STUDIES ON THE TOXIC EFFECTS OF PLANT SEED OILS AGAINST THE POTATO TUBER MOTH, *Phthorimaea operculella* ZELLER (GELECHIIDAE : LEPIDOPTERA)

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By

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IN

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To My Parents

Dr. H. Nagaraja

and

Mrs. Ratnamala Nagaraja

Department of Agricultural Entomology
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CERTIFICATE

This is to certify that the thesis entitled **STUDIES ON THE TOXIC EFFECTS OF PLANT SEED OILS AGAINST THE POTATO TUBER MOTH, PHTHORIMAEA OPERCULELLA Zell. (GELECHIIDAE:LEPIDOPTERA)** submitted by Ms.Rama H.N., for the degree of MASTER OF SCIENCE in AGRICULTURAL ENTOMOLOGY of the University of Agricultural Sciences, Bangalore, is a record of bonafide research work done by her during the period of her study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I INTRODUCTION

Potato (*Solanum tuberosum* Linn.) is one of the important and widely grown vegetable crops of the world, which is cultivated both under dry and irrigated conditions. It is a native of South America, later introduced into Europe by early Spanish explorer during the sixteenth century. It was introduced into India in the seventeenth century (Pal and Pushkarnath, 1951).

It is an important source of carbohydrates and is extensively used in various preparations in the daily diet. Potato occupies an area of 20.05 m ha and the total world production 308.56 m tons (Anonymous, 1986). In India it is grown over an area of 0.8 m ha with a production of 106.96 m tons. In Karnataka, potato is grown over an area of 11,474 ha with a production of 81,769 tons (Anonymous, 1985-86).

Potato, an important crop of great nutritive and commercial value is subjected to attack by a number of insect pests from seedling stage to harvest and storage. The most devastative of the pests is the potato tuber moth, *Phthorimaea operculella* Zell. (Lepidoptera: Gelechiidae). The control of this pest is mandatory, more so because its attack starts in the field and assumes serious proportions on stored potatoes. It is reported to cause 30 to 70 per cent loss in the country stores in India (Nirula, 1960 and Lall, 1964).

In Karnataka, Belgaum and Hassan are endemic areas and the damage at harvest ranges from 0-65% and 0-25%, respectively (Trivedi, 1988). Trivedi (1987) reported that potato tuber moth is the major pest prevalent in Bangalore, Kolar, Chickmagalur, and Belgaum.

Frequently, chemical insecticides are used for the control of the pest. However, toxic insecticidal approach, especially on potato being a readily consumable produce, is limited due to its various drawbacks. Therefore there has been an increasing need to look for better and environmentally safer methods of control.

In the recent past plant products have been identified as one of the novel approaches in this direction. They are cheap and easily available, not known to leave toxic residues *in the ecosystem, harmless to natural enemies and also* phytotoxicity and resurgence problems are not known with plant products.

Plant seed oils have been reported to be possessing insecticidal, antifeedant, repellent and sterility properties. Practically no information is available in literature with regard to the use or effect of plant seed oils against potato tuber moth. In the present studies an attempt has been made to elucidate information on the above properties with the following objectives:

1) To determine the effect of candidate seed oils on the different stages of the potato tuber moth.

2) To determine the best concentration for the effective management of different stages of insect.

3) To determine reproductive inhibitory effect of candidate oil against the test insect.

4) To determine the toxic effects, if any, on the natural enemies.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

Literature reviewed on the use of plant products in pest control, the potato tuber moth: its life history, nature of damage on the host plants, it's chemical control, etc, are presented under the following two broad categories:

2.1 Work done on potato tuber moth.

2.2 Work done on the use of plant products.

2.1 Work done on potato tuber moth

2.1.1 Life history

Mukherjee (1949) reported that the life cycle of potato tuber moth takes 17-24 days in summer and 25-40 days in winter. The incubation period was 2-4 days in summer and 6-11 days in winter.

Gubbiah and Thontadarya (1977) reported that a female, on an average laid 72.5 eggs. The incubation period was 5 days and the larval period was 19.6 days. The larvae had four instars. The adults emerged 8.5 days after pupation. The pre-oviposition, oviposition and post-oviposition periods lasted 1-5.5, 4-7 and 1-2 days, respectively. The authors were able to rear 13 generations of the potato tuber moth in a year in the laboratory.

Singh and Charles (1977) reported that potato tuber moth when reared on an artificial diet took 23 days to complete one generation as compared with 18.5 days on potato tubers.

2.1.2 Nature of damage

Akhade et al. (1970) reported that the female moth lays eggs on the dorsal side of the leaflet of the growing plant. On hatching, the larvae become leaf miners. The partially grown leaf miners thereafter descend to the tubers borne near the soil surface, and start untunnelling them. The fully grown larvae come out of the tubers and pupate. Late in the season, at maturity, the moths lay eggs directly on the partially exposed tubers in or around the eyes. The tubers thus infested later go to the stores.

2.1.3 Alternate hosts

Phthorimaea operculella is primarily a serious pest on potato; however, a number of other plant species are also known to be attacked by this pest.

Among the wild plants *Datura stramonium* has been known to be attacked by potato tuber moth (Broodyrk, 1971; Meisner *et al*., 1974).

Leaves of egg plant (*Solanum melongena*) were recorded to have been accepted by potato tuber moth for egg laying (Fenemore, 1980).

Gubbiah (1971) reported that tobacco is also preferred by the insect. The larvae were observed to feed on the leaves of tobacco (*Nicotiana tabaccum*), brinjal (*Solanum melongena*), tomato (*Lycopersicum esculentum*) and on a solanaceous weed, *Solanum indicum* as a leaf miner and also as a fruit borer of brinjal and tomato.

2.1.4 Use of plant products against *Phthorimaea operculella*

An oil derived from garlic and the synthetic oil diallyl disulfide were found to have insecticidal properties when tested against various insects including potato tuber moth (Murthy and Amonkar, 1974).

Pandey *et al*. (1982) tested the effects of extracts of the seeds of *Ocimum basilium*, rhizomes of *Acorus calamus* against the larvae of *Phthorimaea operculella*. At 2% concentration, the extracts were found to cause mortality of 44.07% and 42.54%, respectively.

Shelke *et al*. (1985) conducted laboratory trials using seven vegetable oils and extracts with respect to their ovipositional deterrent properties against potato tuber moth. Of the oils and extracts used, neem oil at 0.05% and 0.1% levels, and mohwa, karanj (Pongamia glabra), ratnajothi oils and dodi leaf extract at 0.1% level recorded high ovipositional deterrence (91.96 to 100 per cent).

Lal (1987) conducted studies on natural repellents against potato tuber moth. The effect of the leaves of Ambrosia artemisiifolia, Anemone elongata, Eupatorium odoratum, Eucalyptus globulus and Lantana aculeata was investigated. Of the above plant species, Lantana aculeata, it was reported, gave the maximum protection to the tubers, reducing damage to below 5% and sprout damage to below 3%, compared with 70% and 45%, respectively in the untreated control, the next most effective treatment being Eucalyptus globulus.

Extensive research was carried out by Raman et al. (1987) on the control of potato tuber moth using dried foliage of Eucalyptus globulus, Lantana camara and Minthostachys sp. - both in dried-and-shredded and powdered form. Both the forms were found to be effective in controlling the damage to potatoes stored for four months.

2.1.5 Chemical control of potato tuber moth

Asher *et al*. (1970) conducted experiments to find out the effect of 2 organotins, TD-5032 and Plictran, their role as antifeedants against potato tuber moth. They observed that the larvae of *P. operculella* were effectively deterred from entering the leaves of egg plant that had been dipped in TD-5032. But, they reported that this compound appeared to be poorly translocated through the petioles of egg plant leaves and when used in this manner, its deterrent effect was less marked.

Assem and El-Nahal (1970) conducted field plot tests in Egypt on the control of the larvae of *P. operculella* on tomato and egg plant. Based on the percentage of infested leaves and fruits, the number of larvae, and the yield, they concluded that 0.4% sprays of wettable carbaryl powder (Sevin) gave the best control on both crops.

Akhade *et al*. (1970) tried 3 insecticides, chlordane, heptachlor and DDT against potato tuber moth. Dusts of 5% chlordane or haptachlor were applied to the soil at 75 kg per hectare with or without a later spray of DDT. At harvest it was found that in most cases the percentage of uninfested tubers was lower than for no treatment and it was concluded that none of these chemicals afforded protection against the tuber moth.

Singh (1970) suggested that potatoes kept for seed purpose may be treated with 0.05% malathion. In case of field infestation spraying with 0.05% malathion afforded good control.

Abdel-Salam and Assem (1972) evaluated six insecticidal formulations in Egypt for the control of P. operculella in stored potatoes and in the field. It was found that dusting the tubers in storage with malathion 1% dust or carbaryl 10% dust at the rate of 1 kg per ton of tubers gave effective protection from attack. In the field, a spray of carbaryl 85% WP at 0.4% or azinphos-methyl (Guthion) 50% WP at 0.2% were the most effective of the insecticides tested, causing 93.3% and 86.7% mortality, respectively.

Dethe and Naik (1975) evaluated the effectiveness of soil application of dust of insecticides for the control of the larvae of P. operculella just prior to pupation. Chlordane 10%, BHC 5%, lindane 0.06%, malathion 5%, carbaryl 10%, DDT 5%, heptachlor 6% and parathion 2% were used. Of the seven,chlordane, BHC, lindane, malathion, all at the rate of 2 kg toxicant per hectare were found to be the most effective treatments, the per cent pupation was found to be

8.75, 15.00, 15.00 and 12.50, respectively as against 96.25% in the untreated plot.

In Karnataka experiments were conducted by Gubbiah and Thontadarya (1975) with respect to the control of potato tuber moth in stores and in the field. They reported that foliar sprays containing 0.03% phosphamidon applied three times at 10- day intervals starting 50 days after planting was the most effective, the corresponding leaf damage being only 2.15%. Storage of health tubers in gunny bags treated with 50% EC of malathion at 0.5 per cent protected tubers from attack for 30 days.

Butani and Verma (1976) reported that in case of field infestations, 2-3 fortnightly sprayings with 0.2% carbaryl at the rate of 800 litres per hectare controls the pest.

In the laboratory, Foot (1976) tested five insecticides against various stages in the life history of Phthorimaea operculella. Of the insecticides tested azinphos-ethyl was found to be superior as an ovicide and larvicide but was reported to give poor results against adults. Endosulfan and acephate were reportedly effective against the adults.

Laboratory tests of insecticides used to dip pieces of potato showed that Phthorimaea operculella was susceptible to monocrotophos, diazinon and pirimphos-methyl (Actellic) and also to Thuricide-HP. The LC_{50}'s of the chemicals were reported to be 0.0096%, 0.029% and 0.087%, respectively (Ali, 1978).

Mahajan _et al_. (1978) conducted field experiments in order to try the efficacy of twelve insecticides. Of them, azinphos 0.03% gave significant reduction of foliage infestation and was on par with malathion, parathion at 0.05% and isobenzan at 0.03% concentrations with corresponding infestation levels of 9.00%, 13.67%, 13.00% and 15.67%, respectively as against 69.67% in control.

Awate and Naik (1979) concluded that the dust application of parathion and carbaryl to soil at the rate of 2 kg a.i. per hectate were effective wherein the tuber infestation was found to be 17.61% and 20.71%, respectively, as against a tuber infestation level of 61.73% in the control.

Collantes _et al_. (1986) evaluated the toxicity of six synthetic pyrethroids, permethrin, cypermethrin, flucythrinate, fenvalerate, cyfluthrin and deltamethrin to 2 populations of _P. operculella_. Deltamethrin was reported to be the most toxic at an LC_{50} of 120 and 133 µg/ml for males and females, respectively, for one of the populations, and 130 and 137 µg/ml, respectively for the other. Fenvalerate was found to be the least toxic and the other four insecticides were found to be intermediate in toxicity.

Field plot tests were conducted in Peru by Raman and Palacois (1986) to assess the effectiveness of foliar or soil treatments with various insecticides for the control of potato tuber moth. They opined that, of the foliar treatments, sprays of methomyl applied at the rate of 1.08 kg a.i. per hectare of chlorofenvinphos at 0.38 kg provided good control. They have further reported that compared to foliar treatments, the soil treatments generally gave inadequate protection.

2.2 Work done on the use of plant products

Plant products have been occupying the fore in the formulation of futuristic designs for progressive and scientific plant protection for almost a couple of decades. Plants are natural nutritional, protective and developmental substrates for many insects, among these are chemicals, usually in minuscle quantities which have definite effects on behaviour, physiology or development of some insects (Sharma, 1985).

It has been reiterated that one of the major advantages of plant products is that they are amenable to cottage or small scale level production, especially if crude extracts, or at least, enriched fractions are used (Sharma, 1983). The 'profits' in case of the plant extractives may be small in economic terms but would be huge in sociological and ecological terms and would accrue largely to the weaker sections.

The plant kingdom is a vast storehouse of chemicals. These natural products are isolated from plants and tested for their insect-controlling properties viz., repellent, antifeedant, hormonal and insecticidal activity (Rajasekaran and Kumaraswami, 1985). The search for botanical compounds will help to lessen the dependence on synthetic insecticides.

In this section, literature has been reviewed on the use of several products of neem, pongamia, argemone, mahagony and cashew.

2.2.1 Work done for the past two decades in the use of products of neem(*Azadirachta indica*) and karanj (*Pongamia glabra*) is being briefly reviewed:

Powdered neem seed kernel when applied to wheat seeds at the rate of 1 to 2 parts per 100 parts of seed were reported to offer protection against the storage pests, *Sitophilus oryzae*, *Rhizopertha dominica* and *Trogoderma granarium* for at least about 269, 321 and 379 days, respectively (Jotwani and Sircar, 1965).

Jotwani and Sircar (1967) have reported that application of powdered neem seed kernel when mixed with the seeds of mung, bengal gram, cowpea and peas at the rate of 1 to 2 parts per 100 parts of grain, the damage by the bruchid, *Callosobruchus maculatus* was prevented for about 8,11,9 and 9 months, respectively.

Joshi and Rai (1968) have reported that *Pongamia glabra* is known for its insecticidal and piscicidal properties. Its effect was tested against tobacco ground beetles. The cake was powdered and mixed with fine sand and applied at the base of the plant two days after planting at the rate of 1 gram, 5 grams, and 10 grams per plant. It was found to be very effective in killing the beetles thereby protecting the young transplants. A dosage as low as 1 gram per plant was toxic to the beetles. The authors have quoted that pongamia cake is completely indigenous and has distinct advantage over chlorinated hydrocarbons like dieldrin and aldrin which are the common soil insecticides in use, because it is very safe and does away with the problem of accumulation of harmful residues in the soil.

It has been reported by Ascher (1970) that 0.1% suspension of neem revealed good antifeedant effect against locusts. It is claimed that the protectant efficacy of the spray persisted on foliage for two weeks. In the U.S.A., fruit and leaf extracts of neem were treated as antifeedants and insect growth retardents. It has been reported that fruit extracts were only phagostimulatory to the larvae of corn earworm, whereas, leaf extracts offered phagostimulatory effect on the larvae of tobacco budworm.

Deshmukh and Borle (1976) evaluated the insecticidial activity of suspensions and extracts of parts of twenty plants to the larvae of Spodoptera litura and the adults of Dactynotus carathemi. They reported that the seeds of Croton tiglium, roots of Aconitum ferox, flowers of Spilanthes acmela and the seeds of Embelia ribes, and absolute alcohol extracts of the seeds of Annona squamosa and Pongamia glabra were found to be 0.103, 0.125, 0.096, 0.033, 0.064, 0.064 and 0.023 times as toxic as nicotine sulfate to Dactynotus carathemi.

Application of 1 to 3 parts of neem oil to 100 parts of gram reportedly gave efffective control against the bruchid, Callosobruchus chinensis for at least 135 days (Pandey et al., 1976).

Nigam (1977) tried the cakes of eight different plants known to have insecticidal properties. The type of cake most effective in keeping the white grub populations low was that made with karanj (Pongamia glabra), followed by those made with neem, mustard or linseed.

Parmar (1977) compared the seed oil of Pongamia glabra with piperonyl butoxide and sesame oil with respect of synergistic activities when used with pyrethrins. In tests against Musca domestica L. in the laboratary, preparations of pyrethrins and synergistis at 1:4, 1:8 and 1:12, pongamia oil was 0.72, 0.72 and 0.70 times as potent, respectively, as piperonyl butoxide. Sesame oil, however, was found to be better than pongamia oil when used as a synergist. The author also reported that the oil was as effective as piperonyl butoxide as a synergist for pyrethrins against Periplanata americana and was less effective than piperonyl butoxide or sesame oil as a synergist for pyrethrins against Triboleum castaneum (Hbst.).

Sangappa (1977) has reported that the oil of Pongamia glabra could be used as a protectant of red gram against the bruchid, Callosobruchus chinensis. When red gram seeds were treated with honge (P. glabra) oil at 1.0%, there was no insect emergence from the treated seeds upto a period of 319 days and the adult emergence was quite low even after 375 days (12.00 adults as against 48.60 adults in control).

'Neem oil extractive', a waste from neem oil refinery, was found to be an effective mosquito larvicide, causing complete failure of the first instar larvae of Culex fatigans to emerge successfully as adults at 0.005% concentration. A concentration of 0.04% resulted in 100% mortality of larvae after 7 days, whereas, a higher concentration of 0.04% caused a 100% mortality of the larvae within 24 hours (Attri and Prasad, 1980).

Devi and Mohandas (1982) discovered that neem oil at 1.0% and neem extract at 0.5% mixed with paddy (unhusked rice) grains gave a good control of Rhizopertha dominica (with infestation of 17.75% and 15.40%, respectively), and of Sitotroga cerealella (with infestation of 13.8% and 14.46%, respectively).

Mariappan et al. (1982) have reported that treatment of rice seedlings with oil extracted from neem significantly reduced the life span of samples of Nephotettix virescens carrying rice tungro virus. When neem and custard apple oils were applied at 50% concentration, 2.5% of the insects and 0%, respectively, survived as against 86.5% in the control. Both the oils at 5% concentration were found to significantly reduce rice tungro virus infections.

Ali *et al*. (1983) conducted an experiment to find out the effects of neem oil against the eggs, grubs and adults of the pulse beetle, *Callosobruchus chinensis*. At 0.5 ml oil per 100 gram of seed the egg mortality was 100%. A 100% mortality of the grubs and adults of the beetle was recorded when the oil was mixed at 1 ml per 100 gram (*Cicer arietinum*) seed.

Chiu *et al*. (1983) showed that the seed oil of neem had strong antifeedant effects on the nymphs of the rice brown plant hopper, *Nilaparvatha lugens*. The median antifeedant concentrations (AFC_{50}) of the oil for 2nd and 3rd instar nymphs were reported to be 0.518%. They also have reported that neem seed exhibited moderate systemic properties in rice plants and contact insecticidal activity against the plant hopper.

Mariappan and Saxena (1983) demonstrated that neem oil caused significant mortality of *Nephotettix virescens* and also affected the transmission of rice tungro virus (RTV). The survival was about 2.5% at concentrations of 30% and 50% by the second day, and by the third day, insect survival was found to be near zero. After 2 days, it was reported that the percentage of RTV infection was very less (13.6%) when compared to control (35.5%) even at the concentration of 5% neem oil. Increase in oil concentration resulted in a corresponding increase in insect mortality and decrease in RTV transmission. The cicadellid failed to transmit RTV to oil-sprayed plants beyond 3 days of exposure. Similar results have been reported by Saxena et al. (1985).

Neem oil when applied at 8 ml per kg of cowpea, good protection against Callosobruchus maculatus was afforded for 3 months. When applied at 8 ml per kg of seed, there was reduced oviposition (39.2% as against 100% in control). The per cent egg hatch (13.2% Vs. 88.4% in control) and adult emergence (3.8% Vs. 93.3% in control) were also reduced (Periera, 1983).

Methanolic cold seed extract of neem was reported to produce a delay in the growth and development of the rice ear-cutting caterpillar, Mythimna separata and the emerging moths showed varying degrees of wing deformities. When the rice leaf-folder, Cnaphalocrosis medinalis was treated with the extract, the larvae showed symptoms of paralysis of thoracic legs and prolegs, followed by a gradual blackening of the body and eventual death (Schmutterer et al., 1983).

The oil of neem when mixed at 5 ml per kg of stored rice inhibited the population growth of weevils, Sitophilus oryzae and S. zeamais by about 90% (Zhang and Zhao, 1983).

Naik and Dumbre (1984) studied the effect of a few edible and non-edible oils as surface protectants on the biology of the pulse beetle, Callosobruchus maculatus, some of the oils being neem, castor, karanj, ground nut, coconut, etc. Neem and karanj oils were found to inhibit adult emergence at 0.5% level and above, wherein, the adult emergence was zero per cent. The number of eggs laid was found to decline progressively with increase in dosage. The largest reduction in egg laying was noticed with neem oil extractive at 1% when only 46 eggs were found being laid on 40 seeds as against 92 eggs in control. When the effect of oils on the hatching of eggs was recorded, application of neem oil at 1.0% was found to produce only 20% hatching.

El-Sayed (1985) reported that neem seed was a powerful antifeedant and ovipositional repellent for the Egyptian cotton leaf-worm, Spodoptera littoralis. The number of eggs laid in the laboratory by the females of S. littoralis on leaves that had been treated with a 2% suspension of the ground seeds of neem were less than half the number laid in untreated leaves. The amount of untreated food consumed by the fourth instar larvae was about 7.2 times that of the food that had been treated with a 1% suspension. When the adults were exposed to a 2% suspension in their feedling solution, it was reported that only 5.6% of the eggs they laid hatched.

When the larvae of the Europen corn borer Ostrinia nubilalis were treated with aqueous neem seed kernel extract there was complete absence of pupation even at 0.25% extract (Meisner et al., 1985).

Conducting studies on the effect of vegetable oils on the storability and qualitities of cowpea against pulse beetle, Callosobruchus maculatus, Naik and Dumbre (1985) reported that neem oil gave complete protection at 0.75% and 1.00% levels, upto 150 days after application while karanj oil did so at 1.00% level.

The reproductive potential (as expressed in terms of egg yield and egg viability) in case of the rice moth, Corcyra cephalonica was found to be significantly lowered when the pest was exposed to the vapours of neem oil emanating from 160 µl of the oil (Pathak and Krishna, 1985).

Rajasekaran and Kumaraswami (1985) tested the oil of Pongamia glabra for its feeding inhibitory activity against the larvae of Spodoptera litura. The oil was found to be effective at 3% concentration in which leaf consumption was reduced to an extent of 33%.

Neem oil was reported to change the feeding behaviour in the green leaf hopper, Nephotettix virescens. Phloem feeding by the intsect on plants sprayed with neem oil at 1.25%

2.50%, 5.00% and 10.00% concentrations was significantly reduced. It was further reported that the ingestion period on neem oil treated plants was significantly less than that of control plants (Saxena and Khan, 1985a).

Saxena and Khan (1985b) opined that neem seed oil was highly effective in reducing the survival of Nilaparvatha lugens and the transmission of grassy stunt and ragged stunt viruses. They reported that insect survival and disease transmission decreased with increasing concentrations on neem oil.

Shelke et al. (1985) reported that pongamia oil at 0.10% showed high ovipositional deterrence against the potato tuber moth, Phthorimaea operculella. At the concentration of 0.10%, the oil of pongamia was found to produce an oviposition deterrence to the extent of 76.00%.

Singh et al. (1985) conducted field trials by using neem seed kernel extracts against the pod borers of pigeon pea, Cajanus cajan. Use of 10% neem oil was found to be effective against the podfly, Melanagromyza obtusa wherein the damage was 2.94% as compared to 4.76% in the control. Two per cent ethanolic extract of neem seed kernel was the most effective treatment in which case, the damage was found to be 2.23% by the pod fly and 7.20% by the lepidopterous borers when compared to the control wherein the damage was reported to be 4.76% and 22.11%, respectively. The extract however was found to offer less protection when compared with fenvalerate.

Hellpap and Mercado (1986) conducted laboratory experiments to study the effect of seed kernel extracts on the oviposition behaviour of *Spodoptera frugiperda*. Egg laying by the females was found to be about 50% lower on the neem-treated cloth under normal laboratory conditions.

Pathak and Krishna (1986) subjected the adults of the spotted bollworm, *Earias fabia* to the vapours of the oil expelled from the seeds of the neem tree and studied the reproductive efficiency. It was found that there was a reduction in reproduction.

2.2.2 Potential use of *Argemone mexicana*

Trehan (1956) has reported that 'dharek' (*Melia azedarach*), 'satyanasi' (*Argemone mexicana*) and sweetflag (*Acorus calamus*) exhibited promising insecticidal properties against the larvae of *Pieris brassicae* L. and the adults of *Aulacophora fovicollis*, *Bagrada picta* and *Lipaphis erysimi*.

Petroleum ether extracts of the leaves and seeds of *Argemone mexicana* were tested in laboratory and field experiments for insecticidal activity against the painted bug, Bagrada hilarius (Burm.) (Pandey et al., 1981). The seed extract at 2.00% caused 93.33% mortality after 24 hours in the laboratory and after 72 hours in the field while the leaf extract of this plant at 2.00% caused 86.66% mortality in the laboratory after 24 hours and 56.66% mortality in the field after 72 hours.

2.2.3 Work done on the use of products of cashew (Anacardium occidentale)

Gopalan and Madhusudan (1968) reported that cashew caused high mortality of the larvae of Spodoptera litura. Cashew shell oil when applied at 350 µg per larvae caused about 75.10% death in S. litura.

Ahmed and Gupta (1976) reported that cashew shell oil enhanced the activity of pyrethrins.

Bose and Biswas (1985) analysed the chemical constituents of the gum exudate of cashew and showed that it contains D-galactose, L-arabinose, D-galacturonic acid and L-rhamnose. They further opined that the gum is extensively used in book binding due to its insecticidal and adhesive properties.

2.2.4 Use of *Swietenia mahagoni*

Rajasekaran and Kumaraswami (1985) tested extracts from mahagony, jacaq seeds, rhizomes of *Sanseveria marginata*, fruits of *Solanum* sp. and *Acacia dealbata*, leaves of *Pogostemmon* sp., whole plant of *Andrographis paniculata* as antifeedants against *Spodoptera*. Among them, mahagony seed extract and extract of *A. paniculata* were found to be quite promising.

Much of the work on plant products has been focussed on neem and, to a certain extent on pongamia. Very little attention has been paid on those plant species namely, *Argemone mexicana*, *Leucaena leucocephala*, *Swietenia mahagoni* and *Anacardium occidentale*, which are being tested presently, which possess properties of repellence, antifeedancy, reproduction inhibition, growth retardation, etc.

These call for needed attention in future.

MATERIAL AND METHODS

III MATERIAL AND METHODS

The techniques and methodologies adopted for conducting the various experiments as setforth in the objectives of the studies are presented under the following heads:

3.1 Rearing of potato tuber moth under controlled conditions (laboratory).

3.2 Extraction of oils from the test plant species.

3.3 Studies on the toxic effects of plant oils in the test insect.

3.4 Effect of plant seed oils on the parasite of potato tuber moth.

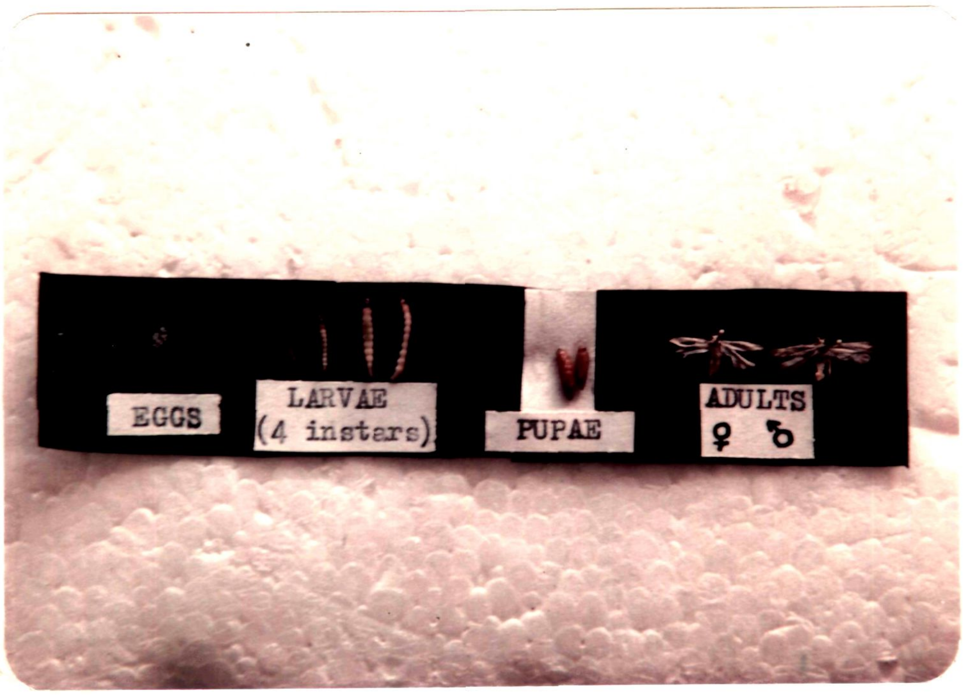
3.5 Statistical analysis of the results.

3.1 Rearing of potato tuber moth, *Phthorimaea operculella*

The nucleus culture of potato tuber moth was obtained from the Central Biological Control Station (CBCS), (Directorate of Plant Protection and Quarantine, Govt. of India, Faridabad), Ganganagar, Bangalore - 560 032.

Plate 1 Potato tuber moth: Different stages of development

Plate 2 Infested potato tubers: Damage by potato tuber moth


EGGS
LARVAE
(4 instars)
PUPAE
ADULTS
♀ ♂

Rearing was done in two types of cages:

a) Infestation cages: Each cage consisted of a plastic tub, measuring 12" diameter x 4" height. The mouth of the tub was covered with a muslin cloth secured by means of a lid having two big holes for aeration (Plate 3).

b) Emergence cages: Each was a wooden cage, the walls of which were lined with wire mesh or glass. The bottom of the cage was nailed to support the potatoes (Plate 4). A layer of sterilised sand (2-3 cms) was placed at the base for pupation.

Before infestation the potatoes were washed to remove mud and other extraenous matter and dried. The dried tubers were perforated using a nail brush (Plate 5) and were again dried.

The perforated tubers were placed in infestation cages and the egg sheet (a piece of muslin cloth on which the moths have laid the eggs) was spread on them. After about a fortnight when the eggs had hatched and the larvae had bored inside the tubers, the potatoes were removed and were placed in the emergence cages. The larvae came out of the tubers and most of them fell on the sand for pupation. After about 10 days the adults emerged.

Plate 3 Infestation cage

Plate 4 Emergence cage

The emerging adults were collected from the emergence cages and transferred to egg-laying chamber (Plate 6).

The oviposition chamber consisted of a cylindrical transparent plastic container (6 1/2" long and 5" diameter). The base of the plastic jar was cut out. Both the openings were covered by 2 layers of muslin cloth secured with a rubber band. Ten per cent honey solution was provided as food.

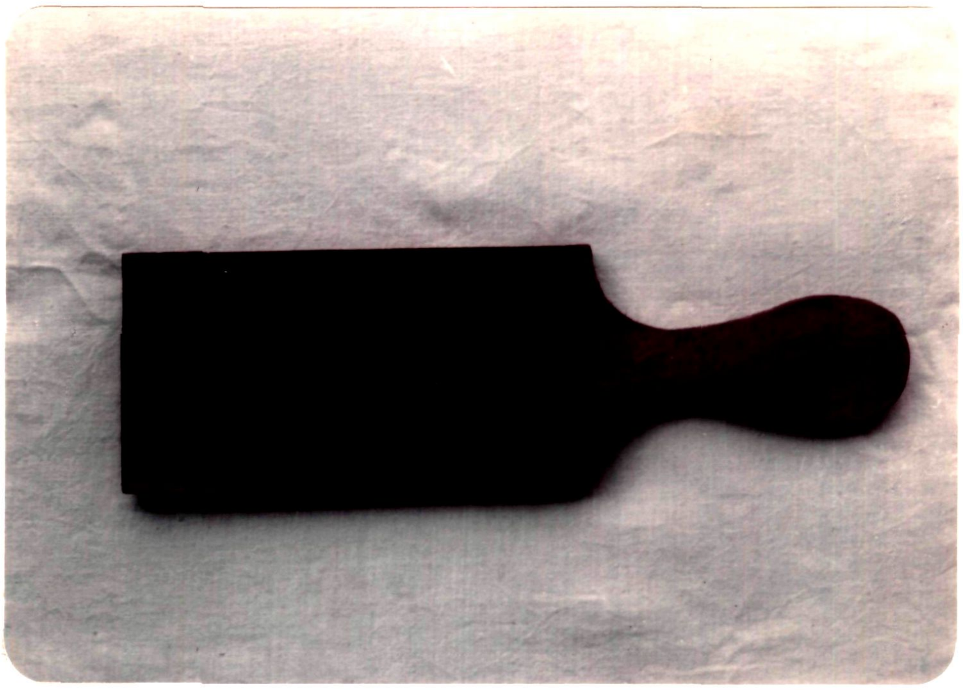
After 48 hours, the muslin cloth on which the eggs were laid was removed and the jars were covered with fresh pieces of cloth. The egg sheet was again spread on perforated tubers for infestation.

3.2 Extraction of oils

The plant species used for the present study are presented in Table 1 (Plate 9).

Plate 5 Nail brush: To perforate potato tubers

Plate 6 Oviposition chamber



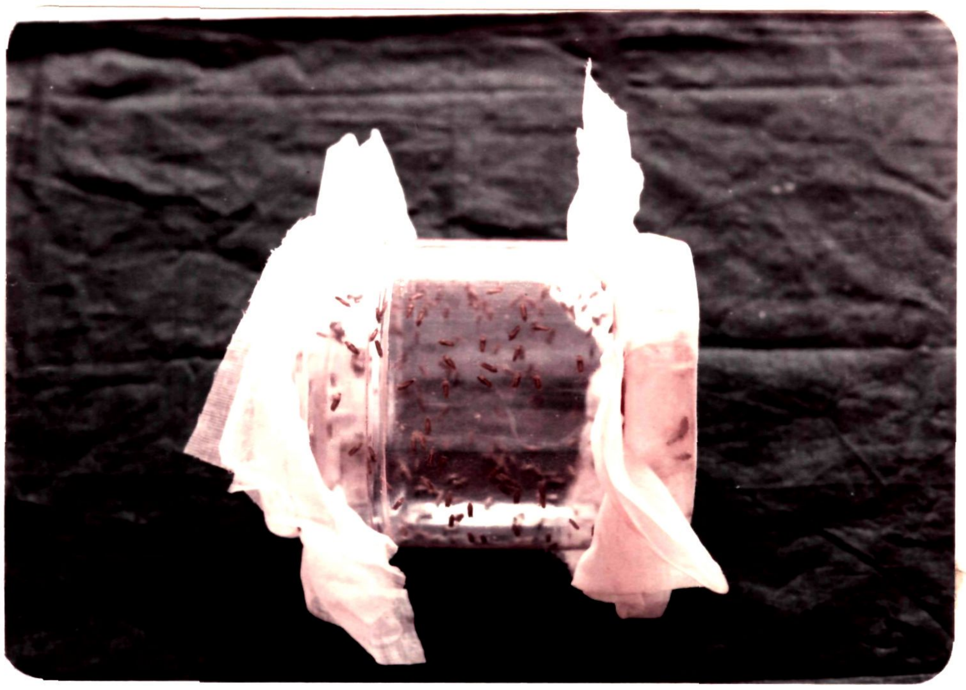


Plate 7 Rearing of potato tuber moth

Plate 8 Mass rearing of potato tuber moth (over all view)

Plate 9 Seeds of the plant species used for study

(1) *Anacardium occidentale* Linn.
(2) *Argemone mexicana* Linn.
(3) *Azadirachta indica* Juss.
(4) *Leucaena leucocephala* Benth.
(5) *Pongamia glabra* Vent.
(6) *Swietenia mahagoni* Linn.

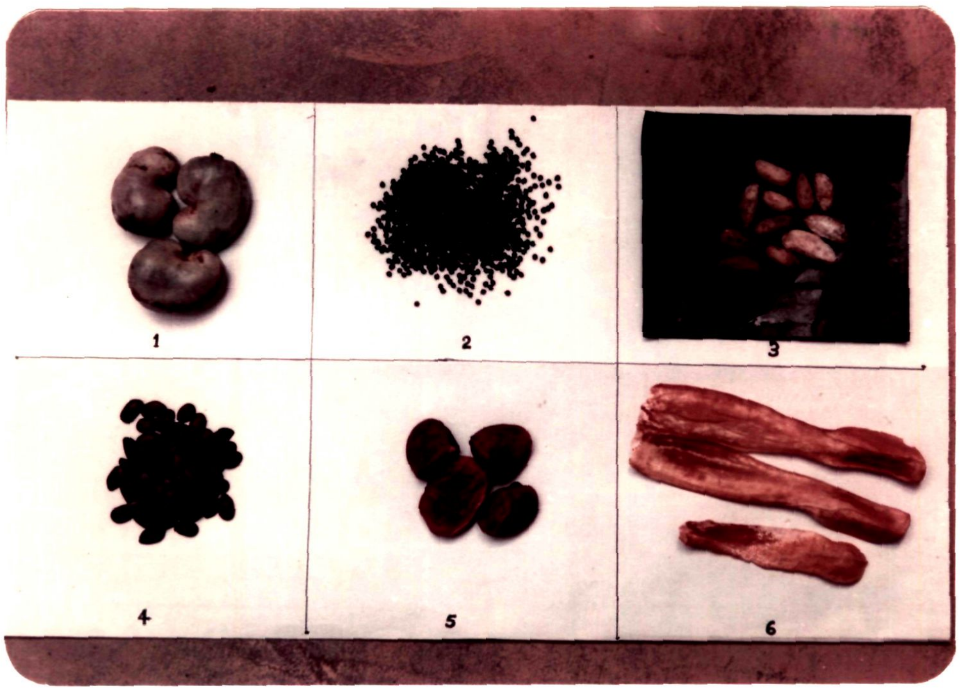

1
2
3
4
5
6

Table 1. List of the plant species whose seed oils were extracted.

Sl. no.	Plant species	Family
1.	*Anacardium occidentale* Linn.: Cashew (shell)	Anacardiaceae
2.	*Argemone mexicana* Linn.: (seeds)	Papaveraceae
3.	*Azadirachta indica* Juss: Neem (seeds)	Meliaceae
4.	*Leucaena leucocephala* Benth.:Soobabul (seeds)	Leguminosae
5.	*Pongamia glabra* Vent.: Pongamia (seeds)	Leguminosae
6.	*Swietenia mahagoni* Linn.: Mahagony (seeds)	Meliaceae

Cashew shell oil was obtained from a local oilmill in Bangalore. Neem seed oil was obtained from Mr. Ketkar, 471, Shaniwar Peth, Pune- 411030. The seeds of the other four plant species were bought from the local shops in Bangalore. The seeds were dried in a hot air oven at 95^{o}C for 24 hours. The dried seeds were ground into a fine powder using a waring blender. The oil extraction was made from the powdered seeds using Soxhlet apparatus (Plate 10).

The Soxhlet apparatus is a device used for extracting a soluble part of substance by running a boiling solvent through it. It consists of three parts: a round bottomed container at the base, a long cylindrical container above it

Plate 10 Soxhlet apparatus: Extraction of plant seed oils

Plate 11 Distillation : Recovery of petroleum ether from the oils

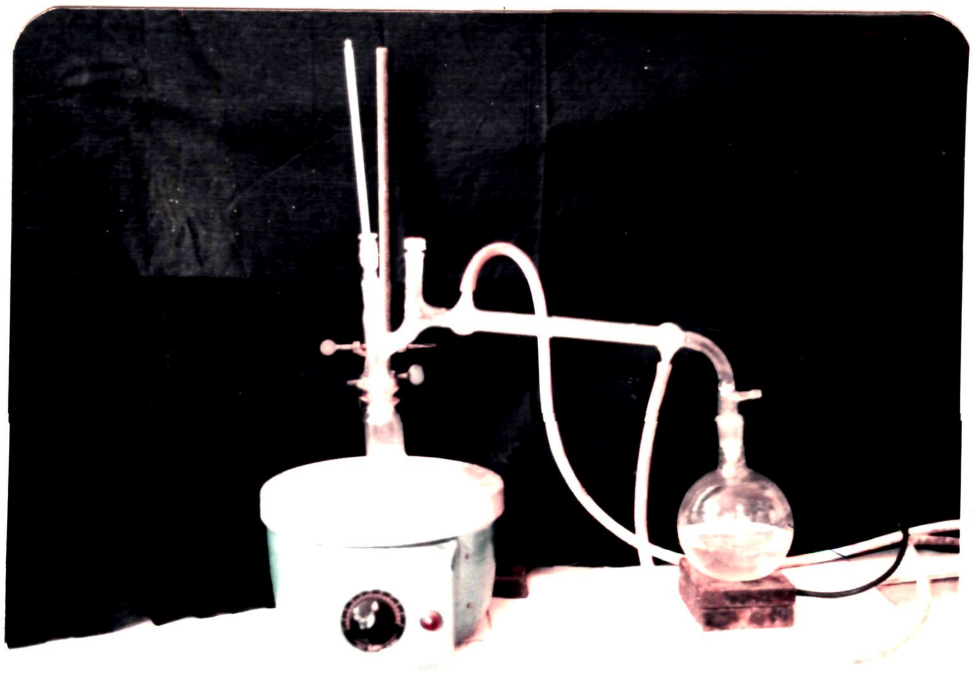


Plate 12 Potter's Tower: Determination of LC_{50} values

and a condenser to condense the vapours of the boiling solvent to a liquid form.

The solvent used was petroleum ether (BP 40-60^{o}C). About 1.5 litres of petroleum ether was taken in the basal unit. The seed powder was filled in a cotton bag (7" long and 2" wide) and the mouth of the bag was closed tightly. The entire apparatus was placed on a heating mantle and the temperature was adjusted to 40^{o}C. At this temperature the solvent boils and becomes vapour. The vapours of the solvent rise up and get condensed to liquid by the condenser. As the vapours cool down, the liquid drops fall on the bag of seed powder. From the seeds the soluble part gets dissolved in the solvent and the solvent becomes turbid, sometimes the colour of the solvent changes. This solvent which collects in the middle unit gets cycled back into the basal unit. In this manner, petroleum ether is cycled and recycled till the solvent becomes clear as before indicating the completion of extraction. Thus, the solvent with the oil portion of the seed gets collected in the basal unit. It was then taken in a distillation apparatus (Plate 11). By distillation petroleum ether was recovered and the oil was separated.

3.3 Studies on the toxic effect of oils

The oils were tested against all the four stages of potato tuber moth. In all the experiments each oil was sprayed at five different concentrations. Each treatment was replicated four times. Malathion 50 EC (Cythion) at 0.50% was taken as a standard for comparison with the respective plant seed oils.

3.3.1 Studies on the ovicidal action of the oils

A 0.10% emulsified water was prepared using Labolene as the emulsifier. A 5.00% benzene solution was prepared using emulsified water as the diluent. This mixture was used to prepare various concentrations of the oils. Two controls were used:

1) a mixture of emulsified water and benzene, and
2) distilled water.

Each oil was tried at five different concentrations given in Table 2.

Table 2. Concentrations of plant seed oils to study their ovicidal effect

Oil	Treatment (%) concentrations				
	T_1	T_2	T_3	T_4	T_5
Argemone	2.00	3.00	4.00	5.00	6.00
Cashew shell	0.25	0.50	0.75	1.00	1.25
Mahagony	0.50	1.00	1.50	2.00	2.50
Neem	0.25	0.50	0.75	1.00	1.25
Pongamia	2.00	3.00	4.00	5.00	6.00
Soobabul	2.00	3.00	4.00	5.00	6.00

3.3.1.2 Procedure of the experiment to test the ovicidal action of the oils

Discs of tissue paper (4" diameter) were taken and each was placed in a petri plate (4" diameter). 20 freshly laid eggs of potato tuber moth were placed on the paper. Using a hand atomiser, 2 ml of the test solution was sprayed on them. After the treatment the discs with the eggs were dried under an electric fan. The eggs were then kept for hatching at room temperature. After 6 days, the eggs were observed under the microscope and the number unhatched eggs was recorded. The same procedure was followed for all the replicates.

The data were subjected to statistical analysis.

3.3.2 Studies on the larvicidal action of the oils

Two larval instars were taken: the third and the fourth. The third instar measures 5.70 mm in length and 0.54 mm in diameter. Only such measured larvae which were obtained by cutting open the infested tubers were used in this experiment.

The larva in the final (fourth) instar measures 9.50 mm in length and 1.02 mm in breadth (Gubbiah, 1971). It usually turns bright red. The larvae come out of the tubers for pupation. Such larvae were selected for the study.

The different concentrations used in the study are presented in Table 3.

Table 3. Concentrations of plant seed oils used against the larvae of potato tuber moth

	Treatment (%) concentrations				
Oil	T_1	T_2	T_3	T_4	T_5
Argemone	2.00	3.00	4.00	5.00	6.00
Cashew shell	0.01	0.02	0.03	0.04	0.05
Mahagony	0.50	1.00	1.50	2.00	2.50
Neem	2.00	3.00	4.00	5.00	6.00
Pongamia	2.00	3.00	4.00	5.00	6.00
Soobabul	2.00	3.00	4.00	5.00	6.00

The concentrations were prepared as mentioned before. As in the previous experiment, 0.50% malathion and 2 controls were run.

For each replicate experiment, a unit of 10 larvae of uniform size was used. They were placed in petri dishes (4" diamter) each of which had a paper disc of the same size. The test solutions at the respective concentrations were sprayed and the treated ones were dried under electric fan. Small potato pieces were provided as food to the third instar larvae.

Observations were taken at intervals of 24h, 48h, 72h, 96h and 120h after treatment, in case of the fourth instar larvae; at 24h and 48h after treatment in case of the third instar. The number of dead larvae was noted down. Moribund larvae (i.e., which showed a slight movement when prodded with a needle) were considered as 'dead'.

The data thus obtained were subjected to statistical analysis.

3.3.3 Studies on the effect of oils on the pupae

The final instar larvae (fourth instar) which had come out of the tubers were taken and transferred to petri plates containing sand for pupation. These pupae were used for the experiment.

Table 4 gives information about the concentrations of the oils used.

Table 4. Concentrations of plant seed oils for treating the pupae of potato tuber moth.

Oil	Treatment (%) concentrations				
	T_1	T_2	T_3	T_4	T_5
Argemone	6.00	8.00	10.00	12.00	14.00
Cashew shell	0.25	0.50	0.75	1.00	1.25
Mahagony	6.00	8.00	10.00	12.00	14.00
Neem	6.00	8.00	10.00	12.00	14.00
Pongamia	6.00	8.00	10.00	12.00	14.00
Soobabul	6.00	8.00	10.00	12.00	14.00

The two controls were run even in this experiment.

Each replicate experiment consisted of 10 pupae. Two ml of the test solution was sprayed and the treated pupae were dried. The treated sets of pupae were separately kept in glass vials (3" x 1") the mouths of which were covered with 2 layers of muslin cloth secured with a rubber band. After 10 days, the number of adults emerged was counted, noting down the number of dead pupae. Deformities, if any, in the emerging adults were also recorded.

The data were subjected to statistical analysis.

3.3.4 Studies on the effect of oils on the adults

In this experiment, the seed oils and malathion were given to the insects with food (El-Sayed, 1985). Plastic containers (2 1/2" height and 2" diameter) were taken. 5 pairs (males and females) of freshly emerged moths were taken in each plastic container.

The various concentrations used are presented in Table 5.

Table 5. Concentrations of plant seed oils for treating the adults of potato tuber moth

Oil	Treatment (%) concentrations				
	T_1	T_2	T_3	T_4	T_5
Argemone	8.00	9.00	10.00	11.00	12.00
Cashew shell	0.75	1.00	1.25	1.50	1.75
Mahagony	2.00	3.00	4.00	5.00	6.00
Neem	4.00	4.50	5.00	5.50	6.00
Pongamia	2.00	3.00	4.00	5.00	6.00
Soobabul	3.00	4.00	5.00	6.00	7.00

Malathion was used at the concentration of 0.50%. The concentrations were prepared in the following manner:

A 10% honey solution was prepared with honey and distilled water. Using honey solution various concentrations of the oils were prepared. Small cotton wads dipped in test solutions were kept as food for the moths in the plastic containers. Ten per cent honey solution was used as control. The mouths of the containers were tied with two layers of muslin cloth secured with a rubber band.

The following observations were recorded:

1) Number of moths dead after ingesting the test chemical.
2) Reproductive inhibitory effects, if any, in the moths.

The reproductive potential is expressed in terms of the number of eggs laid and the viability of the eggs (Pathak and Krishna, 1985). To measure this, observations were taken in two stages:

a) The number of eggs laid by the moths under each treatment was counted under the binocular microscope. This count was compared with the number of eggs laid under control

Using these two parameters, reproductive inhibition expressed in percent was calculated using the following formula:

$$\frac{\text{No. of eggs laid in control - No. of eggs in treated}}{\text{No. of eggs in control}} \times 100$$

2) Secondly, the hatchability of the laid eggs was recorded. After 7 days, the number of eggs that hatched under each treatment was recorded. The per cent hatchability was calculated thus:

$$\frac{\text{No. of eggs hatched}}{\text{No. of eggs laid}} \times 100$$

3.4 Effect of oils on the parasite of potato tuber moth

One species of the egg-larval parasite, Chelonus blackburni (Hymenoptera: Braconidae) was taken. The culture was obtained from the National Centre for Integrated Pest Control, Hebbal, Bangalore.

Table 6 gives the concentrations of the oils used.

Table 6. Concentrations of plant seed oils for testing the extent of parasitism in potato tuber moth

Oil	Treatment (%) concentrations				
	T_1	T_2	T_3	T_4	T_5
Argemone	2.00	3.00	4.00	5.00	6.00
Cashew shell	0.25	0.50	0.75	1.00	1.25
Mahagony	2.00	3.00	4.00	5.00	6.00
Neem	2.00	3.00	4.00	5.00	6.00
Pongamia	2.00	3.00	4.00	5.00	6.00
Soobabul	2.00	3.00	4.00	5.00	6.00

Two controls (one, a mixture of emulsified water and benzene [illegible] and the second, distilled water) were run.

Small paper discs (1" diameter) were taken and treated with the respective test solutions and were dried. In the centre of each paper disc, another small paper disc (1/2 cm diameter) was stuck using gum. On this small inner paper disc 25 fresh eggs of potato tuber moth were pasted. The entire paper disc was placed in a vial (3" height and 1" diameter). To each vial one adult of Chelonus blackburni was allowed. The eggs were exposed to the parasite for 12 hours. After 12h the egg card was taken out.

Small plastic containers (2 1/2" height and 2" diameter) were taken. About 1/2 cm layer of sand was added. Small perforated potato tubers were placed in containers (one tuber in each container). The parasitised egg cards were placed on the tubers. The mouth of each container was covered with 2 layers of muslin secured with a rubber band.

The adult C. blackburni lays eggs, usually singly in the eggs of potato tuber moth (Usman, 1956). Parasitism was determined on the basis of the number of host adults that emerge out, from the tubers. After 40 days, the number of moths emerged was recorded, and this consequently gave the number unemerged moths. The per cent parasitism was calculated using the following formula:

$$\frac{\text{No. eggs treated} - \text{No. moths emerged}}{\text{No. eggs treated}} \times 100$$

The data so obtained were subjected to statistical analysis.

3.5 Statistical analysis of the data

3.5.1 Calculation of LC_{50} values

Using the data of the ovicidal, larvicidal and pupicidal studies the LC_{50}'s of the respective oils were calculated using a computer.

Using neem as the standard the relative toxicity of the other oils were calculated with the formula:

$$\text{Relative toxicity of the oil} = \frac{LC_{50} \text{ of neem}}{LC_{50} \text{ of the oil}}$$

As neem is the most commonly used plant product, it was used as the standard for the calculation of relative toxicity.

3.5.2 <u>Analysis of variance</u>

In all the experiments the number of oils tried was 6, and each was tried at 5 different concentrations. In most experiments two controls (water, and a mixture of benzene and emulsified water) were run only to test whether the emulsifier or the solvent contribute to the mortality of the test individuals. Therefore, the data obtained from the controls were not used for analysis, but that obtained from malathion was considered for analysis.

Therefore, 6 oils, each at 5 concentrations and with one standard chemical, the total number of treatments was: (6 X 5) + 1=31. The analysis that was done was one-way analysis of variance.

Comparison among the treatment means was done using the Student-Newman-Keuls test (Zar, 1959).

The results of the experimental findings are discussed in the next chapter.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Studies were conducted to assess the toxicity effects of six different seed oils: neem (Azadirachta indica), pongamia (Pongamia glabra), argemone (Argemone mexicana), soobabul (Leucaena leucocephala), mahagony (Swietenia mahagoni) and cashew (Anacardium occidentale) - against potato tuber moth, Phthorimaea operculella Zell. (Lepidoptera: Gelechiidae). Malathion was used as a standard insecticide for comparison. The results obtained from the above studies are presented under the following heads:

4.1 Effect of plant seed oils on the eggs of potato tuber moth.

4.2 Studies on the larvicidal action of the candidate seed oils.

4.3 Effect of the oils on the pupae.

4.4 Effect of oils on the adult moths.

4.5 Effect of oils on the extent of parasitism of the potato tuber moth.

4.6 Bioassay studies on Phthorimaea operculella.

4.1 Effect of plant seed oils on the eggs of potato tuber moth

Observations on the mortality of eggs taken after 6 days are presented in Table 7.

Table 7 Effect of different plant seed oils on the eggs of potato tuber moth

Oil	Concentration (%)	Mean no. eggs killed	Percentage eggs killed
Neem	0.25	7.75 +	38.75
	0.50*	13.25 a	66.25
	0.75	14.00 a	70.00
	1.00	15.00 a	75.00
	1.25	16.00 a	80.00
Pongamia	2.00	11.75 a	58.75
	3.00*	13.25 ab	66.25
	4.00	13.50 b	67.50
	5.00	15.00 b	76.25
	6.00	15.75 b	77.50
Argemone	2.00	10.75 a	53.75
	3.00	11.75 a	58.75
	4.00	12.25 a	61.25
	5.00	12.50 a	62.50
	6.00*	16.50 b	82.50
Soobabul	2.00	8.50	42.50
	3.00	11.25 a	56.25
	4.00	12.75 ab	63.75
	5.00	14.75 b	73.75
	6.00*	18.50 c	92.50
Mahagony	0.50	9.25 a	46.25
	1.00	11.75 ab	58.75
	1.50	13.50 bc	67.50
	2.00 *	15.25 cd	76.25
	2.50	16.75 d	83.75
Cashew shell	0.25	11.50 a	57.50
	0.50	13.75 ab	68.75
	0.75*	15.00 bc	75.00
	1.00	15.75 c	78.75
	1.25	17.25 c	86.25
Malathion	0.50	20.00	100.00
$Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Neem	(0.50)	13.25 a
Pongamia	(3.00)	13.25 a
Cashew shell	(0.75)	15.00 ab
Mahagony	(2.00)	15.25 b
Argemone	(6.00)	16.50 b
Soobabul	(6.00)	18.50 c

$ Water with 0.1% Labolene and 5% benzene

\+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

From the table it is seen that, in general as the concentrations of each oil increased the corresponding mortality also increased, and in most cases the differences observed were found to be statistically significant. Neem and pongamia seed oils at 3.00% caused a mortality of 66.25% and the mortality percentages caused at higher concentrations were found to be statistically on par with that caused by the application of 3.00% of the oil.

Six per cent concentration of argemone oil gave 82.50% mortality of the eggs.

The seed oil of soobabul at 6.00% gave a significantly high mortality of 92.50%.

A mortality of 76.25% was recorded on spraying the eggs with 2% seed oil of mahagony.

In case of cashew shell oil the best concentration was 0.75% which caused a corresponding mortality of 75%.

On estimating the relative efficacy of the best concentrations of the six oils, it was observed that the oils of argemone and soobabul, both at the concentration of 6.00%, ranked first; the differences in their corresponding mortality percentages were found to be statistically insignificant. Of the remaining oils the least effective were found to be the oils of neem and pongamia (Table 7).

When the performance of the best concentrations of the oils was compared with that of malathion (which caused a hundred per cent mortality), it was noted that the standard chemical was on par with the oil of soobabul (at 6.00% concentration).

It was observed that the eggs that failed to hatch turned black, lost their turgidity and eventually became shrivelled. No other deformities were observed.

4.2 Studies on the larvicidal action of the candidate seed oils

Observations of mortality of the fourth instar larvae of potato tuber moth recorded after 24, 48, 72, 96 and 120 hours and of the third instar larvae 24 and 48 hours after treatment are presented in Table 8.

As soon as the oils were sprayed the larvae displayed vigorous convulsions and similar behaviour was noted in those larvae that were sprayed with a mixture of 5% benzene and emulsified water. Some of the larvae recovered when they were dried under an electric fan and some recovered later.

Table 8: Effect of plant seed oils on the larvae of potato tuber moth (mean larvae killed)

Oil	Concentration (%)	III instar 24 hours	III instar 48 hours	IV instar 24 hours	IV instar 48 hours	IV instar 72 hours	IV instar 96 hours	IV instar 120 hours
Neem	2.00	4.98 (2.34)	5.70 (2.49)	3.70 (2.05)	4.25 (2.18)	5.50 (2.45)	6.74 (2.69)	7.74 (2.87)
	3.00	5.70 (2.49)	7.50 (2.83)	3.66 (2.04)	4.74 (2.29)	5.75 (2.50)	7.01 (2.74)	8.44 (2.99)
	4.00	6.74 (2.69)	8.20 (2.95)	4.47 (2.23)	5.45 (2.44)	5.75 (2.50)	8.26 (2.96)	8.44 (2.99)
	5.00	7.97 (2.91)	9.49 (3.16)	4.47 (2.44)	5.45 (2.44)	6.95 (2.73)	9.23 (3.12)	9.23 (3.12)
	6.00	8.44 (2.99)	9.99 (3.24)	4.70 (2.28)	5.45 (2.44)	7.74 (2.87)	9.74 (3.20)	9.74 (3.20)
Pongamia	2.00	4.47 (2.23)	6.68 (2.68)	3.42 (1.98)	5.70 (2.49)	7.23 (2.78)	8.44 (2.99)	8.99 (3.08)
	3.00	5.45 (2.44)	7.45 (2.82)	4.12 (2.15)	6.16 (2.58)	8.44 (2.99)	9.23 (3.12)	9.49 (3.16)
	4.00	7.74 (2.87)	8.44 (2.99)	4.47 (2.23)	6.21 (2.59)	8.74 (3.04)	9.23 (3.12)	9.74 (3.20)
	5.00	8.74 (3.04)	8.74 (3.04)	4.79 (2.30)	7.62 (2.85)	8.74 (3.04)	9.49 (3.16)	9.99 (3.24)
	6.00	8.99 (3.08)	9.49 (3.16)	6.68 (2.68)	7.97 (2.91)	8.99 (3.08)	9.74 (3.20)	9.99 (3.24)
Argemone	2.00	1.43 (1.39)	1.94 (1.56)	1.46 (1.40)	1.46 (1.40)	1.93 (1.56)	5.50 (2.45)	8.26 (2.96)
	3.00	2.96 (1.86)	3.19 (1.92)	2.22 (1.65)	2.74 (1.80)	3.74 (2.06)	5.50 (2.45)	8.74 (3.04)
	4.00	3.46 (1.99)	4.74 (2.29)	3.07 (1.89)	3.95 (2.11)	4.74 (2.29)	6.21 (2.59)	8.99 (3.08)
	5.00	4.25 (2.18)	7.23 (2.78)	3.42 (1.98)	4.74 (2.29)	6.21 (2.59)	8.44 (2.99)	8.99 (3.08)
	6.00	6.47 (2.64)	8.68 (3.03)	4.47 (2.23)	5.26 (2.40)	8.26 (2.96)	8.44 (2.99)	8.99 (3.08)
Soobabu	2.00	2.49 (1.73)	4.98 (2.34)	2.22 (1.65)	4.21 (2.17)	6.21 (2.59)	7.23 (2.78)	8.74 (3.04)
	3.00	3.22 (1.93)	5.45 (2.44)	3.22 (1.93)	5.21 (2.39)	6.47 (2.64)	7.50 (2.83)	8.99 (3.08)
	4.00	3.46 (1.99)	5.70 (2.49)	3.50 (2.00)	5.21 (2.39)	6.47 (2.64)	7.74 (2.87)	8.99 (3.08)
	5.00	4.98 (2.34)	6.00 (2.55)	3.95 (2.11)	5.50 (2.45)	7.00 (2.74)	7.74 (2.87)	9.23 (3.12)
	6.00	5.70 (2.49)	7.23 (2.78)	4.47 (2.23)	5.74 (2.50)	7.97 (2.91)	8.20 (2.95)	9.49 (3.16)
Mahagony	0.50	4.47 (2.23)	4.74 (2.29)	2.74 (1.80)	4.74 (2.29)	7.45 (2.82)	8.44 (2.99)	8.74 (0.04)
	1.00	6.00 (2.55)	6.74 (2.69)	4.47 (2.23)	6.00 (2.55)	8.74 (3.04)	9.23 (3.12)	9.49 (3.16)
	1.50	7.23 (2.78)	7.97 (2.91)	6.47 (2.64)	7.74 (2.87)	9.49 (3.16)	9.74 (3.20)	9.99 (3.24)
	2.00	8.44 (2.99)	8.99 (3.08)	7.51 (2.83)	7.74 (2.87)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)
	2.50	9.23 (3.12)	9.49 (3.16)	7.97 (2.91)	8.99 (3.08)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)
Cashew shell	0.01	6.00 (2.55)	7.00 (2.74)	3.87 (2.09)	4.98 (2.34)	6.00 (2.55)	6.74 (2.69)	7.00 (2.74)
	0.02	6.21 (2.59)	7.23 (2.78)	4.43 (2.22)	5.21 (2.39)	6.47 (2.64)	7.01 (2.74)	7.00 (2.74)
	0.03	7.01 (2.74)	7.97 (2.91)	5.75 (2.50)	6.26 (2.60)	7.50 (2.83)	7.74 (2.87)	7.97 (2.91)
	0.04	8.44 (2.99)	8.99 (3.08)	7.23 (2.78)	7.51 (2.83)	8.74 (3.04)	8.74 (3.04)	9.49 (3.16)
	0.05	9.23 (3.12)	9.49 (3.16)	7.74 (2.87)	8.74 (3.04)	9.49 (3.16)	9.99 (3.24)	9.99 (3.24)
Malathion	0.50	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)	9.99 (3.24)
Control	(B+L)	0	0	0	0	0	0	0
Control	(Water)	0	0	0	0	0	0	0

Figures in parentheses are the sq. root transformed $\sqrt{X+1/2}$ values

4.2.1 Effect on the fourth instar larvae

The mortality per cent of the larvae increased as the concentration of the oils increased and also when the time duration (after treatment) increased.

4.2.1.1 Observations recorded after 24 hours of treatment

The results are presented in Table 9.

Neem oil application at 3% concentration resulted in 36.60% mortality of the larvae. The highest mortality (47.00%) was observed at 6.00% spray. However, the differences in mortality were found to be non-significant.

Application of pongamia oil at 2.00% concentration caused the least mortality (34.20%) and the highest mortality (66.80%) was recorded at the maximum (6.00%) concentration.

The oil of argemone seed at 2.00% caused 14.60% larval mortality while at 6.00% it was 44.70%, the most preferred concentration being 3.00% with a corresponding mortality of 22.20%.

Though a minimum of 22.20% mortality (at 2.00% concentration) and a maximum of 44.70% (at 6.00% oil) were recorded in case of soobabul oil, the differences were found to be statistically non-significant.

Table 9 Mortality counts of fourth instar larvae 24 hours after treatment with plant and oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00*	3.70 a+	37.00
	3.00	3.66 a	36.60
	4.00	4.47 a	44.70
	5.00	4.47 a	44.70
	6.00	4.70 a	47.00
Pongamia	2.00	3.42 a	34.20
	3.00*	4.12 ab	41.20
	4.00	4.47 ab	44.70
	5.00	4.79 ab	47.90
	6.00	6.68 b	66.80
Argemone	2.00	1.48 a	14.80
	3.00*	2.22 b	22.20
	4.00	3.07 b	30.70
	5.00	3.42 b	34.20
	6.00	4.47 b	44.70
Soobabul	2.00*	2.22 a	22.20
	3.00	3.22 a	32.20
	4.00	3.50 a	35.00
	5.00	3.95 a	39.50
	6.00	4.47 a	44.70
Mahagony	0.50	2.74 a	27.40
	1.00	4.47 ab	44.70
	1.50 *	6.47 bc	64.70
	2.00	7.51 c	75.10
	2.50	7.97 c	79.70
Cashew shell	0.01	3.87 a	38.70
	0.02	4.43 a	44.30
	0.03*	5.75 ab	57.50
	0.04	7.23 b	72.30
	0.05	7.74 b	77.40
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Argemone	(3.00)	2.22 a
Soobabul	(2.00)	2.22 a
Neem	(3.00)	3.66 ab
Pongamia	(3.00)	4.12 ab
Cashew shell	(0.03)	5.75 b
Mahagony	(4.00)	6.47 b

+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

In case of the seed oil of mahagony, the best concentration was found to be 1.50% with a corresponding mortality of 64.70% though a minimum of 27.40% (at 0.5%) and the highest mortality of 79.70% (at 2.5% concentration) were observed.

Similarly, a concentration of 0.03% of cashew shell oil was found to be the most preferrable wherein a mortality of 57.50% was recorded which was statistically on par with the highest mortality of 77.40% (at 0.05%) of the oil.

Comparison of the effective concentrations indicated that the oils of neem (3.00%), pongamia (3.00%), cashew shell (0.03%) and mahagony (1.5%) were equally effective, the differences among their corresponding mortality percentages being found to be non-significant.

However, malathion was found to be significantly on par with the oils of cashew (0.04 and 0.05%) and mahagony (2.00 % and 2.50%).

4.2.1.2 <u>Observations recorded 48 hours after treatment</u>

The results are presented in Table 10.

All the five concentrations of neem oil were found to be on par with one another statistically. Neem oil at a

Table 10 Mortality counts of fourth instar larvae 48 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00*	4.25 a+	42.50
	3.00	4.74 a	47.40
	4.00	5.45 a	54.50
	5.00	5.45 a	54.50
	6.00	5.45 a	54.50
Pongamia	2.00	5.70 a	57.00
	3.00*	6.16 ab	61.60
	4.00	6.21 ab	62.10
	5.00	7.62 ab	76.20
	6.00	7.97 b	79.70
Argemone	2.00	1.46 a	14.60
	3.00	2.74 b	27.40
	4.00*	3.95 c	39.50
	5.00	4.74 c	47.40
	6.00	5.26 c	52.60
Soobabul	2.00*	4.21 a	42.10
	3.00	5.21 a	52.10
	4.00	5.21 a	52.10
	5.00	5.50 a	55.00
	6.00	5.75 a	57.50
Mahagony	0.50	4.74 a	47.40
	1.00	6.00 ab	60.00
	1.50 *	7.74 bc	77.40
	2.00	7.74 bc	77.40
	2.50	8.99 c	89.90
Cashew shell	0.01	4.98 a	49.80
	0.02	5.21 a	52.10
	0.03	6.26 ab	62.60
	0.04 *	7.51 bc	75.10
	0.05	8.74 c	87.40
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Argemone	(4.00)	3.95 a
Soobabul	(2.00)	4.21 a
Neem	(2.00)	4.25 ab
Pongamia	(3.00)	6.16 bc
Cashe shell	(0.04)	7.51 c
Mahagony	(1.50)	7.74 c

+ Comparison among the five concentrations of an oil.

Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

concentration of 2.00% causing a mortality of 42.50% was found to be the most effective.

In case of pongamia seed oil, a concentration of 3.00% was found to be the best wherein a mortality of 61.60% was recorded. This was found to be on par with the concentration of 6.00% wherein a mortality of 79.70% was recorded.

A concentration of 4.00% of the seed oil of argemone was observed to be the most effective (mortality of 39.50%) which in turn was found to be on par with 6.00% concentration (mortality of 52.60%).

As in the case of neem oil all the five concentrations of soobabul oil were found to be on par with one another, the most preferred being 2.00% with a corresponding mortality of 42.10%.

A mortality of 77.40% was recorded with the application of mahagony seed oil at 1.50%, which was observed to be the most effective concentration.

As far as cashew shell oil was concerned, 0.05% of the oil was observed to be best which gave a mortality of 75.10%.

Comparing the efficiency of the best concentrations of the six different oils, the oils of pongamia (3.00%), cashew shell (0.04%) mahagony (1.50%) fared better than the other oils.

Malathion was found to be on par with the oils of mahagony (2.50%) and cashew shell (0.05%).

4.2.1.3 Observations recorded after 72 hours of treatment

As can be seen from Table 11, a concentration of 5.00% of neem oil with a corresponding mortality of 69.50% was found to be the most effective.

No significant differences in the respective per cent mortalities were observed among the five concentrations of pongamia oil. Therefore, a concentration of 2.00% was observed to be the most preferrable, wherein a mortality of 72.30% was recorded.

In the case of argemone oil, the highest concentration (6.00%) was found to be the best in which case a mortality of 82.60% was recorded.

A concentration of 3.00% of the seed oil of soobabul which showed a mortality of 64.70% was found to be the most effective.

A mortality of 87.40% was observed when the larvae were sprayed with 1.00% mahagony oil.

Table 11 Mortality counts of fourth instar larvae at 72 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00	5.50 a+	55.00
	3.00	5.75 ab	57.50
	4.00	5.75 ab	57.50
	5.00*	6.95 bc	69.50
	6.00	7.74 c	77.40
Pongamia	2.00*	7.23 a	72.30
	3.00	8.44 a	84.40
	4.00	8.74 a	87.40
	5.00	8.74 a	87.40
	6.00	8.99 a	89.90
Argemone	2.00	1.93 a	19.30
	3.00	3.74 b	37.40
	4.00	4.74 c	47.40
	5.00	6.21 d	62.10
	6.00 *	8.26 e	82.60
Soobabul	2.00	6.21 a	62.10
	3.00 *	6.47 ab	64.70
	4.00	6.47 ab	64.70
	5.00	7.00 ab	70.00
	6.00	7.97 b	79.70
Mahagony	0.50	7.45 a	74.50
	1.00 *	8.74 ab	87.40
	1.50	9.49 b	94.90
	2.00	9.99 b	99.90
	2.50	9.99 b	99.90
Cashew shell	0.01	6.00 a	60.00
	0.02	6.47 a	64.70
	0.03 *	7.50 ab	75.00
	0.04	8.74 b	87.40
	0.05	9.49 b	94.90
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Soobabul	(3.00)	6.47 a
Neem	(5.00)	6.95 ab
Pongamia	(2.00)	7.23 ab
Cashew shell	(0.03)	7.50 ab
Argemone	(6.00)	8.26 b
Mahagony	(1.00)	8.74 b

+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

A concentration of cashew shell oil as low as 0.03% was inferred to be the best which resulted in a mortality of 75.00%.

Of the six most effective concentrations of the candidate oils, the performance of neem oil (5.00%), pongamia oil (2.00%), cashew shell oil (0.03%), argemone oil (6.00%) and finally mahagony oil (1.00%) were all found to be on par with one another.

The performance of malathion was on par with that of mahagony oil (1.50, 2.00 and 2.50%), cashew shell oil (0.05%) and argemone oil (6.00%).

4.2.1.4 <u>Observations recorded 96 hours after treatment</u>

The results are presented in Table 12.

A 4.00% concentration of neem oil which killed 82.60% of the larvae was found to be the best concentration.

As in the previous case, pongamia oil with the most effective concentration of 2.00% was observed to cause 84.40% mortality.

A five per cent concentration of argemone caused 84.40% mortality of the larvae.

Table 12 Mortality counts of fourth instar larvae at 96 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00	6.74 a +	67.40
	3.00	7.01 a	70.10
	4.00*	8.26 ab	82.60
	5.00	9.23 b	92.30
	6.00	9.74 b	97.40
Pongamia	2.00*	8.44 a	84.40
	3.00	9.23 a	92.30
	4.00	9.23 a	92.30
	5.00	9.49 a	94.90
	6.00	9.74 a	97.40
Argemone	2.00	5.50 a	55.00
	3.00	5.50 a	55.00
	4.00	6.21 a	62.10
	5.00*	8.44 b	84.40
	6.00	8.44 b	84.40
Soobabul	2.00*	7.23 a	72.30
	3.00*	7.50 a	75.00
	4.00	7.74 a	77.40
	5.00	7.74 a	77.40
	6.00	8.20 a	82.00
Mahagony	0.50*	8.44 a	84.40
	1.00	9.23 a	92.30
	1.50	9.74 a	97.40
	2.00	9.99 a	99.90
	2.50	9.99 a	99.90
Cashew shell	0.01	6.74 a	67.40
	0.02	7.01 a	70.10
	0.03	7.74 ab	77.40
	0.04*	8.74 bc	87.40
	0.05	9.99 c	99.90
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Soobabul	(2.00)	7.23 a
Neem	(4.00)	8.26 a
Pongamia	(2.00)	8.44 a
Argemone	(5.00)	8.44 a
Mahagony	(0.50)	8.44 a
Cashew shell	(0.04)	8.74 a

+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

Both in case of soobabul and mahagony, all the five concentrations were noted to be on par among one another and the best concentrations were noted to be 2.00% of soobabul oil (mortality of 72.30%) and 0.50% of mahagony oil (mortality of 84.40%).

A mortality of 87.40 per cent was observed at a concentration of 0.04% of cashew shell oil.

Comparison of the best concentrations among the six oils revealed that there were no significant differences among them.

Malathion was found to be on par with the best concentrations of all the oils except with that of soobabul.

4.2.1.5 <u>Observations recorded after 120 hours of treatment</u>

From Table 13, it can be noted that a concentration of 3.00% of neem oil with a mortality of 84.40% was found to be the most effective.

All the five concentrations of the oils of pongamia, argemone, soobabul and mahagony were found to be on par among one another.

Table 13 Mortality counts of fourth instar larvae at 120 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00	7.74 a+	77.40
	3.00*	8.44 ab	84.40
	4.00	8.44 ab	84.40
	5.00	9.23 b	92.30
	6.00	9.74 b	97.40
Pongamia	2.00*	8.99 a	89.90
	3.00	9.49 a	94.90
	4.00	9.74 a	97.40
	5.00	9.99 a	99.90
	6.00	9.99 a	99.90
Argemone	2.00*	8.26 a	82.60
	3.00	8.74 a	87.40
	4.00	8.99 a	89.90
	5.00	8.99 a	89.90
	6.00	8.99 a	89.90
Soobabul	2.00*	8.74 a	87.40
	3.00	8.99 a	89.90
	4.00	8.99 a	89.90
	5.00	9.23 a	92.30
	6.00	9.49 a	94.90
Mahagony	0.50*	8.74 a	87.40
	1.00	9.49 a	94.90
	1.50	9.99 a	99.90
	2.00	9.99 a	99.90
	2.50	9.99 a	99.90
Cashew shell	0.01	7.00 a	70.00
	0.02	7.00 a	70.00
	0.03	7.97 ab	79.70
	0.04*	9.49 bc	94.90
	0.05	9.99 c	99.90
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Argemone	(2.00)	8.26 a
Neem	(3.00)	8.44 a
Soobabul	(2.00)	8.74 a
Mahagony	(0.50)	8.74 a
Pongamia	(2.00)	8.99 a
Cashew shell	(0.04)	9.49 a

+ Comparison among the five concentrations of an oil.

Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

In case of cashew shell oil, the concentration of 0.04% was the most preferred one wherein a mortality of 94.90% was recorded.

No significant differences were observed among the six best concentrations of the different oils.

Even in this case, malathion was found to be on par with the best concentrations of all the oils.

It was observed that those larvae which survived the oils successfully entered into the pupal stage. No deformities were observed in the pupae or the adults. The adult emergence was not affected.

4.2.2 Effect on the third instar larvae

The third instar larvae seemed to be more affected than the fourth instar ones. A greater percentage of mortality was recorded even at 24 hours. Therefore, observations were recorded only at 24 hours and 48 hours after treatment.

4.2.2.1 Observations recorded 24 hours after treatment

The results are presented in Table 14.

A maximum of 99.90% mortality was recorded in case of neem at 6.00%, and a minimum of 57.00% at 2.00%. However,

Table 14 Mortality counts of third instar larvae at 24 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00	4.98 a[+]	49.80
	3.00	5.70 a	57.00
	4.00*	6.74 ab	67.40
	5.00	7.97 b	79.70
	6.00	8.44 b	84.40
Pongamia	2.00	4.47 a	44.70
	3.00	5.45 a	54.50
	4.00*	7.74 b	77.40
	5.00	8.74 b	87.40
	6.00	8.99 b	89.90
Argemone	2.00	1.43 a	14.30
	3.00	2.96 b	29.60
	4.00	3.46 bc	34.60
	5.00	4.25 c	42.50
	6.00*	6.47 d	64.70
Soobabul	2.00	2.49 a	24.90
	3.00	3.22 a	32.20
	4.00	3.46 a	34.60
	5.00*	4.98 b	49.80
	6.00	5.70 b	57.00
Mahagony	0.50	4.47 a	44.70
	1.00	6.00 ab	60.00
	1.50*	7.23 bc	72.30
	2.00	8.44 c	84.40
	2.50	9.23 c	92.30
Cashew shell	0.01	6.00 a	60.00
	0.02	6.21 ab	62.10
	0.03	7.01 b	70.10
	0.04*	8.44 bc	84.40
	0.05	9.23 c	92.30
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* **Best concentration**

Comparison among six best concentrations of oils

Soobabul	(5.00)	4.98 a
Argemone	(6.00)	6.47 ab
Neem	(4.00)	6.74 b
Mahagony	(1.50)	7.23 b
Pongamia	(4.00)	7.74 b
Cashew shell	(0.04)	8.44 b

\+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

the effective concentration was found to be 4.00% with a corresponding mortality of 82.00%.

In case of pongamia, a maximum of 94.90% mortality was observed at 6.00%, the effective being 4.00% with a corresponding mortality of 77.40%.

Of the five concentrations, 6.00% of argemone oil was found to be the best in which case a mortality of 64.70% was observed.

About 49.80% mortality was noted in soobabul oil treated larvae at the concentration of 5.00%.

The highest mortality per cent values of 92.30 were recorded in case of mahagony oil (2.50%) and cashew shell oil (0.05%) and their respective best concentrations were 1.50% (with a mortality of 72.30%) and 0.04% (with a corresponding mortality of 84.40%).

Among the best concentrations of oils, argemone oil (6.00%), neem oil (4.00%), mahagony oil (1.50%), pongamia oil (4.00%) and cashew shell oil (0.04%) were found to be on par among one another, with no significant differences among their respective mortality percentages.

But malathion was found to cause a higher mortality of 99.90%. Nevertheless, it was found to be on par with pongamia (6.00%), mahagony (2.50%) and cashew shell oil (0.05%).

4.2.2.2 Observations recorded 48 hours after treatment

The results are presented in Table 15.

An effective concentration of 4.00% of neem oil caused 82.00% mortality, the maximum being 99.90% at 6% concentration.

Pongamia oil at an effective concentration of 3.00% caused mortality to the tune of 74.50% which was not found to be significantly different from the application of 6.00% which showed a mortality of 94.90%.

A mortality of 72.30% at 5.00% was recorded in case of argemone which was found to be on par with that of 86.80% caused by 6.00% of the oil.

The most effective concentration of soobabul was found to be 3.00% the corresponding mortality of which was 54.50%.

Mahagony seed oil at 4.00% was found to be the best. The mortality recorded was 79.70%. This was found to be on par with 94.90% mortality casued by 6.00% of the oil.

Table 15 Mortality counts of third instar larvae at 48 hours after treatment with different plant seed oils

Oil	Concentration (%)	Mean no. larvae killed	Percentage larvae killed
Neem	2.00	5.70 a+	57.00
	3.00	7.50 ab	75.00
	4.00*	8.20 bc	82.00
	5.00	9.49 bc	94.90
	6.00	9.99 c	99.90
Pongamia	2.00	6.68 a	66.80
	3.00*	7.45 ab	74.50
	4.00	8.44 ab	84.40
	5.00	8.74 ab	87.40
	6.00	9.49 b	94.90
Argemone	2.00	1.94 a	19.40
	3.00	3.19 b	31.90
	4.00	4.74 c	47.40
	5.00*	7.23 d	72.30
	6.00	8.68 d	86.80
Soobabul	2.00	4.98 a	49.80
	3.00*	5.45 ab	54.50
	4.00	5.70 ab	57.00
	5.00	6.00 ab	60.00
	6.00	7.23 b	72.30
Mahagony	0.50	4.74 a	47.40
	1.00	6.74 b	67.40
	1.50*	7.97 bc	79.70
	2.00	8.99 bc	89.90
	2.50	9.49 c	94.90
Cashew shell	0.01	7.00 a	70.00
	0.02*	7.23 ab	72.30
	0.03	7.97 b	79.70
	0.04	8.99 b	89.90
	0.05	9.49 b	94.90
Malathion	0.50	9.99	99.90
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Comparison among six best concentrations of oils

Soobabul	(3.00)	5.45 a
Argemone	(5.00)	7.23 ab
Cashew shell	(0.02)	7.23 ab
Pongamia	(3.00)	7.45 b
Mahagony	(4.00)	7.97 b
Neem	(4.00)	8.20 b

+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

A concentration of 0.02% of cashew oil was the most preferred one as it killed 72.30% of the larvae treated.

Comparison of the six best concentrations of the oils indicated that the seed oils of argemone (5.00%), cashew shell (0.02%), pongamia (3.00%), mahagony (1.50%) and neem (4.00%) did not differ from one another significantly with respect to their corresponding mortality percentages.

In this case, malathion and neem at a concentration of 6.00% were found to kill 99.90% of the larvae. No significant differences were observed among malathion, mahagony oil (1.5%) and neem oil (4.00%).

Those larvae that were unaffected by the oils were found to bore into the tuber pieces and the moulting was not hampered. But the surviving larvae were found to be slightly sluggish, less active than the normal ones. No changes were observed in the colouration of the larvae.

In both the experiments (in the third and the fourth instars) no mortality was recorded in either control regimens.

4.3 Effect of oils on the pupae of potato tuber moth

The emergence of the adults from the treated pupae recorded 10 days after treatment is presented in Table 16.

Table 16 Effect of different plant seed oils on the pupae of potato tuber moth

Oil	Concentration (%)	Mean no. pupae killed	Percentage pupae killed
Neem	6.00	(2.06) 3.74 a[+]	37.40
	8.00	(2.11) 3.95 a	39.50
	10.00*	(2.40) 5.26 ab	52.60
	12.00	(2.55) 6.00 b	60.00
	14.00	(2.83) 7.51 b	75.10
Pongamia	6.00	(1.79) 2.70 a	27.00
	8.00	(2.28) 4.70 b	47.00
	10.00*	(2.55) 6.00 bc	60.00
	12.00	(2.87) 7.74 c	77.40
	14.00	(3.00) 8.50 c	85.00
Argemone	6.00	(1.73) 2.49 a	24.90
	8.00	(2.40) 5.26 b	52.60
	10.00*	(2.55) 6.00 bc	60.00
	12.00	(2.69) 6.74 c	67.40
	14.00	(2.83) 7.51 c	75.10
Soobabul	6.00	(2.34) 4.98 a	49.80
	8.00	(2.64) 6.47 ab	64.70
	10.00*	(2.78) 7.22 abc	72.20
	12.00	(3.04) 8.74 bc	87.40
	14.00	(3.12) 9.23 c	92.30
Mahagony	6.00*	(2.40) 5.26 a	52.60
	8.00	(2.54) 5.95 a	59.50
	10.00	(2.68) 6.68 a	66.80
	12.00	(2.69) 6.74 a	67.40
	14.00	(2.78) 7.23 a	72.30
Cashew shell	0.25	(2.32) 4.88 a	48.80
	0.50	(2.38) 5.16 a	51.60
	0.75	(2.68) 6.68 ab	66.80
	1.00*	(2.96) 8.26 bc	82.60
	1.25	(3.20) 9.74 c	97.40
Malathion	0.50	(3.04) 8.75	87.50
Control (B + L)		0.00	0.00
Control (water)		0.00	0.00

* Best concentration

Figures in parentheses are the sq. root transformed values ($\sqrt{X+1/2}$)

Comparison among six best concentrations of oils

Neem	(10.00)	5.26 a
Soobabul	(6.00)	5.26 a
Pongamia	(10.00)	6.00 ab
Argemone	(10.00)	6.00 ab
Mahagony	(10.00)	7.22 ab
Cashew shell	(1.00)	8.26 b

+ Comparison among the five concentrations of an oil.

Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

As it can be seen, higher concentrations of the oils were used to kill the pupae.

A concentration as high as 10.00% of neem oil was required to bring about mortality to the extent of 52.60%. This extent of mortality was found to be significantly on par with that caused by 14.00% of the oil. A low mortality of 37.40% was recorded at 6.00%.

At the same concentrations the seed oil of pongamia seemed to show a wide range of mortality percentages. At 6.00% about 27.00% of the pupae were killed. At 14.00% the percentage kill was 85.00. However, a concentration of 10.00% whose corresponding mortality was 60.00% was found to be the most preferred one.

Similarly in case of argemone seed oil an effective concentration of 10.00% was found to cause 60.00% mortality of the pupae.

No significant differences were observed among the five concentrations of the seed oil of soobabul with respect to the death of the pupae. A mortality of 52.60% at 6.00% was found to be statistically on par with the mortality of 72.30% at 14.00% concentration.

The effective concentration of mahagony oil was found to be 10.00% which showed a corresponding mortality of 72.20%.

Of all the oils, cashew shell oil was found to cause the maximum mortality of 94.70% at a concentration of 1.25%. But this was found to be par with 1.00% concentration whose corresponding kill was 82.60%.

When the six best concentrations of the six oils were compared for significant differences, the oils of pongamia (10.00%), argemone (10.00%), mahagony (10.00%) and cashew shell oil (1.00%) were found to be on par with one another.

Only 87.50% of the pupae were killed when malathion was sprayed on them. Mahagony oil at 14.00% concentration with a corresponding mortality of 92.30% and cashew shell oil at 1.25% with a corresponding mortality of 97.40% were found to fare better than malathion. Only mahagony oil at 12.00% was found to be statistically on par with malathion. The remaining oils were found to be less effective when compared to malathion.

Most of the pupae that were dead were shrivelled and shrunken, the adult emergence was also hampered. The moths were killed during the process of emergence - some were stuck to the pupal cases, some were half-emerged and in some cases only the head had emerged.

The maximum number of deformed pupae were observed in soobabul oil and cashew oil (18.5%). Those pupae treated with neem showed deformity to the extent of 1.00%. The other oils: mahagony, pongamia and argemone fell in between (Table 17).

Table 17 Number of deformed pupae as a result of application of plant seed oils

Oil	No. of pupae treated	No. of deformed pupae	% deformed pupae
Neem	200	2	1.00
Pongamia	200	17	8.50
Argemone	200	33	16.50
Soobabul	200	37	18.50
Mahagony	200	10	5.00
Cashew shell	200	37	18.50

Pupae in cases of both the controls did not show any deformity and the adult emergence was normal.

4.4 Studies on the effect of oils on the adults of potato tuber moth

This study was conducted with two objectives:

a) To observe mortality of the moths

b) To look for the reproductive inhibition in the moths

4.4.1 Effect of the oils on survival of the moths

None of the oils seemed to affect the survival of the moths and no mortality was observed. In case of control wherein no oil was used, the moths remained unaffected. But in the treatment wherein malathion was used, the moths died within three hours.

4.4.2 Effect of oils on the reproductive potential of the moths

The number of eggs laid by the moths subjected to different oils and recorded after 48 hours is presented in Table 18.

The number of eggs laid by the moths steadily decreased as the concentration of the oils increased. The per cent reproductive inhibition was found to increase with increase in concentration of respective oils.

When neem oil at 6.00% was provided to the moths a maximum reproductive inhibition of 78.86% was recorded. This concentration of the oil was found to be the most effective one.

The maximum reproductive inhibition was observed in the seed oil of pongamia. A concentration of 6.00% was found to cause inhibition in reproduction to the extent of 89.04%.

Table 18 Fecundity of the moths of potato tuber moth as affected by the application of different plant seed oils

Oil	Concentration (%)	Mean no. eggs laid	Percent reproductive inhibition
Neem	4.00	285.25 a+	24.64
	4.50	262.50 a	30.65
	5.00	241.00 a	36.33
	5.50	150.00 b	60.37
	6.00*	80.00 c	78.86
Pongamia	2.00	221.00 a	41.61
	3.00	222.50 a	41.21
	4.00	133.75 b	64.66
	5.00	94.50 b	75.03
	6.00*	41.50 c	89.04
Argemone	8.00	308.25 a	18.56
	9.00	230.50 b	39.10
	10.00	190.00 b	49.80
	11.00*	89.50 c	76.35
	12.00	75.25 c	80.12
Soobabul	2.00	275.00 a	27.34
	3.00	210.00 b	44.52
	4.00	191.25 b	49.47
	5.00*	132.50 c	65.00
	6.00	90.50 c	76.09
Mahagony	3.00	303.50 a	19.82
	4.00	254.75 ab	32.69
	5.00	222.00 b	41.35
	6.00*	163.25 c	56.87
	7.00	140.50 c	62.88
Cashew shell	0.75	308.25 a	18.56
	1.00	257.25 ab	32.03
	1.25	209.50 bc	43.60
	1.50*	183.25 cd	51.59
	1.75	145.75 d	61.49
Control (honey solution)		378.50	0.00

* Best concentration

Comparison among six best concentrations of oils

Pongamia	(6.00)	89.04 a
Neem	(6.00)	78.86 b
Argemone	(11.00)	76.35 bc
Mahagony	(5.00)	65.00 cd
Soobabul	(6.00)	56.87 de
Cashew shell	(1.50)	51.59 e

+ Comparison among the five concentrations of an oil.
Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

In case of argemone oil concentrations of 11.00% and 12.00% produced a reproductive inhibition of 76.35% and 80.12%, respectively. However, the differences were not found to be statistically significant. A concentration of 11.00% was found to be the best.

A five per cent concentration of mahagony oil due to which a reproductive inhibition of 65.00% was recorded was found to be the most effective. However, a maximum of 76.09% was recorded at concentration of 6.00%. But it was not found to be significantly different from that caused by 5.00% oil.

The most preferred concentration of cashew shell oil was found to be 1.50% with reproductive inhibition of 51.59%.

Of all the oils, it was analysed and inferred that pongamia oil at 6.00% with a corresponding reproductive inhibition capacity of 89.04% was the best, the oils of neem (6.00%) and argemone (11.00%) ranking next. The least effective were found to be soobabul oil (6.00%) and cashew oil (1.50%), with reproductive inhibition of 56.87% and 51.59%, respectively.

4.4.2.2 <u>The effect of oils on the hatchability of eggs of the treated moths</u>

The results are presented in Table 19.

Table 19 Hatchability of the eggs laid by the moths treated with different plant seed oils

Oil	Concentration (%)	Percent hatchability of the eggs	
Neem	4.00	(37.31)	36.72 a[+]
	4.50	(33.61)	30.62 a
	5.00*	(23.92)	16.41 b
	5.50	(24.79)	17.59 b
	6.00	(21.59)	13.55 b
Pongamia	2.00	(74.06)	92.49 a
	3.00	(71.52)	89.93 a
	4.00	(61.85)	77.81 b
	5.00*	(54.14)	65.62 c
	6.00	(52.23)	62.43 c
Argemone	8.00*	(81.83)	97.97 a
	9.00	(79.55)	96.74 a
	10.00	(81.54)	97.82 a
	11.00	(78.53)	96.03 a
	12.00	(75.51)	93.73 a
Soobabul	3.00*	(80.01)	96.98 a
	4.00	(76.62)	94.63 a
	5.00	(76.23)	94.31 a
	6.00	(76.63)	94.63 a
	7.00	(80.15)	97.10 a
Mahagony	2.00	(81.97)	98.06 a
	3.00	(80.54)	97.28 a
	4.00	(79.85)	96.92 a
	5.00*	(66.78)	84.48 b
	6.00	(62.17)	78.10 b
Cashew shell	0.75*	(81.25)	97.71 a
	1.00	(77.86)	95.61 a
	1.25	(78.37)	95.96 a
	1.50	(77.12)	95.02 a
	1.75	(77.74)	95.46 a
Control		(82.35)	98.25

* Best concentration

Figures in parenthesis are the angular transformed values ($\sin^{-1}\sqrt{x}$)

Comparison among six best concentrations of oils

Neem	(5.00)	16.41 a
Pongamia	(5.00)	65.62 b
Mahagony	(5.00)	84.48 c
Soobabul	(3.00)	96.98 d
Cashew shell	(0.75)	97.71 d
Argemone	(8.00)	97.97 d

+ Comparison among the five concentrations of an oil.

Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

A hatchability of 16.41% was recorded in case of neem oil at 5.00%.

A concentration of 5.00% of pongamia oil was recorded to be the best which showed a corresponding hatchability per cent of 65.62.

In case of argemone and soobabul oils all the five concentrations were found to be on par with one another with hatchability of more than 90.00% in both the cases. Similar observations were recorded in cashew shell oil also.

A hatchability of 84.48% was recorded in mahagony oil at a concentration of 5.00% which was found to be on par with a hatchability of 78.10% caused by 6.00% of the oil.

Of the oils, it was observed that soobabul oil (3.00%), cashew shell oil (0.75%) and argemone oil (8.00%) were on par with one another. The best oil was found to be neem (5.00%) in which case the hatchability recorded was just 16.41%.

In case of the control, the hatchability was found to be 98.25% (the remaining eggs failed to hatch) and on analysis it was revealed that this statistically was on par with soobabul (3.00%), cashew shell oil (0.75%) and argemone oil (8.00%).

4.5 Effect of oils on the parasitism of potato tuber moth

The extent of parasitism was calculated based on the number of potato tuber moth adults that failed to emerge. The results are presented in Table 20.

No significant differences in parasitism were observed among the respective concentrations of all the six oils. Nevertheless a maximum of 48.00% parasitism was observed in case of cashew shell oil at 0.25%. The least parasitism of 31.00% was recorded in the seed oil of soobabul at 5.00% and 6.00%.

Of all the oils, the differences among the extent of parasitism as a consequence of the application of pongamia (2.00%), neem (2.00%), mahagony (2.00%) and cashew shell oil (0.25%) were found to be non-significant.

In case of the two controls, 47.00% parasitism was recorded in case of the one wherein a mixture of emulsified water and 5.00% benzene was used and a parasitism of 49.00% was observed wherein only water was used as the other control. However, no significant difference was observed between the two.

Table 20 Effect of different plant seed oils on parasitism of potato tuber moth

Oil	Concentration (%)	Mean no. moths unemerged	Percentage parasitism
Neem	2.00*	11.50 a+	46 (93.88)
	3.00	11.25 a	45 (91.84)
	4.00	11.50 a	46 (93.88)
	5.00	11.25 a	45 (91.84)
	6.00	11.25 a	45 (91.84)
Pongamia	2.00*	11.25 a	45 (91.84)
	3.00	11.25 a	45 (91.84)
	4.00	11.00 a	44 (89.80)
	5.00	10.75 a	43 (87.76)
	6.00	10.75 a	43 (87.76)
Argemone	2.00*	9.50 a	38 (77.55)
	3.00	9.75 a	39 (79.59)
	4.00	8.75 a	35 (71.43)
	5.00	8.75 a	35 (71.43)
	6.00	8.50 a	34 (69.39)
Soobabul	2.00*	8.25 a	33 (67.35)
	3.00	8.25 a	33 (67.35)
	4.00	8.00 a	32 (65.31)
	5.00	7.75 a	31 (63.27)
	6.00	7.75 a	31 (63.27)
Mahagony	2.00*	11.75 a	47 (95.92)
	3.00	11.75 a	47 (95.92)
	4.00	11.50 a	46 (93.88)
	5.00	11.50 a	46 (93.88)
	6.00	11.25 a	45 (91.84)
Cashew shell	0.25*	12.00 a	48 (97.96)
	0.50	11.75 a	47 (95.92)
	0.75	11.75 a	47 (95.92)
	1.00	11.75 a	47 (95.92)
	1.25	11.50 a	46 (93.88)
Control (B + L)		11.75 a	47 (95.92)
Control (water)		12.25 a	49 (100.00)

* Best concentration

Comparison among six best concentrations of oils

Soobabul	(2.00)	34.00 a
Argemone	(2.00)	38.00 a
Pongamia	(2.00)	45.00 ab
Neem	(2.00)	46.00 b
Mahagony	(2.00)	47.00 b
Cashew shell	(0.25)	48.00 b

+ Comparison among the five concentrations of an oil.

Any two means followed by the same letter do not differ significantly at the 5% level by the Student-Newman-Keuls (SNK) test.

Figures in parentheses are the corrected % parasitism values:

$$\frac{\text{Treated parasitism (\%)}}{\text{Control parasitism (\%)}} \times 100$$

No significant differences were observed between the control and the oils of pongamia (2.00%), mahagony (2.00%) and cashew shell oil (0.25%) (Table 20).

When paper discs of malathion were used, it was observed that the parasite was killed within an hour.

4.6 Bioassay studies on *Phthorimaea operculella*

In this case, LC_{50}'s of the six respective oils were calculated at various stages of the test insect. The values are presented in Table 21.

4.6.1 Ovicidal action of the six oils

The LC_{50} values with the corresponding regression equations are presented in Table 22 and graphically represented in Fig. 1.

The LC_{50} of neem oil was found to be 0.3378% and the corresponding regression equation was Y = 5.7198+1.5312x.

Pongamia seemed to have a higher LC_{50} value of 1.3553% with the following regression equation: Y = 4.8468 + 1.1658x.

Argemone oil showed an LC_{50} value of 1.7596% and the corresponding regression equation was calculated to be Y=4.8423 + 0.8966x.

Table 21: LC_{50} values of the plant seed oils treated to several stages of potato tuber moth

Oil	Egg	Larva					Pupa
		III Instar		IV Instar			
		24 hrs.	48 hrs.	24 hrs.	48 hrs.	72 hrs.	
Neem	0.3378	2.2304	1.8578	7.8577	3.4420	1.8760	8.9356
Pongamia	1.3353	2.3756	1.4156	3.9807	1.6931	0.6073	8.3172
Argemone	1.7396	5.0805	3.6252	7.4030	5.3877	3.7509	8.6124
Soobabul	2.6345	5.2597	2.2513	7.7203	3.1278	1.0961	5.2777
Mahagony	0.6473	0.6713	0.5925	1.0137	0.6140	0.2384	6.3248
Cashew shell	0.1878	0.0097	0.0063	0.0184	0.0137	0.0098	0.3305

Table 22 Effect of different concentrations of plant seed oils on the eggs of potato tuber moth

Oil	Concentration (%)	No. of eggs	Number killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	0.25	80	31	38.75		
	0.50	80	53	66.25		
	0.75	80	56	70.00	Y = 5.7198+1.5312x	0.3378
	1.00	80	60	75.00		
	1.25	80	64	90.00		
Pongamia	2.00	80	47	58.75		
	3.00	80	53	66.25		
	4.00	80	54	67.50	Y = 4.8468+1.1658x	1.3553
	5.00	80	60	75.00		
	6.00	80	63	78.75		
Argemone	2.00	80	43	53.75		
	3.00	80	47	58.75		
	4.00	80	49	61.25	Y = 4.8423+0.8966x	1.7396
	5.00	80	50	62.50		
	6.00	80	66	82.50		
Soobabul	2.00	80	34	42.50		
	3.00	80	45	56.25		
	4.00	80	51	63.75	Y = 3.7655+2.9985x	2.6345
	5.00	80	59	73.75		
	6.00	80	74	92.50		
Mahagony	0.50	80	37	46.25		
	1.00	80	47	58.75		
	1.50	80	54	67.50	Y = 5.2850+1.4874x	0.6473
	2.00	80	61	76.25		
	2.50	80	67	83.75		
Cashew shell	0.25	80	46	57.50		
	0.50	80	47	58.75		
	0.75	80	60	75.00	Y = 5.8709+1.1959x	0.1878
	1.00	80	63	78.75		
	1.25	80	69	86.25		

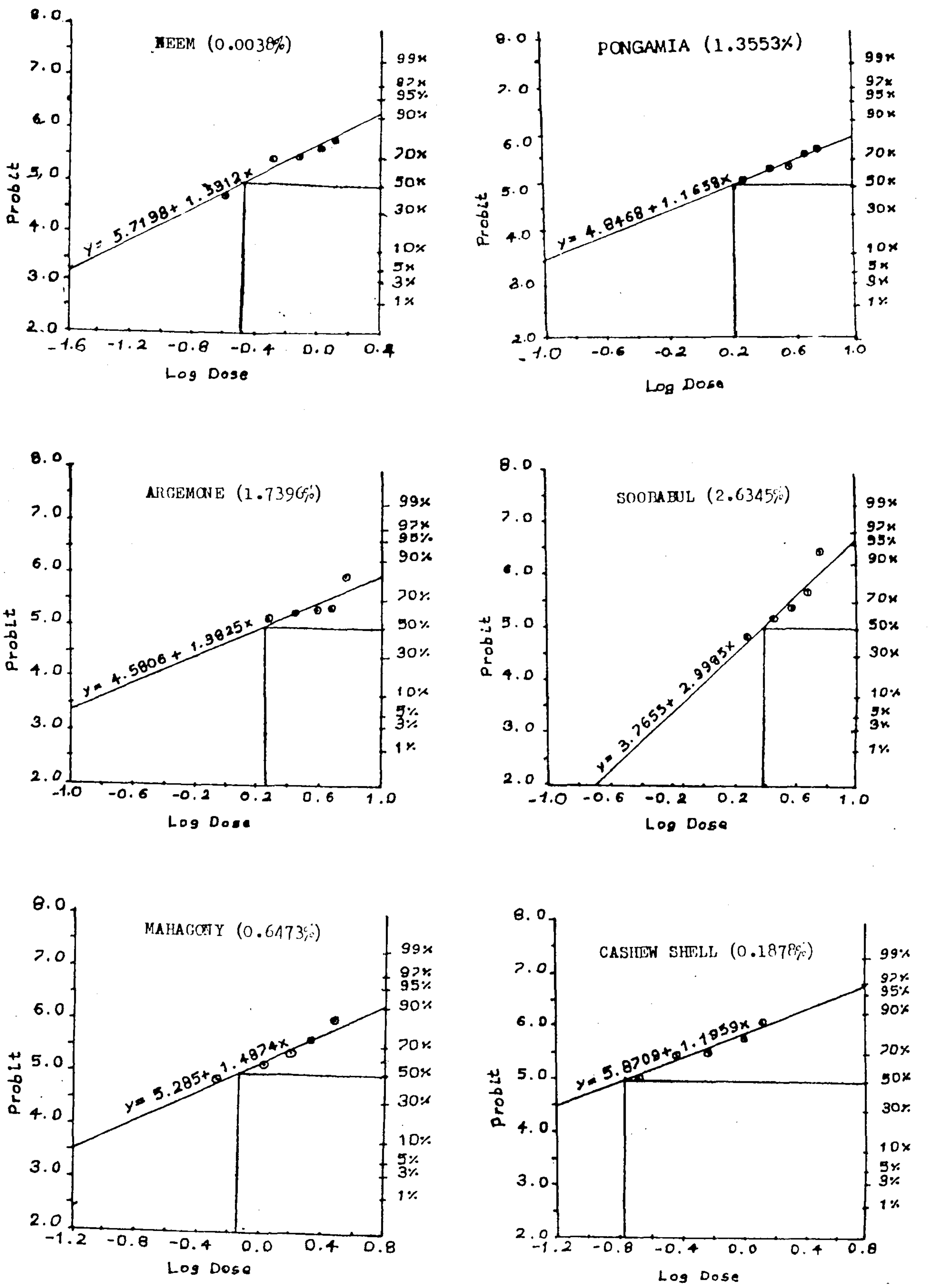


Fig. 1 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE EGGS OF <u>PHTHORIMAEA</u> <u>OPERCULELLA</u> ZELL.

The highest LC_{50} was observed in soobabul which was found to be 2.6345% and the regression equation was Y = 3.7655 + 2.9985x.

An LC_{50} value of 0.6473% was recorded in mahagony oil and the regression equation was Y = 5.285 + 1.4874x.

Cashew shell oil was found to have the least LC_{50} value of 0.1878% and the corresponding regression equation was Y = 5.8709 + 1.1959x.

4.6.2 Larvicidal action of the six oils

4.6.2.1 Effect of the oils on the fourth instar larvae

4.6.2.1.1 Observations at 24 hours

The LC_{50} values of the six oils taken at 24 hours are presented in Table 23 and Fig. 2.

A maximum LC_{50} value of 7.8577% was observed in neem oil. The corresponding regression equation was Y = 4.4785 + 0.587x.

Pongamia oil showed an LC_{50} value of 3.9307% and the regression equation was worked out to be Y = 4.1842 + 1.3649x.

Argemone showed a higher value of 7.4030%. The regression equation was found to be Y = 3.3913 + 1.8506x.

Table 23 Effect of different concentrations of plant seed oils on the IV instar larvae of potato tuber moth 24 hours after treatment

Oil	Concentration (%)	No. of larvae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	2.00	40	15	37.50		
	3.00	40	15	37.50		
	4.00	40	18	45.50	Y = 4.4785+0.5870x	7.8577
	5.00	40	18	45.00		
	6.00	40	19	47.50		
Pongamia	2.00	40	15	37.50		
	3.00	40	17	42.50		
	4.00	40	18	45.50	Y = 4.1842+1.3649x	3.9807
	5.00	40	20	50.00		
	6.00	40	27	67.50		
Argemone	2.00	40	06	15.00		
	3.00	40	09	22.50		
	4.00	40	13	32.50	Y = 3.3913+1.8506x	7.4030
	5.00	40	14	35.00		
	6.00	40	18	45.00		
Soobabul	2.00	40	09	22.50		
	3.00	40	13	32.50		
	4.00	40	14	35.00	Y = 3.8927+1.2474x	7.7203
	5.00	40	16	40.00		
	6.00	40	18	45.00		
Mahagony	0.50	40	11	27.50		
	1.00	40	18	45.00		
	1.50	40	26	65.00	Y = 4.9906+2.1342x	1.0137
	2.00	40	30	75.00		
	2.50	40	32	80.00		
Cashew shell	0.01	40	16	40.00		
	0.02	40	18	45.00		
	0.03	40	23	57.50	Y = 7.6049+1.4975x	0.0184
	0.04	40	29	72.50		
	0.05	40	31	77.50		

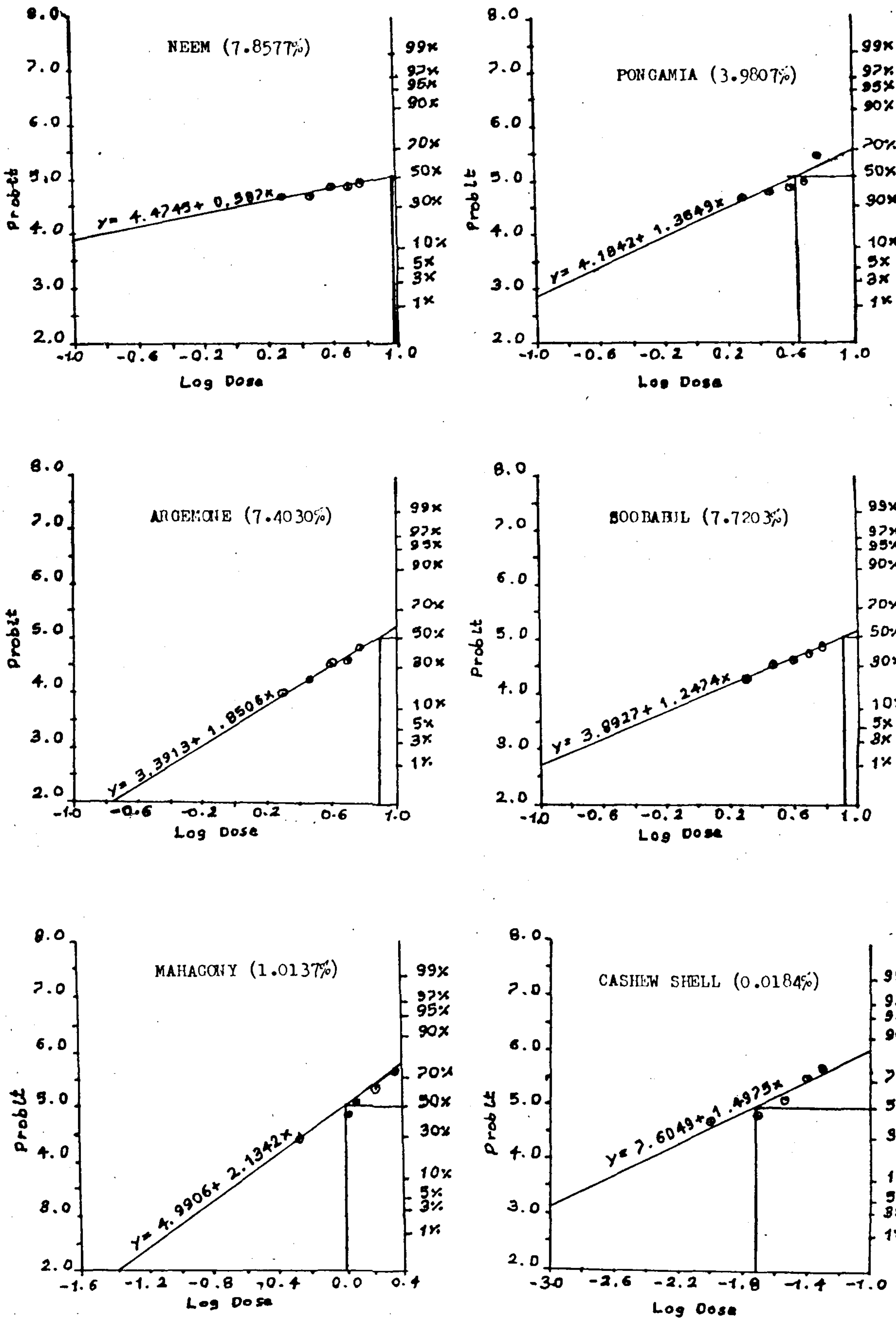


Fig. 2 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE FOURTH INSTAR LARVAE OF PHTHORIMAEA OPERCULELLA ZELL. (24 HOURS AFTER TREATMENT)

The LC_{50} value of soobabul was higher than that of argemone. It was 7.7203%. The regression equation was Y = 3.8927 + 1.2474x.

Mahagony oil was found to have an LC_{50} value as low as 1.1037% and the regression equation was : Y = 4.9906 + 2.1342x.

The least LC_{50} value was observed in cashew shell oil. It was found to be 0.0184%. The regression equation was Y = 7.6049 + 1.4975x.

4.6.2.1.2 Observations at 48 hours

The LC_{50} values of the six oils calculated from the mortalities caused at 48 hours after treatment are presented in Table 24 and Fig. 3.

At 48 hours after treatment the LC_{50} values of all the six oils were found to be less than those at 24 hours.

In this case, the maximum LC_{50} value was observed in aargemone wherein it was 5.387%, Y ± 3.2783 + 2.3523x being the corresponding regression equation.

An LC_{50} value of 3.4420% was found in neem oil and the regression equation was found to be Y = 4.6114 + 0.7237x.

Table 24 Effect of different concentrations of plant seed oils on the IV instar larvae of potato tuber moth 48 hours after treatment

Oil	Concentration (%)	No. of larvae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	2.00	40	17	42.50		
	3.00	40	19	47.50		
	4.00	40	22	55.00	Y = 4.6114+0.7237x	3.4420
	5.00	40	22	55.00		
	6.00	40	22	55.00		
Pongamia	2.00	40	23	57.50		
	3.00	40	25	62.50		
	4.00	40	25	62.50	Y = 4.6838+1.4011x	1.6931
	5.00	40	31	77.50		
	6.00	40	32	80.00		
Argemone	2.00	40	06	15.00		
	3.00	40	11	27.50		
	4.00	40	16	40.00	Y = 3.2783+2.3523x	5.3877
	5.00	40	19	47.50		
	6.00	40	21	52.50		
Soobabul	2.00	40	17	42.50		
	3.00	40	21	52.50		
	4.00	40	21	52.50	Y = 4.6391+0.7192x	3.1728
	5.00	40	22	55.00		
	6.00	40	23	57.50		
Mahagony	0.50	40	19	47.50		
	1.00	40	24	60.00		
	1.50	40	31	77.50	Y = 5.3905+1.7947x	0.6140
	2.00	40	31	77.50		
	2.50	40	36	90.00		
Cashew shell	0.01	40	20	50.00		
	0.02	40	21	50.25		
	0.03	40	25	62.50	Y = 7.8518+1.5217x	0.0137
	0.04	40	30	75.00		
	0.05	40	35	87.50		

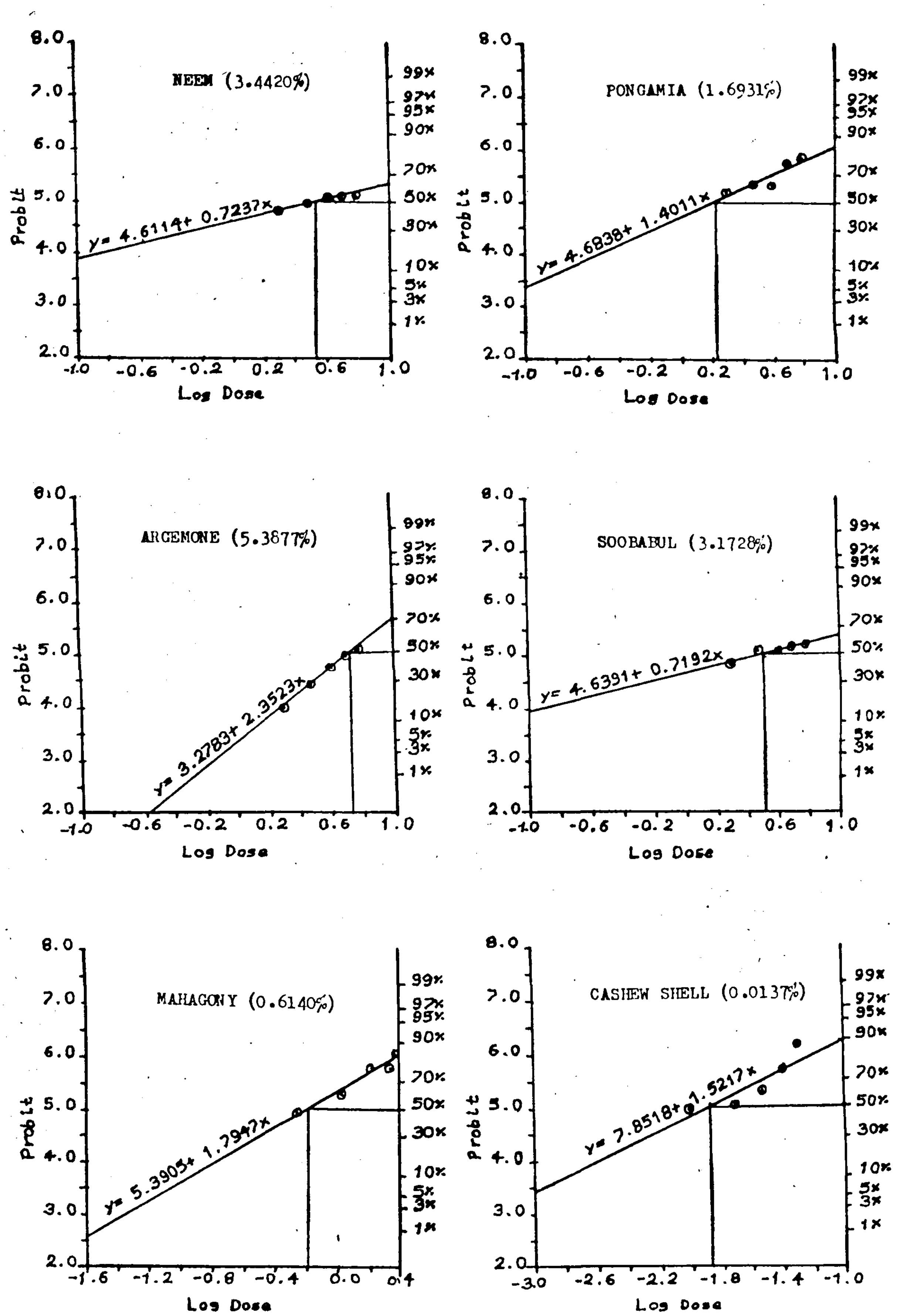


Fig. 3 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE FOURTH INSTAR LARVAE OF PHTHORIMAEA OPERCULELLA ZELL. (48 HOURS AFTER TREATMENT)

Pongamia oil showed an LC_{50} value of 1.6931% with the following regression equation: Y = 4.6838 + 1.4011x.

The LC_{50} recorded in the seed oil of soobabul was 3.1728%. The regression equation was Y = 4.6391 + 0.7192x.

Mahagony oil showed the corresponding LC_{50} value to be 0.614% and the regression equation was Y = 5.3095 + 1.7947x.

Cashew shell oil showed the least LC_{50} value of 0.0137%. The regression equation was Y = 7.8518 + 1.5217x.

4.6.2.1.3 <u>Observations at 72 hours</u>

The LC_{50} values of all the six oils were found to decrease further (Table 25 and Fig. 4).

Maximum was recorded in argemone wherein the LC_{50} value was 3.7509%. The regression equation was Y = 3.0356 + 3.448x.

Neem oil had an LC_{50} of 1.8760% and the regression equation was Y = 4.654 + 1.2746x.

In case of pongamia oil the regression equation was Y = 5.2337 + 1.3206x, and the corresponding LC_{50} value was 0.6073%.

Table 25 Effect of different concentrations of plant seed oils on the IV instar larvae of potato tuber moth 72 hours after treatment

Oil	Concentration (%)	No. of larvae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	2.00	40	22	55.00		
	3.00	40	23	57.50		
	4.00	40	25	62.50	Y = 4.6540+1.2746x	1.8760
	5.00	40	28	70.00		
	6.00	40	31	77.50		
Pongamia	2.00	40	29	72.50		
	3.00	40	34	85.00		
	4.00	40	35	87.50	Y = 5.2887+1.3206x	0.6073
	5.00	40	35	87.50		
	6.00	40	36	90.00		
Argemone	2.00	40	08	20.00		
	3.00	40	15	37.50		
	4.00	40	19	47.50	Y = 3.0356+3.4480x	3.7509
	5.00	40	25	62.50		
	6.00	40	33	82.50		
Soobabul	2.00	40	25	62.50		
	3.00	40	26	65.00		
	4.00	40	26	65.00	Y = 4.9668+0.9169x	1.0961
	5.00	40	28	70.00		
	6.00	40	32	80.00		
Mahagony	0.50	40	30	75.00		
	1.00	40	35	87.50		
	1.50	40	38	95.00	Y = 6.2395+1.9865x	0.2384
	2.00	40	40	100.00		
	2.50	40	40	100.00		
Cashew shell	0.01	40	24	60.00		
	0.02	40	26	65.00		
	0.03	40	30	75.00	Y = 8.7957+1.8774x	0.0098
	0.04	40	35	87.50		
	0.05	40	38	95.00		

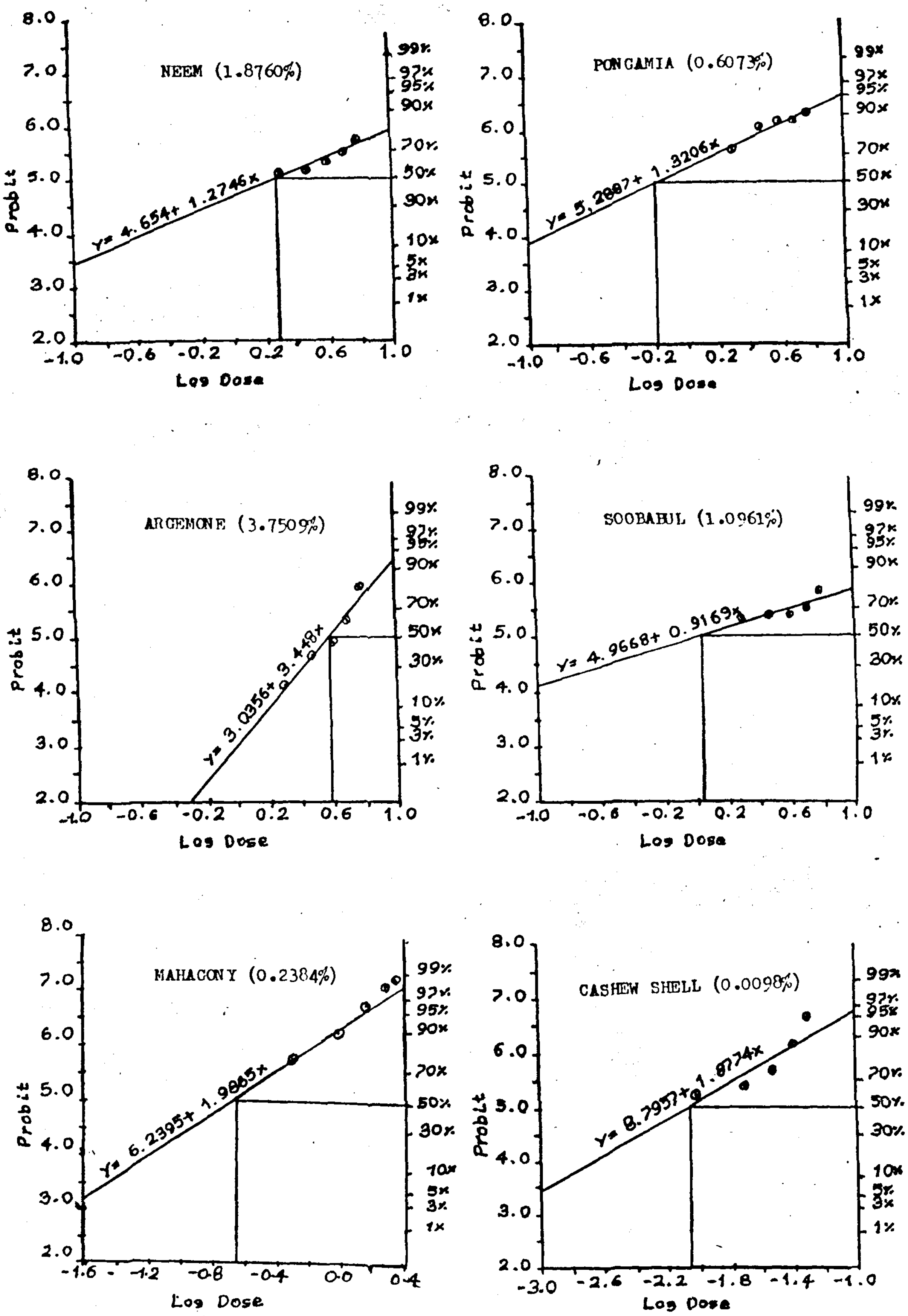


Fig. 4 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE FOURTH INSTAR LARVAE OF PHTHORIMAEA OPERCULELLA ZELL. (72 HOURS AFTER TREATMENT)

An LC_{50} value of 1.0961% was recorded in soobabul and the regression equation was Y = 4.9668 + 0.9169x.

In case of seed oil of mahagony the LC_{50} of 0.2384% was recorded and the regression equation was: Y = 6.2395 + 1.9865x.

An LC_{50} value as low as 0.0098% was observed in cashew shell oil and the regression equation was Y = 8.7957 + 1.8774x.

4.6.2.2 Effect of oils on the third instar larvae

4.6.2.2.1 Observations at 24 hours

The respective LC_{50} values of the six oils were found to be less than those recorded at 24 hours for the fourth instar larvae. The results are presented in Table 26 and Fig. 5.

Neem oil was found to have an LC_{50} value of 2.2304% with a regression equation of Y = 4.2254 + 2.2375x.

The LC_{50} value of pongamia oil was 2.3756% and the regression equation was Y = 3.7984 + 3.2183x.

The regression equation of the oil of argemone was Y = 3.1466 + 2.631x with the corresponding LC_{50} value of 5.0805%.

Table 26 Effect of different concentrations of plant seed oils on the III instar larvae of potato tuber moth 24 hours after treatment

Oil	Concentration (%)	No. of larvae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	2.00	40	20	50.00		
	3.00	40	23	57.50		
	4.00	40	27	67.50	Y = 4.2254+2.2375x	2.2304
	5.00	40	32	80.00		
	6.00	40	34	85.00		
Pongamia	2.00	40	18	45.00		
	3.00	40	22	55.00		
	4.00	40	31	77.50	Y = 3.7984+3.2183x	2.3756
	5.00	40	35	87.50		
	6.00	40	36	90.00		
Argemone	2.00	40	06	15.00		
	3.00	40	12	30.00		
	4.00	40	14	35.00	Y = 3.1466+2.6310x	5.0805
	5.00	40	17	42.50		
	6.00	40	26	65.00		
Soobabul	2.00	40	10	25.00		
	3.00	40	13	32.50		
	4.00	40	14	35.00	Y = 3.7192+1.7779x	5.2597
	5.00	40	20	50.00		
	6.00	40	23	57.50		
Mahagony	0.50	40	18	45.00		
	1.00	40	24	60.00		
	1.50	40	29	72.50	Y = 5.3915+2.1676x	0.6713
	2.00	40	34	85.00		
	2.50	40	37	92.50		
Cashew shell	0.01	40	24	60.00		
	0.02	40	25	62.50		
	0.03	40	28	70.00	Y = 8.2676+1.6117x	0.0097
	0.04	40	34	85.00		
	0.05	40	37	92.50		

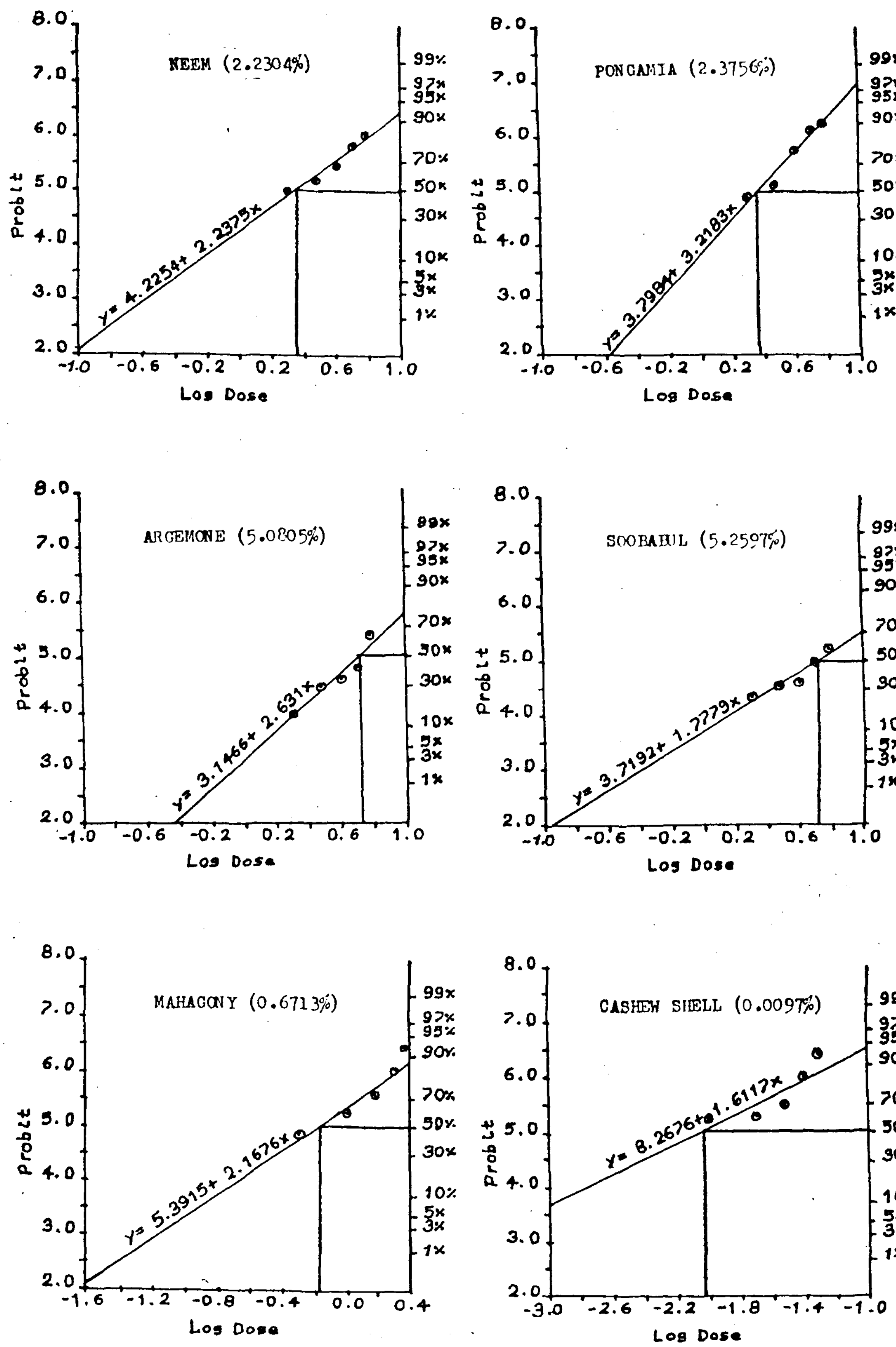


Fig. 5 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE THIRD INSTAR LARVAE OF <u>PHTHORIMAEA OPERCULELLA</u> ZELL. (24 HOURS AFTER TREATMENT)

The highest LC_{50} value was observed in soobabul seed oil. It was found to be 5.2597% and the regression equation was **Y** = 3.7192 + 1.7779x.

A low LC_{50} value of 0.6173% was recorded in mahagony. The regression equation was calculated to be Y = 5.3915 + 2.1676x.

The least LC_{50} value was seen in cashew shell oil and it was 0.0097%. Y = 8.2676 + 1.6117x was the corresponding regression equation.

4.6.2.2.2 Observations at 48 hours

The results in detail are presented in Table 27 and Fig. 6.

Neem oil showed an LC_{50} value of 1.8578% and the corresponding regression equation was Y = 4.0665 + 3.5008x.

The LC_{50} value of pongamia oil was found to be 1.4156%. The regression equation was Y = 4.6544 + 2.3406x.

The highest LC_{50} value of 3.6252% was found in argemone oil with the following regression equation: Y = 2.7333 + 4.1031x.

The seed oil of soobabul showed an LC_{50} value of 2.2513%. The regression equation was Y = 4.6302 + 1.0546x.

Table 27 Effect of different concentrations of plant seed oils on the III instar larvae of potato tuber moth 48 hours after treatment

Oil	Concentration (%)	No. of larvae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	2.00	40	23	57.50		
	3.00	40	30	75.00		
	4.00	40	34	85.00	Y = 4.0665+3.5008x	1.8578
	5.00	40	38	95.00		
	6.00	40	40	100.00		
Pongamia	2.00	40	27	67.50		
	3.00	40	30	75.00		
	4.00	40	34	85.00	Y = 4.6544+2.3406x	1.4156
	5.00	40	35	87.50		
	6.00	40	38	95.00		
Argemone	2.00	40	08	20.00		
	3.00	40	13	32.50		
	4.00	40	19	47.50	Y = 2.7333+4.1031x	3.6252
	5.00	40	29	72.50		
	6.00	40	35	87.50		
Soobabul	2.00	40	20	50.00		
	3.00	40	22	55.00		
	4.00	40	23	57.50	Y = 4.6302+1.0546x	2.2513
	5.00	40	24	60.00		
	6.00	40	29	72.50		
Mahagony	0.50	40	19	47.50		
	1.00	40	27	67.50		
	1.50	40	32	80.00	Y = 5.5568+2.3962x	0.5925
	2.00	40	36	90.00		
	2.50	40	38	95.00		
Cashew shell	0.01	40	28	70.00		
	0.02	40	29	72.50		
	0.03	40	32	80.00	Y = 8.4197+1.5412x	0.0063
	0.04	40	36	90.00		
	0.05	40	38	95.00		

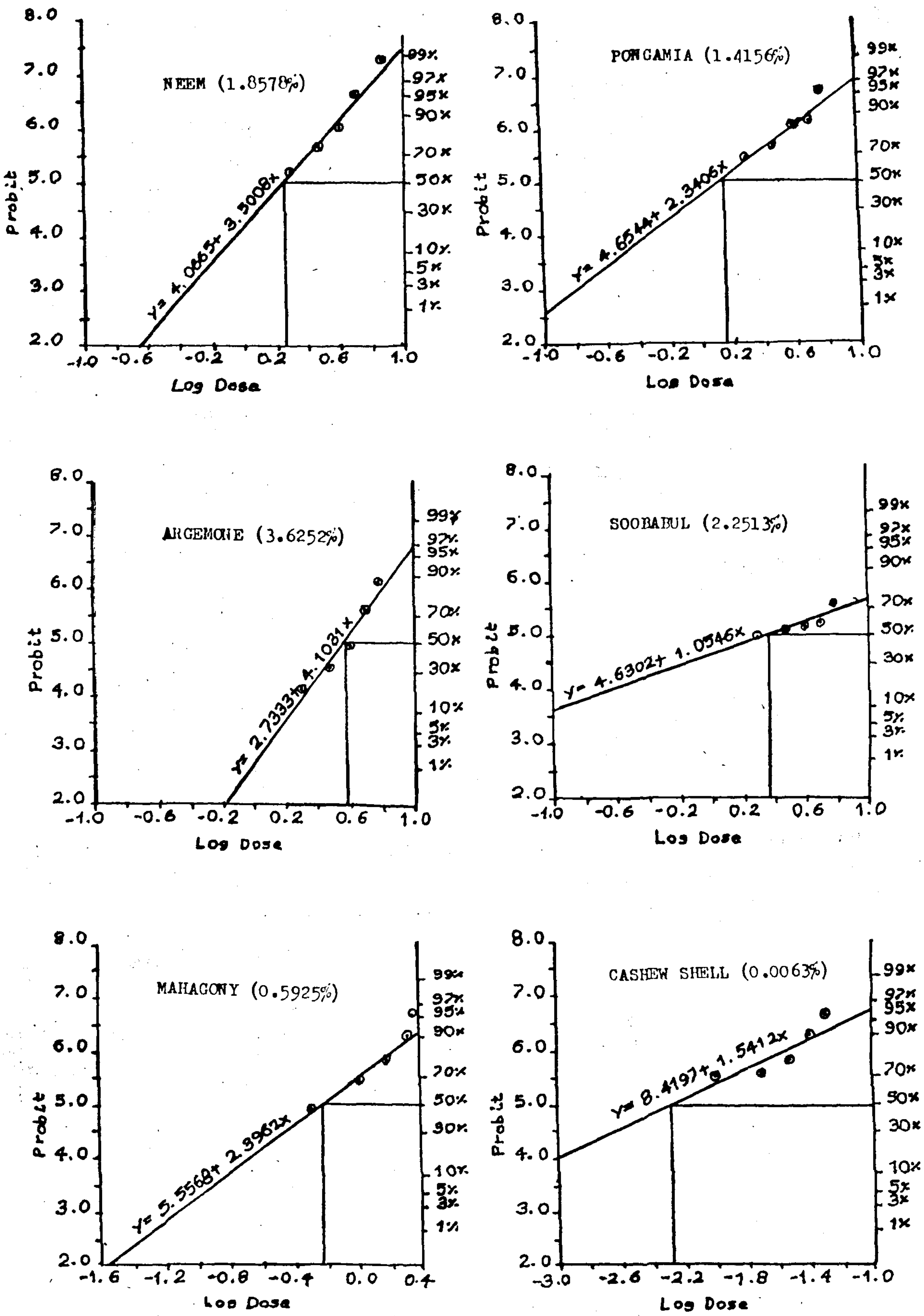


Fig. 6 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE THIRD INSTAR LARVAE OF PHTHORIMAEA OPERCULELLA ZELL. (48 HOURS AFTER TREATMENT)

The LC_{50} value of mahagony oil was 0.5925%. The corresponding regression equation was Y = 5.5568 + 2.3962x.

The least LC_{50} was calculated in cashew shell oil. It was found to be 0.0063% and the regression equation was Y = 8.4197 + 1.5412x.

4.6.3 <u>Results of the pupal treatment of the oils</u>

The results are presented in Table 28 and Fig. 7.

Except soobabul oil, the Lc_{50} values of the other oils were found to be higher than those obtained for the other stages treated.

Neem oil showed a maximum LC_{50} value of 8.9356%. The corresponding regression equation was Y = 2.5108 + 2.6219x.

Pongamia oil showed a slightly lower LC_{50} value. It was worked out to be 8.3172%. The regression equation was Y = 0.9123 + 4.4478x.

The regression equation calculated in argemone oil was Y = 1.7584 + 3.4601x. The LC_{50}. was 8.6124%

A LC_{50} value of 5.2777% was calculated in soobabul oil and the regression equation was Y = 3.9389 + 1.4064x.

Table 28 Effect of different concentrations of plant seed oils on the pupae of potato tuber moth

Oil	Concentration (%)	No. of pupae	No. killed	Percentage killed	Regression equation	LC_{50} (%)
Neem	6.00	40	15	37.50		
	8.00	40	16	40.00		
	10.00	40	22	52.50	Y = 2.5108+2.6219x	8.9356
	12.00	40	24	60.00		
	14.00	40	30	75.00		
Pongamia	6.00	40	11	27.50		
	8.00	40	19	47.50		
	10.00	40	24	60.00	Y = 0.9123+4.4478x	8.3172
	12.00	40	31	77.50		
	14.00	40	34	85.00		
Argemone	6.00	40	10	25.00		
	8.00	40	21	52.50		
	10.00	40	24	60.00	Y = 1.7584+3.4601x	8.6124
	12.00	40	27	67.50		
	14.00	40	30	75.00		
Soobabul	6.00	40	21	52.50		
	8.00	40	24	60.00		
	10.00	40	27	67.50	Y = 3.9839+1.4064x	5.2777
	12.00	40	27	67.50		
	14.00	40	29	72.50		
Mahagony	6.00	40	20	50.00		
	8.00	40	26	65.00		
	10.00	40	29	72.50	Y = 1.8700+3.9178x	6.3248
	12.00	40	35	87.50		
	14.00	40	37	92.50		
Cashew shell	0.25	40	20	50.00		
	0.50	40	21	52.50		
	0.75	40	27	67.50	Y = 5.9454+1.9663x	0.3305
	1.00	40	33	82.50		
	1.25	40	39	97.50		

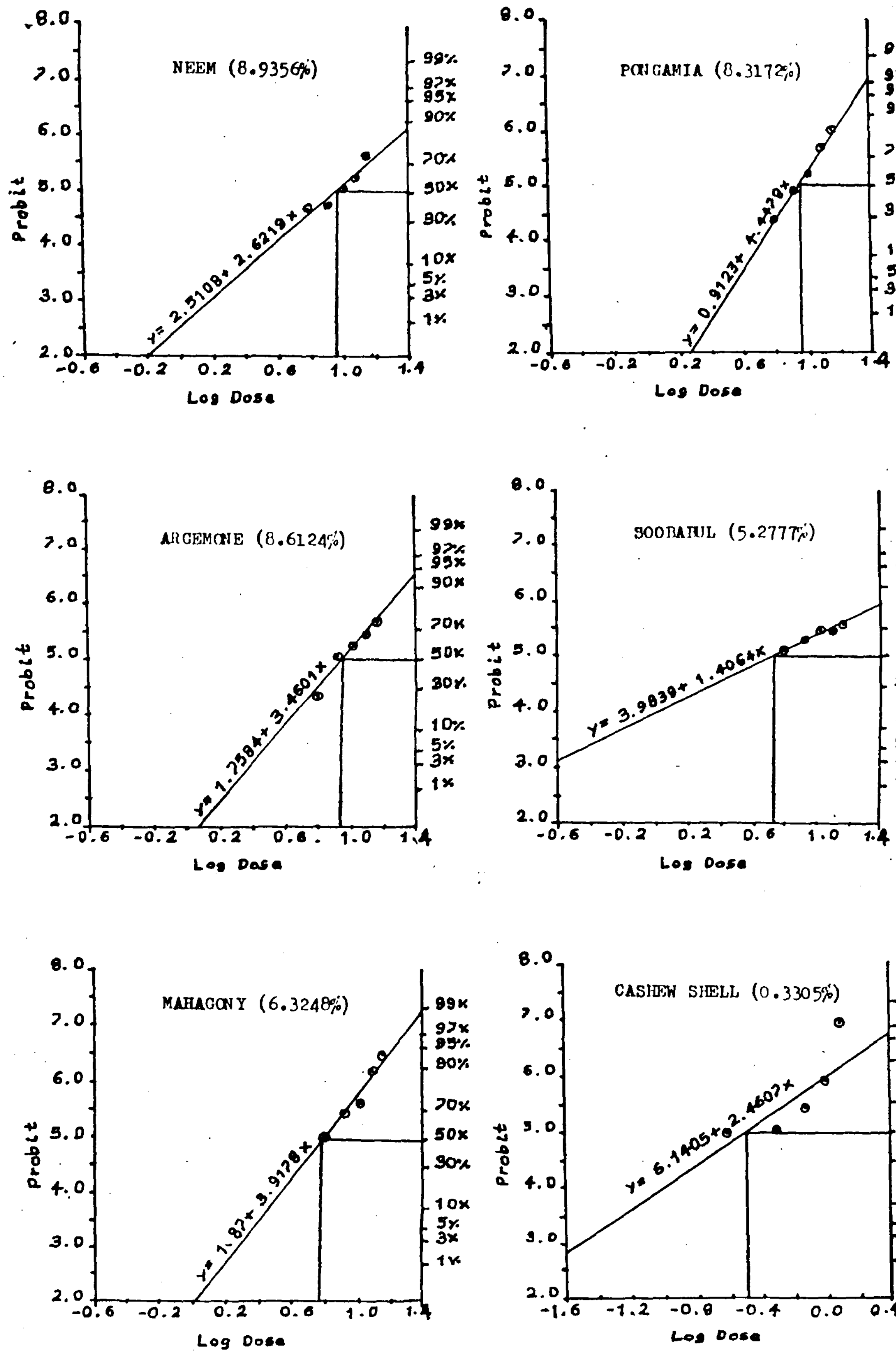


Fig. 7 FITTING PROBIT REGRESSION LINE TO THE DATA OF THE SIX SEED OILS TREATED TO THE PUPAE OF <u>PHTHORIMAEA</u> <u>OPERCULELLA</u> ZELL.

A higher LC_{50} value of 6.3248% was calcuated in mahagony oil and the regression equation was Y = 1.87 + 3.9178x.

The least LC_{50} value of 0.3305% was calculated in cashew shell oil and the regression equation was Y = 5.9454 + 1.9663x.

4.6.4 Relative toxicity of the oils

4.6.4.1 Ovicidal property

As mentioned before, relative toxicity of the oils were calculated taking neem as the standard (as this plant species is the most widely used in insect pest management). The relative positions of the oils are presented in Table 29 and graphically represented in Fig. 8. Cashew shell oil was found to be the best being 1.80 times as toxic as neem. The next best was found to be the oil of neem. The least toxic was the seed oil of soobabul with a relative toxicity of 0.13.

4.6.4.2 Larvicidal property

In case of the third and the fourth instar larvae cashew shell oil was found to be most effective. At 24 hours after the treatment of the fourth instar larvae, neem oil was the least effective. Mahogany oil with a relative toxicity of 7.75 ranked second (Table 30 and Fig. 9). At 48 hours after

Table 29 *Relative toxicity of different oils treated to the eggs of potato tuber moth

Oil	LC_{50} (%)	Relative toxicity
Neem	0.3378	1.00
Pongamia	1.3553	0.25
Argemone	1.7396	0.19
Soobabul	2.6345	0.13
Mahagony	0.6473	0.52
Cashew shell	0.1878	1.80

* Relative toxicity $\dfrac{LC_{50} \text{ of neem}}{LC_{50} \text{ of the oil}}$

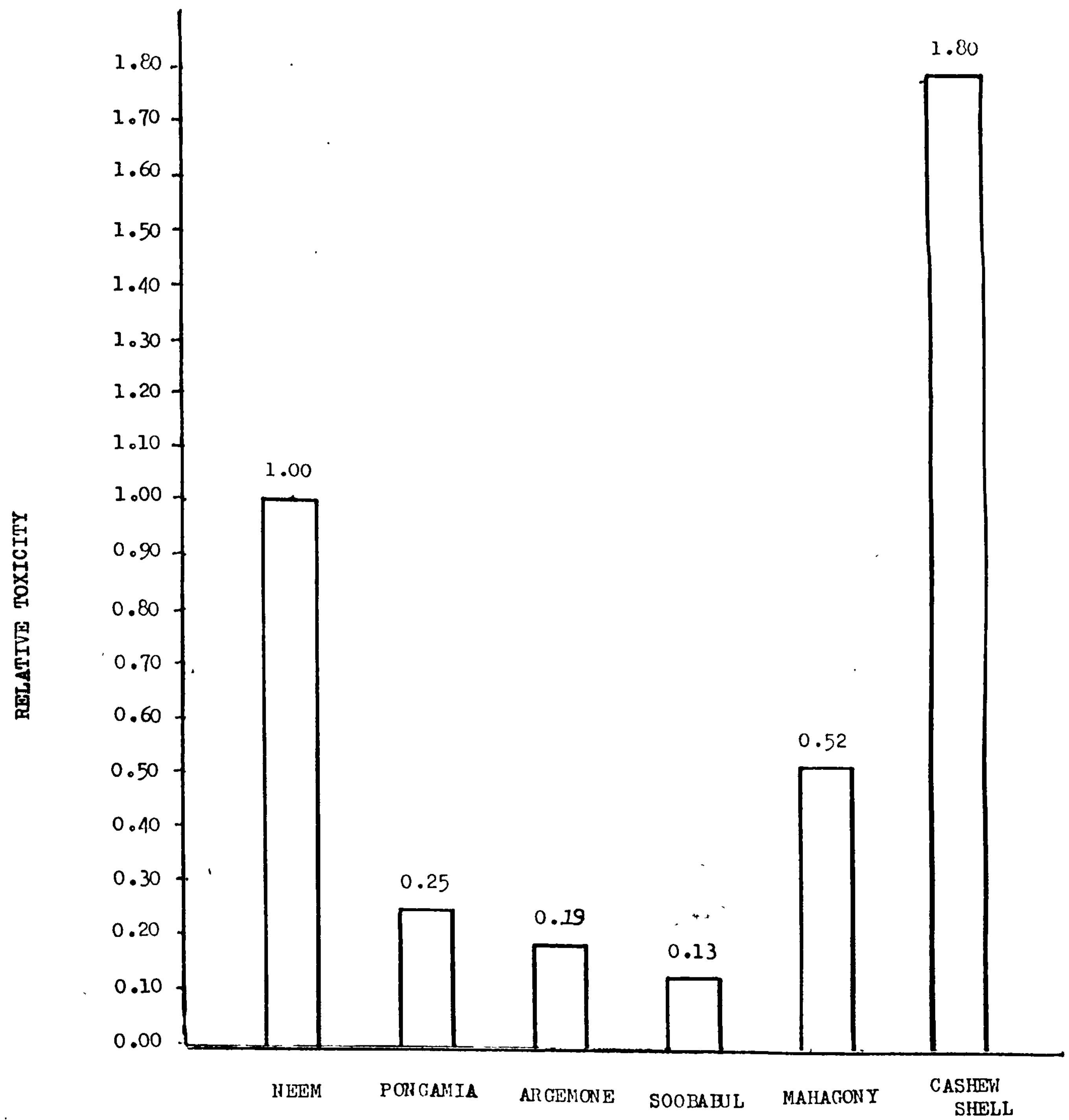


Fig. 8 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE EGGS OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES

Table 30 Relative toxicity of different plant seed oils treated to the IV instar larvae of potato tuber moth 24 hours after treatment

Oil	LC_{50} (%)	Relative toxicity
Neem	7.8577	1.00
Pongamia	3.9807	1.97
Argemone	7.4030	1.06
Soobabul	7.7203	1.02
Mahagony	1.0137	7.75
Cashew shell	0.0184	427.05

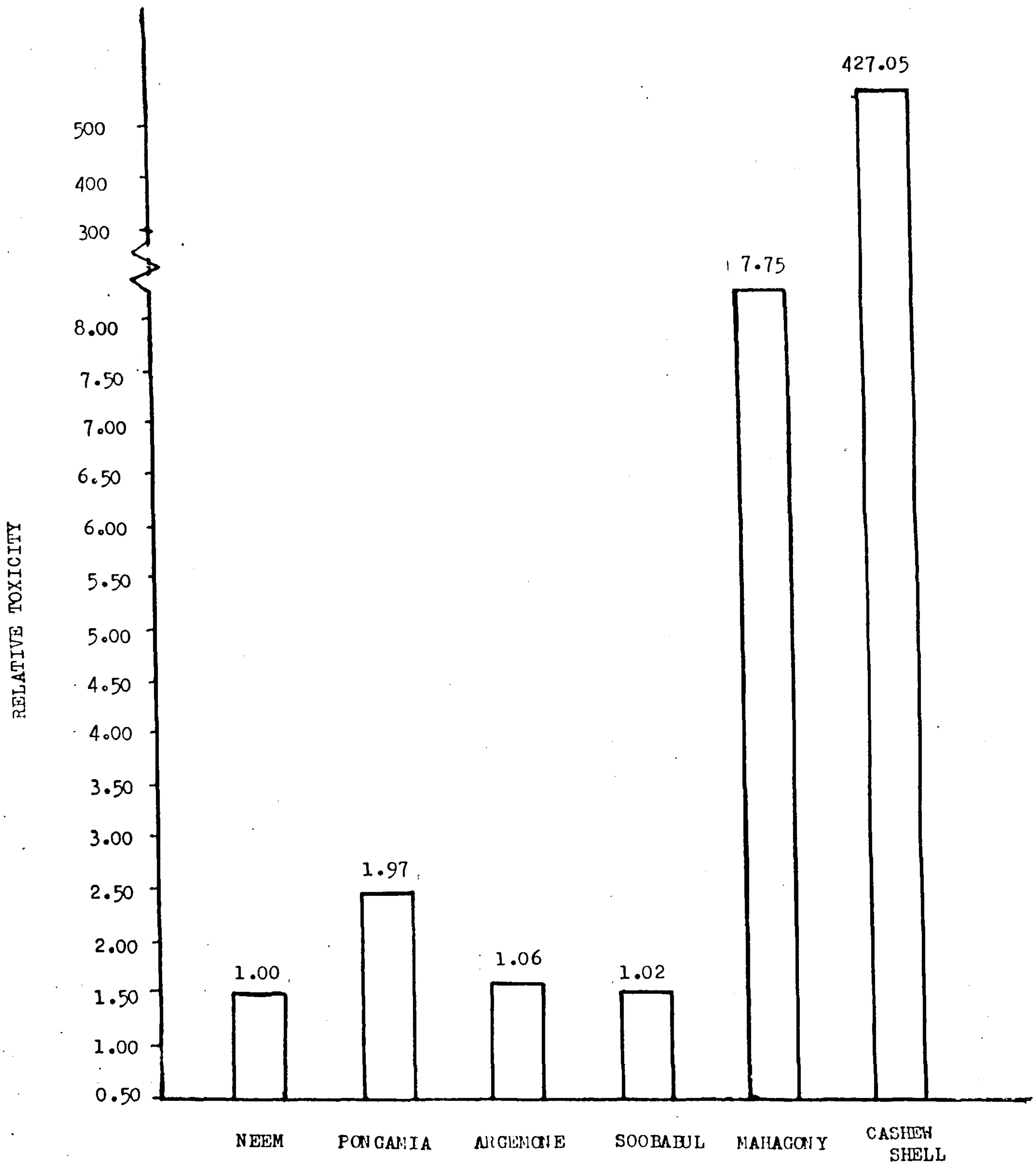


Fig. 9 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE FOURTH INSTAR LARVAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES (24 HOURS AFTER TREATMENT)

treatment, cashew shell oil showed a relative toxicity of 251.24 and again mahagony oil was the next best (with a relative toxicity of 5.61). Argemone was the least effective which had a relative toxicity of 0.64 (Table 31 and Fig.10). Cashew shell oil was found to be best oil at 72 hours fter the treatment of fourth instar larvae. It showed a relative toxicity value of 191.43. As before argemone oil ranked last with a relative toxicity of 0.50 (Table 32 and Fig.11).

In case of the third instar larvae, at 24 hours after treatment, neem with a relative toxicity of 1.00 ranked third, the first position being occupied by cashew shell oil (relative toxicity of 229.94) and the oil of mahagony taking the second position whose relative toxicity was 3.32. In this case soobabul oil was the least effective (Table 33 and Fig. 12). At 48 hours after treatment, argemone oil was the least effective with a relative toxicity of 0.51 and cashew shell oil was found to be the most effective as it was found to be 294.89 times as effective as neem oil. Mahagony oil was found to take the next position and it was found to be 3.14 times as effective as neem oil (Table 34 and Fig. 13).

4.6.4.3 Pupicidal property

Relative toxicity values of the oils treated to the pupae showed that cashew shell oil was the most toxic. Its

Table 31 Relative toxicity of different oils treated to the IV instar of larvae of potato tuber moth 48 hrs. after treatment

Oil	LC_{50}(%)	Relative toxicity
Neem	3.4420	1.00
Pongamia	1.6931	2.03
Argemone	5.3877	0.64
Soobabul	3.1728	1.08
Mahagony	0.6140	5.61
Cashew shell	0.0137	251.24

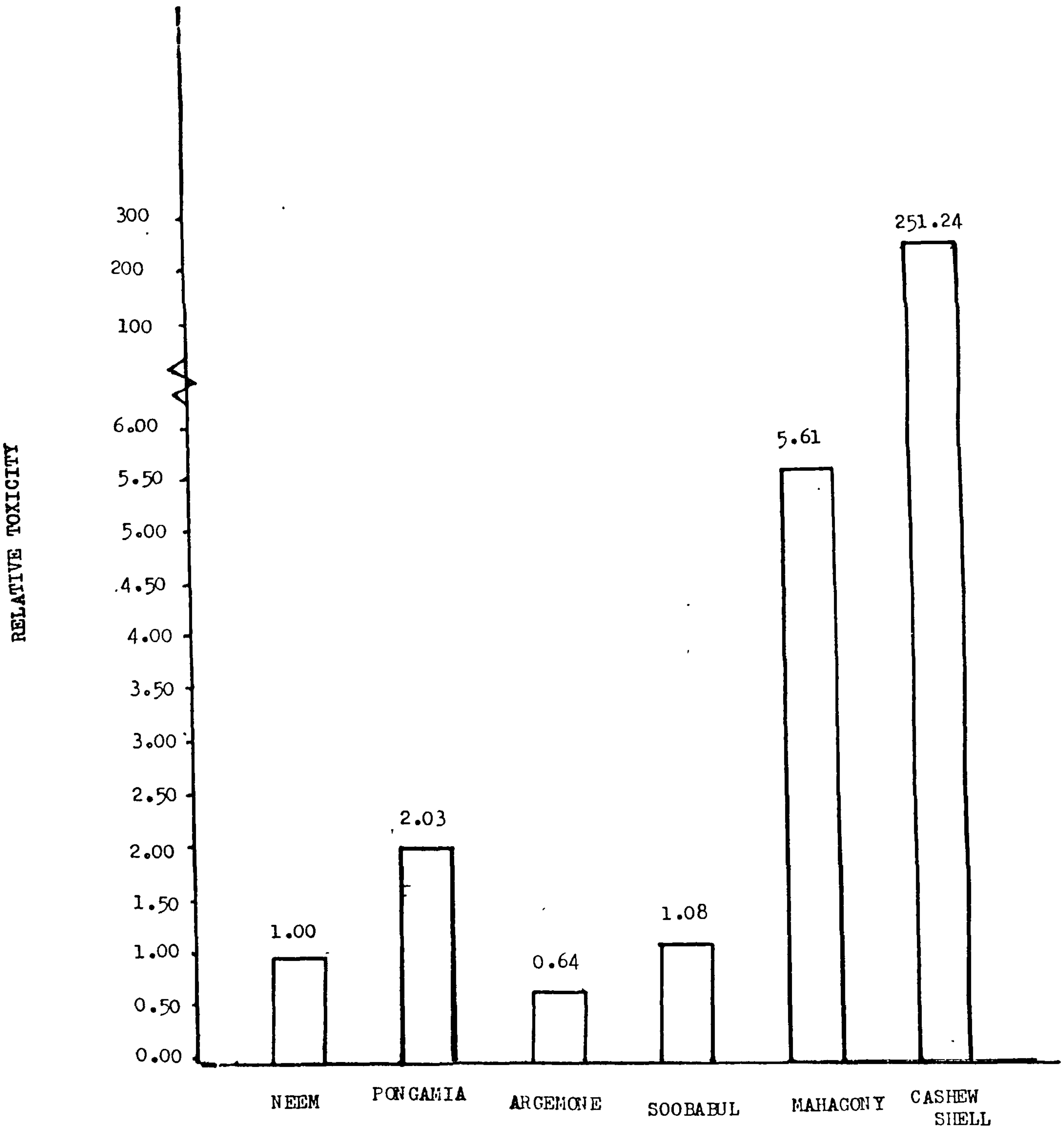


Fig. 10 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE FOURTH INSTAR LARVAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES (48 HOURS AFTER TREATMENT)

Table 32 Relative toxicity of different oils treated to the IV instar larvae of potato tuber moth 72 hours after treatment

Oil	LC_{50} (%)	Relative toxicity
Neem	1.8760	1.00
Pongamia	0.6073	3.09
Argemone	3.7509	0.50
Soobabul	1.0961	1.71
Mahagony	0.2384	7.87
Cashew shell	0.0098	191.43

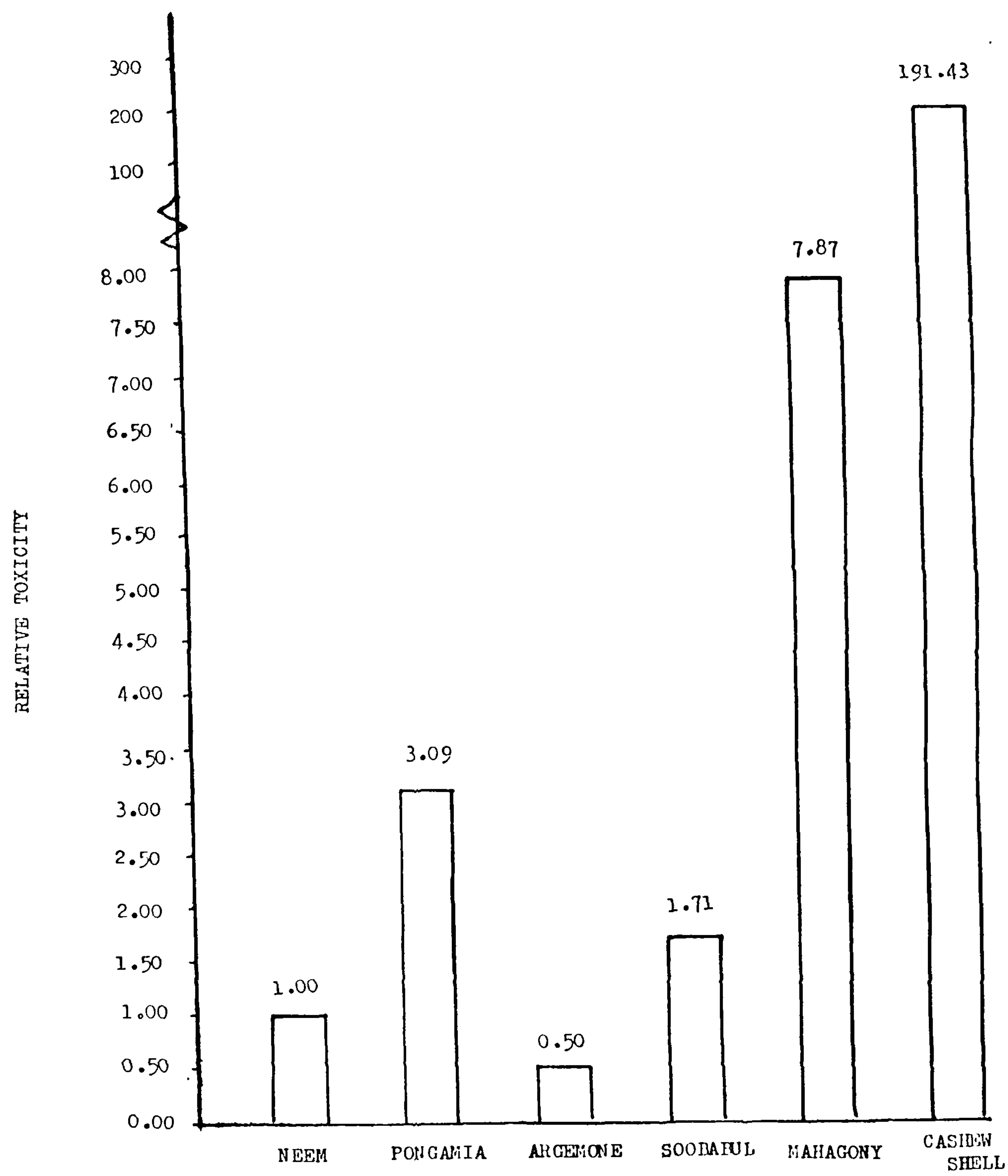


Fig. 11 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE FOURTH INSTAR LARVAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES (72 HOURS AFTER TREATMENT)

Table 33 Relative toxicity of different oils treated to the III instar larvae of potato tuber moth 24 hours after treatment

Oil	LC_{50} (%)	Relative toxicity
Neem	2.2304	1.00
Pongamia	2.3756	0.94
Argemone	5.0805	0.44
Soobabul	5.2597	0.42
Mahagony	0.6713	3.32
Cashew shell	0.0097	229.94

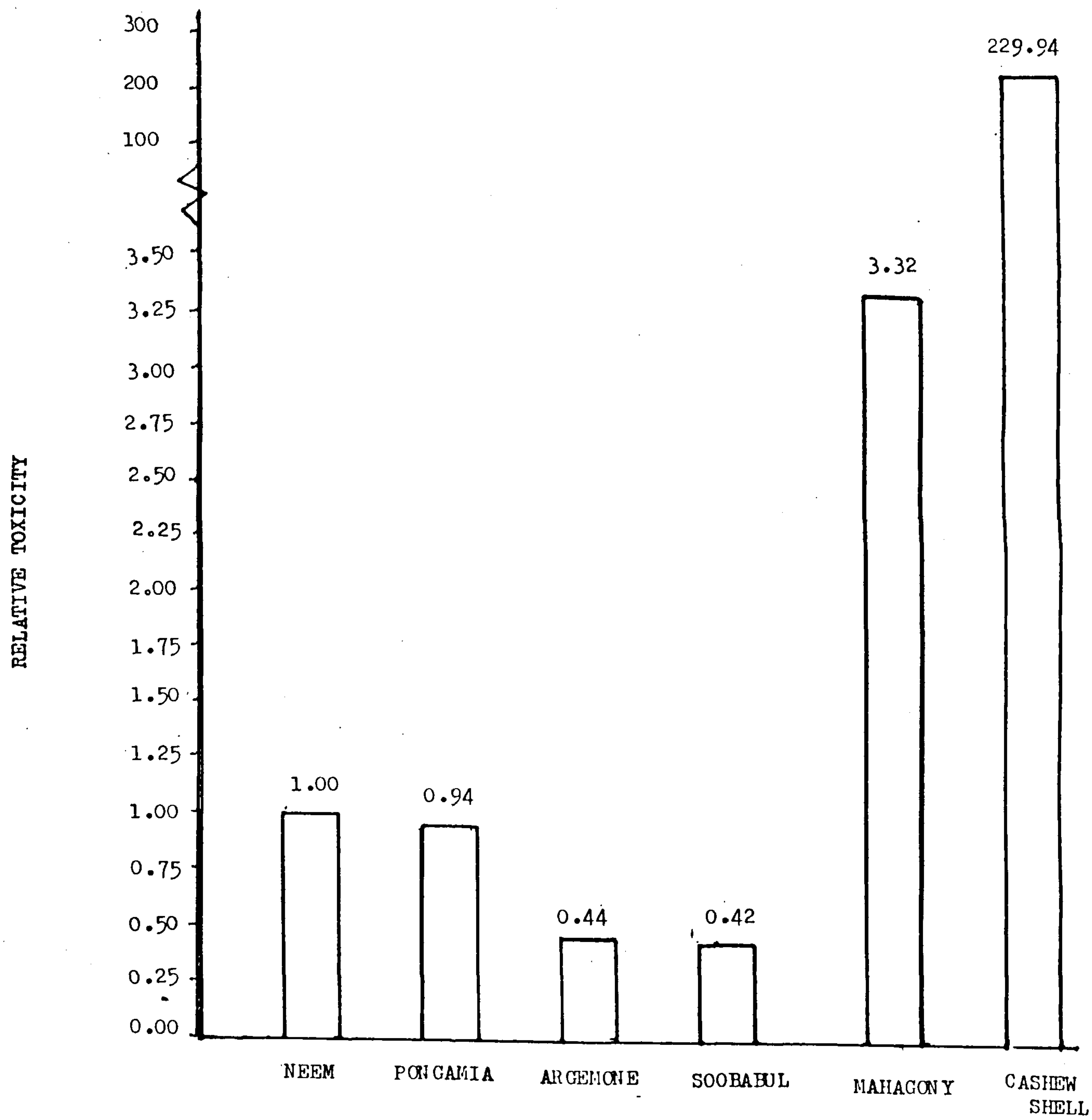


Fig. 12 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE THIRD INSTAR LARVAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES (24 HOURS AFTER TREATMENT)

Table 34 Relative toxicity of different oils treated to the III instar larvae of potato tuber moth 48 hours after treatment

Oil	LC_{50} (%)	Relative toxicity
Neem	1.8578	1.00
Pongamia	1.4156	1.31
Argemone	3.6252	0.51
Soobabul	2.2513	0.83
Mahagony	0.5925	3.14
Cashew shell	0.0063	294.89

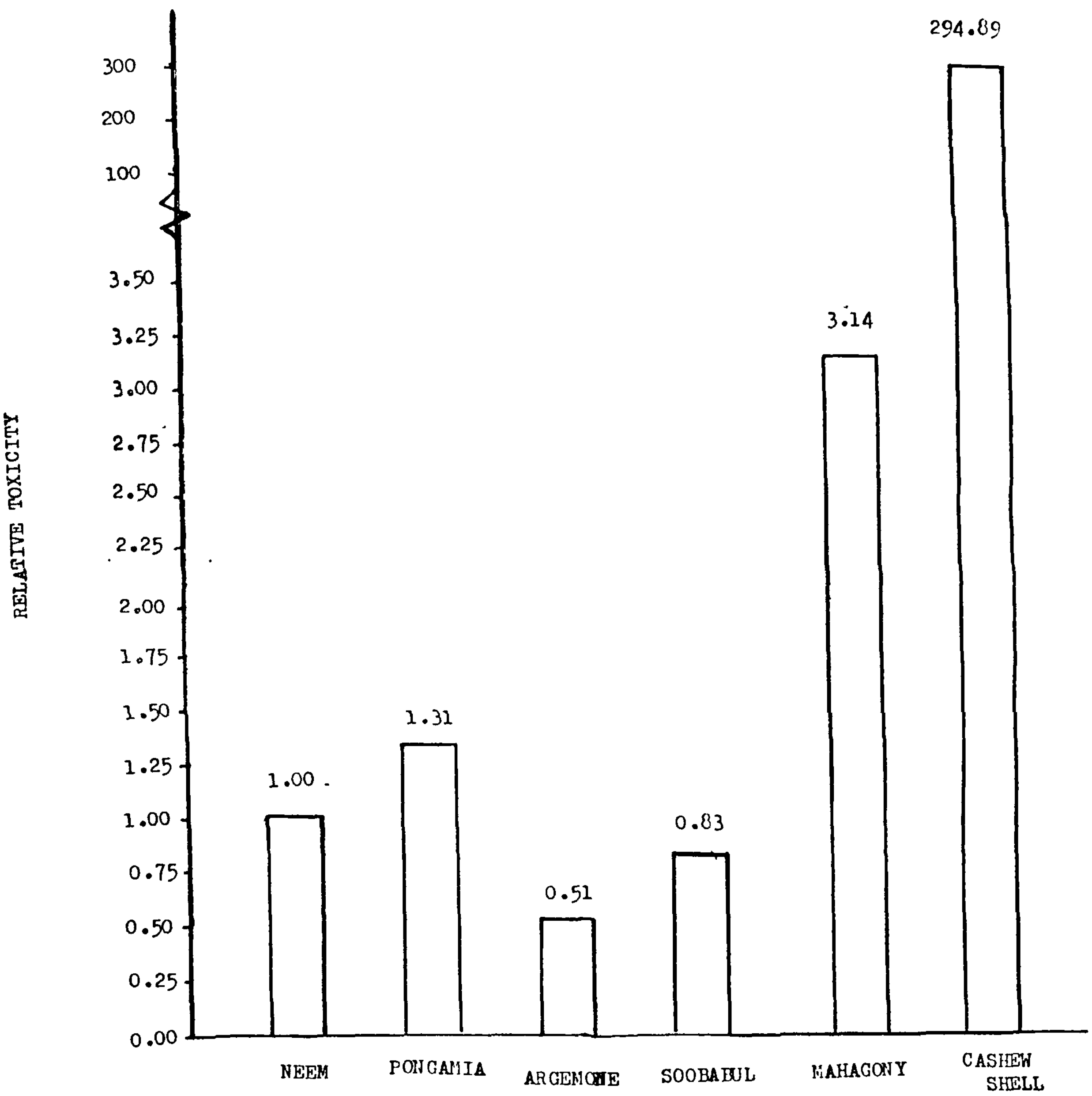


Fig. 13 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE THIRD INSTAR LARVAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES (48 HOURS AFTER TREATMENT)

relative toxicity was found to be 27.04. Soobabul oil was observed to be the next best and its relative toxicity was 1.69. Therefore soobabul oil was found to be more effective on the pupae than on the other stages. Neem oil was found to be the least effective. The remaining oils, argemone, pongamia and mahagony fell in between the relative toxicity values of 1.04, 1.07 and 1.41, respectively.

The results are presented in Table 35 and Fig. 14.

The above results are being discussed in the next chapter.

Table 35 Relative toxicity of different oils treated to the pupae of potato tuber moth

Oil	LC_{50} (%)	Relative toxicity
Neem	8.9356	1.00
Pongamia	8.3172	1.07
Argemone	8.6124	1.04
Soobabul	5.2777	1.69
Mahagony	6.3242	1.41
Cashew shell	0.3305	27.04

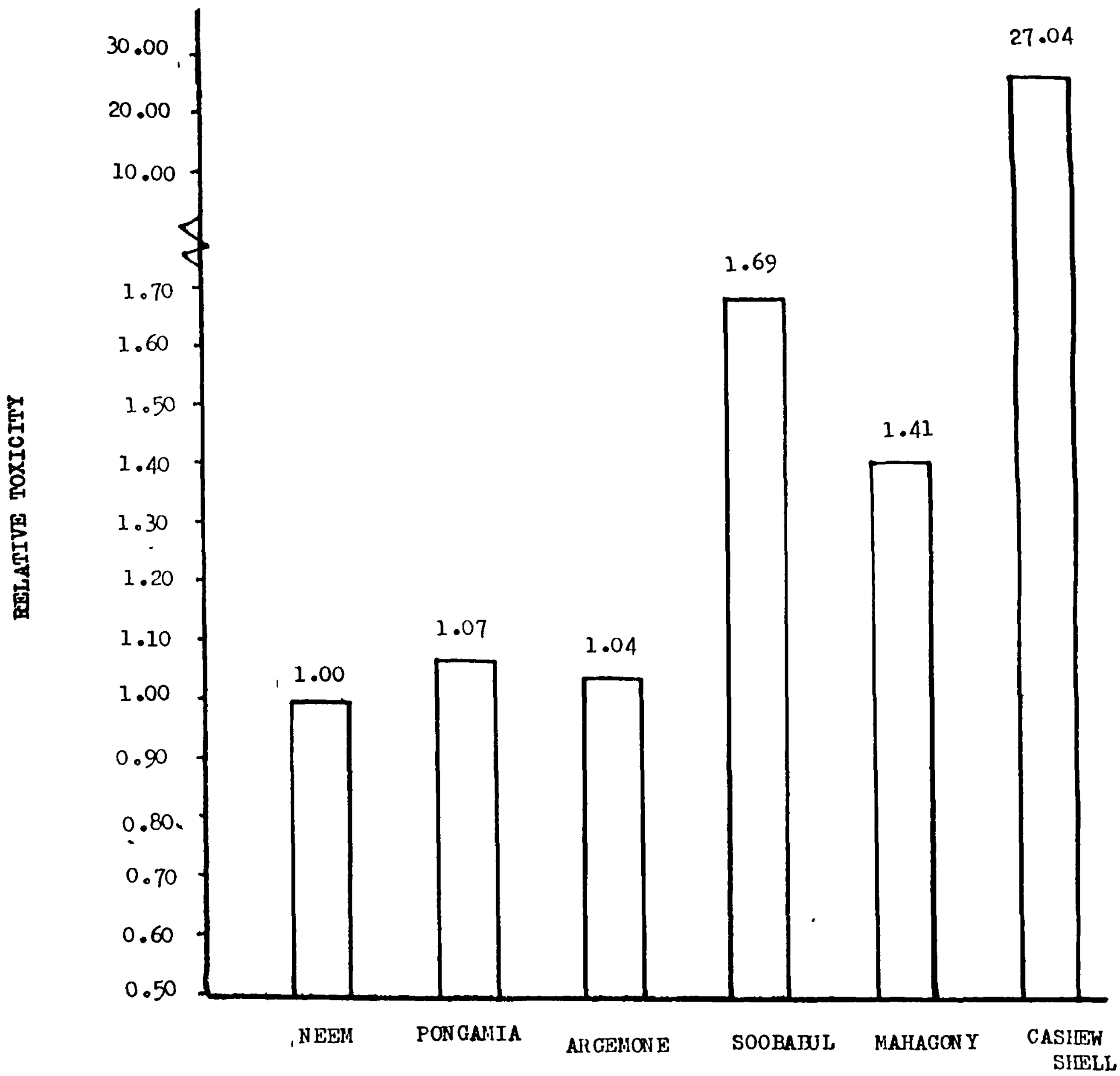


Fig. 14 RELATIVE TOXICITY OF DIFFERENT SEED OILS (TREATED TO THE PUPAE OF POTATO TUBER MOTH) BASED ON LC_{50} VALUES

DISCUSSION

V DISCUSSION

The results of the experimental findings are discussed in this chapter.

5.1 Studies on the ovicidal properties of the oils.

Six plant seed oils of neem (*Azadirachta indica*), pongamia (*Pongamia glabra*), argemone (*Argemone mexicana*), soobabul (*Leucaena leucocephala*), mahagony (*Swietenia mahagoni*) and cashew (*Anacardium occidentale*), each at five concentrations, were tried on the eggs of potato tuber moth. A wide range of percentage mortality was observed: 38.75% (Neem at 0.25%) to 92.50% (soobabul at 6.00%). Comparison among the treatment means showed that soobabul oil caused a significantly high mortality of the eggs. A hundred per cent mortality of the eggs was observed in case of malathion and was found to be statistically on par with that of soobabul oil at 6.00%. It was also seen that there was no mortality of the eggs in case of the control wherein benzene and emulsified water were used. Therefore, it can be inferred that the death of the eggs was mainly due to the toxic components present in the seed oils.

A look into the past literature revealed that neem has an active component - azadirachtin which is toxic (Anonymous, 1948). Karanjin is the active principle in pongamia

(Anonymous, 1969). Anacardic acid is the toxic component in cashew shell oil which is a powerful antibiotic and antihelminthic compound (Eichbaum, 1946). The results are in confirmity with the findings of Ali et al. (1983) who reported the ovicidal action of neem wherein it caused a 100% mortality of the eggs of the pulse beetle, Callosobruchus chinensis when the oil was mixed at 0.5 ml and 1.0 ml per 100 grams of seeds.

Periera (1983) also reported the ovicidal action of the oils of neem kernel, palm and ground nut. At 3 ml per kg of ground nut a higher percentage kill of the eggs of Callosobruchus maculatus was observed.

The possible mode of action of the oils - imparting them the property of ovicidal toxicity - is given by Tikku et al. (1981) in the case of a bruchid. The reasons given were:

1) Hardening of the outer membrane of the eggs.
2) Interference in water balance because of which the eggs shrink.
3) Oil could permeate the lipoid or wax layer on the inside of the chorion and comes in contact with the developing embryo, thereby breaking the existing barrier for the further development which was found to be very well

evident from the eggs with the partially developed embryos in them.

When the relative toxicity of the oils with neem as the standard was worked out, the maximum toxicity was seen in cashew shell oil which was observed to be 1.8 times as toxic as neem oil. The order of the oils with respect to their relative toxicity was: Cashew shell oil (1.8) > Neem (1.00) > Mahagony (0.52) > Pongamia (0.25) > Argemone (0.19) > Soobabul (0.13).

Soobabul was the least toxic of all the oils.

5.2 Larvicidal properties of the seed oils.

The mortality observed in the larvae might be due to two reasons (i) they block the spiracles causing asphyxiation (Luca, 1982); (ii) the death is also brought about by the toxic components in the oils.

As reported, as soon as the larvae were sprayed with the oils, they showed convulsions. Similar display was observed when control - a mixture of benzene and emulsified water - was sprayed. When the larvae were dried, they recovered. Therefore, this immediate 'knockdown' of the larvae might be due to benzene but at the same time, the solvent is not lethal as the larvae recovered almost immediately when the organic solvent evaporated. Thus, it should be concluded that the death of the larvae was due to the toxic effects of the oils alone.

5.2.1 Treatment of fourth instar larvae

At 24 hours after treatment, the effectiveness of the oils of neem (3.00%), pongamia (3.00%), cashew shell (0.03%) and mahagony (4.00%) were found to be on par with one another. Of the four oils, it can be said, cashew shell oil was the most effective one as it produced effects same as the other oils at a concentration as low as 0.03%. Therefore, it can be concluded that cashew shell oil is the most preferrable followed by neem and pongamia.

The order of effectiveness of the oils based on their relative toxicity was: Cashew shell oil (427.05) $>$ Mahagony (7.75) $>$ Pongamia (1.97) $>$ Argemone (1.06) $>$ Soobabul (1.02) $>$ Neem (1.00).

The conclusions can be drawn in the following manner:

As neem oil was found to be the least toxic at 24 hours after treatment, it had a less knockdown effect on the larvae. The knockdown effect was the best seen in cashew shell oil and next in mahagony oil.

Even at 48 hours after treatment, cashew shell oil was found to be the best, wherein a mortality of 75.10% at a concentration of 0.04% was observed. Other oils which were found to cause similar effects were: pongamia (3.00%) with a mortality of 61.60% and mahagony (1.50%) with a mortality of 77.40%.

Based on the relative toxicity, the following was the order of the effectiveness of the oils: Cashew shell oil (251.24) > Mahagony (5.61) > Pongamia (2.03) > Soobabul (1.08) > Neem (1.00) > Argemone (0.64).

At 72 hours after treatment also, cashew shell oil was found to be most effective with a corresponding mortality of 75.00% at a concentration of 0.03%. Except soobabul oil, all the other oils were found to be equally effective. The order of the oils based on their relative toxicity: Cashew shell oil (191.43) > Pongamia (3.09) > Soobabul (1.71) > Neem (1.00) > Argemone (0.50).

It is seen from the relative toxicity at 48 and 72 hours that the relative toxicity of pongamia has increased from 24 to 72 hours, indicating that the oil has a greater persistance than the knockdown effect. In case of neem, its position in relation to the oils gives an inference presumably that its persistance is greater than its knockdown effect.

In case of all the other oils, their relative toxicity values have decreased progressively with the increase in time. This probably may be due to the fact that these oils are more effective in bringing about knockdown of the larvae.

At 96 and 120 hours after treatment, in most cases the mortality was more than 70 and 80 per cent, respectively. The best concentrations of all the oils in both the cases were found to be on par with each other. It can be inferred that in the long run, all the oils have the same effect. Yet, cashew shell oil and mahagony oil are the most preferred ones as they are effective in low concentrations. Of the two, mahagony oil was extracted with petroleum ether whereas, cashew shell oil was obtained from the oil mill. Because of the ease of acquisision of the oil, cashew shell oil is preferrable.

5.2.2 Treatment of third instar larvae

In general the third instar larvae were found to be more susceptible to the oils when compared with the fourth instar larvae. Therefore, the later instars are more resistant than the earlier ones.

Of the oils, cashew shell oil at 0.04% was the most preferrable one, as it caused mortality to the extent of 84.40%. Except soobabul oil, the optimum concentrations of the other four oils were found to be equally effective. The LC_{50} values of the six oils were found to be lower than those obtained at 24 hours in case of the fourth instar larvae.

Comparison of the relative toxicity of the oils yielded the following relative positions of the oils: Cashew shell oil (229.94) > Mahagony (3.32) > Neem (1.00) > Pongamia (0.94) > Soobabul (0.42) > Argemone (0.44).

The LC_{50} values at 48 hours were found to be lower than those obtained at 24 hours after treatment. The relative positions of the oils based on their relative toxicity are: Cashew shell oil (294.84) > Mahagony oil (3.14) > Pongamia oil (1.31) > Neem (1.00) > Soobabul oil (0.83) > Argemone oil (0.51).

Neem oil is more effective in the third instar larvae than in the fourth instar larvae. Soobabul is the least effective.

No abnormalities either during moulting or during pupation were observed. This observation does not agree with the findings of Schmutterer (1983) who reported that the activity of azadirachtin resembles that of an artificial ecdysone. He reported growth disruption in numberous species of Hemiptera, Lepidoptera and Coleoptera due to azadirachtin and also that every larval and pupal moult was affected.

The deviation (from the above published findings) in case of the present study may be due to the following reason: The neem oil used was quite old (about 6 months). As the age of the oil increases its efficacy decreases. The activity of azadirachtin deteriorates drastically over a period of time (Attri and Singh, 1977). Therefore, the amount of azadirachtin in the neem oil must have been too low to cause *abnormalities in the insect.*

The larvicidal property of oils, especially of neem and pongamia has been reported by many workers (Joshi and Rai, 1968; Deshmukh and Borle, 1976; Nigam, 1977; Attri and Prasad, 1980; Mariappan et al., 1982; Ali et al., 1983; Meisner et al., 1985). But no report was available on the toxic properties of the oils of argemone, mahagony and soobabul.

5.3 Effect of oils on the pupae.

The pupae required higher concentrations for their mortality. This might be due to the fact that the pupae have a highly chitinised body wall and in fact, the pupal stage is the most resistant one (next to egg stage). Again cashew shell oil was the most effective one.

On comparing the relative toxicity of the oils, the ranking of the oils was as follows: Cashew shell oil (27.04) > Soobabul oil (1.69) > Mahagony oil (1.41) > Pongamia oil (1.07) > Argemone oil (1.04) > Neem oil (1.00).

Soobabul oil was found to be more toxic on pupae than on the other stages. It was in soobabul that the maximum pupal deformities were observed (Table 16).

Neem was the least toxic and a very low percentage of pupal deformities was observed. Pupal deformities have been observed by Schmutterer et al. (1983). As mentioned in case of the larval treatment, this oddity in the behaviour of neem must be due to the low concentrations of the active ingredient, azadirachtin.

5.4 Effect of oils on the reproductive potential of the adults of potato tuber moth

Maximum reproductive inhibition was observed in pongamia (6.00%) which was found to be 89.04%. Neem at 6.00% caused the next highest per cent reproductive inhibition of 78.86. Surprisingly, cashew shell oil did not fare well in the adults; the extent of reproductive inhibition was 51.59%.

On comparing the viability of the eggs laid by the moths treated with different oils, the seed oil of neem at 5.00% showed the least hatchability of 16.41%, the maximum being 97.97% in the case of argemone seed oil at 8.00%.

The reproductive potential is expressed in two terms: Egg yield and egg hatchability (Pathak and Krishna, 1985). On comparing the above two parameters in the present study, it can be opined that neem oil which caused reproductive inhibition of 78.86% and a low egg viability of 16.41% is the most preferrable; the next best being pongamia oil.

The reproductive inhibition properties of neem has been previously reported. Pathak and Krishna (1985) reported the reduction in reproductive potential of the rice moth, <u>Corcyra cephalonica</u> Stn. They presumed that the strength of the mating stimulus - a decisive factor influencing the total number of eggs a species lays - received by the females during copulation is deleteriously affected by the vapour action of neem. Schmutterer (1983) reported the reduction in fecundity of insects (especially in Coleoptera) due to the action of neem and its products.

5.5 Effect of oils on the parasitism of potato tuber moth

No significant differences in per cent parasitism as a result of different concentrations of the oils was observed. In other words, within each oil, all the concentrations were found to be on par with each other with respect to the per cent parasitims.

Both the controls were found to be on par with each other. When the best concentrations of the oils were compared, pongamia oil (2.00%), neem oil (2.00%), mahagony oil (2.00%) and cashew shell oil (0.25%) were all found to be on par with one another. Moreover, even the control (wherein only water was used) was found to be not significantly different from the above mentioned four oils. It is to be inferred that these four oils do not have any adverse effects on the parasites, or the per cent parasitism. The non-emergence of the moths could not have been due to the death of the eggs, as the eggs were separated from the treated paper disc by means of the smaller paper disc of diameter 1/2 cm.

However, the non-emergence might be due to the natural mortality. But this must have happened not only in oils but also in the case of controls. Thus, any variation with respect to the moth-non-emergence is ruled out.

Another interesting observation made was, the parasite was killed in case of malathion. Therefore, this further necessitates the need to rely less on the chemicals like malathion but to prefer the plant products in their places.

Kareem et al. (1977) reported that the treating of the eggs of Corcyra cephalonica with antifeedants (fentin hydroxide, fentin acetate and fentin chloride) did not significantly reduce parasitism (as measured by the emergence of the adult parasites) by Trichogramma australicum.

Joshi et al. (1982) reported that a 2% neem seed kernel suspension sprayed on Spodoptera litura (F.) before or after parasitisation did not adversely affect the emergence of the parasite Telenomus remus Nixon.

Considerable work needs to be done in the use of seed oils against potato tuber moth. The possible future line of work could be:

1) A number of other plants suspected to be poisonous can be screened for their insecticidal, repellent, antifeedant and reproductive inhibitory activities.

2) The oils were used against the insect which is the pest of potato which is directly consumed. Therefore it

would be desirable that tests are to be conducted to determine if the oils leave any toxic residues in the tubers.

3) Based on the lab studies, extensive field-scale experiments need to be carried out and, similar to chemical insecticides standard recommendations need to be developed with respect to the dosage and concentration of oils.

The thrust must be shifted in a phased manner from conventional (hazardous) insecticides to the use of plant products in the future thereby bringing about a semblance of balance in the ecosystem.

SUMMARY

VI SUMMARY

With a view to reduce the dependance on chemical insecticides, and to minimise the usage of hazardous pesticides in pest control programmes studies were conducted to assess the toxic properties of several seed oils against different stages of the potato tuber moth, Phthorimaea operculella Zell. (Lepidoptera: Gelechiidae), seed oils of the following six plant species were used: Neem (Azadirachta indica), pongamia (Pongamia glabra), argemone (Argemone mexicana), soobabul (Leucaena leucocephala), mahagony (Switenia mahagoni) and cashew (Anacardium occidentale). Each oil was tried at five concentrations. For comaprison - a standard chemical - malathion 50 EC (Cythion) was used.

1) All the oils were found to have ovicidal activity among which soobabul oil was found to produce the highest mortality. In all the experiments cashew shell oil was used in the least concentrations. Comparison of LC_{50} values and relative toxicity showed that cashew shell oil was the most toxic to the eggs.

2) Larvicidal property was shown by all the oils. At 24 hours, neem was found to be the least toxic thereby indicating that it has a low knockdown effect, however its

relative toxicity was found to increase gradually which reflects on the persistence and toxic effects. Argemone oil had a higher relative toxicity at 24 hours but the toxicity decreased gradually at 72 hours. Therefore its persistent toxicity is low compared to its knockdown effect. Cashew shell oil was the best of all the oils with respect to per cent larval mortality. The third instar larvae were found to be more susceptible than the fourth instar ones.

3) The pupae were found to be resistant at the same concentrations of the oils. Considerable mortality was observed when the concentrations of all the oils were increased. Soobabul oil was more effective on the pupae than on the other stages. Pupal deformities were observed more in the case of those treated with cashew shell oil and soobabul oil.

4) The reproductive potential was affected by the oils. Neem oil exhibited a very high reproductive inhibition and a very low viability of the eggs laid by the treated adults.

5) The parasitism was not affected by the oils of neem, mahagony, pongamia and cashew shell, whereas, a less per cent parasitism was observed in argemone and soobabul. The oils did not kill the parasite.

From the above findings it can be said that cashew shell oil is the best and the most preferable one as it performed better than the other oils (except in case of reproductive inhibition). Cashew shell oil is easily available and also, is required in low quantities. The next preferred one is the seed oil of mahagony. But, the drawback in the use of this oil is its extraction. (For the study, the oil was extracted with petroleum ether).

From the above studies, it can be concluded that one must speed up the use of plant products.

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