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Effects of Thai Plant Extracts on the Oriental Fruit Fly[1] I. Toxicity Test.

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ABSTRACT

Extracts of plant materials were prepared by employing three procedures, namely the cold-rolling, the soxhlet extraction and the water distillation methods. Three hundred and three extracts from 165 species of plants were tested against two days old adult Oriental fruit flies using the mist spray at the rate of one gram equivalent each. Extracts from plant parts which demonstrated moderately high to high toxicities were rhizomes of *Alpinia officinarium* Hance, fruit skin of *Anona squamosa* Linn., whole plants of *Artemisia pallens* Wall ex Bers, fruits of *Croton tiglium* Linn., branches of *Diospyros philippensis* A.-DC, whole plants of *Euphorbia tirucalli* Linn., leaves of *Nicotiana tabacum* Linn., leaves and branches of *Pedilanthus tithymaloides* Poit., black seeds of *Piper nigrum* Linn., flowers of *Tithonia diversifolia* Gray rhizomes of *Zingiber officinale* Roscoe, and rhizomes of Chang Kan and Phra Taba. Moderate toxicity effect was observed from extracts of nuts of *Areca catechu* Linn., leaves and branches of *Azadirachta indica* var. *siamensis,* Veleton, fruit skin of *Citrus sinensis* Osb., and roots of *Stemona tuberosa* Lour.

Mild toxic potency was detected from extracts of rhizomes of *Acorus calamus* Linn., bulbs of *Allium sativum* Linn., leaves of *Alstonia macrophylla* Wall., seeds of *Amomum cadamomum* Linn., whole plants of *Anetum graveolens* Linn., roots of *Artemisia vulgaris* Linn., roots of *Chrysanthemum coronarium* Linn., rhizomes of *Curcuma comosa Roxb., leaves and flowers of Euphorbia pulcherrima* Willd., fruit skin of *Garcinia mangostana* Linn., rhizomes of *Gastrochilus panduratus* Ridl., flowers of *Gomphrena globosa* Linn., leaves and flowers of *Jussiaea linifolia* Vahl., leaves of *Lactuca sativa* Linn., leaves of *Piper betel* Linn., leaves of *Poederia foetida* Linn., leaves and flowers of *Sphaeranthus africanus* Linn., leaves of *Stephania hernandifolia* Walp., and rhizomes of *Thunbergia laurifolia* Linn. Among unidentified plant species, rhizomes of Kho-Thong-Kae, Klob-Jak-Ka-Wan, Petch-Ma, Plalai-Yai, and Saboo-Thong were under this category.

INTRODUCTION

The Oriental fruit fly, *Dacus dorsalis* Hel., is one of the most important pests of fruit trees in Thailand. The fly attacks by laying eggs under the skin layer of premature fruits and the larvae after hatch feed inside the fruits causing premature drop and rot to the whole fruits. It is a serious pest of almost all tropical fruits in lowlands and almost all temperate fruits in highlands.

There is always a great demand for insecticides from plants, both in domestic and world markets. The reason for this is due to their advantages over synthetic insecticides in many aspects among which importances are their quick knock-down effect, low mammalian to-

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xicity, and non-residue. The recent banning of the use of DDT and many other synthetic compounds due to their harmful effects to human, animals, and the environment have led scientists to investigate and search for more insecticides from plants. An investigation on plants which are left unknown to insecticide world may yield some substances which are tremendously useful to mankind in the controlling of insects and possibly other pests. Since the Thai flora is enriched with several kinds of trees, shrubs, and herbs scarcely found in many parts of the world, most of them are left to be investigated. While most insecticides biosynthesized by plants which are known in the present time are not powerful in the control of the Oriental fruitfly, it is possible to find the effective one.

Synthetic insecticides, such as malathion and trichlorfon, are commonly used in the control of the Oriental fruit fly as poison baits in which the insecticides generally work as stomach poisons. Chemical insecticides, generally, are hardly found to be an effective contact poison against the fly. Most insecticides from plants, such as pyrethrins, are known to be contact poisons with highly knockdown effects. Unfortunately pyrethrins are known to be low in their toxicity against the Oriental fruit fly. The toxicity test was, therefore, aimed to investigate plants which contain active principles possessing contact activity and highly knock down effect against this pest.

METHODS AND MATERIALS

EXTRACTION PROCEDURES

Three plant extraction procedures were employed in this experiment. They were the cold-rolling, the soxhlet extraction, and the water distillation methods.

Cold Rolling Method

Each candidate plant was weighed and ground with a pulvilization machine. The extraction was made by placing plant samples in round bottles containing a solvent at the rate of 1 part of plant material per two parts of the solvent, w/v. In the case of the bulky plant material, the amount of the solvent was increased to soak it thoroughly. The extraction was made by using a rolling machine at the speed of 32 rounds per minute for 30 minutes. Each extract was filtered through a piece of cotton wool and the filtrate was kept in a refrigirator at 5 $\mp$ 1°C until it was ready to test for its active potency against the flies.

Soxhlet Extraction Method

The extraction was made by following the methods described by Horwitz (1975). Parts of plants were ground in a pulvilization machine. Each thimble was filled up with a plant sample and was weighed before placing in a Soxhlet extraction apparatus. Petroleum ether with a boiling point of 40-60°C was mainly used as the solvent and the extraction was made for 8 hours in each sample. The solvent was evaporated to the proper concentration before the extracts were used for the tests.

Water Distillation Method :

Each plant sample was cut into small pieces and mixed with water at the rate of one part of water w/v. They were placed in the water distillation equipment and the extraction was made for 8 hours by following the method of Ferniss *et al.* (1978). The fractions of extracts, i.e. oil, volatile part (condensate), and boiled water obtained from this extraction were used to test against the flies.

Toxicity Test

A total number of 303 extracts from 165 kinds of plants, among which 145 identified and 20 unidentified species, were tested for their toxicity against the Oriental fruit fly. Two days old adult flies were selected for the test because Areekul (1985) found this to be one of the most resistant ages as compared to the

others. Two ml of the extract of each fraction, which is equivalent to 1 gm equivalent of plant, were applied to 25 adult flies using a topical mist spraying machine at a pressure of 15 lbs per square inch. They were left in a room temperature at 25 $\pm$ 2°C and mortality counts were made at 1, 6, 12, and 24 hours respectively after the treatment. Water was used for the check plots for water distillation extracts and petroleum ether for the petroleum ether extracts. The experiment was replicated four times. The Abbott's formula (Abbott, 1925) was employed for the calculation of corrected % mortality in the treatment where ever the natural mortality was found in the check, but generally no natural mortality was encountered in most of this experiment. The rating of the toxicity was based on the 24 hours mortality and was devided into the following classes. Class VH = 86-100 % very high, class H = 76-85 % high, class MH = 61-75% moderately high, class M = 46-60% moderate, class ML = 31-45% moderately low, class L = 16-30 % low, class VL = 1-15 % very low, and class N = 0 % non-toxic. Only the results of the extracts that demonstrate class L or higher are shown in table 1.

Table 1. Toxicity effects of plant extracts against two days old adult flies, *Dacus dorsalis* Hendel.

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours						Class
		1	3	6	9	12	24	
Acorus calamus								
Dried Rhizomes	Soxhlet—P.Ether	0.0	3.0	3.0	10.0	10.0	26.0	L
Allium sativum								
Fresh Bulbs	Rolling—Water	13.0	13.0	13.0	17.0	17.0	23.0	L
	Rolling—Alcohol	27.0	27.0	27.0	27.0	27.0	27.0	L
	Rolling—Acetone	3.0	3.0	3.0	3.0	3.0	13.0	VL
	Rolling—Hexane	0.0	0.0	0.0	0.0	0.0	11.0	VL
	Distill.— condensate	0.0	0.0	0.0	0.0	0.0	0.0	N
	Distill.—Water	0.0	0.0	0.0	0.0	0.0	8.0	VL
Alpinia officinarium								
Fresh Rhizomes	Rolling—Water	37.0	37.0	37.0	37.0	37.0	37.0	ML
	Rolling—Alcohol	66.0	77.0	77.0	80.0	80.0	86.0	VH
	Rolling—Acetone	37.0	40.0	47.0	50.0	57.0	68.0	MH
	Rolling—Hexane	17.0	27.0	27.0	40.0	67.0	100.0	VH
Alstonia macrophylla	Distill—Water							
Dried Leaves	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	0.0	2.0	VL
	Distill—Water	0.0	0.0	16.0	16.0	16.0	18.0	L
Amomum cadamomum								
Fresh Seeds	Rolling—Water	0.0	0.0	3.0	7.0	7.0	7.0	VL
	Rolling—Alcohol	13.0	13.0	13.0	13.0	13.0	14.0	VL
	Rolling—Acetone	0.0	0.0	0.0	0.0	0.0	0.0	N
	Rolling—Hexane	10.0	13.0	13.0	14.0	21.0	31.0	ML
Anethum graveolens Dried Whole Plants	Soxhlet—P.Ether	0.0	0.0	0.0	3.0	5.0	23.0	L

Table 1. (Cont.)

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours 1	3	6	9	12	24	Class
Annona squamosa								
Dried Seeds	Rolling—P.Ether	0.0	0.0	0.0	0.0	0.0	3.0	VL
	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	0.0	0.0	N
Fresh Seeds	Distill.—Water	0.0	0.0	2.85	2.85	9.3	50.8	M
Fresh Fruit Skin	Distill.—Oil	0.0	0.0	0.0	0.0	1.3	16.0	L
	Distill.—Water	0.0	0.0	0.0	10.8	18.8	73.3	MH
Areca catechu								
Fresh Nuts	Rolling—Water	10.0	10.0	10.0	10.0	13.0	27.0	L
	Rolling—Alcohol	27.0	30.0	30.0	33.0	37.0	47.0	M
	Rolling—Acetone	13.0	13.0	17.0	17.0	20.0	27.0	L
	Rolling—Hexane	7.00	10.0	10.0	10.0	13.0	27.0	L
Artemisia pallens								
Fresh Whole Plants (except roots)	Distill.—Condensate	0.0	0.0	0.0	0.0	0.0	0.0	N
	Distill.—Water	0.0	0.0	2.8	6.8	9.3	70.8	MH
Artemisia vulgaris								
Dried Roots	Soxhlet—P.Ether	13.0	17.0	17.0	24.0	28.0	36.0	ML
Azadirachta indica siamensis								
Dried Seeds	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	0.0	0.0	N
Fresh Leaves & Branches	Rolling—Water	17.0	17.0	17.0	23.0	30.0	50.0	M
	Rolling—Alcohol	0.0	0.0	0.0	0.0	7.0	21.0	L
	Rolling—Acetone	7.0	7.0	7.0	10.0	10.0	13.0	VL
	Rolling—Hexane	7.0	7.0	7.0	17.0	17.0	31.0	ML
Chrysanthemum coronarium								
Fresh Whole Plants	Distill.—Condensate	1.3	4.0	4.0	4.0	4.0	4.0	VL
Fresh Roots	Distill.—Water	6.8	13.3	13.3	16.0	16.0	16.0	L
Citrus sinensis								
Fresh Fruit skin	Distill.—Water	0.0	1.3	8.0	10.8	12.0	50.8	M
Croton tiglium								
Dried Fruits	Soxhlet—P.Ether	3.0	3.0	3.0	3.0	4.0	32.0	ML
Fresh Fruits	Rolling—Water	53.0	53.0	53.0	67.0	70.0	100.0	VH
	Rolling—Alcohol	7.0	10.0	10.0	13.0	20.0	53.0	M
	Rolling—Acetone	30.0	30.0	33.0	47.0	63.0	97.0	VH
	Rolling—Hexane	0.0	0.0	7.0	23.0	37.0	63.0	MH

Table 1. (Cont.)

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours						Class
		1	3	6	9	12	24	
Curcuma comosa								
Dried Rhizomes	Soxhlet—P.Ether	9.3	12.0	12.0	12.0	12.0	13.5	VL
Fresh Rhizomes	Distill.—							
	Condensate	30.0	37.0	35.0	38.0	38.0	38.0	ML
Diospyros philippensis								
Fresh Branches	Distill.—							
	Condensate	0.0	0.0	4.0	6.0	13.0	72.0	MH
Euphorbia plucherima								
Dried Leaves & Flowers	Soxhlet—P.Ether	0.0	0.0	0.0	5.0	7.0	33.0	ML
Euphorbia tirucalli								
Fresh Whole Plants (except roots)	Rolling—P.Ether	0.0	1.0	1.0	1.0	1.0	7.0	VL
Fresh Whole Plants	Rolling—P.Ether	0.0	0.0	19.5	19.5	27.4	24.0	L
Fresh Whole Plants	Rolling—Water	23.0	23.0	27.0	30.0	30.0	76.0	H
	Rolling—Alcohol	10.0	10.0	13.0	13.0	13.0	17.0	L
	Rolling—Acetone	33.0	33.0	37.0	40.0	43.0	76.0	H
	Rolling—Hexane	87.0	87.0	87.0	87.0	90.0	97.0	VH
Garcinia mangostana								
Dried Fruit Skin	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	0.0	0.0	N
Fresh Fruit Skin	Soxhlet—P.Ether	20.0	20.0	23.0	28.0	36.0	36.0	ML
Dried Fruit Skin	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	0.0	0.0	N
Fresh Fruit Skin	Distill.—							
	Condensate	0.0	0.0	0.0	0.0	0.0	0.0	N
	Distill.—Water	0.0	0.0	0.0	0.0	0.0	0.0	N
Gastrochilus panduratus								
Fresh Rhizomes	Rolling—Water	10.0	13.0	13.0	13.0	20.0	23.0	L
	Rolling—Alcohol	0.0	0.0	3.0	7.0	7.0	23.0	L
	Rolling—Acetone	10.0	10.0	10.0	17.0	20.0	27.0	L
	Rolling—Hexane	20.0	23.0	23.0	27.0	40.0	43.0	ML
Gomphrena globosa								
Dried Flowers	Soxhlet—P.Ether	0.0	0.0	3.0	3.0	8.0	21.0	L
Jussiaea linifolia								
Dried Leaves & Flowers	Soxhlet—P.Ether	0.0	0.0	0.0	5.0	8.0	26.0	L

Table 1. (Cont.)

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours						Class
		1	3	6	9	12	24	
Lactuca sativa								
Fresh Leaves	Rolling Water	0.0	0.0	0.0	13.0	17.0	25.0	L
	Rolling—Alcohol	13.0	17.0	17.0	17.0	20.0	20.0	L
	Rolling—Acetone	20.0	20.0	20.0	20.0	20.0	20.0	L
	Rolling—Hexane	0.0	0.0	0.0	0.0	0.0	21.0	L
Nicotiana tabacum								
Fresh Leaves	Rolling—Water	83.0	87.0	87.0	90.0	90.0	100.0	VH
	Rolling—Alcohol	97.0	97.0	97.0	97.0	97.0	100.0	VH
	Rolling—Acetone	80.0	80.0	80.0	80.0	80.0	92.0	VH
	Rolling—Hexane	83.0	83.0	83.0	83.0	93.0	95.0	VH
Pedilanthus tithymaloides								
Fresh Leaves & Branches	Rolling—Water	0.0	0.0	3.0	3.0	3.0	10.0	VL
	Rolling—Alcohol	57.0	57.0	57.0	57.0	57.0	97.0	VH
	Rolling—Acetone	0.0	0.0	0.0	0.0	0.0	3.0	VL
	Rolling—Hexane	90.0	90.0	90.0	90.0	100.0	100.0	VH
Dried Leaves	Soxhelt—P.Ether	0.0	0.0	0.0	0.0	0.0	1.0	VL
Piper betel								
Fresh Leaves	Rolling—Water	13.0	13.0	17.0	17.0	23.0	20.0	L
	Rolling—Alcohol	0.0	0.0	0.0	0.0	0.0	18.0	L
	Rolling—Acetone	0.0	7.0	7.0	7.0	10.0	29.0	L
	Rolling—Hexane	0.0	0.0	0.0	0.0	0.0	29.0	L
Piper nigrum								
Dried Young Seeds	Soxhlet—P.Ether	10.0	13.0	13.0	13.0	23.0	27.0	L
Dried Black Seeds	Soxhelt—P.Ether	86.0	96.0	96.0	97.0	97.0	97.0	VH
	Soxhlet—P.Ether	93.0	93.0	93.0	93.0	100.0	100.0	VH
Dried White Seeds	Soxhlet—P.Ether	17.0	17.0	17.0	17.0	17.0	17.0	L
	Soxhlet—MeOH	0.0	0.0	0.0	0.0	0.0	0.0	N
	Distill.—Water	0.0	0.0	0.0	0.0	0.0	0.0	N
Poederia foetida								
Dried Leaves	Soxhlet—P.Ether	0.0	0.0	0.0	8.0	8.0	18.0	L
Sphaeranthus africanus								
Dried Leaves & Flowers	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	3.0	19.0	L
Stemona tuberosa								
Dried Leaves	Soxhlet—P.Ether	0.0	0.0	0.0	0.0	1.0	1.0	VL
Fresh Roots	Rolling—Water	20.0	20.0	23.0	27.0	40.0	53.0	M
	Rolling—Alcohol	17.0	20.0	20.0	23.0	27.0	27.0	L
	Rolling—Acetone	17.0	20.0	20.0	20.0	23.0	27.0	L
	Rolling—Hexane	30.0	30.0	30.0	30.0	40.0	48.0	M

Table 1. (Cont.)

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours 1	3	6	9	12	24	Class
Stephania hernandifolia								
Dried Leaves	Soxhlet—P.Ether	0.0	0.0	0.0	2.0	3.0	24.0	L
Tithonia diversifolia								
Fresh Yellow Petal Buds	Distill.—Condensate	0.0	0.0	0.0	1.3	2.3	12.0	VL
	Distill.—Water	1.3	2.8	5.3	9.3	10.8	48.0	M
Fresh 50 % Floret Open	Distill.—Condensate	59.0	59.0	59.0	59.0	59.0	59.0	M
	Distill.—Water	85.0	85.0	85.0	85.0	85.0	85.0	H
Fresh 100 % Floret Open	Distill.—Condensate	74.0	74.0	74.0	74.0	74.0	74.0	MH
Thunbergia luarifolia								
Dried Rhizomes	Soxhlet—P.Ether	9.5	9.5	9.5	9.5	9.5	9.5	VL
Fresh Rhizomes	Distill.—Cond.	21.5	24.0	24.0	24.0	24.0	24.0	L
Zingiber officinale								
Fresh Rhizomes	Rolling—Water	0.0	0.0	0.0	0.0	10.0	10.0	L
	Rolling—Alcohol	10.0	10.0	10.0	13.0	13.0	28.0	L
	Rolling—Acetone	3.0	3.0	3.0	7.0	7.0	14.0	VL
	Rolling—Hexane	13.0	13.0	20.0	20.0	30.0	31.0	ML
Fresh Rhizomes Skin	Distill.—Water	0.0	0.0	3.0	8.0	23.0	85.0	H
Chang Kan								
Fresh Rhizomes	Distill.—Condensate	0.0	0.0	2.0	5.0	13.0	70.0	MH
	Distill.—Water	2.8	4.0	4.0	4.0	4.0	4.0	VL
Kho—Thong—Kae								
Dried Rhizomes	Soxhlet—P.Ether	0.5	2.8	5.3	5.3	6.8	9.5	VL
Fresh Rhizomes	Distill.—Condensate	19.0	21.0	21.0	21.0	21.0	21.0	L
Krob—Jak—Ka—Waan								
Dried Rhizomes	Soxhlet—P.Ether	12.0	14.8	14.8	14.8	14.8	16.0	L
Fresh Rhizomes	Distill.—Condensate	17.5	17.5	17.5	17.5	17.5	17.5	L
Petch—Ma								
Dried Rhizomes	Soxhlet—P.Ether	8.0	10.8	10.8	10.8	10.8	18.8	L
Fresh Rhizomes	Distill.—Water	0.0	0.0	1.5	1.5	4.0	5.5	VL

Table 1. (Cont.)

Plant Species and Plant Parts	Extracted Methods and Fractions	Corrected % Mortalities at Hours						Class
		1	3	6	9	12	24	
Phra—Taba								
Dried Rhizomes	Soxhlet—P.Ether	21.5	24.0	24.0	24.0	24.0	29.5	L
Fresh Rhizomes	Distill.—Water	72.0	72.0	74.8	74.8	74.8	76.0	H
Plalai—Yai								
Dried Rhizomes	Soxhlet—P.Ether	0.0	0.0	0.0	6.8	6.8	9.5	VL
Fresh Rhizomes	Distill.—Water	32.0	32.0	32.0	32.0	36.0	36.0	ML
Saboo—Thong								
Dried Rhizomes	Soxhlet—P.Ether	4.0	6.8	8.0	8.0	8.0	9.8	VL
Fresh Rhizomes	Distill.—Water	10.8	29.5	29.5	29.5	30.8	32.0	ML

Results and Discussion

A number of plants used in the toxicity test against the Oriental fruit fly in this experiment was reported to be toxic to other insects by some workers. Discussion will be made first on these plants by comparing with some results obtained from our experiment in Table 1.

The petroleum ether extract of the rhizomes of *Acolus calamus* showed low toxicity to the fruit fly and only 26 % were killed in this test. According to the report of Dixit *et al.* (1956), petroleum ether and kerosene extracts of the rhizomes of this plant, as well as a steam-volatile fraction of the rhizomes were toxic to *Musca nebulo* and *Culex fatigans*, and also showed synergistic activity when mixed with DDT. However, Mukerjea and Govind (1959, 1960) found no difference in the toxic potency between ether, petroleum ether, and cold alcoholic extracts to this plant when they tested against *Musca nebulo*. Petroleum ether extracts of the rhizomes of this herb were also highly toxic to the housefly, *Musca domestica* (Abrol and Chopra, 1963), but much less toxic than DDT to the adult of *Sitophilus oryzae, Letheticus oryzae, Tribolium castaneum,* and *Heterotermes indicola* (Paul et al., 1963).

Low toxicity was obtained from water and alcoholic extracts of bulbs of garlic, *Allium sativum;* only 23 and 27% of the fruit fly were killed respectively. Hexane and acetone extracts were even less toxic, killing only 11 and 13 % of the fly respectively. Amonkar and Reeves (1970) found larvicidal activity of both crude methannol extract and oil fraction of this herb when they tested against five species of mosquito larvae. Larvae of four species of ticks were killed within 2-3 minutes when exposed to powdered bulbs (Reznik and Imbs, 1965).

Alcoholic and hexane extracts of the rhizomes of *Alpinia officinarium* were highly toxic to the fruit fly, killing 86 and 100 % respectively. Water and acetone fractions were much less effective showing only 37 and 68 % mortalities respectively. The oil of the rhizomes of this plant, as well as the petroleum ether extract, were highly toxic to house flies but the benzene extract was not so effective (Abrol and Chopra, 1963, Dixit and Perti, 1963).

Larvae of four species of ticks were killed when exposed to powdered leaves, and fresh whole leaves of *Anethum graveolens* (Reznik and Imbs, 1965). Petroleum ether extract of

this plant showed a low toxic action to the Oriental fruit fly, killing only 23 %

The insecticidal properties of the seeds of the custard apple, *Anona squamosa*, have been tested by several workers. The seed oil of this plant was reported to be highly toxic to pumpkin beetles, cabbage aphids, houseflies (Naidu *et al.*, 1953), and the egg-plant lace bug (Reddy, 1958) but were very poor as compared to DDT when used against *Musca nebulo*, *Culex fatigans*, *Tribolium castaneum*, *Anthrenus flavipes*, and *Tinea pellionella* (Chuma *et al.*, 1958). The ether extract of seeds, however, was toxic to *Musca nebulo* and *Tribolium castaneum* adults (Mukerjea and Govind, 1958). Results of our studies reveals that water fractions of distillation of seeds and fruit skins gave 73 % and 50 % kills to the adult fruit flies respectively. Poor results were obtained from seed oils and petroleum ether extracts.

Leaf extracts of chamomile, *Anthemis nobilis*, were nontoxic to the mosquito larvae, *Culex pipiens* (Novak, 1968). Our results indicated that the volatile extract of the whole plants was also ineffective against the fruit fly.

Eight species of *Artemisia* in which their extracts were tried for various pests (Anonymous, 1975), but *A. pallens*, and *A. roxburghiana*, were not included. Among the eight species, *A. absinthium*, and *A. campestris* showed their effective against larvae of the ticks, *Ixodes redikorzevi*, *Haemaphysalus punctata*, *Rhipicephalus rossicus*, and *Dermacentor marginatus*, (Reznik and Imbs, 1965). The essential oil, isolated from flowering tops and leaves of *A. monosperma* was toxic to the house fly, *Musca domestica vicina*,, and the pomace fly, *Drosophila melanogaster* (Fahmy *et al.*, 1958). Alcoholic extracts of the common mugwort, *A. vulgaris*, failed to exhibit toxicity against larvae and adults of the boll weevil. However, our results showed that the petroleum ether extract of dried roots of this species exerted its toxic effect to the adult fruit fly with 36 % kill being obtained. Higher toxicity was observed from the water fraction from the distillation of the whole plant of *A. pallens*, where 70 % of the test files were killed. However the same fraction from *A. roxburghiana* showed little effect to the files.

The common Thai neem tree, *Azadirachta indica* var. *siamensis*, which is a close related species to the common Indian neem tree, *A. indica*, was tested for toxicity against the Oriental fruit fly. The latter had been extensively tried as an insecticide by various workers but obtained rather unsatisfactory results. For examples, alcoholic extracts of the leaves and of the bark used as sprays were non-toxic to houseflies and yellow fever mosquitoes (Abrol and Chopra, 1963). The seed oil and leaf extracts also failed to exhibit the insecticidal property against *Musca nebulo*, *Culex fatigans*, *Tribolium castaneum*, and *Anthrenus flavipes* (Paul *et al.*, 1963). Results of our tests against the Oriental fruit fly, leaf extracts of the common Thai neem tree showed their toxicity varied according to the solvent used as follows; acetone 13 %, alcohol 21 %, hexane 31 %, and water 50 %. On the other hand, the Soxhlet petroleum ether extract of seed kernels was ineffective.

Rao (1957) stated that white kerosene oil extracts of fresh petals of *Bougainvillia* sp., and *Calotropis gigantea* were more toxic to the rice weevil, *Sitophilus oryzae*, than a similar concentration of pyrethrum, and dried petal were less toxic. However, our experiments with *B. spectabilis* and *C. gigantea*, petroleum ether extracts of both fresh and dried flowers were ineffective against the fly.

Plant extracts of cinnamon, *Cinnamonum zeylenicum*, were non-toxic to larvae of Aedes *aegypti* (Novak, 1968). Our results reveal that the volatile fraction of this plant unaffected to the adult flies. The oil, isolated by petroleum ether extraction of the seeds of *Croton tiglium*

exhibited its toxic effect by killing 20-30 % knockdown of house flies in 40 minutes and caused 70 % mortality within 24 hours (Abrol and Chopra, 1963). Our results reveal that the Oriental fruit flies were susceptible to acetone and water fractions extracted from fresh fruits of this plant, when 97 % and 100 % mortalities of the test flies were obtained. Less toxic effects were found in petroleum ether, alcoholic, and hexane extracts.

Leaves of *Datura metal* are known to contain the active principles, hyoscine or scopolamine, and are believed to kill sand fleas in Africa (Irvine, 1955). Petroleum ether extracts of both dried and fresh leaves of this plant failed to kill the fruit fly in our experiment, with very little toxic effect shown from the petroleum ether extracts of dried fruits.

A few species of *Euphorbia* are known to possess some active insecticidal principles. Extracts of flowers of an *Euphorbia* sp. were promising against weevils, bruchids, beetles, and hairy caterpillars (Rao, 1960). *E. tirucalli* is used as an insecticide in India (Watt and Breyer-Brandwijk, 1962). Plant extracts of four species of this genus were tested for their toxicity against the Oriental fruit fly. They included *E. cotonifolia, E. heterophylla, E. pulcherrima,* and *E. tirucalli.* The highest toxic effect was obtained from the hexane extract of the whole plants of *E. tirucalli,* when 97% of the tested flies were killed. Water and acetone extracts of this plant gave 76 % mortality while the lowest toxicity was derived from the alcoholic extract killing only 17 % of the adult flies. Petroleum ether extract of the whole plant killed 24 % flies as compared to 7 % obtained from the same solvent extract of this plant without roots. There is an evidence from these results that roots of the plant contained a higher amount of toxic principle soluble to petroleum ether than other parts. The tests with *E. cotonifolia* and *E. pulcherrima,* using the petroleum extract of leaves, gave lower toxicity of 6 %, and higher at 33 % mortality respectively as compared to *E. tirucalli.* The extract from *E. heterophylla* was, on the other hand, ineffective.

The petroleum ether extract of the flower heads and the volatile fraction of seeds of the sunflower, *Helianthus annus* failed to kill the Orienttal fruit fly in this experiment. An infusion or decoction of the flower heads was said to be used as a fly killer (Watt and Breyer-Brandwijk, 1962). Petroleum ether extracts of dried flowers of *Hibiscus rosa-chinensis* showed no toxic effect to the fruit fly. Rao (1957) proved that the white kerosene oil extracts of fresh petals of this plant were more toxic to the rice weevil, *Sitophilus oryzae,* than a similar concentration of pyrethrum.

Among the four species of plants in the genus *Jatropha* which were tried against the Oriental fruit fly, only *Jatropha curcas* showed some effect through the petroleum ether extract of the seeds, but the toxicity was very low. Abrol and Chopra (1963) reported that the same kind of the extract from this plant was mildly toxic to the common house fly, *Musca domestica* and the yellow fever mosquito, *Aedes aegypti.* An alcoholic extract of the fruits was ineffective to these insect species. Petroleum ether extract of dried leaves of *Lantana camara* was proved to be nontoxic to the Oriental fruit fly. This result was similar to that of Abrol and Chopra (1963) who reported that petroleum ether and alcohol extracts of the leaves and alcohol extracts of the roots were nontoxic to houseflies and yellow fever mosquitoes. Mild toxicity to the rice weevil was demonstrated by Rao (1957) from the use of kerosene extracts of flowers of this plant.

The bead tree, *Melia azedarach,* was sometimes confused with the common Indian neem tree, *Azadirachta indica.* Toxicity tests against the Oriental fruit fly revealed that mortalities obtained from spraying with hexane, water,

alcohol, and acetone extracts from fresh fruits of *M. azedarach* were 77, 61, 47 and 36 % respectively. On the other hand 20, 13, 23 and 23 % mortalities were obtained respectively from the same solvents extracts of fresh leaves. Low toxicities were obtained from petroleum ether extracts of both fresh and dried fruits and leaves.

Momordica charantia, was claimed to be used as a general insecticide in Haiti (Watt and Breyer - Brandwijk, 1962). However, when the petroleum ether extract of dried leaves of this plant was sprayed against the Oriental fruit fly, it showed nontoxic to the pest. Rao (1957, 1960) reported that white kerosene oil extracts of flowers of the Indian oleander, *Nerium indicum,* were promising against rice weevils, bruchids, beetles, and hairy caterpillars. Extracts of leaves, stems, roots, flowers and fruits were tested as contact insecticides against *Musca nebulo* adults and *Culex fatigans* females by Khalsa et al. (1964). They showed that fruits, stems, and roots caused some mortalities. However, no toxic effect was observed in our test against the Oriental fruit fly, using the petroleum ether extract of dried leaves.

Piperettine, piperine, chavicine, and oleoresin, isolated from the black peper, *Piper nigrum,* are known to be effective synergists with pyrethrins. The first constituent was nontoxic to houseflies while the latter three were much less toxic than pyrethrins when tested against *Musca domestica vicina* and larvae of the mosquito, *Culex pipiens pallens.* (Gersdorff and Piquett, 1957, Matsubara and Tanimura, 1966). Results of the test against the Oriental fruit fly, using the petroleum ether extract of black seeds, showed more than 86 % knockdown within an hour and reaching almost 100 % kill in 24 hours. Much less toxic effects were found on white mature and young green seeds.

Spilanthol, contained in flower heads of several species of *Spilanthes,* has been found to be effective against larvae of *Anopheles* and *Culex* mosquitoes (Jacobson, 1956). The fruits of *Spilanthes mauritiana* and leaves and flowers of the yellow oleander, *Thevetia peruviana,* are used as insecticides in India (Watt and Breyer-Brandwijk, 1962). The petroleum ether extracts of leaves and stems of both plants were, however, ineffective against the Oriental fruit fly. Spilanthol was also isolated from some plant species of the genus *Zanthoxylum,* especially the prickly ash, *Z. alatum* Roxb. (Nazir and Handa, 1961). The steam distilled oil from the fruits of this plant caused 90 % mortality in 24 hours when sprayed against house flies (Abrol and Chopra, 1963). But the petroleum ether extract of *Zanthoxylum budrunga* was found to be ineffective when tested against the fruit fly.

The toxic effect of petroleum ether extract of ginger rhizomes, *Zingiber officinale,* was low when tested against house flies (Dixit and Perti, 1963). The low toxicity was also observed in our experiment with the Oriental fruit fly from acetone, water, alcohol, and hexane extracts of fresh rhizomes when only 14, 21, 28 and 31 % of the flies were killed respectively at 24 hours. However the water fraction remained from distillation showed high toxic activity killing 85 % flies at 24 hours, but the knock down effect was quite low.

Plants which have not been reported elsewhere, but are found to contain some active principles which are promising against the Oriental fruit fly were *Nephelium lappaceum, Pedilanthus tithymaloides,* and *Tithonia diversifolia.* Oil extracted from fresh seeds of *N. lappaceum* killed 81 % of the flies within 24 hours but knockdown activity appeared to be low. All solvents extracts from fresh leaves of *Nicotiana tabacum,* which included acetone, hexane, alcohol, and water, killed 92, 95, 100 and 100 % flies respectively accompained by a high knock-

down effect. Cold alcoholic and hexane extracts of fresh leaves and branches of *Pedilanthus tithymaloides* caused 97 and 100% mortalities to the test flies respectively but acetone and water extracts were ineffective. Water decoctions and volatile fractions of flower heads of *Tithonia diversifolia* showed 85 and 74 % kills within the first hours after spraying, which demonstrated high knockdown effect to the files.

Moderate toxicities were also observed from some extracts of the following plants in this experiment; alcoholic extract from fresh nuts of *Areca catechu,* water fraction of distillation from fresh fruit skin of *Citrus sinensis,* volatile fraction of fresh branches of *Diospyros philippensis,* water and hexane fractions of fresh roots of *Stemmona tuberosa,* and volatile fraction of fresh rhizomes of Chang kan.

SUMMARY

Among the 165 species of plants tested for their insecticidal properties, extracts from 13 species demonstrated high toxicity to two days old adult of the Oriental fruit fly. Moderate and mild toxicities were also obtained from extracts of 4 and 24 species of plants, respectively. The other 124 plant species were found to be ineffective.

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