining treatments which gave mortalities below 40 per cent may be ranked as inferior.

3.8. Juvenomimetic activity of plant extracts

Effects of different plant extracts on the biology of treated insects and the effects on the morphological and physiological changes in the development were assessed in various experiments.

3.8.1. Effects of water extracts of plants on D. cingulatus

The results obtained on the hormonal effects of water extracts of plants to last instar nymphs of D. cingulatus and the statistical analysis of the data are given in Table 12. It was seen that the duration of last nymphal stage was prolonged with the extract of E. odoratum to 18.14 days as against 7.0 days in control and this was significantly longer than those in other treatments. A. indica (15.83) and C.infortunatum (15.50) came on par but varied significantly from E.odoratum and the remaining treatments except C. aromaticus (11.28). A. conizoides, N. oleander, V. negundo, C. papaya, T. neriifolia and A. vasica also prolonged the nymphal period significantly when compared to control and they were on par among themselves (10.00 to 11.00 days).

Application of plant extracts caused some mortality in early fifth instar stage and there was mortality at the next

moult mainly due to the failure of moulted insects to extricate themselves from the exuviae. Hence nymphal mortality was recorded in two categories. The mortality up to five days after treatment was included as category 1 and the mortality after the fifth day was treated as category 2. Water extracts of A. indica, N. oleander, T. neriifolia and C. infortunatum resulted in nymphal mortalities (category 1) ranging from 15.0 to 6.84 days. Significant nymphal mortality was observed five days after application of plant extract (category 2) with T. neriifolia (75.00 per cent). In category 2, N. oleander (30.00), A. conizoides (25.00), C. infortunatum (22.72), A. indica (10.00), L. aspera and V. negundo (6.60) and C. variegatum (5.88) also caused mortality.

Water extract of T. neriifolia prevented the formation of normal adults completely. Out of the remaining 19 plants, twelve inhibited normal adult emergence significantly. With C. variegatum 17.65 per cent nymphs became normal adults and with L. camara, A. indica, N. oleander, P. odoratissimus and M.esculenta, the percentages of normal adults ranged from 21.43 to 31.25. Next in rank came E. odoratum, C.infortunatum and L. aspera. Percentage normal adults in remaining treatments ranged from 75.00 to 100.00.

Longevity of normal adults in different treatments varied from 3.79 to 18.5 days. The shortest survival was with A.indica

Table 12. Hormonal effects of the water extracts of different plants to the last instar nymphs of *D. cingulatus*

extracts of *	duration of nymphal instar (days)	nymphal mortality (%) up to five days after treatment	nymphal mortality (%) after fifth day of treatment	adults emerged (%)	adult longevity (days)	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
A. indica	15.83 bc	15.00	10.00 bcd	N 25.00 ab M 50.00 abc	18.50 j 2.50 bcd	0.00 a 0.00	0.00 0.00	100.00 a
C. infortunatus	15.50 bc	6.84	22.72 abcd	N 47.72 b M 22.72 cde	11.80 def 0.00 a	66.00 fg 0.00	0.00 a 0.00	100.00 a
E. odoratum	18.14 a	0.00	0.00 e	N 45.00 c M 55.00 abc	11.40 d 0.00 a	46.00 defg 0.00	0.00 a 0.00	100.00 a
O. sanctum	7.50 e	0.00	0.00 e	N 80.00 cd M 20.00 cde	16.16 i 3.50 cde	76.75 fgh 0.00	73.22 d 0.00	78.05 b
P. rubra	7.20 e	0.00	0.00 e	N 100.00 e M 0.00 f	14.40 g 0.00	2.40 b 0.00	0.00 a 0.00	100.00 a
T. periifolia	11.00 d	10.00	75.00 a	N 0.00 a M 15.00 cde	0.00 a 0.33 a	0.00 0.00	0.00 0.00	100.00 a
C. gigantea	7.60 e	0.00	0.00 e	N 80.00 cd M 20.00 cde	12.40 f 2.50 bcd	61.50 def 0.00	38.21 b 0.00	67.36 b
V. negundo	10.57 d	0.00	6.66 d	N 93.33 de M 0.00 f	7.50 b 0.00	39.00 bcde 0.00	67.00 d 0.00	63.21 b
N. oleander	10.12 d	10.00	30.00 ab	N 28.00 ab M 32.00 cd	14.25 g 4.80 ef	39.00 bcde 8.50	0.00 a 0.00	100.00 a
C. aromaticus	11.28 cd	0.00	0.00 e	N 95.00 de M 5.00 e	16.28 i 2.00 ab	62.50 def 0.00	82.00 cd 0.00	71.18 b
S. indicum	7.43 e	0.00	0.00 e	N 100.00 e M 0.00 f	11.57 de 0.00	28.66 bc 0.00	98.00 e 0.00	60.99 b
L. aspera	7.85 e	0.00	6.69 cd	N 13.33 ab M 80.00 ab	15.00 gh 4.00 ef	0.00 a 0.00	0.00 0.00	100.00 a
M. esculenta	7.15 e	0.00	0.00 e	N 31.25 ab M 68.75 abc	8.88 c 3.73 ef	0.00 a 0.00	0.00 0.00	100.00 a
L. camara	6.50 e	0.00	0.00 e	N 21.43 ab M 78.57 a	8.88 c 3.27 ef	0.00 a 0.00	0.00 0.00	100.00 a
C. variegatum	7.13 e	0.00	5.88 cd	N 17.65 a M 76.47 ab	12.33 ef 6.00 e	0.00 a 0.00	0.00 0.00	100.00 a
A. vesica	11.00 d	0.00	0.00 e	N 93.33 cde M 6.66 de	3.79 a 2.00 ab	0.00 a 0.00	0.00 0.00	100.00 a
C. papaya	10.02 d	0.00	0.00 e	N 100.00 e M 0.00 f	11.50 d 0.00	32.00 bcd 0.00	85.00 cde 0.00	62.23 b
P. odoratissimus	7.71 e	0.00	0.00 e	N 28.57 ab M 71.43 ab	15.25 gh 2.20 ab	0.00 a 0.00	0.00 0.00	100.00 a
A. conizoides	10.00 d	0.00	25.00 abc	N 75.00 c M 0.00 f	8.00 b 0.00	0.00 a 0.00	0.00 0.00	100.00 a
M. viridis	7.59 e	0.00	0.00 e	N 100.00 e M 0.00 f	11.86 def 0.00	54.16 efgh 0.00	95.00 de 0.00	28.54 c
Control	7.00 e	0.00	0.00 e	N 100.00 e M 0.00 f	16.70 i 0.00	79.00 fgh 0.00	91.14 de 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

* 25 gram dried plant material extracted with 100 ml solvent, applied topically @ 2 µl/specimen.

Each treatment consisted of four replications and 20 insects were treated in each replication.

(3.79 days) and it was significantly different from all other treatments. V. negundo (7.50) and A. conizoides (8.00) were on par and differed significantly from all other treatments. With M. esculenta and L. camara, the adults lived for 8.88 days which also varied significantly from all other treatments. E. odoratum, C.papaya, S.indicum, C.infortunatum and M.viridis with adult longevity ranging from 11.40 days to 11.86 days were on par. Adults emerging from nymphs treated with C.variegatum (12.83), C. gigantea (12.40), P. rubra (14.40), N.oleander (14.25), L. aspera (15.00) and P. odoratissimus (15.25) also had significantly longer longevity than that in control. Extracts of C. aromaticus and O. sanctum were on par with control while the adults emerging from nymphs treated with A. indica lived for a longer period (18.50) than those in control.

Egg laying was completely prevented with A. indica, L. aspera, M. esculenta, L. camara, C. variegatum, A. visica, P. odoratissimus and A. conizoides. Significant reduction in egg laying was caused by P. rubra/S.indicum (28.66), C. papaya (32.0) and V. negundo / N. oleander (39.0). The remaining plant extracts came on par with control.

The hatchability was completely suppressed by C. infortunatum, E. odoratum, P. rubra and N. oleander. In C. gigantea, only 38.21 per cent eggs hatched. O. sanctum, C. aromaticus,

S. indicum, C. papaya and M. esculenta came on par with control, with the hatching percentage ranging from 73.22 to 95.00.

In fourteen treatments malformed adults were observed and the percentages ranged from 5.00 to 80.00. Maximum number was in L. aspera (80.00) and it was followed by L. camara (78.57), C. variegatum (76.47), P. odoratissimus (71.43), M. esculenta (68.75), E. odoratum (55.00), A. indica (50.00), N. oleander (32.00), C. infortunatum (22.72), O. sanctum C. gigantea (20.00), T. neriifolia (15.00), A. vesica (6.66) and C. aromaticus (5.00).

Malformed adults emerging from nymphs treated with C. infortunatum and E. odoratum died soon after emergence and the longevity in other treatments ranged from 0.33 to 6.00 days.

Adults emerging from nymphs treated with N. oleander extract alone laid eggs (8.5) and that also failed to hatch. Water extracts of A. indica, C. infortunatum, E. odoratum, P. rubra, T. neriifolia, N. oleander, L. aspera, M. esculenta, L. camara, C. variegatum, A. vesica, P. odoratissimus and A. conizoides caused 100 per cent sterility. The sterility percentages with remaining plants (excluding M. viridis) came on par (78.05 to 60.99) while that with M. viridis was significantly low (28.54).

3.8.2. Effects of acetone extracts of plants on D. cingulatus

The results of the experiments are presented in Table 13. The duration of last instar nymph ranged from 7.3 to 11.84 days in different treatments as against 7.3 days in control. The prolongation of nymphal duration in C. aromaticus and C. variegatum (11.84 days) were significantly higher than the durations in other treatments. It was followed by the durations in L. camara (11.53), M. esculenta (11.50), C. gigantea (11.3), M. viridis (11.28), P. odoratissimus (10.91), C. papaya (10.81), and V. negundo (10.71) which were on par among themselves and significantly higher than the duration in control. The durations of nymphal stage of insects treated with the extracts of A. conizoides, P. rubra, N. oleander, L. aspera, S. indicum, A. indica, C. infortunatum and T. neriifolia ranged from 10.0 to 9.1 days and they did not differ significantly from that in control. The duration on plants treated with the extracts of E. odoratum, A. vesica and O. sanctum were significantly less than those in C. aromaticus, C. variegatum and M. esculenta and all were on par with control.

Acetone extracts of five plants, C. infortunatum, S. indicum, C. papaya, C. gigantea and C. variegatum only caused (4.76 to 5.0 per cent) mortality in the first category while the mortalities in second category were highly varying in different treatments. The mortalities caused by the

Table 15. Hormonal effects of the acetone extracts of different plants on the last instar nymphs of D. cingulatus

extracts of*	duration of nymphal instar (days)	nymphal mortality (%)		adults emerged (%)	adult longevity (days)	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		up to five days after treatment	after fifth day of treatment					
A. indica	9.31 abc	0.00	9.52 cde	N 4.76 a M 85.72 h	8.00 ab 3.11	3.16 ab 8.00	23.65 abcd 0.00	95.95 ab
C. infortunatum	9.25 abc	5.00	35.00 ab	N 50.00 bcde M 10.00 abcd	11.80 bc 0.00	12.80 bcd 0.00	0.00 a 0.00	100.00 a
E. odoratum	9.00 bc	0.00	45.00 a	N 45.00 bcde M 10.00 abcd	6.33 ab 0.00	34.00 def 0.00	19.05 abc 0.00	91.48 abc
O. sanctum	7.30 c	0.00	0.00 f	N 90.00 h M 10.00 abc	12.87 bc 5.00	64.33 fgh 0.00	72.08 cde 0.00	37.72 e
P. rubra	9.94 abc	0.00	15.00 bcde	N 85.00 fgh M 0.00 a	8.82 abc 0.00	36.62 defg 0.00	100.00 e 0.00	51.11 de
T. peltifolia	9.10 bc	0.00	14.28 cde	N 42.84 bcde M 42.84 efg	9.25 abc 0.00	6.72 bc 0.00	90.00 e 0.00	91.88 abc
C. gigantea	11.30 ab	4.76	0.00 ef	N 80.95 fgh M 14.30 cd	9.76 abc 0.00	17.43 bcd 0.00	65.00 cde 0.00	84.78 bcde
V. negundo	10.71 ab	0.00	6.66 de	N 86.66 fgh M 6.66 abc	2.61 a 2.00	48.00 efgh 0.00	68.00 cde 0.00	56.16 de
N. oleander	9.84 abc	0.00	25.00 abc	N 30.00 b M 45.00 efg	11.24 bc 3.60	0.00 a 0.00	0.00 a 0.00	100.00 e
C. aromaticum	11.84 a	0.00	0.00 f	N 90.00 gh M 10.00 abcd	12.18 bc 3.50	68.75 gh 0.00	73.80 cde 0.00	31.86 e
S. indicum	9.71 abc	5.00	25.00 abc	N 50.00 bcde M 20.00 cde	11.10 bc 0.75	25.20 cde 0.00	98.00 e 0.00	66.83 cde
L. asperа	9.73 abc	0.00	8.00 cde	N 68.00 defg M 24.00 cde	12.70 bc 1.33	19.26 bcd 0.00	29.67 abcd 0.00	91.33 abc
M. esculenta	11.50 a	0.00	0.00 f	N 70.00 efg M 30.00 defg	11.71 bc 0.00	19.43 bcd 0.00	22.22 abc 0.00	91.45 abc
L. camara	11.53 ab	0.00	10.52 cde	N 68.26 defg M 21.05 cde	9.84 abc 0.00	6.66 bc 0.00	10.00 ab 0.00	91.10 abcd
C. variegatum	11.84 a	4.76	4.76 ef	N 85.70 fgh M 4.76 abc	6.77 ab 0.00	19.40 bcd 0.00	23.90 abc 0.00	85.70 bcd
A. vesica	8.57 bc	0.00	5.00 ef	N 35.00 bc M 60.00 fg	5.40 ab 1.14	15.00 bcd 0.00	80.00 cde 0.00	83.88 bcd
C. papaya	10.81 ab	5.00	0.00 f	N 95.00 h M 0.00 a	9.76 abc 0.00	19.32 bcd 0.00	92.12 e 0.00	76.08 bcd
P. odoratissimus	10.91 ab	0.00	22.72 bcd	N 63.48 cdef M 13.63 bcd	7.25 ab 0.00	6.10 b 0.00	100.00 e 0.00	91.31 abc
A. conizoides	10.00 abc	0.00	12.50 cde	N 37.50 bcd M 50.00 efg	10.00 abc 0.00	37.60 defg 0.00	65.00 bcde 0.00	67.18 cde
M. viridis	11.28 ab	0.00	10.00 cde	N 85.00 fgh M 5.00 abc	13.60 bc 4.00	46.50 defg 21.00	88.79 cde 56.74	44.54 def
Control	7.30 c	0.00	10.00 cde	N 90.00 gh M 0.00 a	15.60 c 0.00	84.00 h 0.00	88.64 de 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

* 25 gram dried plant material extracted with 100 ml solvent, applied topically @ 2 µl/specimen.

Each treatment consisted of four replications and 20 insects were treated in each replication.

significantly reduce the longevity of normal adults when compared to control.

The fecundity of females emerging from treated nymphs varied significantly and except those treated with the extract of three plants, O. sanctum (64.33), V. negundo (48.00) and C. aromaticus (68.75), all treatments caused significant suppression of fecundity when compared to control (84.00). Acetone extracts of N. oleander completely inhibited the egg laying and it was followed by A. indica (3.16) and these were on par. The above treatments were followed by P. odoratissimus (6.10), L. camara (6.66), T. neriifolia (6.72), C. infortunatum (12.80), A. vesica (15.0), C.gigantea (17.43), L. aspera (19.26), C. papaya (19.32), C. variegatum (19.40) and M. esculenta (19.43) and they were on par among themselves and also with A. indica. S. indicum (25.20) came on par with the above treatments excluding A. indica.

Hatchability of eggs was also influenced by the treatment of the insect with plant extracts at nymphal stage. Hatchability varied from 0.0 to 100.0 per cent in different treatments. Extracts of C. infortunatum (0.00), L. camara (9.86), E.odoratum (19.06), M. esculenta (22.22) and C. variegatum could reduce the percentages of eggs hatched significantly when compared to that in control (88.64) and the remaining extracts came on par with control.

The treatments resulted in the formation of malformed adults too. The extract of A. indica ranked first causing the formation of 85.72 per cent malformed adults and was significantly superior to all other treatments. This was followed by A. vesica (60.0), N. oleander (45.0), T. neriifolia, A.conizoides (42.80) and M. esculenta (30.00), all the five treatments being on par and except A. vesica, the treatments were on par with L. aspera, L. camara and S. indicum also (24.00 to 20.00). With the remaining eleven plant extracts the percentages of malformed adults ranged from 14.00 to 0.0 and among these only two plants, C. gigantea (14.0%) and A. conizoides (13.63%) differed significantly from control.

The malformed adults formed from the nymphs treated with the extracts of C. infortunatum, E. odoratum, T. neriifolia, C. gigantea, M. esculenta, L. camara, C. variegatum and P. odoratissimus and A. conizoides died immediately after moulting or on the day of emergence itself. Malformed adults formed from the nymphs treated with O. sanctum lived for five days, while in other treatments, the longevity ranged from 4.0 to 0.75 days.

The malformed adults laid eggs in the case of A. indica and M. viridis only. Eggs laid by bugs treated with extract of A. indica were nonviable while in the case of M. viridis there was 56.74 per cent hatchability.

Considering the fecundity and hatchability of eggs laid, the sterility percentages of emerging adults were assessed and it was found that C. infortunatum and N. oleander with 100 per cent sterility could be ranked high. These were followed by A. indica (95.95), T. neriifolia (91.88), E. odoratum (91.48), M. esculenta (91.45), P. odoratissimus (91.31), L. aspera (91.33) and L. camara (91.10).

3.8.3. Effects of benzene extracts of plants on D. cingulatus

Data relating to the experiment and the results of the statistical analysis of the same are presented in Table 14. The durations of last nymphal stage of treated bugs varied significantly in different treatments. In seven plant extracts viz. C. variegatum (14.33 days), L. aspera (13.22), C. papaya (12.77), C. gigantea (12.53), L. camara (12.33) P. rubra (12.33) and S. indicum (12.16), the mean nymphal periods were on par and significantly longer than that of control (7.5 days). Remaining thirteen plants did not show significant differences from control.

Mortalities of nymphs in category 1, were observed in eight treatments and the mortality ranged from 11.76 to 4.76 per cent. Nymphal mortality in category 2, was significantly higher in all treatments than in control excluding A. indica (5.26 per cent), E. odoratum (6.66 per cent), C. aromaticus (5.00 per cent) and M. viridis (5.00 per cent). High mortalities

were observed in C. variegatum (44.44 per cent) which was followed by C. papaya (35.52 per cent), C. infortunatum (35.30 per cent), A. conizoides (33.33 per cent) and C. gigantea (23.81 per cent) and the treatments were on par.

Extracts of A. indica and C. odoratum could completely inhibit the normal adult emergence. T. neriifolia and C. infortunatum ranked next permitting only 5.55 and 5.88 per cent nymphs to emerge as normal adults. These were on par and significantly superior to all other treatments including control. N. oleander was ranked fifth where 15.0 per cent of the treated nymphs emerged as normal adults. Except in the case of M. viridis and C. aromaticus all treatments were significantly superior over control in reducing the emergence of normal adults.

The mean longevity of normal adults varied from 19.00 to 2.0 days in different treatments while in control the mean longevity was 14.20 days. Significant reductions in longevity of bugs emerging from nymphs treated with extract of A. conizoides (2.0 days) V. negundo (3.0), C. variegatum (6.0), C. gigantea (7.57), S. indicum (7.50), L. camara (7.66) and P. odoratissimus (8.50) were observed and the remaining thirteen treatments came on par with control.

Fecundity of the bugs was also affected by the treatments. Egg laying was completely suppressed by the extract of E. odoratum

Table 14. Hormonal effects of the benzene extracts of different plants to the last instar nymphs of D. cingulatus

extracts of*	duration of nymphal instar (days)	nymphal mortality (%)		adult emerged (%)	adult longevity (days)	number of eggs laid per female	percentage of eggs hatched	sterility percentage (normal + malformed adults
		up to five days after treatment	after fifth day of treatment					
A. indica	9.50 bcde	0.00	5.26 fgh	N 0.00 a M 94.73 a	0.00 3.68	0.00 11.60 ab	0.00 0.00	100.00 a
C. infortunatum	9.60 bcde	11.76	35.30 abc	N 5.88 ab M 47.05 cd	12.00 def 4.50	0.00 0.00	0.00 0.00	100.00 a
E. odoratum	10.30 bcde	6.66	6.66 fg	N 0.00 a M 86.66 b	0.00 2.30	0.00 0.00	0.00 0.00	100.00 a
O. sanctum	8.22 c	0.00	10.00 efg	N 70.00 i M 20.00 fg	14.00 def 3.00	65.60 ef 0.00	68.56 bcd 0.00	26.79 f
P. rubra	12.33 abcd	0.00	15.00 cdefg	N 30.00 def M 55.00 cd	9.75 cd 4.55	40.00 bcde 26.75 bc	50.00 abc 0.00	83.45 bcd
T. peniifolia	10.28 bcde	11.11	11.11 defg	N 5.55 bc M 72.22 bc	19.00 f 5.30	25.00 abcd 12.10 ab	0.00 0.00	100.00 a
C. gigantea	12.53 abcd	4.76	23.81 abcde	N 33.33 defg M 38.10 de	7.57 bc 4.87	50.00 def 35.00 cd	70.00 bcd 0.00	74.12 bcde
V. negundo	10.18 bcde	6.66	20.00 bcdef	N 26.66 def M 46.66 cd	3.00 ab 4.80	0.00 0.00	0.00 0.00	100.00 a
N. oleander	9.60 bcde	0.00	15.00 cdefg	N 15.00 cd M 70.00 bc	15.50 ef 3.54	28.00 abcd 12.38 ab	0.00 0.00	100.00 a
C. aromaticus	8.94 cde	0.00	5.00 fgh	N 90.00 j M 5.00 hi	9.78 cd 2.00	26.60 abcd 0.00	88.00 cde 0.00	61.90 de
S. indicum	12.16 abcd	0.00	14.28 cdefg	N 38.57 fgh M 47.14 de	7.50 bc 2.75	0.00 29.00 bc	0.00 0.00	100.00 a
L. aspera	13.22 ab	0.00	15.59 cdefg	N 38.46 efgh M 46.15 d	16.00 f 7.44	36.64 bcde 6.72 a	95.00 de 28.00	70.02 cde
M. esculenta	11.00 abcde	7.69	15.38 cdefg	N 61.54 hi M 15.38 g	9.83 cd 3.16	46.75 cdef 0.00	21.70 a 0.00	83.66 bc
L. camera	12.33 abcd	0.00	14.32 cdefg	N 28.63 def M 57.04 bcd	8.66 c 3.80	32.00 bcde 0.00	93.75 de 0.00	51.32 e
C. variegatum	14.33 a	0.00	44.44 a	N 44.44 fgh M 11.11 gh	6.00 abc 5.76	25.00 abcd 0.00	0.00 0.00	100.00 a
A. vesica	9.81 bcde	5.00	15.00 cdefg	N 55.00 ghi M 25.00 efg	9.82 ef 4.50	11.66 ab 5.00 a	0.00 0.00	100.00 a
C. papaya	12.77 abc	8.80	35.52 ab	N 18.88 ode M 36.72 def	15.00 f 6.88	42.00 ab 55.00 a	70.00 abc 55.00	74.49 bcde
P. odoratissimus	9.09 cde	0.00	6.25 fg	N 50.00 fghi M 43.75 de	8.50 c 0.87	4.33 a 0.00	100.00 e 0.00	92.95 b
A. conizoides	8.75 de	0.00	33.33 abcd	N 66.66 i M 0.00 i	2.00 a 0.00	0.00 0.00	0.00 0.00	100.00 a
M. viridis	9.25 cde	0.00	5.00 fgh	N 95.00 j M 0.00 i	10.74 cde 0.00	16.66 abc 0.00	40.00 ab 0.00	89.15 bc
Control	7.50 e	10.00	0.00 h	N 90.00 j M 0.00 i	14.70 def 0.00	71.20 f 0.00	86.28 cde 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

* 25 gram dried plant material extracted with 100 ml solvent, applied topically @ 2 µl/specimen.

Each treatment consisted of four replications and 20 insects were treated in each replication.

C. infortunatum, V. negundo, S. indicum and A.conizoides. All plants excluding O. sanctum (65.6 eggs/female), C. gigantea (50.0) and M. esculenta (46.20) caused significant suppression in fecundity.

Hatchability of eggs laid by normal adults varied from zero to 100 per cent in treatments. N. olenader, C.variegatum and A. vesica extracts caused the production of nonviable eggs only. The hatchability was significantly lower in M. esculenta (21.70) and M. viridis (40.00) extract than in control (86.28). In the remaining treatments hatchability of eggs was on par with that of control.

The extracts caused emergence of malformed adults. Maximum number was observed in treatment with A. indica (94.73 per cent) which was significantly higher than in other treatments. It was followed by E. odoratum (86.66), T. neriifolia (72.22), N. oleander (70.00) and L. camara (57.04). Except in the case of A. conizoides, M. viridis and C. aromaticus all the treatments caused significantly higher percentage of malformed adults than in control.

The longevity of malformed adults varied from 0.87 to 7.44 days only. The malformed adults in nine treatments laid eggs. Fecundity in A. vesica (5.0%) and L. aspera (6.72%), A. indica (11.6%), T. neriifolia (12.10%) and N. oleander

(12.38%) were on par and significantly low. The maximum number of eggs was laid by bugs emerging from nymphs treated with extracts of C. papaya (55.1) and it was followed by the treatments C. gigantea (35.00), both being on par and the latter came on par with S. indicum (29.00) and P. rubra (26.75).

The hatchability of the eggs laid by the malformed adults was also influenced by the treatments. Except in C. papaya and L. aspera with 55.00 and 28.00 per cent hatch, the eggs laid by malformed adults in all the treatments failed to hatch.

The sterility percentage of D. cingulatus treated with benzene extracts of A. indica, C. infortunatum, E. odoratum, T. neriifolia, V. negundo, S. indicum, C. variegatum, N.oleander, A. vesica and A. conizoides, was 100. Extract of P. odoratissimus caused 92.95 per cent sterility.

3.8.4. Effects of ether extracts of plants to D. cingulatus

The results of the experiment on the hormonal effect of petroleum ether extracts of plants to last instar nymphs of D. cingulatus and the statistical analysis are presented in Table 16.

Maximum prolongation of nymphal duration was observed in treatment with P. rubra extract (14.50 days) followed by M. esculenta (13.14) both being on par. These were followed by L. camara (11.12), C. papaya (11.09), C. variegatum (11.00),

V. negundo (10.82), P. odoratissimus (10.24) and S. indicum (10.28), all the treatments were on par and the durations were significantly higher than in control. The nymphal duration in remaining treatments ranged from 10.12 to 7.78 days and these came on par with control (7.88 days).

Only in eight plants there was nymphal mortality in category 1. The mean mortality percentage ranged from 5.00 in treatment with C. papaya, L. camara and C. gigantea to 19.04 in M. esculenta.

Nymphal mortality five days after application of plant extracts varied significantly in different treatments. Highest mortality percentage was observed with the ether extract of M. esculenta (47.62) which was followed by C. papaya (40.00) and L. aspera (35.00), all the three being on par, but varied significantly from control (14.28).

Normal adult emergence was least in the extract of A. conizoides (10.00 per cent) which was on par with L. aspera (20.00). M. esculenta, C. papaya, C. infortunatum, A. indica and L. camara with 33.33, 40.00, 45.00, 47.62 and 55.00 per cent adult emergence respectively were on par and varied significantly from control (85.72 per cent).

Normal adults emerged from A. conizoides treated bugs died on the day of emergence itself. Adult longevity varied

Table 15. Hormonal effects of the ether extracts of different plants to the last instar nymphs of *D. cingulatus*

extracts of*	duration of nymphal instar (days)	nymphal mortality (%)		adults emerged (%)	adult longevity (days)	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		up to five days after treatment	after fifth day of treatment					
A. indica	8.45 de	0.00	0.00	N 47.62 cde M 52.38 ab	12.35 gh 1.09 ab	17.00 bc 0.00	7.06 a 0.00	98.23 ab
C. infortunatum	9.22 cde	15.00	0.00	N 45.00 cd M 40.00 abc	9.777de 0.375a	32.00 c 0.00	50.00 cd 0.00	76.47 cde
E. odoratum	8.22 de	0.00	4.34 f	N 73.90 fg M 21.74 cd	7.47 bc 3.20 ab	0.00 0.00	0.00 0.00	100.00 a
O. sanctum	8.50 de	0.00	0.00	N 90.00 i M 10.00 g	8.16 bc 5.00 ab	54.37 d 46.25	85.00 efg 68.00	43.77 fg
P. rubra	14.55 a	0.00	22.72 bcde	N 68.18 defg M 0.09 efg	10.93 ef 0.00 a	30.00 c 0.00	45.00 cd 0.00	82.15 bcd
T. peniifolia	9.25 cde	0.00	0.00	N 66.65 defg M 33.33 bcd	10.78 ef 0.85 ab	7.14 ab 0.00	70.00 cdef 0.00	92.65 abc
C. gigantea	10.12 cde	5.00	15.00 def	N 65.00 defg M 15.00 defg	7.30 b 1.66 ab	19.50 bc 0.00	0.00 0.00	100.00 a
V. negundo	10.82 c	0.00	4.76 f	N 80.95 gh M 14.30 defg	3.50 a 2.50 ab	14.00 abc 0.00	67.00 cd 0.00	86.55 bcd
N. oleander	9.85 cde	0.00	4.76 f	N 76.20 fg M 19.05 cdefg	12.50 gh 3.50 ab	56.00 d 0.00	36.50 0.00	67.94 def
C. aromaticus	9.20 cde	0.00	0.00	N 95.00 hi M 5.00 ef	13.26 h 3.00 ab	73.40 d 0.00	82.00 defg 0.00	11.50 h
S. indicum	10.28 cd	0.00	20.00 cde	N 65.00 defg M 15.00 defg	14.50 i 2.35 ab	28.00 c 6.50	95.00 gh 0.00	68.88 def
L. aspera	10.11 cde	15.00	35.00 abc	N 20.00 ab M 30.00 bcd	7.37 b 3.83 ab	0.00 a 0.00	0.00 0.00	100.00 a
M. esculenta	13.14 ab	19.04	47.62 a	N 33.33 bc M 0.00 h	12.43 gh 0.00	3.66 ab 0.00	0.00 0.00	100.00 a
L. camara	11.12 bc	5.00	10.00 ef	N 55.00 de M 30.00 bcd	7.72 bc 0.00 a	8.25 ab 0.00	12.12 ab 0.00	98.53 ab
C. variegatum	11.00 c	7.14	14.28 def	N 78.43 fg M 0.00 h	8.45 bc 0.00	8.00 abc 0.00	0.00 0.00	100.00 a
A. versica	7.78 e	15.00	15.00 def	N 70.00 efg M 0.00 h	8.71 c 0.00	14.75 abc 0.00	11.50 ab 0.00	97.51 ab
C. papaya	11.09 bc	5.00	40.00 ab	N 40.00 ab M 15.00 efg	13.62 hi 0.00 a	7.20 c 0.00	95.00 fgh 0.00	60.88 efg
P. odoratissimus	10.24 cd	0.00	9.52	N 85.72 ghi M 4.76 efg	10.75 ef 5.00 b	28.00 ab 0.00	95.00 gh 0.00	89.94 bcd
A. conizoides	7.88 e	0.00	25.00 bcd	N 10.00 a M 65.00 a	0.00 3.65 ab	0.00 0.60	0.00 0.00	100.00 a
M. viridis	8.40 de	0.00	0.00	N 93.33 hi M 6.66 fg	16.50 j 7.00 b	68.00 0.00	62.00 cde 0.00	38.00 g
Control	7.88 e	0.00	14.28 def	N 85.72 ghi M 0.00 h	11.33 fg 0.00	68.00 d 0.00	100.00 h 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

* 25 gram dried plant material extracted with 100 ml solvent, applied topically @ 2 µl/specimen.

Each treatment consisted of four replications and 20 insects were treated in each replication.

in other treatments from 3.5 days to 16.5 days. In ten treatments the adult longevity was less than that in control (11.33 days). The longevity of adults emerged in V. negundo treated nymphs was the least (3.5 days) and this was significantly shorter than in other treatments. C. gigantea (7.30), L.aspera (7.37), E. odoratum (7.47), L. camara (7.72), O. sanctum (8.16) and C. variegatum (8.45) were on par. A. vesica (8.71) and C. infortunatum (9.78) reduced the longevity significantly when compared to control. Adult longevity of bugs obtained from nymphs treated with C. aromaticus (13.25 days), C. papaya (13.62 days), S. indicum (14.50 days) and E. viridis (16.50 days) were longer than that of control.

Fecundity of the treated bugs also varied significantly in different treatments. out of the twenty plants tested, sixteen plant extracts reduced fecundity of females emerging from treated nymphs when compared to those in control. E. odoratum, A. conizoides and L. aspera fully suppressed the fecundity and M. esculenta (3.66), T. neriifolia (7.14), C. papaya (7.20), C. variegatum (8.0) and L. camara (8.25) came on par in suppressing the fecundity. V. negundo (14.00), A. vesica (14.75), S. indicum (28.00), P. odoratissimus (28.0), P. rubra (30.00) and C. infortunatum (32.00) also caused significant lowering of egg production when compared with control (68.0). Remaining treatments came on par with control.

Hatchability of the eggs laid by insects treated with S. indicum, C. papaya and P. odoratissimus came on par with control. C. gigantea, M. esculenta and C. variegatum caused 100 per cent suppression of egg hatch. Hatchability of eggs was very low in treatments with A. indica (7.06), A. vesica (11.50) and L. camara (12.12) also. In N. oleander only 36.50 of the eggs hatched while in P. rubra and C. infortunatum 45.0 and 50.0 per cent eggs hatched. Extracts of V. negundo, M. viridis, T. neriifolia, C. aromaticus and O. sanctum also reduced the hatchability of eggs significantly, the mean percentages being in the range of 62.00 to 85.00.

Malformed adults were observed in all treatments except in the case of M. esculenta, C. variegatum and A. vesica. Maximum (65.0 per cent) occurrence was in the extract of A. conizoides and it was followed by A. indica (52.38) and C. infortunatum (40.00). The three treatments were on par. Extract of T. neriifolia produced 33.33 per cent malformed adults and the treatment was on par with L. aspera, L. camara (30.00), E. odoratum (21.74), N. oleander (19.05), C. gigantea, S. indicum, C. papaya (15.00) and V. negundo (14.30).

The malformed adults produced by the extracts of P. rubra, L. camara and C. papaya died on the day of emergence and the longevity in other treatments varied from 0.375 days to 7.0 days. Egg laying by malformed adults was observed in two treatments,

PLATE VI

A B B C C

B A B

O. sanctum (46.25 eggs/female) and S. indicum (6.50) In the former treatment 68 per cent of the eggs hatched while the eggs in the latter treatment failed to hatch.

Sterility percentages caused by the extracts of E.odoratum, C. gigantea, L. aspera, M. esculenta, C. variegatum and A. conizoides were 100. Extracts of A. indica (98.25 per cent), L. camara (98.53 per cent), A. vesica (97.51 per cent) and T. neriifolia (92.65 per cent) were also on par with the above treatments. The sterility percentages in the remaining treatments (except C. papaya) were significantly higher than that of control.

3.8.5. Hormonal effects of water extracts of different plants to last instar larvae of S. litura

Data relating to the experiment and the results of statistical analysis of the same are presented in Table 16.

Of the twenty plants tested L. aspera and A. vesica alone caused mortality (20.00 per cent) in the larval stage within five days after treatment. Extracts of eight plants produced malformed pupae with larval heads and larval prolegs which were reduced in size. In some the anterior end metamorphsed while the posterior end remained in the larval form (Plate VI). T. neriifolia caused deformity in 20.00 per cent pupae and S. indicum and M. esculenta in 12.5 per cent each while A. indica, P. rubra, N. oleander, A. vesica and A. conizoides caused 10.0 per cent malformed pupae only

Pupal mortality ranging from 10 to 50 per cent was observed in fourteen treatments and also in control (10.0 per cent). The maximum of 50.00 per cent pupal mortality was recorded in T. neriifolia which was on par with S. indicum, M. esculenta, L. camara, E. odoratum (25.00 per cent in all), N. oleander, A. vesica and C. papaya (20.00 per cent each). These were significantly superior to all other treatments including control.

Inhibition of normal adult emergence was significantly higher with A. indica and T. neriifolia. Extract of A. indica permitted only 20.00 per cent of the treated larvae to emerge as normal adults, while with T. neriifolia 50.00 per cent became normal adults. In the remaining treatments adult emergence ranged from 75 to 100 per cent.

Extract of A. indica was the only treatment which induced deformities in the emerging adults, where 70.00 per cent of the treated insects developed as malformed adults with crumpled wings and wing pads and some failed to emerge out of the pupal moult (Plate VI).

Longevity of adults emerging in different treatments and control varied significantly. Adult longevity with N.oleander (2.5 days), T. neriifolia (2.60), V. negundo (3.30) and A. vesica (3.33) came on par and low. Adults emerging from larvae treated with extracts of M. viridis, C. papaya,

Table 16. Hormonal effects of water extracts of different plants to last instar larvae of S. litura

plants	duration of pupal instar (days)	mean percentage of larvae (mean of 4 replications-out of 20 numbers in each replication)				adult longevity	no.of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		dying as larva	developing as malformed pupa	dying as pupa	developing as adults				
A. indica	14.00	0.00	10.00 a	10.00 b	N 20.00 a M 70.00	12.00 j 1.50	0.00 0.00	0.00 0.00	100.00 a
C. infortunatum	9.00	0.00	0.00	0.00 a	N 100.00 e M 0.00	8.60 hi 0.00	163.95 de 0.00	75.00 cd 0.00	46.89 bcdef
E. odoratum	8.00	0.00	0.00	25.00 ab	N 75.00 bcd M 0.00	7.73 gh 0.00	195.50 ef 0.00	82.00 cde 0.00	30.76 def
O. sanctum	8.88	0.00	0.00	10.00 b	N 90.00 de M 0.00	6.20 efg 0.00	122.00 de 0.00	83.33 cde 0.00	56.09 bcde
P. rubra	8.30	0.00	10.00 a	10.00 b	N 90.00 cde M 0.00	9.60 i 0.00	125.50 de 0.00	40.00 a 0.00	78.32 bc
T. nerifolia	7.50	0.00	20.00 a	50.00 a	N 50.00 b M 0.00	2.60 a 0.00	0.00 0.00	0.00 0.00	100.00 a
C. gigantea	8.80	0.00	0.00	0.00	N 100.00 e M 0.00	5.60 cde 0.00	198.00 ef 0.00	85.00 def 0.00	27.31 ef
V. negundo	5.00	0.00	0.00	0.00	N 100.00 e M 0.00	13.30 ab 0.00	0.00 0.00	0.00 0.00	100.00 a
N. oleander	5.75	0.00	10.00 a	20.00 ab	N 80.00 bcd M 0.00	2.50 a 0.00	0.00 0.00	0.00 0.00	100.00 a
C. aromaticus	6.80	0.00	0.00	0.00	N 100.00 e M 0.00	6.50 efg 0.00	105.00 bc 0.00	78.00 cd 0.00	64.63 bcde
S. indicum	7.75	0.00	12.50 a	25.00 ab	N 75.00 bcd M 0.00	7.20 fg 0.00	225.00 ef 0.00	90.00 def 0.00	12.54 f
L. aspera	8.00	20.00	0.00	0.00	N 80.00 bcd M 0.00	7.75 gh 0.00	68.00 ab 0.00	66.66 bc 0.00	80.42 bc
M. esculenta	9.38	0.00	12.50 a	25.00 ab	N 75.00 bcd M 0.00	5.83 def 0.00	168.00 de 0.00	75.00 cd 0.00	45.58 bcdef
L. camera	9.00	0.00	0.00	25.00 ab	N 75.00 bcd M 0.00	6.20 ef 0.00	63.00 ab 0.00	85.00 def 0.00	76.87 bc
C. variegatum	8.00	0.00	0.00	12.50 b	N 87.50 de M 0.00	6.50 efg 0.00	242.50 ef 0.00	75.00 cd 0.00	31.16 def
A. vesica	6.00	20.00	10.00 a	20.00 ab	N 60.00 bc M 0.00	3.33 ab 0.00	130.00 de 0.00	100.00 g 0.00	43.90 bcdef
C. papaya	10.00	0.00	0.00	20.00 ab	N 80.00 bcd M 0.00	4.81 cd 0.00	60.00 a 0.00	55.00 ab 0.00	85.75 ab
P. odoratissimus	8.43	0.00	0.00	12.50 b	N 87.50 cd M 0.00	7.78 gh 0.00	172.00 de 0.00	85.00 def 0.00	36.85 cdef
A. conizoides	7.50	0.00	10.00 a	10.00 b	N 90.00 cde M 0.00	5.50 cde 0.00	193.50 ef 0.00	80.00 cd 0.00	33.14 def
M. viridis	8.10	0.00	0.00	0.00	N 100.00 e M 0.00	4.25 bc 0.00	90.00 abc 0.00	75.50 cd 0.00	70.61 bcd
Control	6.00	0.00	0.00	10.00 b	N 90.00 cde M 0.00	12.50 j 0.00	245.00 f 0.00	94.50 ef 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

25 gram dried plant material extracted with 100 ml solvent, applied topically @ 5 µl/specimen.

A. conizoides, C. gigantea and M. esculenta lived for 4.25 to 5.83 days and these treatments were on par. With the remaining treatments (excluding A. indica) the longevity ranged from 6.20 to 8.6 days and they were significantly higher than the longevity of adults in control. A. indica came on par with control.

Fecundity was reduced considerably in different treatments. With A. indica, T. neriifolia, V. negundo and N. oleander egg laying was completely suppressed. E. odoratum, C. gigantea, S. indicum, C. variegatum and A. conizoides came on par with control.

Hatchability of eggs laid by treated insects varied significantly in different treatments. Only 40 per cent of the eggs laid hatched with P. rubra and it came on par with C. papaya (35 per cent) and this in turn came on par with L. aspera (66.66 per cent). Among the remaining thirteen plant extracts, six were also significantly superior to control with mean percentages of egg hatch ranging from 75 to 80.

Extract of A. indica alone caused the formation of malformed adults (70.00 per cent) and they were short lived, survived for 1.5 days after emergence and failed to lay eggs.

Extracts of A. indica, T. neriifolia, V. negundo and N. oleander caused 100 per cent sterility in treated insects,

either due to shorter longevity of adults or due to reduced fecundity of the females.

3.8.6. Hormonal effects of acetone extracts of different plant extracts to last instar larvae of S. litura

Data relating to the experiments and the results of the statistical analysis are presented in Table 17. It was seen that in eight plant extracts 5 to 20 per cent larval mortality was recorded in comparison with 10.0 per cent in control. In the remaining treatments there was no larval mortality.

Pupal duration in different treatments varied significantly. Maximum lengthening of pupal period was seen with A. indica (14.0 days). Extracts of E. odoratum (12.50) and A. conizoides (11.50) also could lengthen the pupal period significantly. Other treatments came on par with control.

In E. odoratum 40.00 per cent of the treated larvae developed as malformed pupae. Extracts of S. indicum (20.00), A. indica, A. vesica, P. odoratissimus and A. conizoides (10.00) and T. neriifolia (5.00) also produced deformities in the pupal stage.

Pupal mortality was maximum with E. odoratum (60.00 per cent) and it was followed by O. sanctum (45 per cent), S.indicum (40.00), C. variegatum (37.5), A. indica (30.0) and T.neriifolia

Table 17. Hormonal effects of acetone extracts of different plants to last instar larvae of S. litura

plants	duration of pupal instars (days)	mean percentage of larvae (mean of 4 replications- out of 20 numbers in each replication)				adult longevity	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		dying as larva	developing as malformed pupa	dying as pupa	developing as adults				
A. indica	14.00 a	10.00	10.00	30.00 abcd	N 60.00 abcd M 0.00	6.50 ab 0.00	0.00 0.00	0.00 0.00	100.00 a
C. infortunatum	9.50 cde	0.00	0.00	10.00 cde	N 90.00 def M 0.00	7.22 ab 0.00	38.00 bc 0.00	78.94 bcde 0.00	75.00 bcd
E. odoratum	12.50 ab	0.00	40.00	60.00 a	N 40.00 a M 0.00	4.50 a 0.00	0.00 0.00	0.00 0.00	100.00 a
O. sanctum	8.80 de	0.00	0.00	45.00 ab	N 55.00 abc M 0.00	8.40 ab 0.00	105.00 f 0.00	80.00 bcde 0.00	29.99 f
P. rubra	8.20 de	0.00	0.00	15.00 bcde	N 85.00 cdef M 0.00	5.60 ab 0.00	78.00 de 0.00	61.53 bcde 0.00	60.00 cde
T. neriifolia	7.50 e	15.00	5.00	30.00 abcd	N 50.00 ab M 5.00	3.50 a 1.00	0.00 0.00	0.00 0.00	100.00 a
C. gigantea	7.80 de	5.00	0.00	0.00	N 95.00 ef M 0.00	7.00 ab 0.00	95.00 ef 0.00	73.68 abcd 0.00	41.67 ef
V. negundo	8.20 de	0.00	0.00	5.00 e	N 95.00 ef M 0.00	2.80 a 0.00	0.00 0.00	0.00 0.00	100.00 a
N. oleander	8.45 de	0.00	0.00	20.00 cde	N 80.00 bcde M 0.00	3.50 a 0.00	30.00 ab 0.00	0.00 0.00	100.00 a
C. aromaticus	7.95 de	0.00	0.00	0.00	N 100.00 f M 0.00	7.25 ab 0.00	98.00 ef 0.00	86.24 de 0.00	29.56 f
S. indicum	9.82 cd	0.00	20.00	40.00 ab	N 60.00 abcd M 0.00	4.25 a 0.00	44.00 bc 0.00	75.00 bcde 0.00	72.50 bcd
L. aspera	8.71 de	12.50	0.00	0.00	N 87.50 ef M 0.00	4.50 a 0.00	38.50 bc 0.00	60.00 abc 0.00	80.75 bc
M. esculenta	9.20 de	0.00	0.00	10.00 cde	N 80.00 bcde M 10.00	4.81 a 3.00	112.50 fg 0.00	52.00 ab 0.00	51.25 def
L. camara	9.00 de	0.00	0.00	10.00 de	N 90.00 ef M 0.00	5.11 ab 0.00	89.50 ef 0.00	81.01 bcde 0.00	39.58 ef
C. variegatum	9.42 de	12.50	0.00	37.50 abc	N 50.00 ab M 0.00	3.88 a 0.00	98.50 ef 0.00	75.00 bcde 0.00	38.43 ef
A. vesica	9.20 de	20.00	10.00	20.00 bcde	N 50.00 ab M 10.00	3.50 a 0.00	20.00 a 0.00	85.00 cde 0.00	85.83 b
C. papaya	9.20 de	0.00	0.00	0.00	N 100.00 f M 0.00	4.20 a 0.00	30.00 ab 0.00	73.33 a 0.00	81.67 bc
P. odoratissimus	8.25 de	20.00	10.00	20.00 bcde	N 50.00 ab M 10.00	7.40 ab 3.50	65.67 d 0.00	76.14 bcde 0.00	58.33 cdef
A. conizoides	11.50 bc	20.00	10.00	20.00 bcde	N 60.00 abcd M 0.00	6.83 ab 0.00	45.67 d 0.00	87.59 de 0.00	66.61 bcde
M. viridis	8.85 de	0.00	0.00	0.00	N 100.00 f M 0.00	7.25 ab 0.00	88.50 ef 0.00	76.27 bcde 0.00	43.75 ef
Control	9.25 de	10.00	0.00	10.00 cde	N 80.00 bcde M 0.00	7.62 ab 0.00	132.00 g 0.00	90.90 e 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

25 gram dried plant material extracted with 100 ml solvent, topically applied @ 5/ul/specimen.

(30.0), all being on par. Only E. odoratum, O. sanctum and S. indicum were significantly superior to control.

E. odoratum was the only treatment which produced significantly less number of normal adults (40.00 per cent). T. neriifolia, O. variegatum, A. vesica, P. odoratissimus (50.00), O. sanctum (55.0) and A. indica, S. indicum and A. conizoides (60.00) were also on par with E. odoratum, but they did not differ significantly from control. The longevity of adults in different treatments did not differ significantly. The fecundity of the insects was influenced by the plant extracts Egg laying was completely prevented with A. indica, E. odoratum, T. neriifolia and V. negundo extracts. In the extract of A. vesica the mean number of eggs laid per female was reduced to 20.00 and with N. oleander and C. papaya it was 30.00 each and all the three were on par. Except M. esculenta (112.50), the remaining treatments (mean number 38.00 to 105.0) also caused significantly lower number of eggs when compared to that of control.

The eggs laid by the adults emerging from larvae treated with N. oleander failed to hatch totally. In other treatments the hatchability ranged from 52.00 to 87.59 per cent while in control 90.90 per cent of the eggs hatched.

Caterpillars treated with A. vesica and T. neriifolia developed as malformed adults. The former moths died on the

day of emergence while the latter lived for one day after emergence.

Extracts of A. indica, F. odoratum, T. neriifolia, V. negundo and N. oleander could produce 100 per cent sterility on treated insects.

3.8.7. Effects of benzene extracts of plants to last instar larvae of S. litura

Results are presented in Table 18. It was seen that the application of benzene extracts of thirteen plants caused larval mortality to an extent of 10 to 40.00 per cent. Highest mortalit was observed with the extract of O. sanctum (40.00) followed by C. variegatum (37.50) both being significantly higher than the mortality observed in control.

The pupal periods of treated insects were prolonged significantly in A. indica (13.20 days) and C. gigantea (12.00) and in all other treatments it was on par with control. Twenty per cent of the treated larvae developed as malformed pupae with the extract of M. viridis while A. indica, C. aromaticus, S. indicum, M. esculenta and A. conizoides extracts caused 10.00 per cent deformed pupae.

Sixty per cent of the larvae treated with N. oleander died as pupae. In the remaining treatments pupal mortality ranged from 10.00 to 50.00 per cent, but the treatments were on par with control.

Table 18. Hormonal effects of benzene extracts of different plants to last instar larvae of S. litura

plants	duration of pupal instar (days)	mean percentage of larvae (mean of 4 replications- out of 20 numbers in each replication)				adult longevity	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		dying as larva	developing as malformed pupa	dying as pupa	developing as adults				
A. indica	13.20 a	20.00 abc	10.00 a	30.00 abc	N 50.00 abcd M 0.00	3.80 b 0.00	0.00 0.00	0.00 0.00	100.00 a
C. infortunatum	9.50 cd	20.00 abc	0.00	10.00 c	N 70.00 bcde M 0.00	6.60 efgh 0.00	143.50 fgh 0.00	66.66 abcde 0.00	14.59 e
E. odoratum	8.60 cd	0.00 d	0.00	25.00 abc	N 75.00 cde M 0.00	5.80 de 0.00	176.00 h 0.00	80.00 de 0.00	0.00 f
O. sanctum	10.00 bcd	40.00 a	0.00	20.00 abc	N 40.00 abc M 0.00	6.00 de 0.00	78.50 cde 0.00	85.00 de 0.00	40.43 cde
P. rubra	9.40 cd	0.00 d	0.00	10.00 c	N 90.00 ef M 0.00	6.38 efg 0.00	98.00 cdefg 0.00	35.00 a 0.00	69.38 bc
T. peritifolia	9.80 bcd	10.00 bc	0.00	30.00 abc	N 60.00 abcde M 0.00	3.33 b 0.00	0.00 0.00	0.00 0.00	100.00 a
C. gigantea	12.00 ab	0.00 d	0.00	20.00 bc	N 80.00 def M 0.00	3.50 b 0.00	125.00 defgh 0.00	80.00 cde 0.00	10.72 e
V. negundo	8.80 cd	0.00 d	0.00	0.00 d	N 100.00 f M 0.00	3.50 b 0.00	0.00 0.00	0.00 0.00	100.00 a
N. oleander	9.20 cd	20.00 abc	0.00	60.00 a	N 20.00 a M 0.00	1.50 a 0.00	0.00 0.00	0.00 0.00	100.00 a
C. aromaticus	8.75 cd	20.00 abc	10.00 a	0.00 d	N 70.00 bcd M 0.00	6.00 def 0.00	85.00 bcdef 0.00	88.00 de 0.00	33.22 de
S. indicum	7.90 d	10.00 bc	10.00 a	20.00 abc	N 70.00 bcde M 0.00	8.57 ij 0.00	48.00 ab 0.00	87.50 de 0.00	62.50 bcd
L. aspera	8.60 cd	20.00 abc	0.00	0.00 d	N 80.00 cde M 0.00	6.90 fgh 0.00	54.50 abc 0.00	73.41 bcde 0.00	64.28 bcd
M. esculenta	9.40 cd	10.00 c	10.00 a	40.00 abc	N 50.00 abcd M 0.00	5.50 de 0.00	135.00 efgh 0.00	55.00 abcd 0.00	33.71 cde
L. camara	9.00 cd	0.00 d	0.00	20.00 abc	N 80.00 cde M 0.00	5.25 cd 0.00	72.00 abcd 0.00	90.27 e 0.00	41.97 cde
C. variegatum	8.75 cd	37.50 a	0.00	12.50 bc	N 50.00 abcd M 0.00	5.00 cd 0.00	120.00 defgh 0.00	50.00 abc 0.00	46.43 cd
A. vesica	11.00 abc	0.00 d	0.00	50.00 ab	N 50.00 abcd M 0.00	2.50 ab 0.00	0.00 0.00	0.00 0.00	100.00 a
C. papaya	9.00 cd	30.00 ab	0.00	40.00 abc	N 30.00 ab M 0.00	4.50 c 0.00	50.00 ab 0.00	72.00 bcde 0.00	67.86 bcd
P. odoratissimus	8.45 cd	10.00 bc	0.00	0.00 d	N 90.00 ef M 0.00	7.11 ghi 0.00	165.00 gh 0.00	90.90 e 0.00	0.00 f
A. conizoides	8.00 d	0.00 d	10.00 a	20.00 abc	N 80.00 cde M 0.00	8.00 hij 0.00	64.50 abc 0.00	80.00 cde 0.00	53.93 cd
M. viridis	8.50 cd	20.00 abc	20.00 a	20.00 abc	M 60.00 abcde N 0.00	6.50 efg 0.00	35.00 a 0.00	42.85 ab 0.00	86.61 b
Control	9.00 cd	10.00 bc	0.00	20.00 abc	M 70.00 bcde N 0.00	9.79 k 0.00	128.00 efgh 0.00	87.50 de 0.00	0.00

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

25 gram dried plant material extracted with 100 ml solvent, topically applied @ 5 µl/specimen.

The mean percentage of normal adults emerged ranged from 20.00 to 100.00 per cent. Only in N. oleander extract (20.00) the normal adult emergence was significantly reduced when compared to control.

Adult longevity in different treatments ranged from 1.50 to 8.57 days and the variations were statistically significant. Longevity was minimum with N. oleander (1.50) and it was followed by A. vesica (2.50), both were on par, the latter being on par with V. negundo (3.30), T. neriifolia (3.33), C. gigantea (3.50) and A. indica (3.80) also. Extracts of C. papaya, C. variegatum and L. camara were on par causing the adult longevity ranging from 4.50 to 5.25 days whereas M. esculenta, E. odoratum, O. sanctum and C. aromaticus, with the longevity ranging from 5.50 to 6.0, days were on par.

Adults emerged from larvae treated with A. indica, T. neriifolia, N. oleander, V. negundo and A. vesica did not lay eggs. Fecundity was significantly lowered with M. viridis (35.0), S. indicum (48.0), C. papaya (50.0), L. aspera (54.50), A. conizoides (64.50) and L. camara (72.0); all the other treatments came on par with control (128.0).

Hatching of eggs was suppressed significantly by P. rubra (35.0 per cent), M. viridis (42.85) and C. variegatum (50.00). Others came on par with control. Malformed adults were not observed in any of the treatments.

A. indica, T. neriifolia, V. negundo, N. oleander and A. vesica could cause 100 per cent sterility in S. litura. M. viridis could induce 86.61 per cent sterility and P. rubra (69.38), C. papaya (67.86), L. aspera (64.28) and S. indicum (62.50) were on par in causing sterility.

3.8.8. Hormonal effects of ether extracts of plants to last instar larvae of S. litura

Data on the effect of ether extracts of plants to S. litura and the results of the statistical analysis are presented in Table 19. Larval mortality ranging from 10.00 to 40.00 per cent was observed in six of the treatments. N.oleander caused the highest mortality of 40 per cent and extracts of M. esculenta, C. papaya and C. variegatum gave 20.00 per cent mortality when L. camara and A. indica resulted in 10.0 per cent larval mortality only.

The mean pupal period in different treatments did not vary significantly and it ranged from 8.00 to 9.55 days.

P. rubra caused 100 per cent pupal mortality. With C. variegatum 40.00 per cent pupal mortality was observed while in S. indicum and C. gigantea 30.00% of treated larvae died as pupa. Remaining treatments came on par with control.

P. rubra prevented emergence of normal adults completely while N. oleander and M. esculenta resulted in 20.00 per cent

Table 19. Hormonal effects of ether extracts of different plants to last instar larvae of S. litura

Plants	duration of pupal instar (days)	mean percentage of larvae (mean of 4 replications- out of 20 numbers in each replication)				adult longevity	number of eggs laid per female	percentage of eggs hatched	sterility percentage of normal + malformed adults
		dying as larva	developing as malformed pupa	dying as pupa	developing as adults				
indica	8.85 a	10.00 ab	0.00	20.00 abcd	N 70.00 cde M 0.00	4.85 fgh 0.00	0.00 0.00	0.00 0.00	100.00 a
infortunatum	8.00 a	0.00	10.00 a	10.00 cd	N 90.00 ef M 0.00	5.50 hi 0.00	86.00 efg 0.00	70.00 bcd 0.00	59.87 cde
odoratum	8.75 a	0.00	0.00	20.00 abcd	N 80.00 def M 0.00	6.00 ij 0.00	115.00 gh 0.00	85.00 bcd 0.00	34.84 ef
sanctum	8.50 a	0.00	20.00 a	20.00 abcd	N 80.00 def M 0.00	3.50 bcd 0.00	40.00 bcd 0.00	65.00 b 0.00	82.67 bc
rubra	0.00	0.00	0.00	100.00 a	N 0.00 a M 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 f
perilifolia	9.55 a	0.00	10.00 a	10.00 cd	N 90.00 ef M 0.00	3.55 bcd 0.00	58.00 cde 0.00	68.95 bc 0.00	73.34 abcd
gigantea	9.00 a	0.00	20.00 a	30.00 bcd	N 70.00 cde M 0.00	4.00 def 0.00	24.50 b 0.00	63.25 b 0.00	88.67 ab
negundo	8.25 a	0.00	10.00 a	20.00 abcd	N 80.00 def M 0.00	2.50 a 0.00	60.00 cde 0.00	65.00 b 0.00	74.00 abcd
oleander	8.00 a	40.00 a	20.00 a	20.00 abcd	N 20.00 b M 20.00	4.50 def 0.00	0.00 a 0.00	0.00 0.00	100.00 a
aromaticus	8.25 a	0.00	0.00	10.00 cd	N 90.00 ef M 0.00	5.00 gh 0.00	95.00 fgh 0.00	84.21 bcd 0.00	46.67 bcd
indicum	8.33 a	0.00	30.00 a	30.00 bcd	N 70.00 cde M 0.00	5.50 hi 0.00	190.00 j 0.00	80.00 bcd 0.00	0.00 e
aspera	8.50 a	0.00	10.00 a	10.00 cd	N 90.00 ef M 0.00	3.00 abc 0.00	0.00 a 0.00	0.00 0.00	100.00 a
esculenta	8.00 a	20.00 ab	0.00	20.00 bcd	N 20.00 b M 40.00	3.00 abc 2.50	0.00 a 0.00	0.00 0.00	100.00 a
camara	8.30 a	10.00 b	0.00	10.00 cd	N 80.00 def M 0.00	4.50 efg 0.00	35.00 bc 0.00	85.71 bcd 0.00	80.00 abc
variegatum	8.75 a	20.00 ab	0.00	40.00 bc	N 40.00 bcd M 0.00	3.00 ab 0.00	68.00 def 0.00	0.00 a 0.00	100.00 a
vesica	8.66 a	0.00	0.00	10.00 cd	N 90.00 ef M 0.00	4.11 defg 0.00	30.00 b 0.00	0.00 a 0.00	100.00 a
papaya	8.33 a	20.00 ab	30.00 a	50.00 b	N 30.00 bc M 0.00	4.50 efg 0.00	85.00 ef 0.00	37.64 bcd 0.00	78.67 bc
odoratissimus	8.50 a	0.00	10.00 a	10.00 cd	N 90.00 ef M 0.00	3.77 cde 0.00	135.00 hi 0.00	80.00 bcd 0.00	29.01 d
conizoides	8.66 a	0.00	0.00	10.00 cd	N 90.00 ef M 0.00	4.50 efg 0.00	72.00 ef 0.00	90.27 d 0.00	57.67 bcd
viridis	8.33 a	0.00	0.00	0.00 e	N 100.00 f M 0.00	6.25 ij 0.00	115.00 gh 0.00	75.00 bcd 0.00	42.51 bcd
crol	8.75 a	0.00	0.00	10.00 c	N 90.00 ef M 0.00	6.50 j 0.00	168.00 ij 0.00	89.29 cd 0.00	0.00 e

N - normal M - malformed

Means followed by a common letter in a column are not significantly different at 5% level (DMRT).

normal adults. Percentage of normal adult emergence with C. papaya and C. variegatum were 30.00 and 40.00 respectively. The remaining fifteen plants came on par with control.

Ether extracts of 17 plants reduced the adult longevity significantly. Longevity was least with V. negundo (2.50 days) and it cam on par with C. variegatum (3.00), M. esculenta (3.00) and L. aspera (3.00). O. sanctum, T. neriifolia and P. odoratissimus (3.00 to 3.77 days). C. gigantea, A. vesica, N. oleander, C. papaya, A. conizoides, L. camara and A. indica (4.00 to 4.85 days) came on par and significantly less than that in the control.

Fecundity of S. litura was affected adversely by the plant extracts. A. indica, N. oleander, L. aspera and M. esculenta suppressed the fecundity completely. Fecundity was reduced significantly in C. gigantea (24.50 eggs/female), A. vesica (30.0), L. camara (35.00) and O. sanctum (40.00). The remaining plant extracts also suppressed the egg production significantly when compared to control except P. odoratissimus which came on par with control.

Eggs laid by moths emerging from larvae treated with extracts of C. variegatum and A. vesica failed to develop. C. gigantea, V. negundo and O. sanctum also reduced hatching significantly (63.25 to 65.00 per cent) compared to control (89.29).

With the extract of M. esculenta 40.00 per cent of the treated larvae developed as malformed adults and in treatment with N. oleander 20.00 per cent became deformed adults. In other treatments malformed adults were not observed.

Malformed adults emerged in the treatment with M. esculenta lived for 2.50 days and those with N. oleander died on the day of emergence itself.

Extracts of A. indica, N. oleander, L. aspera, M. esculenta, C. variegatum and A. vesica caused 100.00 per cent sterility in S. litura and C. gigantea (88.67) and L. camara (80.00) also came on par with them

3.8.9. Juvenomimetic activity of five selected plants on D. cingulatus

Acetone and benzene extracts of A. indica, E. odoratum, C. infortunatum, T. neriifolia and N. oleander were bioassayed at varying doses for assessing their juvenomimetic activity on D. cingulatus.

3.8.9.1. Effect of acetone extracts

The data collected and the statistical analysis of the same are presented in Table 20. It was seen that the duration of last nymph in treatments varied significantly from control. The mean duration of nymphs treated with extract of C. infortunatum

was the longest (9.74) and it was followed by N. oleander (9.39), T. neriifolia (8.45), A. indica (8.17) and E. odoratum (7.82). There was a dose dependant increase in the nymphal duration when treated with extracts of C. infortunatum (8.00 to 11.11 days) and N. oleander (8.28 to 11.45) With the other extracts there was no linear relationship between the increasing doses and resultant changes in nymphal duration.

As regards nymphal mortality observed within five days after treatment also C. infortunatum ranked first (24.17 per cent) and it was followed by N. oleander (10.62%). The remaining treatments came on par with control. With C. infortunatum 100 per cent extract had the least mortality (17.5 per cent) while with the remaining three doses the mortalities observed were on par (25 to 30 per cent). With N. oleander extract 50 per cent solution gave the least mortality of 5.12 per cent and the mortalities in higher as well as lower concentration were higher and on par (11.11 to 15 per cent).

Mortality of treated nymphs observed five days after treatment was maximum with A. indica extract (49.58 per cent). It was on par with C. infortunatum also (46.07). Mortality with E. odoratum and T. neriifolia also were significantly higher than that of control while N. oleander came on par with control. The mortalities caused by 100 and 50 per cent extracts of A. indica and C. infortunatum were on par (60 to 66.66 per cent) while in lower concentrations the mortalities were

Table 20. Effect of varying doses of acetone extract of five selected plants, topically applied on the last instar nymph of D. cingulatus, on the biology of the insect

acetone extract of	dosage/nymph: 2/ul emulsion of	mean nymphal duration (days)	nymphal mortality (%)		percentage of nymphs moulted as			longevity (days) of			number of eggs laid per female*	percentage of eggs hatched*
			up to 5 days after treatment	from 5th day after treatment	normal adults	adultoids	sixth instar nymph	normal adults	adultoids	sixth instar nymph*		
A. indica	100% extract	8.69	2.77	66.66	2.77	19.44	8.33	16.00	0.43	0.00	0.00	0.00
	50 ,,	6.30	9.52	66.66	0.00	4.76	19.05	0.00	3.50	2.38	0.00	0.00
	25 ,,	7.90	2.70	45.95	8.11	35.14	8.11	4.33	2.61	3.00	0.00	0.00
	12.5 ,,	9.79	14.28	19.05	52.33	9.52	4.76	8.00	3.00	0.00	85.00	89.41
mean		8.17	7.32	49.58	15.82	17.21	10.06	7.08	2.38	1.35	21.25	23.35
C. infortunatum	100 ,,	11.11	17.50	60.00	0.00	17.50	5.00	0.00	0.00	0.00	0.00	0.00
	50 ,,	10.00	26.19	64.29	0.00	9.52	0.00	0.00	0.00	0.00	0.00	0.00
	25 ,,	9.86	30.00	30.00	0.00	40.00	0.00	0.00	4.70	0.00	0.00	0.00
	12.5 ,,	8.00	25.00	30.00	10.00	35.00	0.00	3.25	4.71	0.00	0.00	0.00
mean		9.74	24.17	43.07	2.50	38.38	1.25	0.81	2.35	0.00	0.00	0.00
E. odoratum	100 ,,	8.96	10.00	28.33	37.50	24.16	0.00	6.29	1.77	0.00	0.00	0.00
	50 ,,	7.30	0.00	16.66	85.33	0.00	0.00	5.83	0.00	0.00	0.00	0.00
	25 ,,	7.50	0.00	5.56	88.89	5.56	0.00	11.75	0.00	0.00	57.33	75.00
	12.5 ,,	7.50	0.00	0.00	100.00	0.00	0.00	13.55	0.00	0.00	74.33	89.00
mean		7.82	2.50	12.63	77.43	7.43	0.00	9.36	0.44	0.00	32.12	41.00
T. neriifolia	100 ,,	8.36	0.00	25.00	55.00	20.00	0.00	2.40	1.75	0.00	0.00	0.00
	50 ,,	8.21	0.00	22.22	61.11	16.66	0.00	4.36	2.00	0.00	37.00	79.74
	25 ,,	9.10	5.00	10.00	70.00	15.00	0.00	4.00	3.33	0.00	65.00	72.00
	12.5 ,,	8.11	5.00	5.00	75.00	15.00	0.00	2.06	3.33	0.00	48.00	70.00
mean		8.45	2.50	15.56	65.28	16.67	0.00	3.21	2.60	0.00	37.50	55.45
N. oleander	100 ,,	11.75	11.11	11.11	44.44	22.22	11.11	3.56	2.00	7.25	0.00	0.00
	50 ,,	8.88	5.26	10.52	68.42	10.53	5.26	8.77	1.00	0.00	39.75	16.98
	25 ,,	8.57	11.11	11.11	72.22	0.00	5.56	4.15	0.00	0.00	70.00	71.43
	12.5 ,,	8.38	15.00	0.00	75.00	10.00	0.00	6.54	2.50	0.00	78.58	75.00
mean		9.39	10.62	8.18	65.02	10.69	5.48	5.76	1.38	1.81	47.02	40.85
Control		6.50	0.00	0.00	100.00	0.00	0.00	16.42	0.00	0.00	165.00	80.50
C.D. for comparing means of different levels of each plant extract		0.25	9.98	4.99	4.55	2.71	4.80	2.66	0.31			
C.D. for comparing different levels of each plant extract		0.22	8.93	4.47	4.07	2.42	4.29	2.58	0.36			
C.D. for comparing treatments with control		0.49	19.96	9.99	9.09	2.54	9.60	6.31	0.80			

* Data not statistically analysed

significantly lower (30 to 45.95 per cent). In the case of E. odoratum and T. neriifolia also a linear increase in response with the increase in dosage was observed.

Extracts of C. infortunatum was the most effective in suppressing emergence of normal adults. The three higher concentrations prevented the normal adult emergence and in the lowest concentration of 12.5 per cent only 10.0 per cent of the treated nymphs developed as normal adults. In A. indica the higher two concentrations were on par in reducing adult emergence. Only 2.77 per cent of treated nymphs developed normally at 100.00 per cent concentration while at 50.0 per cent no insects emerged as normal adults. At 25.0 per cent also the inhibition was significantly high with only 8.11 per cent normal adult emergence. But with 12.5 per cent extract 52.38 per cent emerged as normal adults. The mean percentages of nymphs moulting as normal adults when treated with T.neriifolia (65.28) and N. oleander (65.02) extracts were on par and significantly less than that of E. odoratum (77.43). With these three extracts a negative linear association was observed between the dosages and percentages of adult emergence.

Longevity of normal adults emerging from nymphs treated with plant extracts was significantly shorter than that of the adults in control. In treatments the longevity ranged from 2.06 to 13.55 days as against 16.42 days in control. Shortest

longevity was observed in T. neriifolia extracts (2.06 to 4.36 days). With C. infortunatum normal adults emerged in the lowest concentration and they lived for 3.25 days only. With N. oleander the longevity ranged from 3.56 to 8.77 days while with A. indica it ranged from 4.33 to 16.0 days both being on par. Adult longevity was maximum in insects treated with E. odoratum in which the adults lived for 5.83 to 13.55 days. With none of plant extracts adult longevity was found dose-dependant.

Extracts of C. infortunatum caused maximum number of malformed adults (38.38) and it was followed by A. indica (17.21) and T. neriifolia (16.67) both being on par. N.oleander (10.69) was ranked next and E. odoratum produced the least number of malformed adults (7.43). A linear dose dependant increase in the occurrence of adultoids was not observed in the data. With C. infortunatum and A. indica maximum adultoids emerged at 25.0 per cent concentration while in the remaining three extracts maximum number of adultoids was seen in the highest dosage.

The longevity of adultoids was shortest in C.infortunatum/ E. odoratum. Adultoids emerging in treatments with 100 and 50 per cent extracts of C. infortunatum and 25.0 per cent extract of E. odoratum died on the day of emergence itself.

concentration of 12.5 per cent the fecundity of emerging bugs and hatchability of eggs were high (85.00 and 89.41 per cent respectively). With E. odoratum egg laying was completely inhibited in the normal adults at 100.0 and 50.0 per cent concentrations while in the two lower concentrations the fecundities were 57.33 and 74.33 per cent respectively and hatchings were 75.0 and 89.0 per cent respectively. In the case of acetone extracts of T. neriifolia and N. oleander the highest concentration alone could completely inhibit the fecundity while in the lower concentrations the fecundities ranged from 37 to 65.0% and 39.75 to 78.58% and hatchability from 70 to 79.74% and 16.98 to 75.0% respectively.

3.8.9.2. Effect of varying doses of benzene extracts of selected plants on the biology of D. cingulatus

The results of the experiment and the statistical analysis of the data are presented in Table 21. Except C. infortunatum all the plant extracts influenced the nymphal duration significantly. Lengthening of nymphal stage was maximum with the extracts of N. oleander (9.27 days) and it was closely followed by E. odoratum (9.18) both being on par. Next in position was A. indica (7.75) which varied significantly from T. neriifolia (7.15). The variations in nymphal period did not show any linear relation with the dosages of extracts. In A. indica

nymphal duration was minimum in the highest dose (6.50) while in lower three doses the durations were higher and on par (8.07 to 8.33).

Extracts of C. infortunatum ranked top in causing nymphal mortality (27.18 per cent) which was significantly higher than those of other plant extracts. This was followed by A. indica (21.60), N. oleander (21.02) and T. neriifolia (19.98) all the three being on par. Extracts of E. odoratum ranked last which was significantly inferior to the other four plants and was on par with control. In the case of N. oleander the mortality showed a linear relation with the increasing doses. Highest mortality percentage was obtained with 50.0 per cent extract of A. indica (37.50) which was significantly higher than the mortality obtained in the higher concentration of 100.0 per cent (21.42). With C. infortunatum mortalities caused by 100.00 per cent extract (31.2) and 12.5 per cent extract (30.0) were on par.

Mortality of treated nymphs five days after application was maximum in the extract of A. indica (58.45 per cent) which was followed by C. infortunatum (56.04). Both treatments were on par and were significantly superior to the remaining three treatments. E. odoratum was next with 29.90 per cent nymphal mortality. T. neriifolia and N. oleander were on par causing 17.08 and 15.89 per cent mortality respectively. The response

Table 21. Effect of varying doses of benzene extract of five selected plants, topically applied on the last instar nymph of D. cingulatus on the biology of the insect

benzene extract of	dosage/nymph: 2 µl emulsion of	mean nymphal duration (days)	nymphal mortality (%)		percentage of nymphs moulted as			longevity (days) of			number of eggs laid per female*	percentage of eggs hatched*
			up to 5 days after treatment	from 5th day after treatment	normal adults	adultoids	sixth instar nymph	normal adults	adultoids	sixth instar nymph*		
A. indica	100% extract	6.50	21.42	73.81	0.00	4.76	0.00	0.00	0.00	0.00	0.00	0.00
	50 ,,	8.10	37.50	50.00	0.00	10.00	2.50	0.00	4.25	2.00	0.00	0.00
	25 ,,	8.07	10.00	57.50	5.00	25.00	5.00	5.00	1.60	2.50	0.00	0.00
	12.5 ,,	8.33	17.50	52.50	12.50	12.50	5.00	8.20	2.57	2.00	0.00	0.00
mean		7.75	21.61	58.45	4.38	13.06	3.13	3.30	2.11	1.63	0.00	0.00
C. infortunatum	100 ,,	6.00	31.20	64.15	4.54	0.00	0.00	1.00	0.00	0.00	0.00	0.00
	50 ,,	6.50	20.00	70.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25 ,,	7.22	27.50	50.00	5.00	17.50	0.00	7.00	1.50	0.00	0.00	0.00
	12.5 ,,	6.00	30.00	40.00	20.00	10.00	0.00	2.00	2.00	0.00	0.00	0.00
mean		6.43	27.18	56.04	9.89	6.88	0.00	2.50	0.88	0.00	0.00	0.00
E. odoratum	100 ,,	9.40	15.78	57.88	5.26	13.75	7.50	5.00	2.25	4.67	0.00	0.00
	50 ,,	10.21	21.73	14.54	19.54	30.13	14.54	8.66	4.33	3.66	0.00	0.00
	25 ,,	8.48	12.50	37.50	35.00	17.50	2.50	9.36	2.10	2.00	1.00	0.00
	12.5 ,,	8.61	0.00	10.00	57.50	17.50	15.00	6.60	3.57	3.60	0.00	0.00
mean		9.18	12.50	29.99	29.32	19.72	9.94	7.41	3.06	3.48	0.00	0.00
T. neriifolia	100 ,,	8.14	23.80	33.33	19.05	23.80	0.00	6.50	3.50	0.00	0.00	0.00
	50 ,,	6.37	25.00	35.00	25.00	15.00	0.00	8.90	12.00	0.00	9.00	0.00
	25 ,,	7.64	20.00	0.00	35.00	45.00	0.00	6.09	2.00	0.00	41.00	18.25
	12.5 ,,	6.45	11.11	0.00	55.55	33.33	0.00	6.50	2.20	0.00	63.00	48.00
mean		7.15	19.98	17.08	33.65	29.28	0.00	7.00	4.92	0.00	28.25	16.56
N. oleander	100 ,,	11.11	31.57	21.05	5.27	0.00	42.10	11.00	0.00	7.33	62.00	0.00
	50 ,,	10.17	25.00	15.00	20.20	20.00	20.00	6.33	2.00	5.00	34.00	16.12
	25 ,,	7.80	15.00	15.00	20.00	30.00	20.00	4.56	2.17	6.50	0.00	0.00
	12.5 ,,	8.00	12.50	12.50	37.50	37.50	0.00	10.66	2.66	0.00	0.00	0.00
mean		9.27	21.02	15.89	20.74	21.87	20.52	8.14	1.22	4.71	24.00	4.03
Control		6.75	10.00	0.00	90.00	0.00	0.00	15.30	0.00	0.00	92.50	85.00
C.D. for comparing plants		0.42	2.82	3.16	5.71	4.70	4.73	2.04	0.34	0.67		
C.D. for comparing levels		0.37	2.52	2.83	5.11	4.21	4.23	1.82	0.31	0.60		
C.D. for comparing treatments vs control		0.83	5.63	6.32	11.42	9.41	9.46	4.07	0.69	1.34		

* Data not statistically analysed

was not linear. Maximum mortality was obtained with the highest concentration of A. indica (73.81) which was significantly superior to the lower three doses. At 25.0 per cent, extract of A. indica gave 57.5 per cent mortality which was higher than that obtained with 50.00 per cent (50.00). The lowest concentration, 12.5 per cent scored 52.5% mortality and it did not vary significantly from the higher concentration.

In the case of C. infortunatum maximum mortality was caused by 50.00 per cent extract (70.00) and it was followed by 100.00 per cent extract with 64.15 per cent mortality, both being on par. With E. odoratum mortality at different levels varied significantly, and ranged from 57.88 to 10.00 per cent. In T. neriifolia and N. oleander the response with change in dosage was not significant.

Extract of A. indica ranked top in producing less number of normal adults (4.38 per cent). This was followed by C. infortunatum (9.89) and both were on par. N. oleander with 20.74 per cent normal adults was ranked third and two other plants E. odoratum and T. neriifolia with 29.32 and 33.65 per cent normal adults were on par. In general with increased doses there was a linear decrease in the percentage of the normal adults in different treatments. With 100 and 50 per cent extract of A. indica, the normal adult emergence was completely suppressed while with 25 per cent only 5.00 per cent of the treated

nymphs developed normally. With the lowest concentration 12.5 per cent of the nymph became normal adults.

In the case of C. infortunatum, 25.0 per cent extract was as effective as 100.0 per cent in preventing normal adult emergence, the percentage adult emergence being 5.00 and 4.54 per cent respectively. In E. odoratum extracts, there was a graded increase in the percentage of adult emergence with decrease in dosage of the plant extract. It ranged from 5.26 to 57.50 per cent at the four levels and all the treatments varied significantly from each other. The same trend was observed in T. neriifolia extracts also, the percentages of normal adults ranging from 19.05 to 55.55. In N. oleander the highest concentration produced 5.27 per cent normal adults. At 50.00 and 25.00 per cent concentrations the response was same allowing 20.0 per cent of treated nymphs to become normal adults.

Application of plant extracts influenced significantly the longevity of normal adults in different treatments. Adults developed from untreated nymphs lived for 15.3 days, when the treated insects lived for 0.0 to 10.00 days only. Mean adult longevity was least in the extract of C. infortunatum (2.50) and the treatment was closely followed by A. indica (3.3) both being on par. With T. neriifolia (7.00), E.odoratum (7.405) and N. oleander (8.14), mean longevity did not vary much.

Adults emerging from nymphs treated with 50.0 per cent C. infortunatum extract died on the day of emergence, while at 100.00 per cent and 12.5 per cent they lived for 1 and 2 days respectively. At 25.00 per cent concentration the emerging adults lived for 7 days. With A. indica extract a linear response to increasing dosages was observed. But with the remaining extracts such linearity was lacking.

Application of plant extracts induced emergence of adultoids in all the treatments. T. neriifolia ranked first in producing malformed adults (29.28%) and it was followed by N. oleander (21.87%), E. odoratum (19.72), A. indica (13.06) and C. infortunatum (6.88).

No linear association was noted between the dosages of the plant extracts and the response. Highest percentage of adultoids was obtained with 25.00 per cent extract of T.neriifolia (45.00) and was significantly higher than all the other treatments except 12.5 per cent extract of N. oleander (37.50).

The longevity of adultoids was shortest with C.infortunatum (0.88 days) and the treatment was superior to all other treatments. This was followed by N. oleander (1.22), A. indica (2.10), E. odoratum (3.06) and T. neriifolia (4.92). Adultoids emerging in treatments with 100 per cent extract of A. indica died on the day of emergence and with lower doses the longevity varied from

1.60 to 4.25 days. Longevity of adultoids in C. infortunatum treatments ranged from 1.50 to 2.0 days, in E. odoratum 2.10 to 4.33 days, in T. neriifolia 2.0 to 12.0 days and in N. oleander 2.0 to 2.66 days. The response to varying concentrations was not in general, linear.

Extracts of A. indica, E. odoratum and N. oleander induced formation of sixth instar nymphs also. Maximum number of sixth instar nymphs was obtained with N. oleander (mean 20.52) and it was followed by E. odoratum (9.94) and A. indica (3.13). With 100 per cent extract of N. oleander, 42.10 per cent of the treated nymphs moulted as sixth instar nymphs and the two lower doses gave 20.0 per cent each of supernumerary nymphs.

The longevity of sixth instar nymphs emerging from treatment with highest concentration of N. oleander was maximum (7.33 days) while that with 50.0 and 25.0 per cent extracts were 5.0 and 6.5 days respectively. With A. indica and E. odoratum the longevity of sixth instar nymphs ranged from 2.00 to 2.50 and 2.00 to 4.67 days respectively.

With 25 and 12.5 per cent extracts of T. neriifolia and 100 and 50 per cent extracts of N. oleander 34 to 63 eggs per female were obtained as against 92.5 in control and among these lots of eggs 16.12 to 48 per cent hatching was observed while the hatching of the eggs in control was 85 per cent. Normal

Table 22. Juvenilising effects of acetone extracts of different plants, topically applied on fifth instar nymphs of D. cingulatus

acetone extracts of	concentrations (%)	mean No.of insects surviving after treatment (out of 20)	number of surviving insects						degree of juvenilising effect
			moulting as normal adults	moulting as adultoids			failing to moult	moulting as supernumerary nymphs	
				Grade I	Grade II	Grade III			
			Score I 0%	Score II 20%	Score III 40%	Score IV 60%	Score V 80%	Score VI 100%	
A. indica	100	17.5	0.5	0.0	3.0	0.5	12.0	1.5	72.03
	50	19.0	0.0	0.0	0.0	1.0	14.0	4.0	83.62
	25	18.0	1.5	0.0	0.0	6.5	8.5	1.5	67.78
	12.5	18.0	10.5	0.0	1.0	0.0	4.5	1.0	31.47
mean									63.10
C. infortunatum	100	16.5	0.0	0.0	0.0	3.5	12.0	1.0	76.95
	50	15.5	0.0	1.0	0.0	1.0	13.5	0.0	75.04
	25	14.0	0.0	0.0	6.0	2.0	6.0	0.0	60.00
	12.5	15.0	2.0	0.0	4.0	3.0	6.0	0.0	54.06
mean									66.62
E. odoratum	100	17.0	7.0	0.5	0.0	4.0	5.5	0.0	42.62
	50	18.0	15.0	0.0	0.0	0.0	3.0	0.0	12.56
	25	18.0	16.0	0.0	0.0	1.0	1.0	0.0	7.77
	12.5	20.0	20.0	0.0	0.0	0.0	0.0	0.0	0.00
mean									15.42
T. neriifolia	100	20.0	11.0	0.0	4.0	0.0	5.0	0.0	27.91
	50	18.0	11.0	2.0	0.0	1.0	4.0	0.0	23.25
	25	19.0	14.0	1.0	0.0	2.0	2.0	0.0	15.77
	12.5	19.0	15.0	3.0	0.0	0.0	1.0	0.0	7.36
mean									18.62
N. oleander	100	16.0	8.0	0.0	4.0	0.0	2.0	2.0	32.50
	50	18.0	13.0	0.0	2.0	0.0	2.0	1.0	18.88
	25	16.0	13.0	0.0	0.0	0.0	2.0	1.0	16.25
	12.5	17.0	15.0	0.0	1.0	1.0	0.0	0.0	5.88
mean									18.38
C.D.									3.83
C.D.									3.43

Data on juvenilising effect alone had been statistically analysed

hatching of eggs and consequent contribution to the next generation was lacking in other treatments too.

3.8.9.3. Intensity of juvenilising effects of acetone extracts of different plants on the fifth instar nymphs of D. cingulatus

The data on the degree of juvenilising effect and the results of statistical analysis of the same are presented in Table 22. It was seen that among the five plants tested, C. infortunatum had the highest juvenilising effect on D. cingulatus (mean rating 66.62) which was closely followed by A. indica (63.10) both being on par and significantly superior to all other plants. T. neriifolia (18.62), N. oleander (18.38) and E. odoratum (15.42) were on par. In general the juvenilising effect had a linear relation with the concentration of the extracts used. In the case of A. indica and C. infortunatum the ratings ranged from 31.47 to 83.62 and 54.06 to 76.95 respectively. The ratings of E. odoratum, T.neriifolia and N. oleander ranged from 0 to 42.62, 7.36 to 27.91 and 5.88 to 32.50 respectively.

3.8.9.4. Intensity of juvenilising effects of benzene extracts of selected plants on last instar nymphs of D. cingulatus

Results of the experiment and statistical analysis of the data are given in Table 23. Extract of A. indica ranked

Table 23. Juvenilising effects of benzene extracts of different plants, topically applied on fifth instar nymphs of D. cingulatus

benzene extracts of	concentrations (%)	mean No.of insects surviving after treatment (out of 20)	number of surviving insects						degree of juvenilising effect
			moulting as normal adults	moulting as adultoids			failing to moult	moulting as supernumerary nymphs	
				Grade I	Grade II	Grade III			
			Score I 0%	Score II 20%	Score III 40%	Score IV 60%	Score V 80%	Score VI 100%	
A. indica	100	16.5	0.0	0.0	0.0	1.0	10.5	0.0	78.79
	50	12.5	0.0	0.0	0.5	1.5	10.0	0.5	76.80
	25	18.0	0.5	0.0	0.0	5.0	11.5	1.0	73.33
	12.5	16.5	2.5	1.0	0.5	1.0	10.5	1.0	65.03
mean									72.91
C. infortunatum	100	14.5	1.0	0.0	0.0	0.0	13.5	0.0	78.48
	50	15.0	1.0	0.0	0.0	0.0	14.0	0.0	74.66
	25	14.0	0.5	0.0	1.0	2.5	10.0	0.0	70.71
	12.5	14.0	4.0	0.0	0.0	2.0	8.0	0.0	54.28
mean									68.53
E. odoratum	100	16.0	1.0	0.0	1.0	1.5	11.0	1.5	72.50
	50	16.5	4.0	0.0	2.5	4.0	3.0	3.0	53.33
	25	17.5	7.0	0.0	2.5	1.0	6.5	0.5	41.71
	12.5	20.0	11.5	0.0	2.5	1.0	2.0	3.0	31.00
mean									49.65
T. neriifolia	100	16.0	4.0	5.0	0.0	2.0	7.0	0.0	46.25
	50	15.0	5.0	3.0	0.0	0.0	7.0	0.0	41.33
	25	16.0	7.0	5.0	4.0	0.0	0.0	0.0	16.25
	12.5	16.0	10.0	2.0	3.0	1.0	0.0	0.0	13.75
mean									29.39
N. oleander	100	13.0	1.0	0.0	0.0	0.0	4.0	8.0	86.15
	50	15.0	4.0	0.0	4.0	0.0	3.0	4.0	53.33
	25	17.0	4.0	3.0	1.0	2.0	5.0	4.0	50.28
	12.5	14.0	6.0	0.0	0.0	6.0	2.0	0.0	37.14
mean									56.73
C.D.									3.66
C.D.									3.28

Data on juvenilising effect alone had been statistically analysed

first showing the highest degree of juvenilising effects on D. cingulatus (mean rating 72.91). It was followed by C. infortunatum (68.53), N. oleander (56.73), E. odoratum (49.64) and T. neriifolia (29.39). All the five extracts varied significantly among themselves. With the increase in the concentrations of the extracts of the plants used in the experiment, there was corresponding increases in the ratings observed. The highest dose of N. oleander extract had the highest juvenilising effect (86.15) though in the mean rating the plant was ranked below A. indica (range 63.03 to 78.79) and C. infortunatum (54.28 to 78.48). At 100 per cent concentration E. odoratum also showed high juvenilising effect (72.50).

3.8.10. Influence of plant extracts on the ovarian development and mating of D. cingulatus

Ovarian development and mating in the normal adults/ adultoids/supernumerary instars produced by the application of different plant extracts were observed in detail and the results are shown in Table 23a. It may be seen that the nature and degree of ovarian inhibition in the emerging individuals varied much with different plant extracts and also there was an increase in effect with increases of dosage.

With C. infortunatum extracts, at higher dosages, either the emerging individuals were dying soon after emergence or

the normal adults were lacking. With decreasing dosages, the ovaries of normal adults/adultoids remained nymphal type without any vitellogenic ova and this structural deformity was accompanied by lack of mating in all these treatments. At the lowest dose of acetone extract of C. infortunatum, the normal adults had adult type ovaries and were capable of mating. But they died before egg laying. Thus application of C. infortunatum extracts led to complete suppression of next generation irrespective of the dosages tested.

Similar trend was exhibited by extracts of A. indica also which produced normal adults and adultoids with nymphal type ovaries without vitellogenesis. Supernumerary nymphs were also produced by the two extracts at different concentrations either with nymphal type ovaries or with adult type ovaries having deformed ovarioles. However, at the lowest dose of acetone extract of A. indica (12.5 per cent) the normal adults had adult type ovaries and could mate and lay viable eggs indicating the inefficiency of the extract at lower concentrations.

In the case of benzene extract of E. odoratum more effective suppression of ovarian development was seen than with acetone extract. At all dosages of benzene extract egg laying was prevented because of the nymphal type ovaries or ovarioles. In the deformed ovarioles the linear arrangement of oocytes was completely lost and ova was seen loosely

Table 23a. Effect of different plant extracts on the ovarian development and mating of D. cingulatus

treatments		normal adults					adultoids					supernumerary nymphs					
		nature of ovary	nature of abdomen	mating	egg laying	hatchability	nature of ovary	nature of abdomen	mating	egg laying	hatchability	no.of tersal segment	nature of ovary	nature of abdomen	mating	egg laying	hatchability
I. indica																	
Acetone extract	100	-	-	-	-	-	-	NS	NM	-	-	2	-	-	-	-	-
	50	-	-	-	-	-	-	-	NM	-	-	2,3	N,AD	NS,S	NM,M	NE	-
	25	N	NS	NM	NE	-	-	NS	NM	-	-	2	-	-	NM	-	-
	12.5	AN	S	M	E	H	N	NS	NM	NE	-	2	-	-	NM	-	-
Benzene extract	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	50	-	-	-	-	-	-	NS	NM	-	-	2	-	-	NM	-	-
	25	N	NS	NM	NE	-	-	-	-	-	-	3,2	N	NS	NM	NE	-
	12.5	N	NS	NM	NE	-	N	NS	NM	-	-	2	N	NS	NM	-	-
I. odoratum																	
Acetone extract	100	N	NS	NM	-	-	N	NS	NM	-	-	-	-	-	-	-	-
	50	AD	SM	M	NE	-	-	-	-	-	-	-	-	-	-	-	-
	25	AN	S	M	E	H	-	-	-	-	-	-	-	-	-	-	-
	12.5	AN	S	M	E	H	-	-	-	-	-	-	-	-	-	-	-
Benzene extract	100	N	NS	NM	-	-	N	NS	NM	-	-	3.2	AD,N	NS	NM	NE	-
	50	N	NS	NM	-	-	N	NS	NM	-	-	2	N	NS	NM	-	-
	25	N,AD	S	M	NE	-	N	NS	NM	-	-	2	N	NS	NM	-	-
	12.5	N	NS	M	-	-	N,AD	NS,S	NM,M	NE	-	2	N	NS	NM	-	-
C. infortunatum																	
Acetone extract	100	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25	-	-	-	-	-	N	NS	NM	-	-	-	-	-	-	-	-
	12.5	AN	S	M	NE	-	N	NS	NM	-	-	-	-	-	-	-	-
Benzene extract	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25	N	NS	NM	NE	-	-	-	-	-	-	-	-	-	-	-	-
	12.5	N	NS	NM	NE	-	-	-	-	-	-	-	-	-	-	-	-
T. peniifolia																	
Acetone extract	100	AN	S	M	NE	-	-	NS	M	-	-	-	-	-	-	-	-
	50	AN	S	M	E	H	-	NS	NM	-	-	-	-	-	-	-	-
	25	AN	S	M	E	H	-	NS	NM	-	-	-	-	-	-	-	-
	12.5	AN	S	M	E	H	-	NS	NM	-	-	-	-	-	-	-	-
Benzene extract	100	N	NS	NM	-	-	-	NS	NM	-	-	-	-	-	-	-	-
	50	AN	S	M	E	NH	AD	S	M	E	NH	-	-	-	-	-	-
	25	AN	S	M	E	H	-	-	NM	-	-	-	-	-	-	-	-
	12.5	AN	S	M	E	H	-	-	NM	-	-	-	-	-	-	-	-
N. oleander																	
Acetone extract	100	AN	S	M	NE	-	-	NS	NM	-	-	-	-	-	-	-	-
	50	AN	S	M	E	H	-	-	NM	-	-	-	-	-	-	-	-
	25	AN	S	M	E	H	-	-	NM	-	-	-	-	-	-	-	-
	12.5	AN	S	M	E	H	-	-	NM	-	-	-	-	-	-	-	-
Benzene extract	100	AN	S	M	E	NH	-	-	-	-	-	3	AD	S	M	NE	-
	50	AN	S	M	E	H	AN	S	M	E	NH	3	AN	S	M	NE	-
	25	AN	S	M	NE	-	-	-	-	-	-	2,3	AD,N	S,NS	M,NM	NE	-
	12.5	N	NS	NM	NE	-	-	NS	NM	-	-	-	-	-	-	-	-

AN - Adult type - normal
AD - Adult type - deformed
N - Nymphal type
NS - Not swollen
S - Swollen
NM - Not mated
M - mated
NE - No eggs laid
E - Eggs laid
NH - Not hatched
H - Hatched

scattered in the ovariole. At lower dosages mating was not impaired both in the normal adults and in the adultoids even though eggs were not laid. Supernumerary nymphs were also produced with all the concentrations which had either nymphal ovaries or deformed ovaries. In the case of acetone extract of E. odoratum the higher dosages alone could affect the ovarian development adversely while the two lower dosages did not hamper the vitellogenesis, fecundity or hatchability of eggs in the normal adults.

In the case of T. neriifolia and N. oleander the extent of ovarian suppression was similar. The acetone extracts produced adults with normal ovaries and mating. The eggs laid were also viable. But at 100 per cent concentrations the normal adults died before egg laying. Similarly the adultoids produced with acetone extracts of T. neriifolia and N. oleander died within 2-3 days after emergence and they had nymphal type of ovary only.

The extent of ovarian inhibition differed in the benzene extracts of both the plants. With T. neriifolia normal adults and adultoids produced with the highest dosage retained the nymphal type of ovary. At 50 and 25 per cent levels the ovarian development, mating and oviposition were not affected but the eggs laid were not viable. Adultoids mated with normal adults, but laid only nonviable eggs. However, in the lowest dosage, vitellogenesis was not affected and normal progeny was produced.

PLATE VII

Abdominal prolapse caused by the application of plant extracts on *D. cingulatus*

PLATE VII

In the case of benzene extract of N. oleander the effect was not dose dependent. The extract produced adults/ adultoids and sixth instar nymphs and the males and females in each category were found mating normally. At 100 per cent concentration the adults were with normal ovary but the eggs laid were nonviable. With 50 per cent concentration, the eggs were found viable also. But at 25 per cent concentration adults with nymphal type ovaries were found and mating and oviposition were lacking. With the dosages of 12.5 per cent T. neriifolia and N. oleander extracts, the normal adults produced exhibited a protrusion of last abdominal segment along with male genetalia (Plate VII) which might have caused the absence of mating in normal adults.

The supernumerary nymphs caused by extracts of A. indica, E. odoratum and N. oleander were of two types. Those having two tarsal segments (nymphal character) had nymphal type of ovary and those having three tarsi (adult character) had nymphal or adult type ovaries which were reduced or deformed.

3.8.11. Effects of benzene extracts of different plants on the hatching of the eggs of D. cingulatus

The relative efficacy of the benzene extracts of different plants in suppressing the hatching of the eggs of D. cingulatus is presented in Table 24. Among the five plant extracts N. oleander was most lethal to the eggs (IC 50 0.37873) and

Table 24. Effect of the benzene extract of different plants on the hatchability of eggs of D. cingulatus

treatments	heterogeneity $X^2_{(3)}$	regression equation	IC 50 (%)	fiducial limits	relative ovicidal action
A. indica	1.6306	y = 1.5346x + 3.124835	1.667	1.752 1.528	1
E. odoratum	5.7532	y = 1.4911x + 3.1534275	1.732	2.907 1.030	0.9625
C. infortunatum	1.2944	y = 2.2012x + 2.825	0.9727	1.275 0.742	1.7138
T. neriifolia	2.2731	y = 1.5746x + 3.2173	1.355	1.548 1.187	1.2303
N. oleander	4.8848	y = 2.2228x + 3.6928	0.3873	0.501 0.299	4.3042

it was followed in the descending order by C. infortunatum (0.9727), T. neriifolia (1.355), A. indica (1.667) and E. odoratum (1.732).

Taking A. indica as standard, N. oleander, C.infortunatum, T. neriifolia and E. odoratum were 4.30, 1.71, 1.23 and 0.96 times toxic.

3.8.12. Juvenomimetic activity of essential oils on last instar nymphs of D. cingulatus

The results of the experiment and the results of the statistical analysis of the data are given in Table 25. It was observed that there was no significant difference among the nymphal durations in various treatments and control. Patcholi oil, camphor oil and eucalyptus oil at 5.0 per cent concentration gave the highest nymphal mortality (60.00 per cent) which was followed by patcholi oil 10.0 per cent (50.00), citrodora oil 10.0 per cent (45.00), oil of wintergreen 5.0 per cent (45.00), all being on par among themselves. Citronella oil 10.0 per cent and oil of wintergreen and camphor oil 2.5 per cent gave 40.0 per cent mortality and these were on par with citronella oil 5.0 per cent (35.00), eucalyptus oil 10.0 per cent (35.00), oil of wintergreen 10.0 per cent (35.00) and camphor oil 10.0 per cent (35.00). Remaining treatments with mortality ranging from 30.00 to 5.00 per cent were on par with control.

Mortality of the nymphs due to the inability to moult was observed in all the treatments. Geranium oil (10.0%) gave maximum mortality of 70.00 per cent which was followed by 5.0% with geranium oil (60.00), both being significantly superior over other treatments. Citronella oil at 10 and 5 per cent and eucalyptus oil at 2.5% gave 45.0 per cent mortality of the insec These were on par with palmarosa oil 10.0 per cent (35.00), geranium oil 2.5 per cent (30.00), eucalyptus oil 5.0 per cent (30.00), oil of wintergreen 5.0 per cent (35.00), citrodora oil 10.0 per cent (35.00) and camphor oil 2.5 per cent (30.00). Except with oil of wintergreen, eucalyptus and camphor oils, all other treatments had a positive linear relationship between the ranges of mortality and concentrations used.

Emergence of normal adults was significantly less with all the doses of eucalyptus oil and camphor oil, citronella oil and oil of wintergreen 10 and 5 per cent, patcholi oil 10 per cent and citrodora oil 10 per cent. Sixty per cent of the nymphs treated with 2.5 per cent of geranium oil, citrodora oil and palmarosa oil moulted as normal adults and they were also on par with control (80.00 per cent).

The longevity of normal adults in treatments ranged from 2.6 to 10.5 days while that of control was 19 days. The longevity of normal adults emerging from treated nymphs decreased with the increase in concentration of the essential

Table 25. Juvenomimetic activity of essential oils on last instar nymphs of D. cingulatus

treatments	dosage (%)	mean last nymphal duration (days)	nymphal mortality (%)		percentage of nymphs moulted as			longevity (days) of			no.of eggs laid per female	percentage of eggs hatched	sterility percentage
			within 5 days	after 5th day	normal adults	adultoids	sixth instar nymph	normal adults	adultoids	sixth instar nymph			
Citronella oil	10.0	7.2 a	40.0 bcd	45.0 bc	0.0 a	15.0 cd	0.0	0.00 –	2.12 bcde	0.0	0.0	0.0	100.00
	5.0	7.5 a	35.0 bcd	45.0 bc	10.0 ab	10.0 de	0.0	4.50 b	3.50 e	0.0	0.0	0.0	100.00
	2.5	7.0 a	25.0 de	25.0 def	45.0 d	5.0 ef	0.0	8.00 cd	4.00 e	0.0	6.6	0.0	100.00
Palmarosa oil	10.0	7.4 a	20.0 e	35.0 cde	30.0 c	15.0 cd	0.0	5.38 b	1.12 abc	0.0	0.0	0.0	100.00
	5.0	7.8 a	20.0 e	25.0 def	35.0 cd	20.0 bcd	0.0	10.00 def	3.50 e	0.0	18.0	48.0	89.40
	2.5	7.0 a	20.0 e	20.0 ef	60.0 de	0.0 g	0.0	8.50 cd	0.00 –	0.0	23.5	67.5	80.52
Geranium oil	10.0	8.0 a	5.0 f	70.0 a	20.0 bc	0.0 g	5.0	8.50 cd	0.00 –	1.0	0.0	0.0	100.00
	5.0	7.5 a	5.0 f	60.0 ab	20.0 bc	15.0 cd	0.0	8.93 cde	3.12 de	0.0	0.0	0.0	100.00
	2.5	7.2 a	10.0 f	30.0 cde	60.0 de	0.0 g	0.0	9.62 def	0.00 –	0.0	12.5	52.5	91.94
Eucalyptus oil	10.0	7.5 a	35.0 bcd	25.0 def	5.0 ab	5.0 f	30.0	7.50 c	1.50 bcd	1.5	0.0	0.0	100.00
	5.0	7.2 a	60.0 a	30.0 cde	0.0 a	10.0 de	0.0	0.00 –	2.00 bcde	0.0	0.0	0.0	100.00
	2.5	7.0 a	30.0 cde	45.0 bc	0.0 a	25.0 abc	0.0	0.00 –	0.00 a	0.0	0.0	0.0	100.00
Oil of wintergreen	10.0	7.0 a	35.0 bcd	20.0 ef	10.0 ab	35.0 a	0.0	9.34 cde	3.94 e	0.0	0.0	0.0	100.00
	5.0	7.0 a	45.0 abc	35.0 cde	10.0 ab	10.0 de	0.0	9.66 def	3.50 e	0.0	0.0	0.0	100.00
	2.5	7.0 a	40.0 bcd	25.0 def	20.0 bc	15.0 cd	0.0	5.52 b	1.125abc	0.0	0.0	0.0	100.00
Patcholi oil	10.0	7.0 a	50.0 ab	40.0 cd	0.0 a	10.0 de	0.0	0.00 –	3.00 ode	0.0	0.0	0.0	100.00
	5.0	9.8 a	60.0 a	15.0 f	25.0 bc	0.0 g	0.0	2.60 a	0.00 –	0.0	0.0	0.0	100.00
	2.5	7.7 a	30.0 cde	15.0 f	30.0 c	5.0 ef	0.0	3.00 a	1.00 ab	0.0	0.0	0.0	100.00
Citrodora oil	10.0	7.8 a	45.0 abc	35.0 cde	10.0 ab	10.0 de	0.0	7.67 c	1.00 ab	0.0	0.0	0.0	100.00
	5.0	8.2 a	30.0 cde	25.0 def	40.0 cd	5.0 ef	0.0	9.52 de	3.00 cde	0.0	8.0	0.0	100.00
	2.5	7.6 a	20.0 e	20.0 ef	60.0 de	0.0 g	0.0	10.50 ef	0.00 –	0.0	25.0	65.0	80.04
Camphor oil	10.0	7.6 a	35.0 bcd	40.0 cd	0.0 a	25.0 abc	0.0	0.00 –	3.50 e	0.0	0.0	0.0	100.00
	5.0	7.5 a	60.0 a	15.0 f	0.0 a	25.0 abc	0.0	0.00 –	3.88 e	0.0	0.0	0.0	100.00
	2.5	7.0 a	40.0 bcd	30.0 cde	0.0 a	30.0 ab	0.0	0.00–	3.52 e	0.0	0.0	0.0	100.00
Control	–	7.0 a	20.0 e	0.0 g	80.0 ef	0.0 g	0.0	19.0 f	0.00 –	0.0	88.0	92.5	0.00

Means followed by a common letter in a column are not significantly different at 5% level (DMRT)

oil used except in the case of palmarosa oil and oil of wintergreen. All the eight essential oils caused emergence of malformed adults. The number of adultoids caused by oil of wintergreen 10% (35.00 per cent), was followed by all those of the three concentrations of camphor oil (25, 20 and 30 per cent) and 2.5 per cent eucalyptus oil (25 per cent) were high and on par. Palmorasa oil 5 per cent caused 20 per cent adultoids. Remaining treatments which gave 5 or 10 per cent adultoids came on par and the numbers were significantly higher than that of control. The longevity of the adultoids ranged from 0 to 4 days only.

Thirty and five per cent of nymphs treated with eucalyptus oil and geranium oil at their highest concentrations developed into sixth instar nymph.

The fecundity of the insects was reduced significantly in all the treatments. The number of eggs laid per female in treatments ranged from 0 to 25 only whereas in control it was 88.0. Eggs laid by adults emerging from nymphs treated with citronella oil 2.5 per cent and citrodora oil 5 per cent failed to hatch and in the other four treatments the hatchability ranged from 48.00 to 67.50 per cent in contrast to 92.5 per cent hatch in control.

Citronella oil 2.5 per cent, palmarosa oil 2.5 and 5 per cent and geranium oil 2.5 per cent caused sterility to the

extent of 80.4, 80.52, 89.40 and 91.94 per cent respectively. In all other treatments the sterility reached 100 per cent.

3.9. Efficacy of the extracts of selected plants in controlling the pests of brinjal and bitter gourd in field

The water extracts of T. neriifolia and benzene extracts of A. indica, C. infortunatum, E. odoratum, T. neriifolia and N. oleander were tested against the major pests of brinjal viz. epilachna beetle H. vigintioctopunctata, mealy bugs Centrococcus insolitus (Gr.) and aphids Aphis gossypii (G.) and epilachna beetle on bitter gourd, H. vigintioctopunctata.

3.9.1. Brinjal spotted beetle H. vigintioctopunctata

The data relating to the experiment and the results of the statistical analysis of the same are presented in Table 26. The pretreatment counts of the grubs in various treatments showed significant variations. Therefore analysis of covariance of the data on the population counts were done for assessing the results. The effect of the plant extracts was evident two days after spraying. The populations observed in all the plant extracts showed highly significant difference over control. The mean number of grubs ranged from 0.66 to 21.27 in various treatments while the mean population in control was 36.58. The least population of H. vigintioctopunctata was observed on

Table 26. Control of spotted beetle of brinjal, E. vigintioctopunctata in field using various plant extracts and carbaryl

treatments	dose	pre-treatment count	mean number* of epilachna grubs observed at different intervals after spraying (in days)		
			2	7	14
A. indica (benzene extract)	2%	23.30 (4.929)	18.27 (4.39)	2.834 (1.968)	22.699 (4.868)
E. odoratum (benzene extract)	,,	15.68 (4.084)	19.34 (4.51)	7.433 (2.904)	32.166 (5.759)
C. infortunatum (benzene extract	,,	54.17 (7.432)	12.17 (3.63)	6.767 (2.787)	26.290 (5.224)
T. neriifolia (benzene extract)	,,	32.08 (5.752)	21.27 (4.72)	10.316 (3.364)	18.536 (4.415)
N. oleander (benzene extract)	,,	14.34 (3.917)	6.62 (2.76)	1.958 (1.719)	26.562 (5.249)
T. neriifolia (water extract)	,,	43.22 (6.648)	0.93 (1.39)	0.833 (1.353)	15.958 (4.118)
Carbaryl	0.2%	65.60 (8.161)	0.66 (0.58)	0.000 (1.000)	10.560 (3.400)
Control		32.34 (5.774)	36.58 (6.13)	47.122 (6.936)	48.970 (7.069)
C.D.		1.622	0.82	2.133	1.044

Figures in parentheses are transformed values, $\sqrt{x+1}$

* mean of four observational plants

plants treated with carbaryl 0.1 per cent and it was followed by water extract of T. neriifolia. The above two treatments were on par and significantly superior to all other treatments. These were followed by benzene extracts of N. oleander and C. infortunatum the mean population in the two treatments being significantly different but the latter was on par with the extract of A. indica. A. indica was closely followed by extracts of E. odoratum and T. neriifolia, there being no significant variation among the three treatments.

The population observed at seven days after treatments showed highly significant reduction in the pest population in all the treatments. Carbaryl caused complete suppression of the pest and the other treatments came in the following descending order: water extract of T. neriifolia, benzene extracts of N. oleander, A. indica, C. infortunatum, E. odoratum and T. neriifolia with mean populations of 0.833, 1.958, 2.834, 6.767, 7.433 and 10.316 respectively. The mean number of grubs in control was as high as 47.122. The treatments were on par and significantly superior to control.

Observations made on the 14th day after application showed that the population of the pest was being built up. However, the populations in all the treatments were significantly lower than that of control. The mean number of grubs in treatments ranged from 10.56 to 31.17 while the mean

Table 27. Control of mealy bug, C. insolitus in field using various plant extracts and carbaryl

treatments	dose	pre-treatment count	mean number* of mealy bugs observed at different periods after spraying (in days)		
			2	7	14
A. indica (benzene extract)	2%	14.793 (3.974)	5.45 (2.54)	11.45 (3.53)	21.24 (4.07)
E. odoratum (benzene extract)	"	24.939 (5.093)	1.69 (1.64)	11.53 (3.54)	20.45 (4.51)
C. infortunatum (benzene extract)	"	14.920 (3.990)	12.18 (3.63)	9.30 (3.21)	18.30 (4.32)
T. neriifolia (benzene extract)	"	57.814 (7.667)	12.25 (3.64)	15.24 (4.03)	24.00 (4.96)
N. oleander (benzene extract)	"	33.176 (5.846)	15.65 (4.08)	13.75 (3.84)	29.25 (5.48)
T. neriifolia (water extract)	"	75.073 (8.722)	2.46 (1.86)	4.29 (2.30)	17.40 (4.21)
Carbaryl	0.2%	18.731 (4.442)	3.52 (2.14)	7.01 (2.83)	16.90 (4.06)
Control		17.456 (4.296)	19.52 (4.53)	20.27 (5.41)	32.80 (5.40)
C.D.		2.186	1.02	1.70	NS

Figures in parentheses are transformed volues, $\sqrt{x+1}$

* mean of 12 leaves from four observational plants

Table 28. Control of aphids on brinjal, *A. gossypii* in field using various plant extracts and carbaryl

treatments	dose	pre treatment count	mean number* of aphids observed at different occasions after spraying (in days)			
			2	4	8	12
A. indica (benzene extract)	2%	445.18 (21:123)	13.52 (3.81)	0.00 (1.000)	12.10 (3.62)	10.87 (3.444)
C. infortunatum (benzene extract)	,,	728.00 (27.00)	9.37 (3.22)	14.66 (3.957)	69.56 (8.34)	10.73 (3.425)
T. neriifolia (benzene extract)	,,	695.38 (26.37)	266.65 (16.36)	100.00 (10.050)	160.80 (12.72)	46.51 (6.893)
N. oleander (benzene extract)	,,	874.86 (29.595)	5.92 (2.63)	64.95 (8.071)	55.85 (7.54)	25.13 (5.112)
T. neriifolia (water extract)	,,	840.75 (29.013)	45.92 (6.85)	288.61 (17.018)	298.29 (17.30)	141.18 (11.924)
Carbaryl	0.2%	369.10 (19.238)	28.05 (5.39)	0.00 (1.00)	18.54 (4.42)	10.46 (3.386)
Control		416.88 (20.442)	618.01 (24.88)	422.04 (20.568)	528.92 (23.02)	36.39 (6.115)
C.D.		5.365	7.02	5.742	7.94	NS

Figures in parentheses are transformed values, $\sqrt{x + 1}$

* mean of twelve leaves from four observational plants

the mean numbers of the insect being in the range of 4.29 to 15.24. But the benzene extracts of T. neriifolia and N.oleander were on par with control also. The population of the insect further increased and the variations observed in the data collected at 14 days after treatment became statistically insignificant.

3.9.3. Aphids on brinjal A. gossypii

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 28. The pretreatment count of the aphids showed heterogeneity and hence the data were subjected to analysis of covariance. The population observed two days after spraying ranged from 5.92 to 266.65 in treatments while in the control the population was 618.01. Population was least in benzene extract of N. oleander (number of aphid 5.92) and it was closely followed by the populations in C. infortunatum (9.37), A. indica (13.527), carbaryl (28.05) and water extract of T. neriifolia (45.92), there being no significant difference among the treatments. The efficacy of benzene extract of T. neriifolia (266.65) was significantly lower than other treatments but this also was superior to control.

On the fourth day the population had a further reduction in all treatments. In A. indica and carbaryl treated plants

the population came to zero level and it was followed by extracts of C. infortunatum (14.66) the variations among the treatments being insignificant. This was followed by N.oleander (64.95). The mean number of aphids in benzene extract of T. neriifolia did not vary significantly from that of N.oleander. A rapid increase in aphid population was observed in plants treated with water extract of T. neriifolia and it came on par with that of the control plots which had a population of 422.04.

The data collected at eighth day after spraying showed an increase in aphid population in all the treatments. The mean population of aphid in water extract of T. neriifolia came on par with control while the other treatments retained the efficacy. Lowest population of aphids was observed with A. indica extract with a mean number of 12.10 and it was followed by carbaryl (18.54), N. oleander (55.85) and C. infortunatum (69.56) the variations among the treatments being statistically insignificant. T. neriifolia extracts (benzene as well as water) were less effective.

Twelve days after treatment the population of aphid came on par in all the treatments including control.

3.9.4. Epilachna beetle on bitter gourd H.vigintioctopunctata

The data on the effect of plant extracts on the epilachna grubs and the results of the statistical analysis of the same

Table 29. Control of spotted beetle on bitter gourd, *H. vigintioctopunctata* in field using various plant extracts and carbaryl

treatments	dose	pre-treatment count	mean number* of epilachna grubs observed at different periods after spraying (in days)		
			2	7	14
A. indica (benzene extract)	2%	62.31 (7.957)	10.83 (3.44)	16.68 (3.887)	22.33 (4.83)
E. odoratum (benzene extract)	,,	59.98 (7.809)	20.62 (4.65)	14.11 (3.887)	37.81 (6.23)
C. infortunatum (benzene extract)	,,	86.14 (9.335)	6.51 (2.74)	7.08 (2.843)	17.75 (4.33)
T. neriifolia (benzene extract)	,,	29.74 (5.444)	29.14 (5.49)	14.82 (3.978)	29.80 (5.55)
N. oleander (benzene extract)	,,	34.13 (5.927)	10.49 (3.39)	3.38 (2.094)	19.88 (4.57)
T. neriifolia (water extract)	,,	38.49 (6.284)	6.34 (2.71)	0.40 (1.183)	14.92 (3.99)
Carbaryl	0.2%	106.38 (10:463)	2.28 (1.81)	1.92 (1.710)	8.86 (3.14)
Control		86.22 (9.339)	71.25 (8.50)	46.17 (6.868)	34.05 (5.92)
C.D.		3.064	1.29	1.57	NS

Figures in parentheses are transformed values $\sqrt{x + 1}$

* mean of four observational plants

are presented in Table 29. There was significant reduction in grub population two days after treatment and the efficacy persisted up to two weeks after treatment. Two days after spraying least population was observed in carbaryl treated plot (2.28) and it was followed by water extract of T. neriifolia (6.34) and benzene extract of C. infortunatum (6.51) and they were on par. C. infortunatum was followed by N. oleander and A. indica which had mean populations of 10.49 and 10.83 respectively. There was no significant variations between the two treatments. Benzene extract of E. odoratum with mean population of 20.62 and T. neriifolia with mean population of 29.14 were less effective and they were on par with each other.

At the seventh day after spraying also water extract of T. neriifolia had the least population (0.40) and the treatment came on par with carbaryl (1.92), N. oleander (3.38). They were on par. It was followed by benzene extracts of C. infortunatum (7.08), E. odoratum (14.11), T. neriifolia (14.82) and A. indica (16.68), the populations in the treatments showed significant variations.

On 14th day after spraying the populations in different treatments showed a conspicuous rise and the treatments including control came on par.

DISCUSSION

4. DISCUSSION

4.1. Screening of plants

Taking neem, the most potent plant source for biocides known till date, as standard twenty locally available plants were screened for their feeding inhibitory, insecticidal and juvenomemitic activities using some important crop pests as test insects. It is well known that phytochemicals include behaviour modifying compounds which deter/repel organisms, cause toxicity to them or interfere with the normal development. The active principles are known to be present in roots, stem, bark, leaves, flowers, fruits and seeds of plants (Ketkar, 1976; Atal and Kapur, 1977; Pandey et al., 1977; Deshmukh and Borle, 1975; Rao, 1982). The concentration of active principles is comparatively lower in leaves. But the availability of leaves throughout the year and the easiness for mass production render this plant part the most suited one for crude extraction and direct use in the field for pest control purposes. Since the objectives of the present investigation was to identify the locally available plants for such use the bioefficacy of the leaves alone was assessed in the different experiments. The leaves used were of uniform age. Too tender and too old leaves were excluded to avoid the influence of possible variations in the concentration of active principles in the test extracts since it is known that

in the leaves of different age groups of the same plant the quantities of allelochemics may vary (Norris, 1986).

Different solvents have been in use for the extraction of biocidal principles or allelochemics from plants. Kuhn et al. (1950) found aqueous extracts of wild tomato and potato leaves effective against L. decemlineata. Maxwell et al., 1965 showed that water soluble materials in the calyx of cotton buds deterred A. grandis from the host. Rao and Mehrotra (1977) found benzene and water extracts of leaves of C. gigantea to be deterrent to locusts. Acetone was more effective than methanol in extracting the antifeedant materials from neem seed (Ascher, 1980; Schauer and Schmutterer, 1980). Rao (1982) reported that methanol was suitable for extracting phagostimulants from the leaves and latex of C. gigantea while chloroform was found better for extracting antifeedants from the plant. From these solvents commonly used for extracting phytochemicals water, acetone, benzene and petroleum ether were chosen for the present studies on cost and efficiency basis.

4.2. Screening of plants for antifeedant action

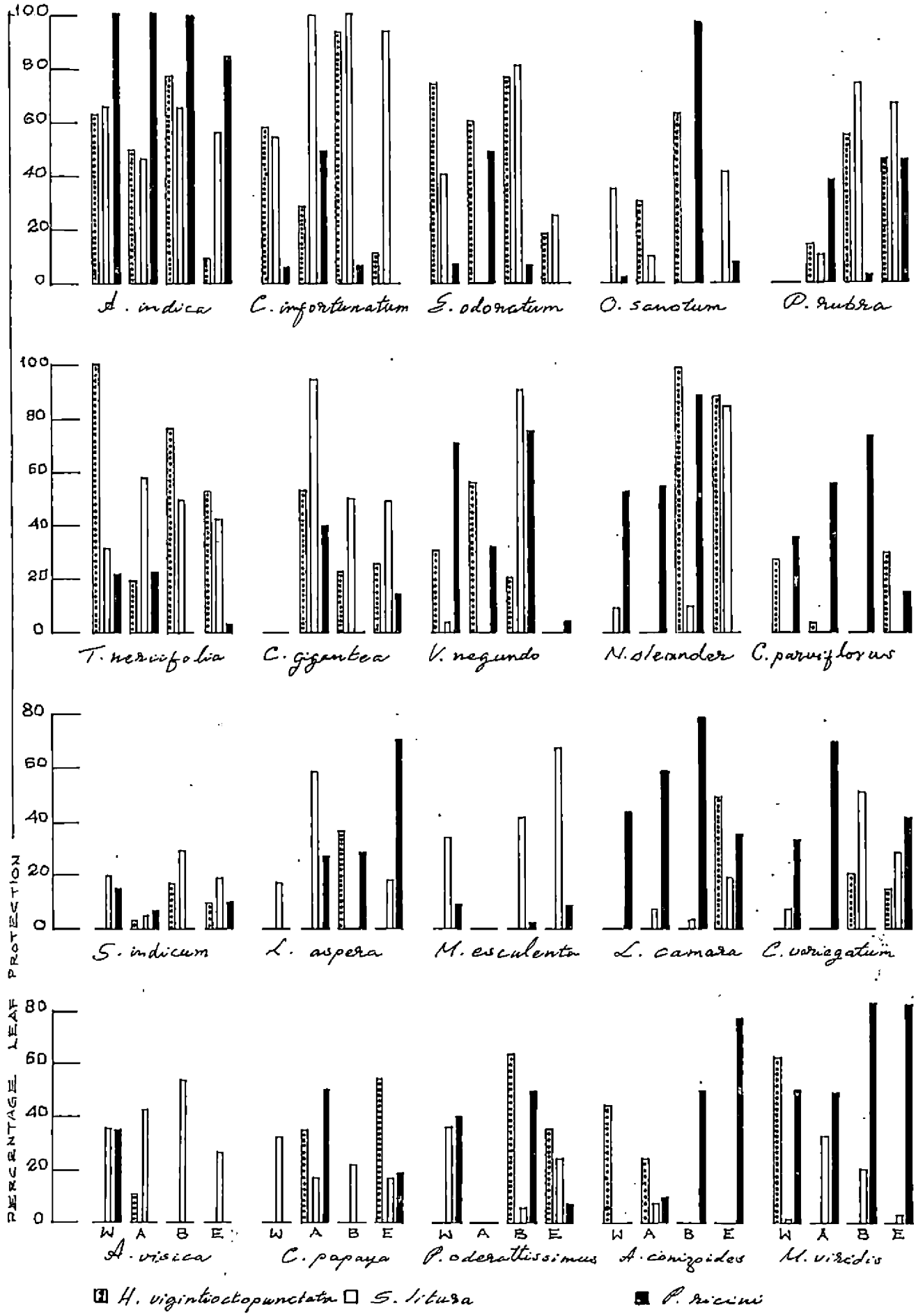
The results described in para 3.1.1 to 3.1.3 have been summarised in Fig. 3 and 4 and in Table 30. As shown in the Table out of twenty plants screened deterrent principles got

Table 30. Plants grouped under different categories based on the extent of leaf protection obtained from different test insects and the larval starvation when used as extracts prepared with different solvents

test insect used	extractants used																			
	water					acetone					benzene					ether				
	leaf protection (score)																			
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
										Leaf protection										
H. vigintioctopunctata	12	2	2	3	1	12	4	3	1	0	9	3	1	5	2	12	3	5	0	0
S. litura	11	7	1	1	0	13	1	4	0	2	7	3	5	2	3	8	5	3	2	2
P. ricini	10	4	4	1	1	7	5	6	1	1	10	1	2	3	4	13	2	1	2	2
										Larval starvation										
H. vigintioctopunctata	2	0	5	10	2	8	5	1	3	3	4	4	6	2	4	10	5	2	2	1
S. litura	11	5	3	1	0	10	3	4	1	2	10	3	3	2	2	11	4	2	1	2
P. ricini	9	6	4	0	1	15	3	0	1	1	12	5	2	0	1	15	2	2	1	0

Score 0 extent of leaf protection 0-20 per cent
,, 1 do. 20-40 ,,
,, 2 do. 40-60 ,,
,, 3 do. 60-80 ,,
,, 4 do. 80-100 ,,

FIG. 3.


PERCENTAGE LEAF PROTECTION
100
80
60
40
20
0
A. indica
C. inforturnatum
E. odoratum
O. sanctum
P. rubra
T. nervifolia
C. gigantea
V. negundo
N. oleander
C. parviflorus
S. indicum
L. aspera
M. esculenta
L. camara
C. variegatum
W A B E
A. visica
C. papaya
P. oderatissimus
A. conizoides
M. viridis
H. vigintioctopunctata
S. litura
P. ricini

extracted from a higher number of plants with benzene than with other extractants and in the case of all the three test insects. More number of plants extracted with benzene showed higher antifeedant activity and came under scores 3 and 4. The results thus showed that benzene was the best among the solvents used for extracting allelochemics from the leaves.

On same criteria benzene extract was found slightly inferior to water extract in causing larval starvation of H. vigintioctopunctata and P. ricini while acetone and ether came on par and inferior. In their efficacy in causing larval starvation of S. litura benzene and acetone were on par and superior to water and ether.

As shown in Table 30, the antifeedant activity was detected in more number of plants when H. vigintioctopunctata was used as test insect and benzene as extractant. The response to antifeedant activity in plants was also more intense in H. vigintioctopunctata than in S. litura, since a larger number of plants came under higher score when assayed with the former test insect. With reference to water, acetone and ether extracts H. vigintioctopunctata did not show any superiority over S. litura and P. ricini as test insects for detecting the antifeedant activity of phytochemicals in plants.

With reference to the larval starvation caused by the different extracts maximum number of plants showing the effect

were detected when H. vigintioctopunctata was used as the test insect than when S. litura or P. ricini was used for the purpose. The comparative performance of the four extractants is evident from Figs. 3 and 4 also. In general it may be concluded that H. vigintioctopunctata is a more sensitive test insect for the bioassay of antifeedant activity of allelochemics in plant than S. litura or P. ricini.

When twenty plants chosen for the study were screened for their antifeedant effect taking benzene as the extractant and H. vigintioctopunctata as test insect, the plants ranking at the top were N. oleander, C. infortunatum, A. indica T. neriifolia and E. odoratum and the extent of leaf protection ranged from 100 to 75 per cent. The plant which came next in rank P. odoratissimus gave 62 per cent leaf protection only. Obviously the first five plants could be ranked as a distinctly superior group. With water extracts, T. neriifolia, E.odoratum, A. indica and C. infortunatum showed high antifeedant action giving 51 to 100 per cent leaf protection. N. oleander came on par with control. This result points out that feeding deterrents in the leaves include polar and nonpolar components as observed by Rao and Mehrotra (1977), the component in N.oleander might have been nonpolar and hence got extracted with benzene and not with water. When extracted with acetone E.odoratum, A.indica and C. infortunatum showed high activity and with ether

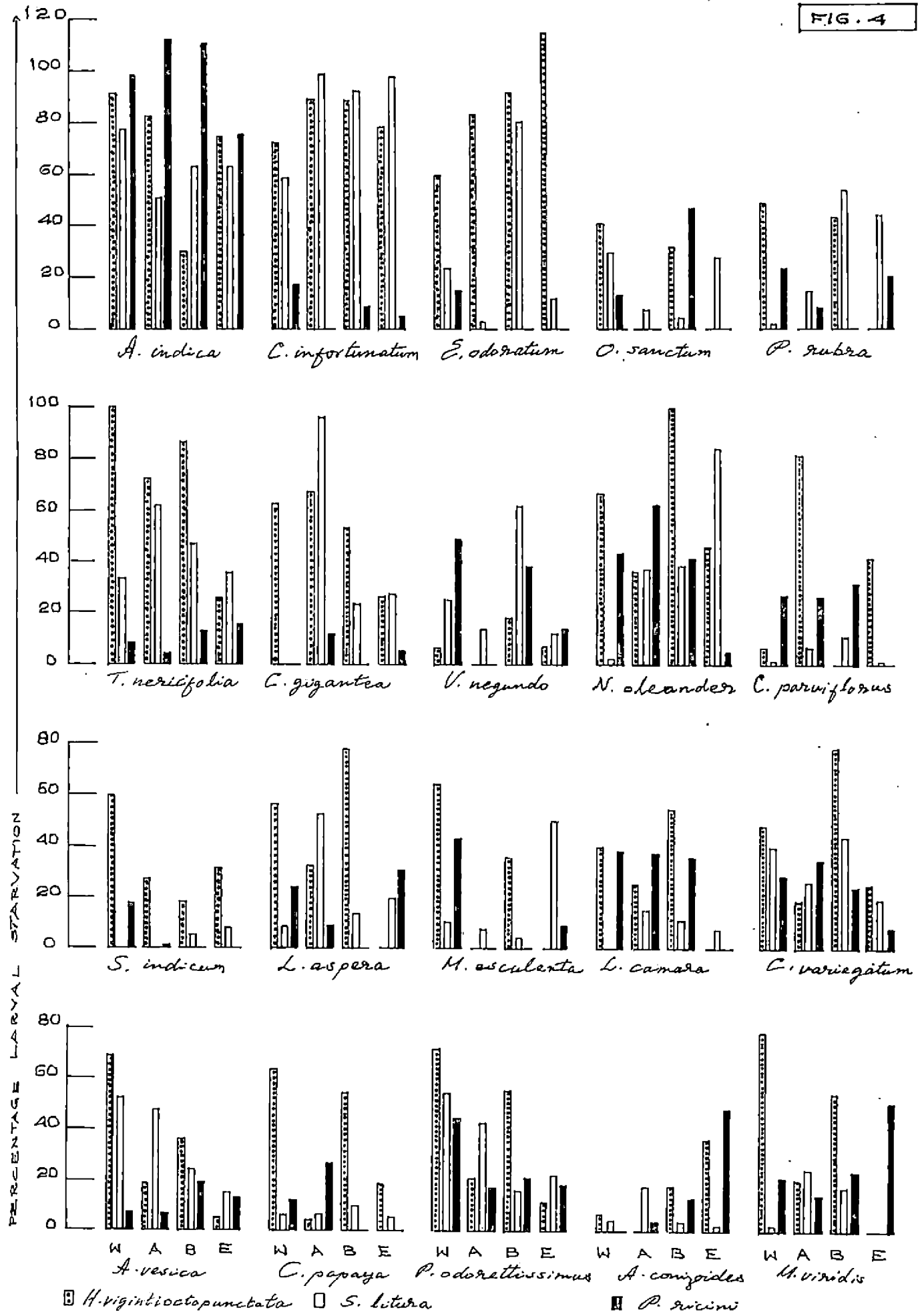
N. oleander and T. neriifolia were good source of antifeedants. Thus T. neriifolia, A. indica, C. infortunatum and E. odoratum came on par in being active in three of the four extractants while N. oleander showed activity in benzene and ether extracts only.

Benzene extracts of all the plants selected with H. vigintioctopunctata were found active against S. litura also except the extract of N. oleander and there was high leaf protection in all the treatments. E. odoratum showed less activity in ether extract also against S. litura. In water extract N. oleander alone failed to show activity while in acetone extract all except N. oleander and E. odoratum were significantly active.

When used against P. ricini all extracts of A. indica were effective giving very high leaf protection. It was followed by N. oleander which was active in water, acetone and benzene extracts. With benzene extracts besides E. odoratum, T. neriifolia also gave significant leaf protection against the insect.

It may be seen that feeding inhibition caused by plant extracts varied considerably with different test insects. Species specificity of antifeeding compounds has been reported by Saxena et al. (1986). Vascicene an alkaloid from A. vesica acted as a strong antifeedant against H. vigintioctopunctata

FIG. 4


PERCENTAGE LARVAL STARVATION
120
100
80
60
40
20
0
A. indica
C. infortunatum
E. odoratum
O. sanctum
P. rubra
T. nericifolia
C. gigantea
V. negundo
N. oleander
C. parviflorus
S. indicum
L. aspera
M. esculenta
L. camara
C. variegatum
A. vesica
C. papaya
P. odoratissimus
A. conizoides
M. viridis
W A B E
H. vigintioctopunctata
S. litura
P. ricini

and A. foveicollis while D. koenigii and T. castaneum accepted vascicene treated food.

Considering the extent of leaf protection obtained with the different extracts against H. vigintioctopunctata and S. litura, A. indica, C. infortunatum, E. odoratum, T. neriifolia and N. oleander were selected as candidate plants for further evaluation. In many of the experiments all the plants came on par and thus the newly identified plants maintained parity with A. indica, the plant well known for antifeedant activity.

The plants identified as good source of antifeedant chemicals in the experiments caused high larval starvation also. However larval starvation of H. vigintioctopunctata was low with the benzene extract of E. odoratum. Similarly against S. litura water extract of N. oleander and acetone and ether extracts of E. odoratum failed to show significant larval starvation. With P. ricini all the extracts of A. indica and water, acetone and benzene extracts of N. oleander caused significant and high larval starvation. Other extracts of the selected plants did not cause larval starvation in P. ricini.

The antifeedant property of the leaves of A.indica has been extensively reported (Volkonsky, 1937; Sergent, 1944; Chauvin, 1946; Krishnamurthy and Rao, 1950; Mc Millan et al., 1969; Chari and Muraleedharan, 1983; Singh and Sharma, 1986;

Abdul Kareem, 1980). The antifeedant activity of the leaf extract of C. infortunatum is being reported for the first time. But clerodendrin A and B extracted and isolated from the leaves of C. tricotamum was found to possess deterrent effect on S. litura (Munakata, 1968). Ether extracts of C. colosomilus, C. cryptophyllum and C. fragrans induced feeding deterrence in S. litura (Hozosawa et al., 1974). Similar antifeedant effect on D. obliqua and Bruchus sp. was reported for the extract of C. bicorne (Tripathi and Rizvi, 1985 and El Ghar and El Sheikh, 1987). Nerifolin extracted from T. neriifolia was reported to deter the feeding of codling moth, striped cucumber beetle and Japanese beetle. Some systemic action also was attributed to this extract of T. neriifolia (Reed et al., 1982). Antifeedant activity and larval starvation of N. oleander and E. odoratum are being reported for the first time.

Though five plants ranking high in the screening were selected for further evaluation all the plants subjected to the screening test showed antifeedant activity in one extract or other or with atleast one of the three test insects used. Obviously these plant extracts may prove effective against pests which have not been covered in these studies. The findings highlight the need for elaborate screening of plants for allelochemics to be used against the different serious pests in a location for identifying the effective source for

controlling any specific pest and on a specific crop. There are indications that an antifeedant found effective on one plant may not be so on another (Meisner et al., 1980).

From among the plants not selected in the screening for further evaluation Pandey et al. (1977) and Sudhakar et al. (1978) had reported the feeding deterrency of water extract of L. camara against A. proxima. Abdul Kareem (1980) reported the ineffectiveness of acetone extract of A. vesica. But Saxena et al. (1988) could get potent alkaloids, from the extract of A. vesica inhibiting the feeding of H. vigintioctopunctata and A. favicollis.

Another interesting observation in the data (Table 1, 2 and 3) is that water and benzene extracts of some plants which showed no antifeedant activity (L. aspera and M. esculenta, L. camara, etc.) against H. vigintioctopunctata caused high larval starvation. This observation indicated that besides the antifeedant principles the extracts of test plants contained some chemicals which had low stomach toxicity (below lethal threshold) or they might have caused some antibiosis interfering with the metabolism of the insects (Jermy, 1966). These constituents in the plant extracts might be useful as additional factors contributing to the regulation of insect populations in the field.

4.3. Feeding inhibition of essential oils

Essential oils are reported to have varied biocidal effects on insects. Feeding inhibitory activity of volatile leaf oils of Western red cedar, T. plicata against pine weevil was reported by Alfaro et al. (1981). Similarly components of oil of tansy (against L. decemlineata) and bittergourd seed oil (against A. proxima) were found to have significant anti-feedant effect (Schrarer, 1984 and Arunkumar et al., 1979). In view of the safety of these biocides in the agro-ecosystem eight essential oils collected from within India were screened in the present investigations. The results presented in para 3.2 revealed that citrodora oil at 10 and 5 per cent, geranium oil 10 per cent and camphor oil 10 per cent gave 70-80 per cent leaf protection against the test insect P. ricini. Geranium oil 10 per cent caused high larval starvation also. Application of essential oils at such high doses for pest management under field situations may not be economically viable and hence these materials were not considered for further detailed investigations.

4.4. Bioassay of five selected plants using epilachna grubs as test insect

The results presented in para 3.3 revealed that N. oleander had the highest antifeedant effect on H. vigintioctopunctata and it was followed by C. infortunatum, A. indica; T.neriifolia

and E. odoratum based on PC 50 values. But when compared at PC 95 level the plants came in the following descending order, N. oleander, A. Indica, C. infortunatum, E. odoratum and T. neriifolia. The difference in relative efficacy at the two levels may be attributed to the variation in slopes of the log-dose - response graph (Fig. 1).

Based on larval starvation also, N. oleander ranked first. At SC 50 level N. oleander was followed by A. indica, T. neriifolia, C. infortunatum and E. odoratum. At SC 95 level N. oleander was followed by C. infortunatum, E. odoratum, T. neriifolia and A. indica.

Ascher and Nissim (1965) suggested the choosing of dosages at PC 95 and SC 95 levels for field application since concentrations giving 50 per cent leaf protection (PC 50) will be inadequate for practical purposes. On this criterion, 1 to 2.5 per cent concentrations may be fixed as the desirable doses for treating brinjal with benzene extracts of the five selected plants for leaf protection. At these concentrations the larval starvation will be around 50 per cent only. When the treatment ensures high leaf protection lower levels of larval starvation are not likely to favour the pest population. Obviously two per cent emulsions of benzene extracts of the plants may be adequate for protecting the crop in the field from leaf damage caused by H. vigintioctopunctata.

In the bioassay studies N. oleander emerged as an antifeedant even more potent than the well known leaf protectant, A. indica, E. odoratum and C. infortunatum also came very close to it in relative efficacy. T. neriifolia comes as the last in rank but not far inferior to A. indica. Based on larval starvation all the four plants ranked above A. indica. Such precise comparisons of the potency of plant extracts was being done for the first time.

4.5. Persistence of the antifeedant activity of the plant extracts under field conditions

In the screening trials the plant extracts were used at 25 per cent concentration. Since two per cent concentration was indicated as the optimum dosage in bioassay the persistence of two per cent emulsions of plant extracts was studied in this experiment. In the screening trial water extract of T.neriifolia also was assessed along with the benzene extracts of other selected plants. The results presented in para 3 and 4 showed that among the extractants included in the experiment water extract of T. neriifolia gave 100 per cent leaf protection and it had the highest persistent toxicity also. N. oleander also gave 100 per cent leaf protection, the persistent toxicity was next to that of the water extract of T. neriifolia. C. infortunatum came as the third on the basis of PT indices but

its persistent toxicity (PT index) was only half of the toxicity of T. neriifolia. Water extract of T. neriifolia and benzene extract of N. oleander gave complete leaf protection up to 10 days after treatment and extended up to 22 days with gradual decrease subsequently. The persistence was sufficiently long to cause disastrous effect on the insect population. Benzene extract of T. neriifolia persisted up to 22 days but it ranked as last on the basis of PT indices. Extracts of E. odoratum, A. indica and T. neriifolia persisted up to 18 days, the PT indices of all the three being on par and far below to that of T. neriifolia. Neem seed extracts at 0.1% concentration was reported to give absolute protection for 2-3 weeks to tobacco against desert locust (Pradhan et al., 1962) and against S. litura (Joshi et al., 1984). Meisher et al. (1980) found that neem seed extract at 0.2 per cent had good activity on sugar beet leaves for 1-4 days after treatment and on lucerne up to one day after treatment. Persistent antifeedant activity of T. neriifolia for one week was reported by Reed et al. (1982) against codling moth, cucumber beetle and Japanese beetle. With the observed persistence on brinjal the treatment appears to come on par with most of the OP compounds. The normal persistence of OP compounds extended between 4 and 15 days under the field conditions (George Koshy, 1982 and Rajukkannu, 1980).

4.6. Insecticidal effect of the extracts of selected plants against D. cingulatus, S. litura and A. craccivora

Data presented in para 3.5.1 (Table 8) showed that the extracts of 20 plants selected in the study were not promising for their insecticidal effect when applied on D. cingulatus, H. vigintioctopunctata and S. litura. However, extracts of T. neriifolia, P. odoratissimus, C. gigantea, A. indica and P. rubra showed toxicity to the pea aphid A. craccivora. Similar results were reported by Deshmukh and Borle (1975) who found that ether extracts of Acorus calamus L., Croton tigtium and Aconitus ferox were toxic to sawflower aphid D. carthami while the extracts had no contact toxicity to S. litura. The assessment of relative toxicity of the extracts of different plants through bioassay using A. craccivora as test insect (para 3.5.2 / Table 9) showed that LC 50 value ranged from 34 to 93 per cent. The concentrations required for effective control of the pest in the field would be much higher than LC 50 levels observed in the laboratory and obviously the treatments may not be viable for adoption in field. El Ghar and El Sheikh (1987) reported that ether extract of C. bicorne was effective against C. chinensis on pulses in field. But it was not clearly reported whether the effect observed was through insecticidal action or through antifeedant and hormonal effects.

Besides contact action, systemic and stomach toxicity of plant extracts had been reported earlier (Gill and Lewis, 1971; Sundaramoorthy, 1979). In the light of these reports the systemic/stomach toxicity of A. indica, E. odoratum, C. infortunatum and T. neriifolia extracts to the second, third, fourth and fifth instar nymphs of D. cingulatus was assessed by releasing the insects on seeds sprouted after soaking in plant extracts for 48 hours. Results presented in para 3.6 (Table 11) revealed that the extracts were toxic to the nymphs of D. cingulatus. Benzene extract of C. infortunatum was the most toxic to all the nymphal instars. It was followed by A. indica, T. neriifolia and E. odoratum. But N. oleander was not toxic to the nymphs of D. cingulatus. The relative toxicity of the extracts to the different nymphal instars was the same. The fourth instar nymphs were more tolerant to the extracts than the fifth instar. This may be due to the added hormonal effect to fifth instar nymph as it is the only larval stage susceptible to the hormonal effect. Toxicity of seed extracts of T. thevetoides when incorporated into the larval diet of European corn borer was reported earlier by Freedman et al. (1979). Reed et al. (1982) also indicated systemic action of T. neriifoli when applied through roots for protecting cartaloape plants A. vittatum. But this aspect has not been investigated in detail so far. The results obtained from the studies strongly indicate

the need for exploring the systemic action of plant extrac since this property will solve the problem of low persiste plant products on treated surface often pointed out as a l tion in exploiting this new method of plant protection.

4.7. Insecticidal effect of essential oils on D. cingulat and S. litura

The insecticidal activity of essential oils was studied in view of the high level of safety attributed to them. Results presented in para 3.7 (Table 10) showed geranium oil and oil of wintergreen at 10 and 5 per cent concentrations respectively gave 100 per cent kill of A. craccivora. Patcholi oil and citrodora oil at 10 per cent and geranium oil and oil of wintergreen at 2.5 per cent also gave high mortalities of the aphid.

Several instances of effective pest control using botanical pesticides have been reported. The rhizome of Acorus calamus was known to possess insecticidal properties against houseflies, mosquitoes and furniture beetle from very early days (Dixit et al., 1956). The treatment was found effective against pulse beetle recently (Yadava, 1974). Insecticidal effect of limonene a constituent of citrus oil, on pulse beetle was reported by Taylor and Vickory (1974). Though some essential oils tried were found effective as insecticides in the present studies, the doses required for the control were too high for economic field use.

4.8. Juvenomimetic activity of plant extracts

All the twenty plants screened for their antifeedant activity were screened for their juvenomimetic activity also using D. cingulatus and S. litura as test insects. It is well known that exogenous juvenile hormone or its analogues applied to sensitive life stages of insects results in the retention of juvenile characters after subsequent moults leading to the development of juvenile-adult conditions. This has been basic principle of all juvenile hormone assay methods (Staal, 1972). The differences in the critical moments of sensitivity to juvenoids in various tissues or cells in developing insects may cause different velocities in the growth and development process. This may result in the prolongation of life stages and may cause the emergence of extra larvae which may even have ripe eggs in the ovaries (Zdarack and Slama, 1972). Covering the above aspects the data on larval mortality, larval duration, percentage of normal and malformed adult emergence, adult longevity, fecundity and egg hatchability were collected in the experiments and sterility percentages of the insects were also calculated.

Prolongation of the larval duration and adult longevity of insects like D. cingulatus (nymphs and adults feeding on the same host) may cause more damage to crops and hence assumes significance. But the prolongation of adult longevity is not

of importance in lepidoptera when the adults do not feed on the same host on which the larva thrives. Since the receptive stage is the last instar larva, enhancement in the post treatment larval duration may not make significant change in the net possible damage on the crop. Hence the data relating to the longevity of larva and adults of S. litura do not seem to have significant bearing on the extent of damage on the host subsequent to the treatment.

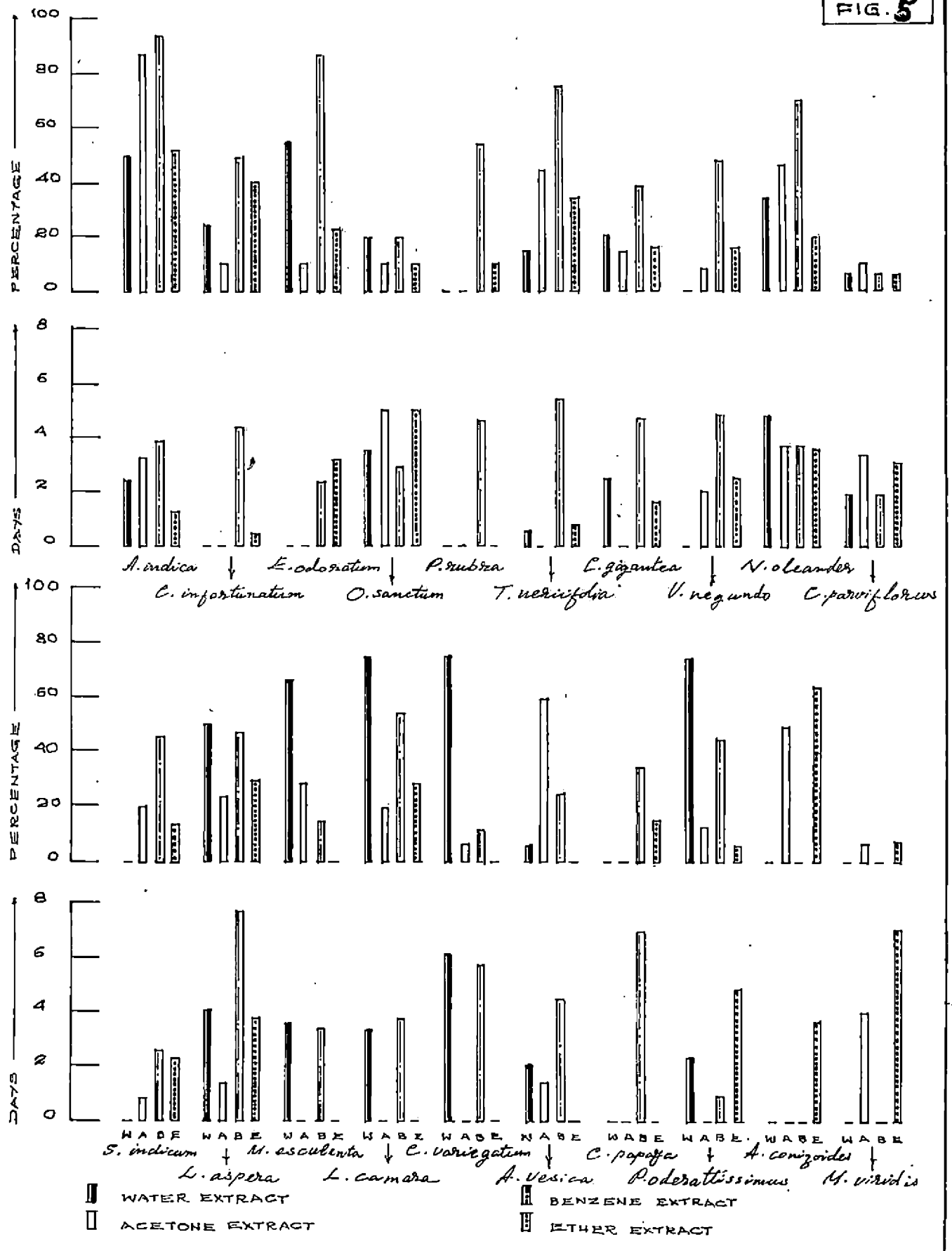
4.8.1. Screening of plants using D. cingulatus as test insect

Since the juvenomimetic effect of plant extract will take time for manifestation and since the effect largely depends on the occurrence of the pest in correct receptive stage in the field, the treatment may not emerge as a single effective technique for controlling any pest in the field situation. In integrated pest control, the strategy is to contain the pest population and not its elimination. Hence the use of allelochemics regulating the growth and development of insects may emerge as important component of an integrated control programme for tackling a pest in the field. In this context the best index for assessing the relative efficacy of the plant extracts will be the possible suppression of the post treatment population of the pests involved. The number of adults emerging from the treated insects and their sterility percentage will decide the future build up of the population.

Data on the hormonal effects of plant extracts have been presented in para 3.8.1 to 3.8.4 (Table 12 to 15). Water acetone and ether extracts of A. indica, E. odoratum, C. infortunatum, N. oleander, A. vesica and A. conizoides prolonged the post duration of fifth instar nymph. Water and ether extract of T. neriifolia and V. negundo and C. aromaticus, water and benzene extract of C. papaya, acetone and ether extracts of O. sanctum, acetone, benzene and ether extracts of L. aspera, acetone and benzene extracts of P. rubra and S. indicum, benzene and ether extract of C. gigantea and benzene extract of L.camara and C. variegatum also had prolonging effect of the fifth instar nymphs of D. cingulatus.

The adult longevity of D. cingulatus was enhanced significantly over control when treated with the ether extract of C. aromaticus and C. papaya. Though the prolongation of duration of nymphs and adults may cause more damage on the crop, in continuously breeding insects like D. singulatus this hormonal effect will reduce the possible number of generations in an year and will thus limit the population build up. Prolonged larval duration due to the application of juvenoids had been recorded earlier also (Slama, 1970 and Koul, 1984). In the remaining treatments the mean nymphal durations remained on par with that of control or were significantly lower than that of corresponding controls. The mean adult longevities of normal

FIG. 5


PERCENTAGE
100
80
60
40
20
0
DAYS
8
6
4
2
0
A. indica
E. odoratum
P. rubra
C. gigantea
N. oleander
C. inoortunatum
O. sanctum
T. neriifolia
V. negundo
C. parviflorus
PERCENTAGE
100
80
60
40
20
0
DAYS
8
6
4
2
0
WABE WABE WABE WABE WABE WABE WABE WABE WABE WABE
S. indicum
M. esculenta
C. variegatum
C. papaya
A. conizoides
L. aspera
L. camara
A. vesica
P. oderatissimus
M. viridis
WATER EXTRACT
ACETONE EXTRACT
BENZENE EXTRACT
ETHER EXTRACT

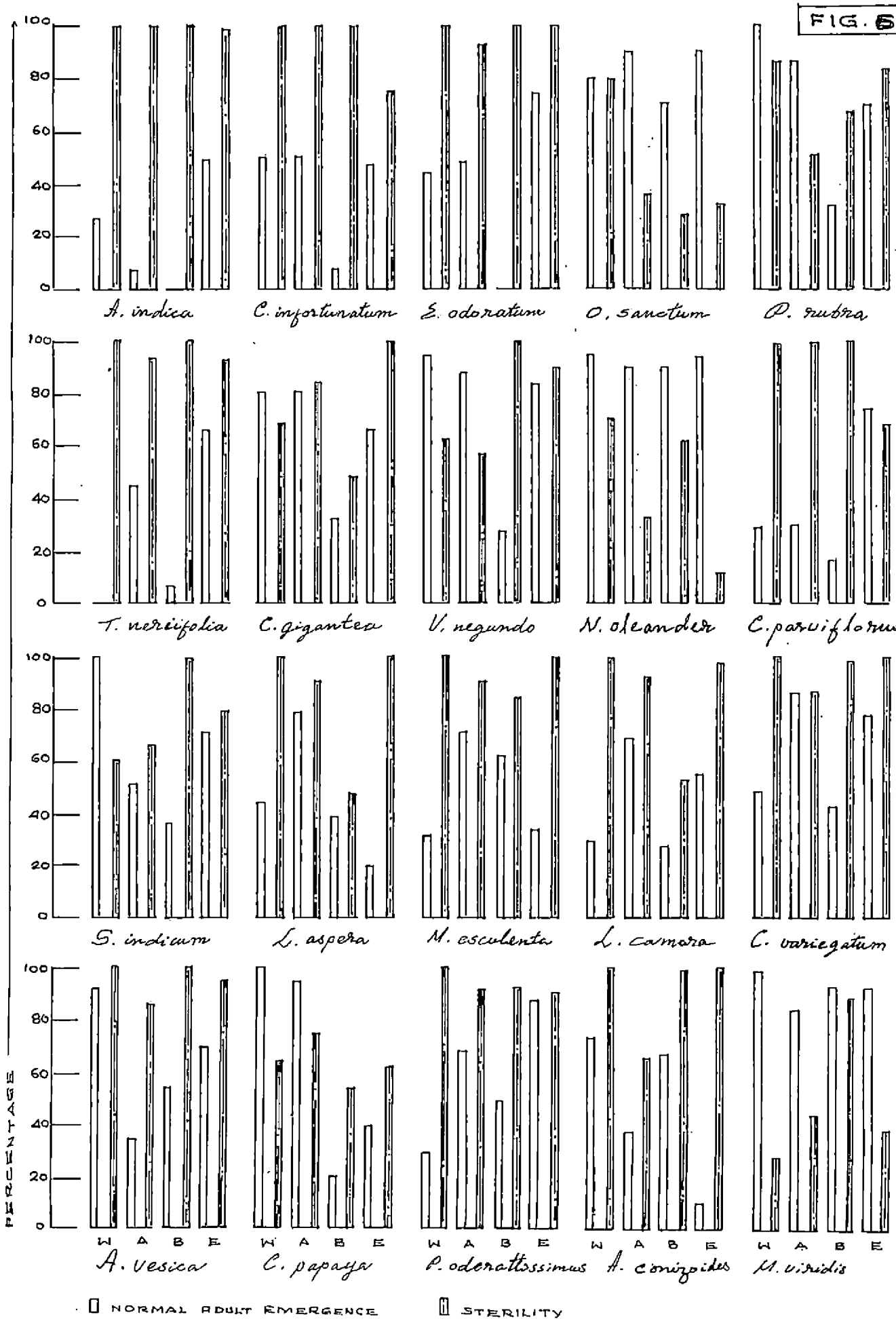
and malformed adults in many treatments came below those of corresponding controls as shown clearly in Fig. 6.

The plant extracts when applied topically caused stray mortalities within short periods (five days) after treatments. This might be due to the toxic action of the extracts. Such mortality was observed in four plant extracts when water was used as an extractant and mortality observed was 10 per cent or below. In acetone extracts five plants showed toxicity and the mortality was in the range of 0-5 per cent. In benzene nine plants showed the activity and the mortality was in the range of 7.5 to 12 per cent. In ether extract some plants showed higher toxicity and the mortalities ranged from 5 to 19 per cent. The observations endorses the earlier finding that the plants included in the study did not posses high insecticidal activity (vide para 3.5).

In the post treatment phase varying levels of mortalities were observed in all the treatments towards the later stage of nymphal instar mainly due to the failure of moulted insects in extricating themselves from the exuviae. This can be attributed to the juvenomimetic activity of phytochemicals in the extract.

Besides in many treatments adultoids also emerged which generally lived for very short periods as shown in Fig. 6. The adultoids retained nymphal characters like presence of two tarsal

FIG. 6.


PERCENTAGE
100
80
60
40
20
0
A. indica
C. inportunatum
E. odoratum
O. sanctum
P. rubra
T. nereifolia
C. gigantea
V. negundo
N. oleander
C. parviflorus
S. indicum
L. aspera
M. esculenta
L. camara
C. variegatum
W A B E
A. vesica
C. papaya
P. oderatissimus
A. conizoides
M. viridis
NORMAL ADULT EMERGENCE
STERILITY

segments, abdominal spots, etc. Such morphogenetic effect of juvenoids has been extensively reported earlier (Slama and Williams, 1965; Man Singh *et al.*, 1970; Deshpande *et al.*, 1974; Prabhu and John, 1975; Jacobson *et al.*, 1975; Saxena *et al.*, 1980; Schmutterer *et al.*, 1983; Chiu, 1985; El Sayed, 1985). Among the plants screened *A. indica* showed high juvenilising effect and more than 50 per cent of treated nymphs emerged as malformed adults in all the four extracts. Such high percentages of malformed adults were seen with water extract of *E. odoratum*, *M. esculenta*, *L. camara*, *C. variegatum* and *P. odoratissimus*. Among the acetone extracts *A. conizoides* alone caused malformed adults above 50 per cent. Benzene extracts of *A. indica*, *E. odoratum*, *P. rubra*, *T. neriifolia*, *N. oleander* and *L. camara* caused the emergence of malformed adults to the extent of 50 per cent or above. Among other extracts *A. indica* and *A. conizoides* alone had appreciable activity. All the plants screened had effect in one experiment or other.

The emerging normal adults and their sterility percentages could give an index of the possible build up of the post treatment population of the test insect. The data relating to these aspects have been summarised in Fig. 5. As in the case of antifeedant action here also benzene was found to be the best extractant. Sixteen out of twenty plants tested had the effect as the test insect in one or more than one extracts tried.

When the four extracts of each plant were ranked on the basis of the suppression of the emergence of normal adults, benzene extracts came in the positions of 1, 2, 3 and 4, in the case of 8, 6, 2 and 0 numbers of test plants respectively. The corresponding numbers of plants for which 1st, 2nd, 3rd and 4th ranks maintained by water, acetone and ether extracts were 5, 2, 3 and 6; 1, 4, 6 and 5 and 2, 5, 4 and 5 respectively. It may be seen that benzene was closely followed by water and the other two extractants were on par and less effective. When the sterility percentages of D. cingulatus treated with different extracts were considered 100 per cent sterility was seen with 13, 2, 10 and 5 numbers of water, acetone, benzene and ether extracts respectively.

Plants which gave significant suppression of adult emergence in benzene and water extracts were T. neriifolia, L. camara, A. indica, N. oleander, E. odoratum and C.infortunatum while C. variegatum, P. odoratissimus, M. esculenta were active as water extract alone. Apart from six among the nine plants listed above A. vesica, A. conizoides and S. indicum were found active in acetone extract. Four among the above plants and L. aspera and C. papaya suppressed the adult emergence in ether extract. All extracts of C. gigantea, O. sanctum, M. viridis and C. aromaticus failed to inhibit the adult emergence significantly.

Based on the number of plants detected with factors suppressing adult emergence with different extractants benzene and water came on par and these were followed by acetone and ether extract. While benzene extracts of 11 plants gave 100 per cent sterility of D. cingulatus with water, acetone and ether extracts the numbers of plants giving 100 per cent sterility were 9, 2 and 6 respectively. Thus benzene and water may be considered as better solvents for isolating chemicals suppressing normal adult emergence in D. cingulatus. This suppression of adult emergence would be attributed to the toxic effects of the constituents, factors causing moulting abnormalties and the juvenomimetic effect resulting in the emergence of malformed adults.

Among the six plants identified as most promising for suppressing emergence of normal adults T. neriifolia, A. indica and E. odoratum caused 100 per cent sterility of D. cingulatus in water and benzene extracts and above 90.0 per cent sterility with other two extracts. C. infortunatum and N. oleander caused 100 per cent sterility in acetone, benzene and water extracts. But in ether extracts the sterility caused by these plants was low. Such adverse effect on the reproductive potential of the insect was noticed with the extracts of other plant too.

The sterility (used in a broad sense from the angle of possible contribution to the ensuing generation) caused by the plant extracts may be due to the suppression of normal adult emergence, lack of egg laying by normal and malformed adults or due to the lack of egg hatching (vide para 3.8.1 to 3.8.4). Reduced fecundity caused by juvenoids was reported earlier by Qutram (1973) in C. fumiferanae and Prabhu et al (1973), Kumuda Sukumar and Osmani (1981) and Narayanan et al. (1984) in D. cingulatus. El Ghar and El Sheikh (1987) reported reduction in fecundity of adult pulse beetles emerging from pulses treated with ether extract of C. infortunatum, N. oleander, I. palmatum and Artiplex sp. Jacobson et al. (1978), Fagoone (1980), Saxena et al. (1980), Hellpap and Morcada (1986) and Velusamy et al. (1987) also reported reduced fecundity of various insects as a result of juvenoid application. Slama (1974) observed that the 'juvenoids do not suppress the egg production as is being done by chemosterilants but the females lay eggs of very low or zero hatchability'. But in many treatments included in the present investigations lack of egg production was observed.

The results showed that all the five plants ranked high as antifeedants to H. vigintioctopunctata effectively reduced the post treatment build up of the population of D. cingulatus too through the juvenomimetic activity. Such growth and development suppressing factors have been identified in plants

earlier also (Prabhu et al., 1973; Deshpande et al., 1974; Prabhu and John, 1975a; Gopakumar et al., 1977; Saxena and Srivastava, 1972; Saxena and Tikku, 1988). But most of these reports were from parts of the plants other than the leaves. The identification of leaves of the potential plants as a rich source of substances having JH activity is being done for the first time. As growth and development arrestants the local plants identified were as effective as neem and in some assays they ranked above neem.

4.8.2. Screening plant extracts for juvenomimetic activity using S. litura as test insect

Many plant extracts found effective as growth arrestants against D. cingulatus were ineffective to S. litura (para 3.8.5 to 3.8.8). The receptive stage of the larvae to the juvenoids being the last instar alterations in the possible damages on the crop in the post treatment phase due to prolongation of larval life would be negligible and the impact on total life cycle due to the change also will be negligible. Hence data on this aspect were not collected from the experiments.

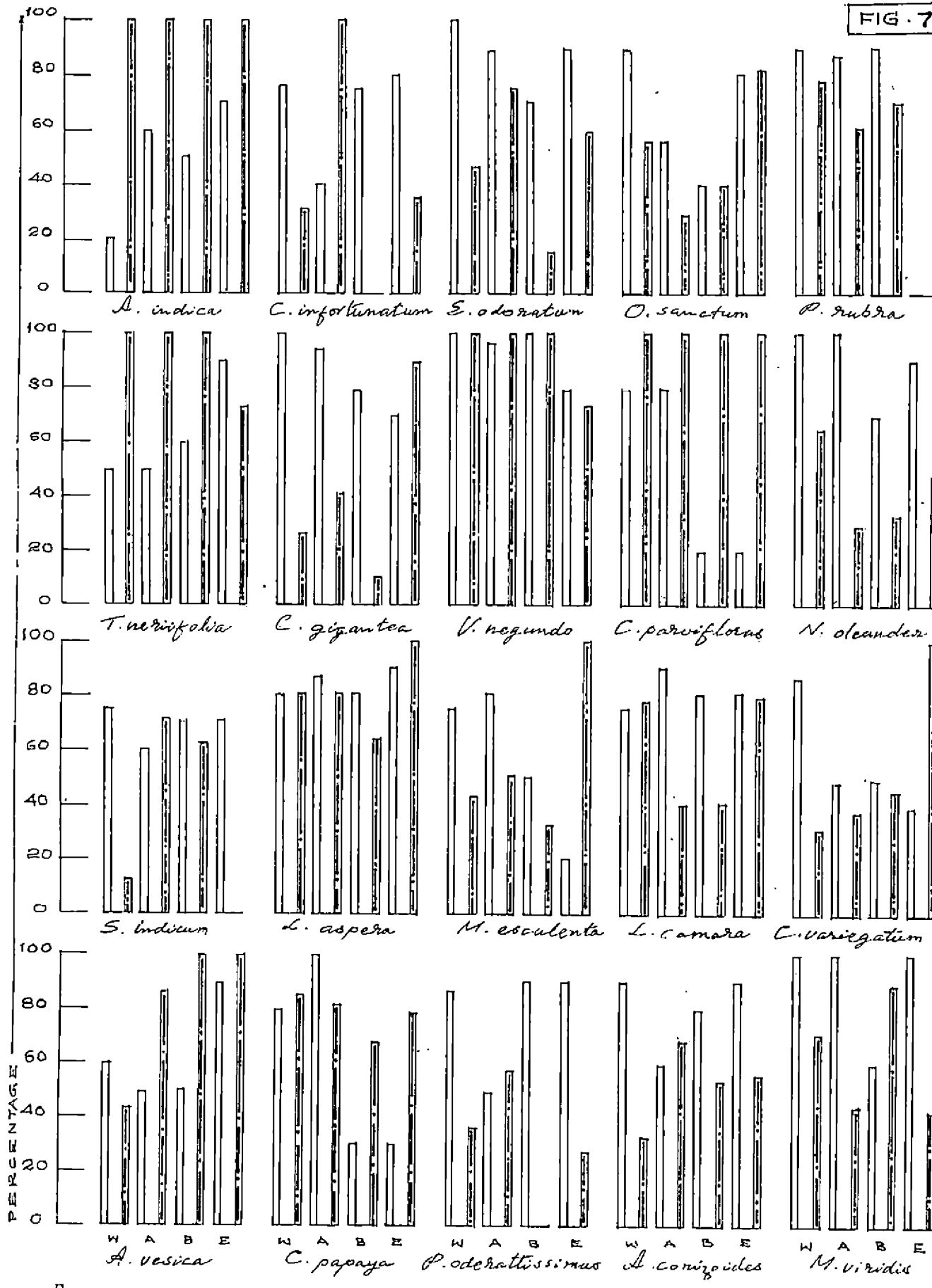
Water extract of A. indica, C. papaya, acetone extract of A. indica, E. odoratum and A. conizoides, benzene extracts of A. indica and A. vesica alone prolonged the pupal duration significantly over control. Other treatments came on par with

control. The results showed that the effect of the plant extract on the pupal duration of S. litura was negligible.

The larval mortality attributable to the insecticidal effect of the extractants were low for the different extracts but it was higher than the response shown by D. cingulatus. In water extracts two plants showed activity and the mortality observed was 20 per cent in both. With acetone extract nine plants showed activity and the mortality ranged from 12.5 to 20 per cent (mortality in control 10 per cent). Benzene extract was more effective; 14 plants caused mortality and the kill ranged from 10 to 40 per cent (control mortality 10 per cent). In ether extract six plants showed activity and the kills were in the range of 10 to 30 per cent. The possible control of the pest through the insecticidal effect would be rather insignificant.

In the four different extracts of twenty plants (80 treatments) in thirty treatments malformed pupae were observed. The percentages of malformed pupae ranged from 5 to 40. Malformed pupae retaining larval heads and larval prolegs and larval-pupal intermediates in which the posterior end retained the larval character while anterior end transformed into pupa were also observed (Plate VI). The uneven distribution of hormone has been attributed as the cause for the development of such mosaics (Willis, 1974). The effect was significantly higher in

FIG. 7


PERCENTAGE
100
80
60
40
20
0
A. indica
C. inforTunatum
E. odoratum
O. sanctum
P. rubra
T. nerifolia
C. gigantea
V. negundo
C. parviflorus
N. oleander
S. indicum
L. aspera
M. esculenta
L. camara
C. variegatum
W A B E
A. vesica
C. papaya
P. oderatissimus
A. conizoides
M. viridis
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the acetone extract of E. odoratum and ether extract of S. indicum and C. papaya.

Pupal mortality was also observed in the treatments. It was largely due to the inability of the insect to emerge out from the pupal skin. According to Outram (1973) the major effect of juvenoids was disruption of the normal mechanism of emergence and the adult deformities observed could be attributed primarily to this factor rather than any disturbance of metamorphosis. Ether extract of P. rubra caused 100 per cent pupal mortality. Acetone extract of E. odoratum and benzene extract of N. oleander also had significant effect with 60.00 per cent pupal mortality. In the case of water extract of T. neriifolia 50.00 per cent of the treated larvae died at the pupal instar.

Since the adults of S. litura do not destroy the crop, the ultimate advantage out of the treatment with the plant extract would be fully reflected in the sterility percentage of the insect as it decides the post treatment population build up of the insect in the field. All the extracts of A. indica and N. oleander, water and acetone extracts of T. neriifolia and V. negundo, benzene and acetone extracts of A. vesica, acetone extract of E. odoratum, ether extract of M. esculenta and C. variegatum which caused 100 per cent sterility (vide Fig. 7)

may be considered as the highly promising juvenoid sources against S. litura since in these treatments the possible contribution to the future generation would be zero. It is interesting to find that many of the local plants came on par with A. indica, the well accepted plant source for biocidal activity.

4.9. Bioassay of selected plants for their juvenilising effect on D. cingulatus

The results presented in para 3.8.9.1 and 3.8.9.2 revealed that the varying concentrations of the plant extracts applied topically on the last instar nymph of D. cingulatus caused significant variations in the manifestation of their juvenilising effect.

Prolongation of last nymphal period was observed in all the treatments. There was a dose dependent increase in the nymphal duration with the acetone extract of C. infortunatum and N. oleander while with benzene extracts the variations in the nymphal period did not show any linear relation with the dosage of extracts. Nymphal mortality due to moulting inhibition was maximum in the case of A. indica but extracts of C. infortunatum was also on par with it. Both the treatments were significantly superior to the remaining three treatments.

In the case of acetone extracts C. infortunatum was most effective in suppressing emergence of normal adults, while in the case of benzene extracts A. indica ranked top. In general, with increased dose there was a linear decrease in the percentage of normal adult emergence. The dose dependence of the degree of juvenile character retained by the post moult individuals was reported earlier also (Sehnal, 1968; Wigglesworth, 1969; Staal, 1972).

The plant extracts affected the longevity of normal adults emerging from the treated nymphs. Adult longevity was not found dose-dependent with acetone extracts of plants. But in the case of benzene extracts a linear response to increasing dosages was observed in the case of A. indica. In other plant extracts also such a linear relationship was not observed.

Acetone extracts of C. infortunatum caused higher number of malformed adults and it was followed by A. indica and T. neriifolia. In the case of benzene extracts T. neriifolia ranked first. Generally there was no linear relationship between the dosages of extracts applied and the number of adultoids formed. Adultoids in all the treatments were short lived.

Induction of sixth instar nymph was observed in all the plant extracts but the emergence was not observed as a dose

dependent factor. The fecundity and hatchability of eggs also failed to show proportionate decrease with increase in the concentrations of the extracts in treatments with acetone extract of N. oleander and benzene extract of T. neriifolia. Production of viable eggs was reduced drastically in treatments with acetone and benzene extracts of A. indica and C. infortunatum and benzene extract of E. odoratum. But with lower doses of acetone extract of E. odoratum and N. oleander and acetone and benzene extracts of T. neriifolia there was not much suppression of fecundity and hatchability of eggs. In the screening trial these treatments caused 100 per cent sterility at 25 per cent level. These variations might be due to possible deficiencies in the respective stages of the test insects chosen in the two experiments.

4.10. Assessment of the juvenilising effect of acetone and benzene extracts of selected plants on D. cingulatus

The determination of biological activity of juvenoids in insect metamorphosis was being made according to reciprocal change of the epidermal morphological patterns between the larva and the adult. Different screening systems for classification of the types of intermediates and assessment of juvenilising effects were being followed. Slama (1974) developed a new system 'in which all the previous screening systems were transferred into percentage of morphological change which are common to metamorphosis instars'. Following this system juvenilising effects of the acetone and benzene extracts of the five selected plants at varying concentrations were assessed. The data presented in para 3.8.9.3 and 3.8.9.4 (Tables 22 and 23)

revealed that with increase in concentration of the extracts used there was corresponding increase in juvenilisation rating.

Among the acetone extracts C. infortunatum showed the highest juvenilising effect on D. cingulatus and it was closely followed by A. indica, T. neriifolia and N. oleander. The juvenilisation rating of E. odoratum was significantly lower than A. indica and T. neriifolia. Among the benzene extracts, maximum juvenilising effect was observed in A. indica and it was closely followed by C. infortunatum. These were followed by N. oleander and E. odoratum. T. neriifolia was least effective. The degree of juvenilising effect caused by acetone and benzene extracts clearly endorsed the relative superiority of the latter solvent in extracting the allelochemics from all the plants included in the experiment. Such precise assessment of the juvenilising effects of test plants to be utilised as source of phytochemicals for plant protection was being done for the first time. Even in such assessment C. infortunatum came on par with A. indica while N. oleander and E. odoratum also were found promising.

4.11. Effect of different plant extracts on the ovarian development and mating behaviour of D. cingulatus

The nature and extent of ovarian inhibition in the normal adults/adultoids/sixth instar nymphs and also the sexual behaviour of the emerging individuals varied considerably in

different treatments (vide para 3.8.10 and Table 23a). The ovaries in surviving adults were either typical adult type with normal ovarioles or nymphal type with less differentiated ova in the ovarioles which were not linearly arranged. The abdomen of the insects with adult type normal ovaries got swollen in 3 to 4 days after emergence. Insects with such ovaries mated even when they existed as adultoids or sixth instar nymphs. Insects with nymphal type ovary did not mate. The sixth instar nymphs with two segmented tarsi (a nymphal character) always had typical nymphal type ovaries irrespective of the quantity of the plant extract applied. In some of the adultoids and sixth instar nymphs having three segmented tarsi, the abdomen was swollen with ripened eggs, but ovarioles were degenerated and hence the egg deposition was inhibited. Zaderk and Slama (1972) obtained extra-larvae of Pyrrhocoris which had ripe eggs or mature spermatozoids in the ovary and sperm ducts respectively. These extra larvae exhibited active sexual behaviour which was normally present only in adult stage. Prabhu and John (1975a) obtained supernumerary nymphs laying perfectly normal eggs which developed into normally reproducing adults. Slama (1974) attributed the differences in the sensitivities of the epidermal cells and other internal organs as the cause for the development of supernumerary instars with normal amitogenesis. Some internal organs such as nervous system, ovaries or prothorasic glands may lose their sensitivity to juvenoids (they develop normally) more than the epidermal cells (remain sensitive resulting in the

suppression of metamorphosis). In the present experiments the sixth instar nymphs did not lay viable eggs. Among the five plants bioassayed benzene and acetone extracts of C. infortunatum showed the highest inhibitory effect on the ovary. At higher concentrations the emerging individuals died soon after emergence and at lower doses the nymphal type of ovary was retained. At the lowest concentration the emerging adults died before egg laying. Similar trend was seen with A. indica also, except that at the lowest dose viable eggs were produced.

In the case of E. odoratum benzene extract was more effective than acetone extract. At all doses benzene extract prevented egg laying due to the retention of nymphal ovaries or deformed ovarioles. With acetone extracts, the higher doses alone could suppress the ovarian development.

Acetone extract of T. neriifolia and N. oleander could suppress ovarian development only at the highest dose. In the case of benzene extract of T. neriifolia at 50 and 25 per cent the eggs laid were not viable. Adultoids also laid nonviable eggs. Benzene extract of N. oleander at the highest concentration also produced nonviable eggs. Slama (1974) observed that the sterility produced by juvenoids is caused not by the reduction in fecundity but by the formation of defective eggs of low or zero hatchability. The results obtained from the studies did not agree with this observation.

With T. neriifolia and N. oleander extracts, the normal adults, exhibited an abnormal protrusion of genetalia. Kumuda Sukumar and Osmani (1981) also reported similar abnormal protrusions of male genetalia on D. cingulatus when treated with catharanthus alkaloids, a good male sterilant.

4.12. Ovicidal effect of plant extracts

In the present investigations the ovicidal effect of the benzene extracts of five selected plants were bioassayed using the eggs of D. cingulatus. The results presented in para 3.8.11 (Table 24) revelaed that N. oleander extract was most lethal and it was followed by C. infortunatum, T. neriifolia, A. indica and E. odoratum.

Effect of juvenoids on embryonic development was first observed by Williams and Slama (1966) and Williams (1967) on P. apterus. Walker and Bowers (1970) and Saxena and Srivatsava (1972) reported the adverse effect of Acorus calamus oil on the embryonic development of E. varivestis and D. koehigii respectively. Adverse effect of neem extract, neem oil and Azadirachtin on the hatchability of eggs of various pests were reported by El Sayed (1985), Dorn (1986), Singh et al. (1987) and Shelke et al. (1987) also.

4.13. Juvenomimetic activity of essential oils on *D. cingulatus*

Most of the reported JH compounds are aliphatic or monocyclic sesquiterpenes and the morphogenetic and diapause disrupting activity of many synthetic terpenoid derivatives were discovered (Menn and Beroza, 1972). Terpenes are important constituents of essential oils. Hence might show JH activity. Oil of *Sterculia foetida* was reported to reduce egg production in the housefly (Beroza and Lebrecque, 1967). Essential oil of *Tagetus minutus* and of some herbaceous plants of South India were reported to show JH activity on *D. koenigii* (Saxena and Srivatsava, 1973; Deshpande *et al.*, 1974). Citral oil showed similar effect on *D. cingulatus* (Osmani et al., 1977). Suppression of reproductive potentiality in males of *M. domestica* (Mathur and Saxena, 1975), *D. koenigii* (Koul et al., 1977) and a number of stored product pests (Saxena *et al.*, 1976) were caused by *A. calamus*. In this context available essential oils were screened for their JH activity.

All the eight essential oils included in the present investigations caused morphogenetic aberrations in the adults emerging from treated nymphs of *D. cingulatus*. Mortality of nymphs due to moulting inhibition was observed in all the treatments. Geranium oil at 10 per cent concentration gave maximum

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mortality of the test insect. In general, there was a positive linear relationship between the mortalities observed and concentrations of essential oils applied, except with oil of wintergreen.

In 10.0, 5.0 and 2.5% concentrations of camphor oil and eucalyptus oil and in the 10.0 and 5.0% concentrations of patcholi oil and citronella oil, normal adult emergence was completely prevented.

The longevity of the adults were significantly lower in all treatments. Eucalyptus oil and geranium oil at highest concentrations induced the formation of supernumerary nymphs.

The fecundity of the insects was reduced significantly in all treatments. Hatchability of eggs was also reduced drastically. The sterility percentages in citrodora oil 2.5 per cent, geranium oil 2.5 per cent and palmarosa oil 5 and 2.5 per cent ranged from 80 to 92. In rest of the treatments viable eggs were totally lacking. Similar JH activity with citronella oil was observed in Tribolium castaneum (Dale et al., 1977). JH activity of extracts of Eucalyptus was reported earlier by Rajendran and Gopalan (1978). The present studies confirmed the finding that essential oils can mimic JH activity in insects. The results indicated the possibility of using essential oils in plant protection as a component of integrated pest control,

comparably active.

4.14. Control of pests of brinjal and bittergourd in field with plant extracts

The results of the field experiments presented in para 3.9.1 to 3.9.4 showed that the benzene extracts of A. indica, E. odoratum, C. infortunatum, T. neriifolia and N. oleander and water extract of T. neriifolia reduced the populations of H. vigintioctopunctata, C. insolitus and A. gossypii on brinjal and H. vigintioctopunctata in bittergourd significantly. The effect persisted for seven to eight days. At 14th day after treatment the populations in treated plots came on par with that of control. This rapid restoration of the population would have been caused by the migration of the pests from adjacent untreated field into the treated plots due to the low toxicity of the plant extract. The water extract of T.neriifolia was the most effective treatment against H. vigintioctopunctata and C. insolitus and the treatment came on par with the spraying of carbaryl 0.2%. Compared to the water extract benzene extract of the plant was far less effective against all the three pests. The water and benzene extracts of the plant were far less effective against A. gossypii than other extracts though the population of the pest in treatments remained less than that of

control even at eighth day after treatment. The relative efficacy of other treatments showed an erratic trend in different experiments but all of them were effective in controlling the pests. The impact of the treatments in the population build up of the pests could not be studied due to the short duration in which the reduced levels of population was restored in treated plots, probably due to the migration from outside the treated area. All the plants found as effective as A. indica in controlling the population build up of the test insects in laboratory studies maintained the parity under field conditions also.

The studies have clearly established the promising antifeedant and juvenomimetic effects of a number of plants which are easily available in many locations of Kerala. The crude extracts of these plants could give high protection of the host plants against the test insects. But the performance of the different solvents in extracting the phytochemicals and the sensitivity of different test insects to the extracts showed considerable variations indicating that the extracts should be evaluated against all the pests existing in an area before using them in field for controlling any specific pest. The extracts of promising plants identified in the screening showed persistence comparable with that of the common OP compounds. The juvenilising effects of the selected plants also were adequately established through the different screening experi-

ments and bioassays. Plants possessing high antifeedant effects showed high JH activity also and it has been confirmed that if applied at the receptive stage of the insect the reproduction can be fully suppressed thus preventing the future build up of the pest. The systemic action of plant extracts shown to the nymphs of D. cingulatus increases the scope for utilising these phytochemicals for pest control. If methods of application ensuring proper systemic effect can be standardised many limitations posed against the extensive use of the technology can be surmounted. The essential oils screened in the studies were not found useful as antifeedants or insecticides. But many of them had significant juvenomimetic activity on the test insects. Their utilisation in the field also will have to be assessed through further experimentations. The plants identified as suitable sources of chemicals having wide antifeedant and juvenomimetic activity can be developed as important components of effective integrated pest control programmes.

SUMMARY

SUMMARY

Taking neem (Azadirachta indica Juss.) as the check, twenty locally available plants were screened in the laboratory for their antifeedant activity on H. vigintioctopunctata, S. litura and P. ricini adopting the disc feeding method. The ultimate aim was to assess the possibilities of using the crude extracts of effective plants in the field for pest control purposes. Water, acetone, benzene and ether were used as solvents for extracting the phytochemicals. In view of the continuous availability and easiness for mass production among the different plant parts the leaves of the plants alone were used in the assays. The experiments led to the following major conclusions:

1. The plant constituents causing the antifeedant effect, on all the test insects, were best extracted with benzene. With reference to the larval starvation caused in H. vigintioctopunctata and P. ricini water was found slightly superior to benzene as an extractant while acetone and ether were on par. In the case of S. litura benzene and acetone were on par and superior to water and ether in causing larval starvation.

2. H. vigintioctopunctata was found to be more sensitive to the antifeedant activity of benzene extracts of plants than S. litura and P. ricini. But with reference to water, acetone and ether extracts all the three test insects showed equal sensitivity.

3. With reference to larval starvation caused by different leaf extracts, H. vigintioctopunctata was found more susceptible than S. litura or P. ricini.

4. It could thus be concluded from the data that benzene was the best solvent for extracting phytochemicals having antifeedant activity and among the three insects used in the experiments H. vigintioctopunctata was the most sensitive test organism.

5. Among the twenty plants screened for their antifeedant activity against H. vigintioctopunctata, C. infortunatum, A. indica, T. neriifolia and E. odoratum gave higher leaf protection with all the four extractants. N. oleander showed high activity in acetone, benzene and ether extracts but not in water.

6. Benzene and ether extracts of C. infortunatum, A. indica, T. neriifolia and N. olenader had high antifeedant effect against S. litura. In water extract among the above plants N. oleander did not show antifeedant effect while E. odoratum showed activity against S. litura. In acetone extract C. infortunatum, A. indica and T. neriifolia alone showed high antifeedant activity.

7. All extracts of A. indica were found active against P. ricini. Water, benzene and acetone extracts of N. oleander was also effective as an antifeedant against the insect. E. odoratum and T. neriifolia had limited activity. Others were ineffective.

8. Majority of plants selected for antifeedant activity caused high larval starvation also in the test insects. But some extracts of E. odoratum, N. oleander and A. indica which showed high antifeedant activity did not cause larval starvation in all the test insects.

9. A number of plant extracts which failed to show significant antifeedant activity (eg. L. aspera, M. esculenta, L.camara) caused high larval starvation in the test insects. This indicated the presence of some chemicals causing antibiosis or stomach toxicity to the insects which may be an additional factor contributing to the possible control of pest population in the field.

Since essential oils were reported to have some antifeedant effect against insects eight of them which were commonly available in India were screened against the above test insects in the laboratory. Citronella oil 10 and 5 per cent, geranium oil 10 per cent, and camphor oil 10 per cent gave significant protection against P. ricini. The effective dosages identified were too high to suggest further evaluation of the essential oils as antifeedants.

Based on precise bioassay studies, which was adopted for the first time for comparing plant extracts, the five potent plants selected in the screening trial could be ranked in the following descending scale of efficacy (PC 95 level) : N. oleander, A. indica, C. infortunatum, E. odoratum. T. neriifolia.

Based on larval starvation the ranking was N. oleander, C. infortunatum, F. odoratum, T. neriifolia and A. indica. Based on the PC 95 values of different plant extracts the desired concentration of benzene extracts of the five plants for use in field could be assessed as two per cent.

Low persistence in the field is often attributed as a major drawback in using antifeedants as an effective plant protection technology. Hence the persistent toxicity of benzene extracts of the five selected plants and the water extract of T. neriifolia (found highly effective in screening), were assessed adopting standard procedures. The toxicity of all the plant extracts remained high up to 14 days and the effect persisted for 18 to 22 days after treatment. On the basis of PT indices the selected plants could be ranked as follows: T. neriifolia (water extract) N. oleander C. infortunatum F. odoratum A. indica.

The insecticidal effects of the benzene extracts of the selected plants on D. cingulatus, S. litura and A. craccivora were assessed by spraying the test insects under Potter's spraying tower with graded concentrations of the extracts. Mortalities of D. cingulatus and S. litura observed, even with high concentrations (100 per cent) of the extracts, were too low for estimating LC 50 values. Toxicity to A. craccivora was higher. But the LC 50 values of the extracts ranged from 34 to 93 per cent and

with this level of toxicity the possibilities for using the extracts as insecticides in field will be remote.

The systemic action of the plant extracts was studied by feeding the second, third, fourth and fifth instar nymphs of D. cingulatus on cotton seeds sprouted after soaking in graded concentrations of the plant extracts for 12 hours. Results showed that C. infortunatum, A. indica, T. neriifolia and E. odoratum had high systemic action on all the nymphal instars of D. cingulatus and the toxicity was significantly high and in the above descending order. N. oleander did not show systemic action. Fourth instar nymphs were tolerant to the insecticidal action of the extracts than the fifth instar, probably because the hormonal effect of the treatment also would have played its role in fifth instar which is the only receptive stage in the life cycle of the insect for hormonal action.

Insecticidal activity of essential oils on D. cingulatus and S. litura larvae was studied in the laboratory through bio-assay and the results showed that geranium oil, oil of winter-green, patcholi oil and citrodora oil had limited toxicity to the test insects. But the dosages required for desirable levels of kill were too high to indicate any possibility of exploiting the materials as viable insecticides.

All the twenty plants screened for antifeedant activity were screened in the laboratory for their juvenomimetic activity

adopting standard JH assay techniques and using D. cingulatus and S. litura as test insects. Important findings were:

1. Nineteen out of the twenty plants tested caused the prolongation of the post treatment nymphal duration of D. cingulatus with one or more of the extracts used. Only O. sanctum extracts did not show any activity. The adult longevity was prolonged only by the extracts of C. aromaticus and and C. papaya. This prolongation of nymphal and adult durations will increase the possible post treatment damages on the crop but reduce the number of possible generations of the insect, especially with repeated treatment.

2. The mortalities observed on treated nymphs soon after treatment was very low and this indicated the poor contact insecticidal activity of the plant extracts. Death due to the failure of adults in extricating themselves from the exuviae, when moulting from the treated nymphal instar, was common in all extracts and this was an established juvenomimetic effect.

3. Emergence of adultoids, a typical juvenomimetic effect, occurred conspicuously in all the treatments. All the plants screened in the expriment showed this activity in one extract or other.

4. Based on the emergence of normal adults from the nymphs treated with the four extracts of test plants benzene was found

to be the best solvent for extracting phytochemicals showing juvenomimetic activity and it was followed by water. Acetone and ether were on par and less effective. Sterility percentages observed were slightly higher in water extracts than in benzene extract and these were followed by ether and acetone extracts.

5. All the plants except, C. gigantea, O. sanctum, M.viridis and C. aromaticus suppressed the emergence of normal adults in one extract or other. Plants found most promising in benzene and water extracts were T. neriifolia, L. camara, A. indica, N. oleander, E. odoratum and C. infortunatum. The sterility percentages caused by the above plant extracts also were high.

6. Many plant extracts found effective against D.cingulatus were ineffective against S. litura. All the extracts of A.indica and N. oleander, water and acetone extracts of T. neriifolia and V. negundo, benzene and acetone extracts of A. vesica, acetone extract of E. odoratum, ether extract of M. esculenta and C. variegatum can be considered as promising juvenoid sources against S. litura because application of these plant extracts could limit the contribution from the treated insects to the next progeny to the zero level. Changes in pupal duration was negligible. Two types of larval, pupal mosaics were observed in the treatments. Malformed adults of S. litura were obtained only with A. indica.

A precise assessment of the juvenilising effect of acetone and benzene extracts of the selected plants on D. cingulatus was done following the methods of Slama (1974). Based on the juvenilisation ratings of acetone extracts the plants could be ranked as C. infortunatum A. indica T. neriifolia N. oleander and E. odoratum. Based on the juvenilisation ratings of benzene extracts the ranking came as A. indica C. infortunatum N. oleander E. odoratum and T. neriifolia. Juvenilisation rating of the two extracts showed that benzene was more efficient than acetone in extracting juvenoids from plants.

The normal adults/adultoids/supernumerary (sixth instar) nymphs of D. cingulatus emerging from the immature stages treated with plant extracts had typical adult type ovaries with normal ovarioles or nymphal type ovaries in which ovarioles had less differentiated ova. The former mated and laid viable/nonviable eggs while the latter never mated and laid eggs. C. infortunatum showed the highest inhibition of ovarian development and emerging adults did not lay eggs. A. indica also was equally effective. But at the lowest dose of 12.5 per cent concentration emerging adults laid viable eggs. The above plants were followed by E. odoratum, T. neriifolia and N. oleander in their suppressing effects on the ovary.

In the bioassay of the plant extracts using the freshly laid eggs of D. cingulatus it was observed that the hatchability of the eggs was significantly reduced by the treatment. N. oleander extract was most lethal and it was followed by the extracts of C. infortunatum, T. neriifolia, A. indica and E. odoratum.

All the eight essential oils included in the present investigation showed morphogenetic aberrations. Mortality due to moulting inhibition, suppression of normal adult emergence, adult longevity, reduction in fecundity and in the hatchability of eggs and induction of supernumerary nymphs were observed in some of the treatments.

The sterility percentage in citrodora oil 2.5 per cent, geranium oil 2.5 per cent dose and palmarosa oil 5 and 2.5 per cent ranged from 80 to 92 only. In other treatments viable eggs were totally lacking. The results indicated the possibility of using essential oils in plant protection as a component of integrated pest control for limiting pest build up if lower doses of the oils would be effective or when related cheaper oils in this category would prove comparably active. At the dosages tried the treatments may not be economically viable.

In the field experiment benzene extracts of A. indica, C. infortunatum, T. neriifolia, N. oleander and E. odoratum and

water extract of T. neriifolia as 2% emulsions reduced the population of H. vigintioctopunctata, C. insolitus and A. gossypii on brinjal and H. vigintioctopunctata on bittergourd significantly. Up to one week after application all the treatments were on par with the insecticide check carbaryl 0.2 per cent suspension.

The results of the present investigations clearly indicate the possibility of utilising crude extracts of plants locally available in Kerala for the control of crop pests, although not as a sole measure but as a component of the integrated pest control system.

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APPENDICES

Summary of analysis of variance relating to

	Source		df	F ratio: nymphal duration	nymphal mortality up to 5th day	nymphal mortality after 5th day	% normal adults	% adultoids	% sixth instar	longevity of adults	longevity of adultoids
Table 20	Treatments		19								
	Between plant extracts		4	86.82**	9.66**	79.03**	299.98**	65.50**	22.13**	12.13**	46.66**
	Between levels of plant extracts	1	3	75.86**	1.37	16.65**	44.02**	31.64	3.04*	4.46*	25.24**
	,,	2	3	63.49**	0.27	7.95**	8.93**	29.19	2.93*	0.81	102.13**
	,,	3	3	20.79**	0.96	19.88**	49.70**	56.90	0.00	4.65*	10.74**
	,,	4	3	7.43*	0.62	8.04*	3.11*	2.54	0.00	0.45	4.88*
	,,	5	3	88.22**	0.69	8.18**	7.12**	41.63	6.04*	1.75	16.76**
	Error		20								
Table 21	Treatments		19								
	Between plant extracts		4	78.89**	14.93**	176.34**	26.21**	25.00**	41.87**	243.52**	12.72**
	Between levels of plant extracts	1	3	9.01**	18.18**	11.88**	17.76**	5.06**	2.88	154.07**	7.95**
	,,	2	3	4.36*	3.39	19.13**	2.99*	15.85**	0.00	109.96**	5.08**
	,,	3	3	9.05**	11.22**	48.57**	41.36**	2.29*	5.34**	20.84**	2.02
	,,	4	3	9.52**	5.27**	42.35**	6.12**	6.78**	0.00	165.85**	0.79
	,,	5	3	32.73**	10.70**	1.39	11.01**	27.86**	27.82**	113.16**	3.81*
	Error		20								

Source		df	F ratio: Juvenilising rating Table 22	Table 23
Treatments		19		
Between plant extracts		4	179.28**	76.00**
Between levels of plant extracts	1	3	27.63**	3.56*
,,	2	3	6.76*	1.99
,,	3	3	39.62**	17.47**
,,	4	3	7.65*	19.33**
,,	5	3	10.75**	20.88**
Error		20		

* Significant at 5% level

** Significant at 1% level

APPENDIX II

Summary of analysis of covariance relating to

	Source	df	F ratio		
			2 DAS	7 DAS	14 DAS
Table 26	Regression	1	42.62**	2.61NS	0.027NS
	Treatment (adj)	7	45.22**	51.38**	7.29**
	Error (adj)	23			
	Treatment (unadj)	7	14.81**	3.29	9.07**
	Error (unadj)	24			
Table 27	Regression	1	53.04**	5.11*	3.271*
	Treatment (adj)	7	11.78**	2.86*	1.09NS
	Error (adj)	23			
Table 29	Regression	1	28.88**	2.71NS	5.15*
	Treatment (adj)	7	23.76**	10.96**	1.94NS
	Error (adj)	23			
	Treatment (unadj)	7		10.64**	
	Error (unadj)				

Summary of analysis of covariance relating to Table 28

Source	df	F ratio			
		2 DAS	4 DAS	8 DAS	12 DAS
Regression	1	6.20*	2.11NS	5.03*	0.278NS
Treatment (adj)	6	14.54**	14.41**	8.69**	1.77NS
Error (adj)	20				
Treatment (unadj)	6	11.08	14.28**	8.80	2.32
Error (unadj)	21				

* Significant at 5% level ** Significant at 1% level

BIOLOGICAL ACTIVITY OF DIFFERENT PLANT EXTRACTS WITH PARTICULAR REFERENCE TO THEIR INSECTICIDAL, HORMONAL AND ANTIFEEDING ACTIONS

BY

K. SARADAMMA

ABSTRACT OF A THESIS
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DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
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ABSTRACT

Twenty locally available plants were screened for their antifeedant activity against three important crop pests of Kerala using water, acetone, benzene and petroleum ether as extractants. Benzene was, in general, the best extractant and as a test insect H. vigintioctopunctata was more sensitive than S. litura or P. ricini. Among the twenty plants screened all the extracts of C.infortunatum, A. indica, T. neriifolia and E. odoratum and benzene and ether extracts of N. oleander gave high leaf protection against H. vigintioctopunctata. Against S. litura benzene and ether extracts of C. infortunatum, A. indica, T. neriifolia and N. oleander were effective. Water extract of E. odoratum and acetone extract of C. infortunatum, A. indica and T. neriifolia also had high antifeedant activity against S. litura. All extracts of A. indica and water, benzene and acetone extract of N. oleander had antifeedant effect on P. ricini.

High larval starvation was caused by most of the plant extracts which showed antifeedant action. But some extracts ineffective as antifeedant also caused high larval starvation.

Eight essential oils obtained from the country were screened for feeding deterrency against P. ricini. Citronella oil, geranium oil and camphor oil gave significant protection, but the dosages required were too high to indicate possibilities of practical exploitation of essential oils as antifeedants for pest control. Based on PC 95 values worked out through bioassay studies using H. vigintioctopunctat as test insect N. oleander ranked first as antifeedant. It was followed by C. infortunatum, A. indica, T. neriifolia and N.odoratum. Based on larval starvation these plants had different ranking.

water and benzene extracts and above 90 per cent sterility in other two extracts. C. infortunatum and N. oleander caused 100 per cent sterility in acetone, benzene and water extracts.

The juvenomimetic effect on S. litura was much lower than that on D. cingulatus. All the extracts of A. indica and N. oleander, water and acetone extracts of T. neriifolia and V. negundo, benzene and acetone extracts of A. vesica, acetone extract of E. odoratum, ether extract of M. esculenta and C. variegatum caused 100 per cent sterility to the insect and hence the treatment would limit the contribution from the treated insects to the next generation to zero level.

Bioassay studies showed that acetone extracts of C.infortunatum had highest juvenilising effect on D. cingulatus. It was closely followed by A. indica. T. neriifolia, N. oleander and E. odoratum were much less effective than A. indica and C. infortunatum. Benzene extracts were more active than acetone extracts and were ranked as A. indica > C. infortunatum > N. oleander > E. odoratum > T. neriifolia. Considering both the extracts C. infortunatum came on par with A. indica. N. oleander and E. odoratum were also found promising.

The essential oils caused morphogenetic abnormalities in the developing nymphs of D. cingulatus. The dosage at which high sterility could be obtained were too high to ensure economic viability of its use in field. Lower effective dosages, cheaper and comparably effective oils may have to be found out for wide use of essential oils for pest control.

Benzene extracts of A. indica, E. odoratum, C.infortunatum, T. neriifolia and N. oleander and water extracts of T.neriifolia as 2% emulsions reduced the populations of H.vigintioctopunctata C. insolitus and A. gossypii on brinjal and H. vigintioctopunctata on bittergourd significantly in the field experiments. All the treatments (except T. neriifolia against A. gossypii) came on par with the insecticide check, carbaryl 0.2 per cent suspension, in reducing the population. The studies have thus established that the antifeedant and juvenoid effects of five plants screened out from the local flora were as promising as those of A. indica, the well recognised plant source for such activity and the extracts of these plants can be exploited effectively in the integrated control of crop pests.