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CONTROL OF POST HARVEST DISEASES ON BANANAS, PINEAPPLES AND CITRUS WITH CARBENDAZIM

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Summary In numerous trials in Costa-Rica, Ecuador, Jamaica, Colombia, St. Lucia and the Ivory Coast, carbendazim (BAS 3460 F, methyl-2-benzimidazole carbamate) proved highly effective against the fungi responsible for crown rot and stem-end or neck rot of bananas. At an application rate of 25 g a.i./100 l water, carbendazim was as effective as, or slightly superior to the standard products used at present.

In pineapples, crown rot and lateral rot were very well controlled by a combination of carbendazim + maneb (150 g a.i. + 240 g a.i./100 l water).

Control of diseases of citrus fruits which occur during storage, was very satisfactory when carbendazim was applied at a rate of 38.5 g a.i./100 l water. Carbendazim proved as effective as Orthophenylphenate and better than Flavorseal + TBZ. Residues found after treatment were well below the tolerance level allowed in the Federal Republic of Germany.

INTRODUCTION

It is a well known fact that perishable tropical fruits such as bananas, pineapples, citrus and others are infested by various post-harvest diseases, on their way from the plantation to the consumer country.

As distances between producer and consumer become greater, crop injury can increase if the produce is stored under unfavourable conditions, resulting in considerable losses. Bananas are particulary susceptible to crown rot and stem-end or neck rot. According to Lukezic et al (1967), crown rot can be caused by a number of fungi such as Cephalosporium sp., Verticillium theobromae, Fusarium roseum, F. moniliforme and Gloeosporium musarum (Colletotrichum musae), but stem-end or neck rot is caused by Gloeosporium musarum and Fusarium roseum.

The main post-harvest pathogens in the fruits of pineapples are Thielaviopsis paradoxa, Penicillium sp., Fusarium sp., Alternaria sp. and various phycomycetes.

According to Eckert and Kolbezen (1971), green mould, caused by Penicillium digitatum, is the most important post-harvest disease in citrus. Depending on the country of origin, the following diseases can also be of significance: P. italicum, blue mould, Diplodia natalensis, Phomopsis citri, Alternaria and Geotrichum candidum.

MATERIALS AND METHODS

With the introduction of systemic fungicides, effective control of post-harvest diseases became very much easier (Beaudoin et al 1969, Shillingford 1970, Brown, McCornack and Smoot 1967). This paper reports on the results achieved with carbendazim in controlling post-harvest diseases in bananas, pineapples, and citrus fruits.

Carbendazim (BAS 3460 F) is the proposed common name for methyl-2-benzimidazole carbamate. It belongs to the group of benzimidazoles and has a very broad spectrum, being effective against Ascomycetes, Fungi imperfecti and various Basidiomycetes.

The oral LD 50 in the rat is 15,000 mg/kg, and the no-effect level in the dog is about 500 ppm.

a) Bananas

Following excellent results in laboratory tests against the above mentioned pathogens, which are the causative agents of crown rot and stem-end or neck rot, numerous field trials were carried out in various African and Latin American countries in 1971 and 1972.

The fungicide solutions of various concentrations were applied by means of a spraying tower with 4 jets at a rate of 0.4 litres per minute. 200 banana clusters were treated in each replication. After 14 days' transport by ship and storage of 5 - 7 days in a maturing shed, the bananas were examined for crown rot in the countries of destination (West Germany, France), i.e. about 20 days after the fungicide treatment.

The degree of infection by crown rot was assessed as follows:

1 = no mycelium)	
2 = mycelium on the crown)	marketable
3 = rot covering up to 1/3 of the crown)	
4 = rot covering up to 2/3 of the crown)	marketable under
5 = rot covering the whole crown)	certain conditions
6 = rot in the fingers)	unmarketable

b) Pineapples

Trials for the control of stem-end rot and lateral rot in pineapples were carried out in Costa Rica. The pineapples were dipped in solutions of various concentrations and assessed for fruit rot on arrival at Hamburg (West Germany) after a 14-day sea voyage.

Infection by stem-end rot in pineapple was classified as follows:

1 = no infection
2 = up to 1/3 of the stem infected
3 = up to 2/3 of the stem infected
4 = fruit infected

Pineapple lateral rot was assessed as follows:

1 = no infection
2 = slight infection (rot covering less than 2 cm^2 of the skin)
3 = severe infection (rot covering more than 2 cm^2 of the skin)

a) Citrus

The oranges, which had a natural infection of various pathogens were washed before treatment, and after being dipped into a fungicide mixture for 3 - 3.5 minutes, were dried and stored at a temperature of 22°C. The trials were carried out in Spain, Peru and Africa.

RESULTS

Bananas

In 8 trials carried out in Costa Rica, carbendazim proved highly effective against crown rot when applied at rates of 15 and 25 g a.i./100 l water. At the higher application rate, carbendazim was better than the other products tested. (Table 1)

Table 1

Efficacy of carbendazim against crown rot in bananas

(8 trials, Costa Rica)

	g a.i./ 100 l water	banana crown rot (%) in infection classes			
		1	2-3	4	5-6
Untreated	-	23.3	48.2	9.6	18.9
Carbendazim	15	63.6	29.8	4.0	2.6
Carbendazim	25	73.8	23.6	1.7	0.9
Benomyl	25	56.9	33.6	4.3	5.2
Thiabendazol	20	49.0	38.3	5.3	7.4

Treatment of clusters

The proportion of marketable bananas was increased from 71.5 % in the untreated control to 93.4 and 97.4 % respectively.

The addition of wetting agents or spreader-stickers did not bring about further improvement, a fact also observed in the results of preliminary trials. Ripening of the fruit was not affected by the fungicidal treatment.

The results listed in Table 2 show that 25 g a.i./100 l water controls crown rot effectively over quite a long period (15-day journey by sea). The fungicidal action can be improved by increasing the application rate, but the improvement is not in proportion to the increase.

Table 2

Effect of various application rates of carbendazim on crown rot in bananas

(3 trials, Costa Rica)

	g a.i./ 100 l water	banana crown rot (%) in infection classes 1	2-3	4	5-6
Untreated	-	39.9	46.6	7.8	5.7
Carbendazim	15	69.9	26.1	2.7	1.3
Carbendazim	25	83.0	15.7	1.3	0
Carbendazim	38.5	87.8	12.0	0	0.2
Carbendazim	50	89.5	10.1	0.4	0
Benomyl	25	73.2	23.6	1.7	1.5
Thiabendazol	20	68.2	28.5	1.2	2.1

Treatment of clusters

Colletotrichum musae is the main organism causing post-harvest disease in West Africa. Frossard (1971) and Griffee (1973) have reported on the effect of carbendazim (BAS 67 054) in the control of this disease.

Further trials in Ecuador, Colombia, Jamaica and St. Lucia confirm the fact that carbendazim gives good control of crown rot in bananas.

Pineapples

As can be seen in Table 3, stem-end rot and lateral rot in pineapples were greatly reduced by the use of carbendazim.

Table 3

Control of post-harvest disease in pineapples with carbendazim

(2 trials, Costa Rica)

	g a.i./ 100 l water	% stem-end rot in infection classes				% lateral rot in infection classes		
		1 no infection	2	3	4	1 no infection	2	3
Untreated	-	13.6	36.5	28.3	21.6	76.1	9.4	14.5
Carbendazim	150	71.7	28.3	0	0	91.7	6.7	1.6
Carbendazim	250	80.0	20.0	0	0	96.6	2.6	0.8
Carbendazim + Maneb	150 240	87.5	13.5	0.8	0	96.6	3.4	0
Benomyl	250	60.0	37.5	2.5	0	87.5	11.7	0.8

When infestation was very severe, 150 or 250 g a.i./100 l water was necessary to achieve economic control of the disease. The best effect resulted from the use of the combination of 150 g carbendazim + 240 g a.i. maneb. The reason for this is that not only *Thielaviopsis paradoxa*, but also a number of other pathogens (*Penicillium sp.* and *Fusarium sp.*, *Alternaria sp.* and various *Phycomycetes*) can be the organisms responsible for this disease, and although not controlled by benzimidazole derivatives, they can be treated effectively with dithiocarbamates, such as maneb.

Citrus

The first results (Table 4) showed an effective reduction in the outbreak of *Penicillium*.

Table 4

Control of disease occuring during storage in oranges of the Valencia variety in Peru

	g a.i./100 l water	14 days after treatment % diseased	28 days after treatment % diseased
Untreated	-	4	18
Carbendazim	50	2	2
Thiophanat-Methyl	70	0	2
Benomyl	50	4	10

Date of treatment: 24.10.1972

At an application rate of 50 g a.i./100 l water, carbendazim proved just as effective as thiophanate-methyl and benomyl.

A large-scale trial in Valencia, Spain confirmed that carbendazim was as good as orthophenylphanate and significantly better than Flavorseal + TBZ (Table 5).

Table 5

Control of diseases occuring during storage in oranges of the Navel Washington variety in Spain

	g a.i./100 l water	rotted fruits weight % of total		
		10.4.73 evaluation	25.4.73	9.5.73
Untreated	-	5.3	18.3	37.9
Orthophenylphenate	2000+	0.7	1.0	7.6
" "	2000*	0.2	1.1	6.7
Carbendazim	37.5	0.6	1.3	3.6
" "	37.5*	0.7	0.9	5.7
Carbendazim	25	0.4	3.1	15.2
Carbendazim	25*	0.5	3.5	10.7
Flavorseal T 1) (Flavorseal + TBZ 0,1 %)		2.4	6.8	16.0
Flavorseal 1)		3.1	13.0	18.3

* = treatment with wax, 1) = sprayed, + = application rate refers to commercial product

Date of treatment: 31.3.1973

An additional treatment with wax had no influence on the biological efficacy, but the appearance and consistency of the fruits were improved considerably when compared to the fruits not treated with wax. 37.5 g of carbendazim had a satisfactory effect, but 25 g were not sufficient. This is confirmed in a further trial, using artificial Penicillium infection (Table 6), which was carried out in co-operation with the IFAC, Corsica. Furthermore the trial shows that higher application rates bring about very little improvement in the results.

Table 6

Effect of carbendazim against Penicillium in oranges of the Hamlin variety

	g a.i./100 l water	30 days after treatment % fruits with Penicillium infection	degree of efficacy (as % increase above control)
Untreated	-	38.05	-
Carbendazim	50	0.86	97.81
Carbendazim	75	1.37	96.39
Carbendazim	100	0.68	98.21
Benomyl	25	2.20	94.21
Benomyl	50	0.83	97.73

Our own trials in South Africa have produced good results with carbendazim against citrus diseases occuring during storage, which will be reported by Pelser (1973).

Apart from its high degree of efficacy, the product is required to be toxicologically harmless. For this reason, a number of residue tests have been organised with carbendazim.

Table 7 shows that the residues found are well below the tolerance levels allowed in West Germany:

Citrus: 7.0 ppm, without peel 1.0 ppm
Bananas: 1.0 ppm, without skin 0.2 ppm.

Table 7

Results of residue analysis with carbendazim in citrus and bananas

Crop	Carbendazim g a.i./100 l water	Type of treatment	Days after treatment	Residue flesh in ppm	ppm in peel/skin
Navel oranges	75	dipped	8	0.6	3.5
Navel oranges	75	dipped	56	0.4	2.5
Bananas	50	sprayed	21	0.1	0.5

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THE USE OF AMITRAZ* FOR THE CONTROL OF CITRUS PESTS

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Summary Amitraz is the proposed common name for 1,5-di-(2,4-dimethylphenyl)-3-methyl-1,3,5-triazapenta-1,4-diene, a new acaricide/insecticide active against a wide range of mites and some insect pests.

It is of interest for use in citrus as it controls several of the major pests including citrus red mite (*Panonychus citri*) and wax scales. Results from several areas have indicated that effective control of *P. citri* can be obtained at a rate of 0.02% a.i. Against wax scales such as white wax scale (*Ceroplastes destructor*) excellent control has been achieved with applications of 0.04-0.05% a.i. with or without the addition of white oil. Encouraging results have also been achieved against California red scale (*Aonidiella aurantii*); high populations have been kept in check following the application of amitraz. Further trials on this and other pests are currently being conducted.

The compound is safe on citrus even at high rates; residue levels are under study.

Résumé Amitraz est le nom ordinaire proposé pour le 1,5-di-(2,4-dimethyl phenyl)-3-methyl-1,3,5-triazapenta-1,4-diene, un nouveau acaricide/insecticide employé dans le contrôle d'un grand nombre d'acariens et certaines insectes nuisibles.

Il convient pour les agrumes car il agit sur un grand nombre de pestes importantes y compris les araignées rouge des agrumes (*Panonychus citri*) et écailles de cire. Les résultats obtenus dans plusieurs régions ont prouvé qu'un contrôle effectif de *P. citri* pouvait entre obtenu à un taux de 0.02% a.i. Dans le cas des écailles de cire telles que l'écaille de cire blanche (*Ceroplastes destructor*), d'excellents résultats ont été obtenus en appliquant 0.04-0.05% a.i. avec ou sans addition d'huile blanche. Des résultats encourageants ont également été obtenus dans le cas de l'écaille rouge de Californie (*Aonidiella aurantii*); des populations denses ont été tenues en échec après application de l'amitraz. D'autres éssais contre cette peste et autres sont actuellement en cours.

* Proposed common name - subject to approval by ISO.

Le compose n'affecte pas les agrumes, même à forte concentration et les niveaux résiduaires sont a l'étude.

INTRODUCTION

Amitraz is the proposed common name for 1,5-di-(2,4-dimethylphenyl)-3-methyl-1,3,5-triazapenta-1,4-diene and represents a new group of biologically active compounds (Watkins et al 1973), effective for the control of red spider mites and certain species of Hemiptera, including scale insects, aphids and suckers. Since 1971 amitraz has been tested extensively throughout the world in a wide variety of crop and pest situations. For the purposes of this paper, however, discussion will be confined to the citrus crop. Full details of the chemical and physical properties are included in a separate paper 'Amitraz - a novel acaricide with selective insecticidal properties' (Weighton et al 1973), presented in Session 10 of this conference.

Although many of the major citrus growing areas of the world are in developed countries such as the United States and Japan, citrus contributes to the foreign currency earnings of several of the North African and South American countries and large quantities are grown in India for domestic consumption.

The average temperature limits for citrus culture are 4.5°C (40°F) in the coldest months and 21-24°C (70-75°F) in summer and although the crop will tolerate a wide range of rainfall citrus growing areas are generally semi-arid. Such conditions, unfortunately, favour a wide range of insects and mites; the major pests being scale insects and mealy bugs, over one hundred species have been observed, and red spider and rust mites.

LABORATORY INVESTIGATIONS

Initial investigational work revealed that amitraz was highly active against mites and certain species of Hemiptera such as California red scale (*Aonidiella aurantii*).

i) Activity against mites.

Amitraz was evaluated against the citrus red mite, (*Panonychus citri*) by dipping infested leaves into various concentrations of the chemical. These were maintained in petri-dishes lined with moistened filter paper; mortality was assessed three days after treatment. At the lowest concentration tested, 37.5 ppm., amitraz gave 100% control compared to 95% for dicofol.

Additional work both in the United States and Japan confirmed this activity. Studies at the University of California showed the compound to be comparable with other materials currently being used. Tests were conducted on organophosphate resistant strains of citrus red mite and Pacific mite (*Tetranychus pacificus*) and a susceptible strain of two spotted mite (*Tetranychus urticae*). Results are shown in Table 1.

Table 1

Comparison of amitraz and other acaricides on citrus mites (University of California)

Treatment	a.i. ppm	Citrus red mite	% mortality Pacific mite	Two spotted mite
Amitraz	50	70	100	70
	100	-	-	-
Tricyclohexyltin hydroxide	50	57	10	85
	100	100	100	100
Parathion	50	75	45	55
	100	-	75	71
Ethion	50	100	60	30
	100	95	100	85

Initial studies on two-spotted mite carried out at Lenton Research Station had shown the compound to be more potent to eggs and larvae than adults and also that organophosphate resistant strains were less susceptible than non-resistant strains. (Harrison et al 1972). This was confirmed by work at the University of California as shown in Table 2.

Table 2

Control of resistant and susceptible strains of Pacific mite & citrus red mite (University of California)

a) Adults

	% mortality at dose rates (a.i. ppm) 1000		500	
	Tp.	Pc.+	Tp.	Pc.
Resistant	48	100	20	87
Susceptible	75	100	75	100

b) Eggs

	% surviving at dose rates (a.i. ppm) 1000		500	
	Tp.	Pc.	Tp.	Pc.
Resistant	0	0	0	6
Susceptible	0	0	0	10

+ Tp. = Pacific mite. Pc. = Citrus red mite.

Subsequent trials both on citrus and other crops have confirmed that amitraz, although effective on all of the above mites is more potent to Panonychus species than Tetranychus species. It is equally effective on organophosphate resistant and non-resistant strains.

ii) Activity against scale insects.

Amitraz was tested at Lenton Research Station on California red scale by confining larvae to the surface of potatoes which had been treated with the chemical. After a 72 hour exposure the number of live sedentary scales was counted. By this method the LD_{50} of amitraz was found to be 16 ppm compared to 27 ppm for malathion. Other tests revealed that amitraz was ineffective against adult scales.

FIELD TRIALS

i) Mites.

The three most important mites which attack citrus are the citrus red mite, the citrus rust mite _Phyllocoptruta oleivora_ and the citrus but mite, _Aceria sheldoni_. Following the encouraging laboratory results obtained on citrus red mite an extensive series of trials on this species has been carried out at citrus research stations in the U.S.A. and Japan and results reveal that excellent control can be achieved with relatively low rates such as 0.02% a.i. Typical results are shown in Tables 3 and 4.

Table 3

Control of citrus red mite on lemons - Arizona U.S.A. (The Upjohn Co. Ltd.,)

Treatment	a.i. lbs/acre (in 150 gals)	Av. % mortality			
		T+5[+]	T+12	T+20	T+30
Amitraz	0.5	88	90	96	100
	1.0	95	98	100	95
	2.0	100	100	95	98
	4.0	100	100	100	100
Tricyclohexyltin hydroxide	1.0	100	95	98	100
Chlorbenzilate	1.0	100	100	96	100
	2.0	100	100	100	98

[+]T = day of treatment.

Table 4

Control of citrus red mite on oranges - Japan

(Nissan Chemical Industries Ltd.,)

Treatment	a.i. ppm	No. of mites				
		T	T+1	T+9	T+19	T+36
Amitraz	200	105	0	0	0	15
	250	112	0	0	0	13
Dicofol		101	0	1	5	33
Chlordimeform		98	0	21	45	123
Untreated		98	49	102	217	259

The few field trials conducted on Tetranychus species on citrus indicate that the compound is effective at rates of 0.04-1.05% a.i.

Few trials have been carried out so far on the eriophyid mites of citrus but preliminary work on citrus rust mite is encouraging and shows amitraz to be comparable with currently available compounds (Table 5).

Table 5

Effect of amitraz on citrus rust mite (The Upjohn Co. Ltd.,)

Treatment	a.i. ppm	No. of mites			
		T	T+7	T+14	T+28
Amitraz	200	66	1	0	3
Acaraben	625	81	2	1	21
Banomite	1200	92	0	1	19

ii) Scale insects.

Following the determination of activity against California red scale in the laboratory, trials were initiated in Australia to determine the efficacy of the compound in the field against the two major scale pests, California red scale and white wax scale (*Ceroplastes destructor*). Red scale is a major pest in the inland areas and trials were laid down in the Murrumbidgee Irrigation Area; white wax scale is a serious pest in the coastal districts and trials were laid down at Boots' Kooree Research Station, north of Sydney. Encouraging results were obtained and further work on red scale, conducted in California, gave the results shown in Table 6.

Table 6

Control of California red scale on grapefruit - California (University of California)

Treatment	a.i. ppm	Av. no. of larvae
Amitraz	60	962.0
	100	301.4
	200	13.7
Untreated		1535.5

In the trial against white wax scale three spray timings were used. As amitraz did not appear to be effective against adult scale, the optimum time for spraying was considered to be during the period of maximum larval migration, when the pest is at its most vulnerable stage. Spraying was done at this time, 10 days before the 'optimum time' and 20 days after and in each case amitraz was compared with current spray programmes. Results are shown in Table 7.

Table 7

Control of white wax scale on Valencia oranges

Treatment	a.i. ppm	Early(4/1)	'Optimal'(17/1)	Late(3/2)
Amitraz	500	12	57	322
Amitraz + white oil	500(1:100)	6	20	390
Malathion	1000	440	508	1004
Malathion + white oil	1000(1:100)	25	167	760
White oil	1:100	76	224	393
	2:100	31	189	277
Carbaryl	500	-	-	374
Carbaryl + white oil	500(1:100)	-	-	319
Untreated		1145	1738	1706

Assessment date - 24/3.

The results clearly show that it is essential that amitraz be applied early before larval migration reaches its peak.

Trials in Italy on fig wax scale (*Ceroplastes rusci*), black scale (*Saissetia oleae*) and citrus mealybug (*Pseudococcus citri*) have given the results amassed in Table 8.

Table 8

Control of fig wax scale, black scale and citrus mealybug (Monteshell S.p.A.)

Treatment	a.i. ppm	% mortality				
		Fig wax scale on tangerine		Black scale on orange		Mealy bug on orange
		T+5	T+15	T+3	T+26	T+26
Amitraz	200	90.7	100.0	88.6	91.8	51.1
Phenthoate	500	81.3	98.7	98.8	99.1	-
Dimethoate	500	-	-	-	-	89.2

iii) Persistence.

Results obtained both in the U.S.A. and Japan have confirmed that persistent control of mites can be achieved for a considerable period. In Japan amitraz was still giving control 30-50 days after treatment depending on weather conditions and in one trial in the U.S.A. mites were just beginning to re-colonise leaves 3 months after treatment.

iv) Crop Safety.

Amitraz has been applied to a wide range of varieties in differing climatic conditions and no damaging effects have been noted. In Australia, oranges (var. Valencia) and lemons (var. common) did not show any phytotoxic symptoms following two applications of amitraz at 0.25% a.i.

Relatively little compatibility work has been done on citrus although on pome and stone fruits the compound is compatible with a wide range of pesticides. However, as with many other chemicals amitraz does not appear to be compatible with alkaline substances such as Bordeaux mixture and results from both Italy and Japan confirm this.

v) Residues.

Residue levels are currently under study and will be reported in a separate paper.

DISCUSSION

Amitraz has been tested extensively on several of the most important pests of citrus and consistently good control can be achieved. On mites, the compound is particularly effective against Panonychus species, control of citrus red mite being achieved at low rates of use (0.02% a.i.). Other Tetranychid mites closely related to the two spotted mite are of importance in the Mediterranean region. Preliminary work in Spain has shown that this mite can be controlled effectively with amitraz at higher rates (0.04-0.05% a.i.). This agrees with findings in trials on other crops such as pome fruit. Work on other mites is in progress; of particular importance are the rust mites and others of the Eriophyidae. Because of their life cycle these mites are difficult to kill and results of trials frequently tend to be erratic. Results of trials in the U.S.A., Greece and Lebanon against the citrus rust mite, however, are encouraging.

Amitraz is effective against the unarmoured or wax scales and excellent control of white wax scale, black scale and fig wax scale has been obtained. Wax scales, however, are generally less of a problem than armoured scales, California red scale being regarded as the most important citrus pest in the world. Results of trials against this pest have been variable; although high mortalities have been achieved even a few surviving larvae can cause considerable damage. The problem is aggravated by the fact that all stages are present at any period of the year and amitraz is not effective against adult scale. Very few materials are completely effective, but the relatively cheap oil sprays are used most widely despite the fact that they can be somewhat phytotoxic. It is envisaged that the effects of amitraz on scale insects will be secondary, the compound serving to suppress populations of scale when used in a mite programme. Some further work, however, is in progress in North Africa.

Against citrus mealybug, another 'hard-to-kill' insect, amitraz failed to give acceptable control. The rate, however, was low (0.02% a.i.).

Amitraz is not sufficiently active against the moth *Prays citri* nor the citrus whitefly (*Dialeurodes citri*) to warrant further work and it appears doubtful whether it will control citrus bugs such as the bronze citrus bug (*Musgraveia sulciventris*).

Results against aphids are more encouraging; aphids such as the black citrus aphid (*Toxoptera citricidus*) and the spirea aphid (*Aphis spiraecola*) can cause considerable damage and although amitraz has not yet been tested against these particular species, it has proved effective against the hop-damson aphid (*Phorodon humuli*) and the peach-potato aphid (*Myzus persicae*).

Control of such a wide range of pests has always been a problem and it is hoped that amitraz will be of considerable value to the citrus grower.

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Proceedings 7th British Insecticide and Fungicide Conference (1973)

CHEMICAL TREATMENT OF SUGAR CANE SMUT

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Summary BAS 3192 F (W.P.,50% 2.5-dimethyl-furane-3-carbonic acid anilide) and BAS 3271 F (W.P.,50% N-cyclohexyl-2.5-dimethyl-furane-3-carbonic acid amide) appear to be highly effective against sugar cane smut (Ustilago scitaminea Syd.) in laboratory and greenhouse experiments. BAS 3192 F and BAS 3271 F act systemically, they are absorbed by the roots and transported via the xylem into the stem. In order to control the fungus in buds and emerging spikes of sugar cane the fungicidal material has to be available in the soil for a certain period. Granulates (5% a.i.) of BAS 319 F proved to be suitable. Release of active ingredient was almost constant over a period of 10 days.

INTRODUCTION

Sugar cane smut (Ustilago scitaminea Syd.) is a common disease in various cane-growing areas. By planting smut resistant varieties heavy losses can normally be avoided. In recent years, however, the disease has reached an economically serious level in several African countries. It appears that the resistance of commonly grown varieties has broken down and no suitable replacements have been found to date. Losses due to decrease in yield and, more so, increase of production costs have become dangerously high. By keeping to a very strict regime of sett treatment, roguing of propagation fields and using only healthy cane of the first growing cycle for propagation, infection of plant cane can be kept at a minimum (below 0.1%). Systemic infection can be eradicated by means of hot water treatment of cane setts. Contaminant spores are well controlled by chemical treatment, e.g. with 0.25% cuprous oxide or 0.25 - 0.5% methoxyethyl mercury chloride.

While smut infection of plant cane can be kept low, smut in the ratoon can so far only be controlled by means of constant inspection and elimination of "suspect" plants. This is only possible until the cane has reached a certain height and requires well trained and supervised labor, but even in well managed estates more than 30% of the infected plants are not detected and eliminated before forming a smut whip.

Under unfavorable conditions 50 - 70% of the plant population of a susceptible variety becomes infested in the first ratoon (growing cycle after the first cutting), with the consequence that the cane has to be replanted after the first harvest. Plantations with well organized smut control schemes suffer from high labor costs, loss of potential yields and a reduced number of ratoon harvests. Under high smut infestation the profitability of sugar growing is, therefore, seriously affected.

Since it is possible to keep the first growing cycle almost free of smut, our investigation aimed at methods suitable for the control of the disease in sugar cane ratoons. The same principle can, of course, be applied to newly planted cane.

Some experiments on the chemical control of sugar cane smut are reported on in this paper.

METHOD AND MATERIALS

In our work on the control of <u>Ustilago</u> species in cereals 2.5-dimethyl-furane-3-carbonic acid anilide (Pommer and Kradel, 1970) and N-cyclohexyl-2.5-dimethyl-furane-3-carbonic acid amide (Pommer et al,1971) have shown excellent systemic efficacy. In the experiments in sugar cane, wettable powder formulations containing 50% a.i. were used under the following code numbers:

BAS 3192 F (W.P.,50% 2.5-dimethyl-furane-3-carbonic acid anilide)
BAS 3271 F (W.P.,50% N-cyclohexyl-2.5-dimethyl-furane-3-carbonic acid amide)

In addition, granular formulations containing 5% a.i. of the compound BAS 319 F were tested. Also included was a 50% W.P. containing the active ingredient 2-(methoxy-carbamoyl)-benzimidazol (Code No. BAS 3460 F).

Bio-assays were carried out on 8% malt extract agar (MEA). Agar plates inoculated with smut spores were incubated at 31°. Evaluation of fungicidal activity by measuring the inhibition zones was carried out after 24 hours.

Sugar cane of the variety NCO 310, cut into single node setts, were placed in wet cloth until shortly before sprouting of the buds. They were then dipped for 30 minutes into a suspension containing approximately 10^9/ml chlamydospores. In order to promote the formation of infection hyphae, the infected setts were incubated for 24 hours at a high relative humidity and 31°C constant temperature. Afterwards they were planted into a greenhouse at a rate of 8 setts (8 buds) per m^2. Incorporation of the fungicide granulars and soil treatment with fungicide suspensions was carried out during planting. Plastic sheets were used to separate controls and different treated series of cane setts.

RESULTS

Several laboratory tests were carried out with the aim of finding out at which rate the fungicides inhibit the growth of Ustilago scitaminea. Discs of filter paper (diameter 15 mm, thickness 1 mm) were dipped in fungicide suspensions containing 3, 6 and 12 ppm a.i. and then placed on inoculated MEA plates. As shown in Table 1, BAS 3192 F was more effective than both BAS 3271 F and BAS 3460 F.

Table 1

Product	Concentration ... ppm a.i.	Inhibition Zones ... mm after 48 hours
BAS 3192 F	3	2
	6	4
	12	9
BAS 3271 F	3	0
	6	0
	12	2
BAS 3460 F	3	0
	6	0
	12	1

As an effective control of the smut fungi can be obtained only when the fungicide is absorbed by the plant root and then transported into the infected plant parts, a model experiment with nutrient solutions was carried out. The studies were carried out on maize seedlings which were grown in nutrient solutions containing different concentrations of fungicides. After 72 hours the plants were dissected and the amount of active ingredient transported into the stems was determined by means of a bio-assay. The diameters of inhibition zones induced by 10 mm long stem sections are summarized in Table 2.

Table 2

Product	Concentration in the nutrient solution ... ppm a.i.	Inhibition Zones ... mm stem sections of Zea Mays
BAS 3192 F	25	2
	50	9
	250	9
BAS 3271 F	25	3
	50	4
	250	9
BAS 3460 F	25	0
	50	0
	250	0

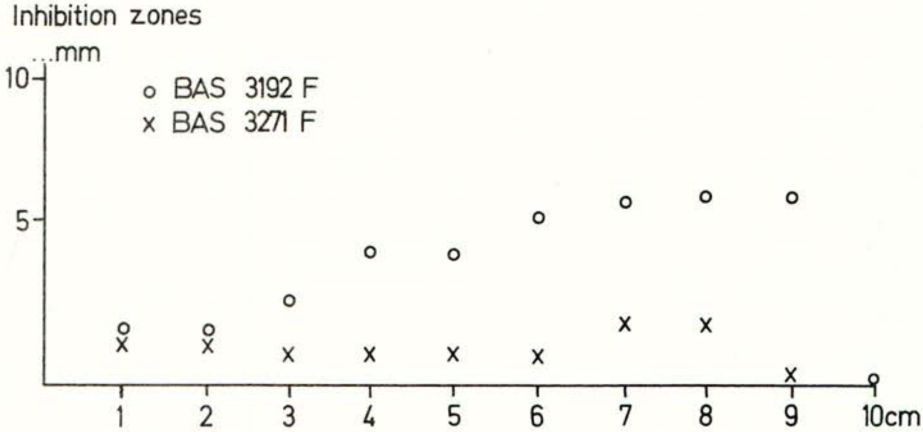
BAS 3192 F and BAS 3271 F gave similar results in this experiment whilst the benzimidazole derivative BAS 3460 F was not effective.

Inhibition zones were observed only when 500 ppm or more of BAS 3460 F was added to the nutrient solution.

In order to study the translocation of active ingredient in sugar cane, 6 months old cane stools were subjected to a single soil drenching treatment with 3.4 l of an 0.1% suspension of BAS 3192 F and BAS 3271 F. 3 days after application the stems were cut at ground level and divided into 5 mm long sections. The sections were placed on inoculated MEA plates.

Inhibition zones diameters in relation to position above ground are shown in Figure 1.

FIGURE 1

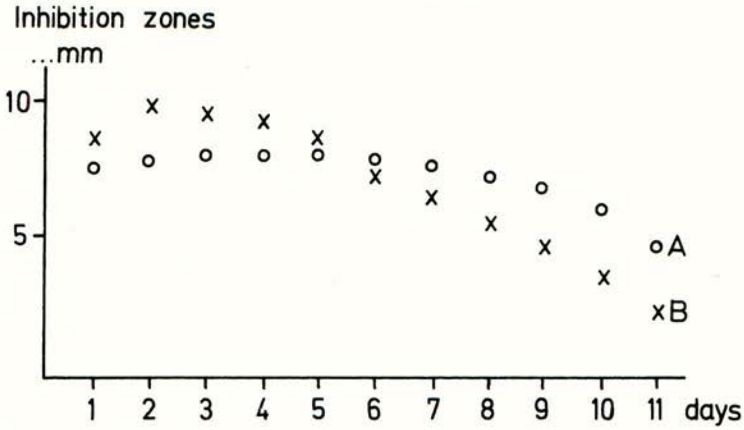


TRANSLOCATION OF ACTIVE INGREDIENT IN SUGAR CANE STEMS

The results suggest a rather slow translocation. However, BAS 3192 F shows markedly better results than BAS 3271 F.

Since BAS 3192 F proved to be the most promising of the materials studied, several granular formulations were tested in order to study the release of the active ingredient. Figure 2 shows the results of a comparison of 2 granular formulations. 3 mg of each type of granular (5% a.i.) were placed on previously inoculated MEA plates. Every 24 hours they were transferred to fresh plates and the inhibition zones were measured every day. The figure shows that the impregnated granular releases the active ingredient substantially faster than a granular formulation in which the a.i. was incorporated.

FIGURE 2



RELEASE OF ACTIVE INGREDIENT OF 2 DIFFERENT GRANULAR FORMULATIONS OF BAS 319 F

A = A.I. INCORPORATED
B = A.I. IMPREGNATED

The greenhouse experiments on the chemical control of sugar cane smut started in February 1973 are not yet concluded. In spite of successful infection of the cane setts no smut whips were formed until August 1973. Only few "suspects" were found in the control plot. By microscopic inspection of the apical meristems, mycelium of smut could be found only in untreated control plants. Table 3 summarizes the rates of application and the results of the microscopic inspections in the greenhouse experiment.

Table 3

Fungicide	**Rate of Application Formulated Product per sett**	**Mycelium in apical meristem**
BAS 3192 F	**40 mg**	**-**
BAS 3271 F	**40 mg**	**-**
5% Granular of BAS 319 F	**400 mg**	**-**
5% Granular of BAS 327 F	**400 mg**	**-**
Control (no fungicide)		**+**

DISCUSSION

Careful treatment of sugar cane setts with hot water, if necessary combined with fungicides for surface disinfection, results in negligible smut infection rates of plant cane. Heavy infestation of smut in the following ratoon as can be often observed indicates that the buds are susceptible to infection or are already infected when the standing crop is harvested. The smut whips, even in small numbers, represent a serious infection potential. Antoine (1961), Bock (1964) and Waller (1970) have shown that bud infection plays a decisive part in the formation of smut whips. Bock proved in his experiments that cane spikes can be infected up to a length of 10 cm. This also applies to the infection of secondary tillers and of "bull shots" which appear late in the season and often show the highest percentage of infection.

As the fungicidal compounds BAS 319 F and BAS 327 F are highly effective against Ustilago scitaminea in low concentrations in vitro and are readily absorbed by sugar cane roots and transported into the stem, it should be possible to eradicate existing bud infections and to prevent infections of sprouting tillers during or after breaking through the soil. Granular formulations which release the active ingredients over a longer period of time (2-3 weeks) will be more suitable than wettable powders which would have to be applied by means of soil drenching. Besides being unpractical the active material would most probably be transported too fast into the upper parts of the cane, thus leaving no or too little active ingredient in the basal parts. The microscopic studies of 6-months old artificially infected plants treated with BAS 3192 F or BAS 319 F and BAS 3271 F or BAS 327 F suggest that rates of 20 - 40 mg a.i. are sufficient to kill the mycelium in the plant or at least to reduce its vitality to such an extent that the cane "outgrows" the pathogen.

Considering these results it should be possible to control sugar cane in the field, both by large scale application in heavily infested ratoon and by directed treatment of "suspect" plants. Field experiments have been initiated accordingly.

Acknowledgements

HVA International, Amsterdam, and HVA-staff of the sugar estates in Metahara and Wonji-Shoa, Ethiopia, have been very helpful in discussing the practical aspects of sugar cane smut, and providing healthy cane setts and infected material for this study. Their cooperation is gratefully acknowledged.

The authors wish to thank also the staff of the Sugar and Breweries Corporation, Republic of the Sudan, for their cooperation.

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NOTES

Proceeding 7th British Insecticide and Fungicide Conference (1973)

COMPARATIVE TOXICITY OF SOME OP COMPOUNDS AGAINST THE DIFFERENT STAGES OF THE MEDITERNANEAN FRUIT FLY, CERTITIS CAPITATA (WIED).

By

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SUMMARY: The effectiveness of five new organophosphorous insecticides has been tested against the different stages of *C. capitata*, (Wied), by using different laboratory techniques. Using the dipping technique on the egg stage, results indicated that dicrotophos was the most effective followed by fenthion, mecarbam, dimethoate and tetrachlorvinphos. Feeding larvae on carrot medium diet treated with different concentrations of different insecticides indicated that fenthion was the best in its effect on larvae followed by mecarbam, dicrotophos, dimethoate and tetrachlorvinphos.

Topical application or soil treatment with different insecticides for the control of pupal stage indicated that the pupal stage of this pest is able to tolerate higher doses of insecticides than other stages.

Testing chemicals against the adult flies using two different techniques indicated that fenthion, dimethoate and dicrotophos were the most promising chemicals for the control of this stage.

RESUME L'effectivité de cinq nouveaux insecticides d'organophosphorus avait été testée envers les differents stages des la *Ceratitis capitata*(Wied.), par l'emploi de differentes techniques de la boratoire, Apres l'emploi de la technique d'immersion sur le statium de l'oauf, les resultas prouvérent que le dicrolophos etait le plus effectife suivant par le feuthion, mecarbam, dimethoate et tetrachlorovinphos. Nourrissant les larves sur un medium de diette de carrotes traités avec differentes concentrations de differents insecticides les resultats indiquerent que l'effect du fenthion était le plus efficace sur les larves, suivit par le mecarbam, le dicrotophos, le dimethoate et le tetrachlorovinphos.

L'application de surface, au le traitement de la terre avec differents d'insecticides pour le controle de stadium de pupae, indiquèrent que cette peste, à l'etat de pupae peut tolérer des doses beaucoup plus importantes d'insecticides que dans n'importe quel autre état.

L'emploi de produits chimiques en trois techniques differentes contre les mouches adultes, pouverent que le fenthion, le dimethoate et le dicrotophos etaient les produits chimiques les plus promettant pour le controle de ce stadium.

INTRODUCTION

The Mediterranean fruit fly, Ceratits capitata (Wied), has been known to occur in the Mediterranean regions for about a century. It causes serious and increasing damage which affects the quality and quantity of fruit production. Although chemical control is still the main measure currently used against this pest, relatively little toxicological work has been done with the different stages of C. capitata. Previous laboratory work was largely confined to screening and evaluating the effect of different insecticides on adults. Studies on the relative toxicity of some insecticides to the adult flies were reported by Viel and Changcagne (1958), and El-Hakim, (1967). The response of the pupal stages of the medfly to insecticides applied to the soil to control the larvae entering the soil to pupate were reported by Puzzi and Orlando (1957) and Costantino (1957). These data are available for comparison. No data were reported on the effect of the insecticides either on eggs or the mining larvae of this pest.

The present work was aimed to investigate the effect of different insecticides using different methods of application on the different stages of the insect.

MATERIALS AND METHODS

Insects used in these experiments were obtained from the established mass rearing culture of the Plant Protection Department, Ministry of Agriculture, Dokki, A.R.E. Rearing method and handling techniques are those used by Hafez et al. (1967).

All toxicological work was conducted under laboratory conditions ($27^{\circ}C \pm 2$ and R.H. 60 % $\pm$ 5). Three replicates were used for each insecticide dilution and experiments were repeated two to three times. This makes the number of insects used in each dilution between 60 - 90 insects. In all experiments, an untreated check was carried out with the same technique but without insecticides. All mortality data were corrected for the natural mortality using Abbott's formula.

1. Testing insecticides on eggs. The technique used is a modification of that used by Dittrich (1962), on adults of two spotted spider mites. A small piece of double faced adhessive tape was adhered on a glass slide and ten eggs, (one-day old) were transferred to the upper surface of the tape. The slides then were dipped for 5 seconds in the different insecticides dilutions, after which they were left to dry under room conditions. The slides with treated eggs were placed on small plastic cubes over water in a petridish. After three days, eggs were examined for viability.

2. Testing insecticides on Larvae: Poisoned carrot medium treated with different dilutions of insecticides were prepared. 12 eggs of C. capitata were placed on a small sheet of black paper, then placed on the surface of the poisoned medium in a small vials. After three days, eggs were examined and the number hatched were recorded. Vials containing the poisoned medium and the hatched larvae were placed in jars containing fine sand (3-4 cm. in depth). The jars were covered with clean cloths. After 12 days, the pupated larvae found in the sand were counted. Larval mortalities were calculated according to the numbers of eggs hatched.

3. Testing chemicals on Pupae. Testing chemicals on pupae were carried out using two different methods:

A. Topical application method, Thirty, oneday old pupae were treated topically with different dilutions of the chemicals on the mid-region of the pupae. After 9 days the emerged adults were counted and percent mortalities were recorded.

B. Soil treatment. 5 ml. of the different dilutions of the insectidides were added to 100 cc (158 gm.) of fine sand in glass jars. Ten, 1-day old, pupae of C. capitata were transferred to each jar, one hour after the addition of the insecticides and left under the laboratory conditions. Emerging flies were counted after 9 days and corrected for the natural mortality.

4. Testing chemicals on Adults. Testing Chemicals on adults was performed using two different methods:

A. Topical application method; in which thirty flies were dosed with different dilutions of the chemicals on the undersurface of the ventral part of the abdominal region. Treated flies were held for 24 hours, after which percent mortalities were recorded.

B. Exposure Limited Time method. The method described by Keller (1960) and Brady (1966) was modified and used in this experiment. Ten flies of C. capitata were exposed to a deposite film of different dilutions of the insecticides on petri-dishes. After a certain time interval they were transferred to clean ones. Flies were supplied with sugar and water and held for 24 hours after which mortality data were recorded.

Insecticides used:

Several preliminary tests were carried out with different concentrations of different insecticides to establish the suitable ranges of effective dilutions to be tried in this work.

Insecticides used were:

1. Dimethoate (Rogar): N-monomethylamide of 0,0-dimethyl-dithoiophosphorylacetic acid (94-96 % a.i.) obtained from Kafr El-Zayat Chem. Com. A.R.E.

2. Fenthion (Lebaycid):0, O-dimethyl -O- (4- methylthio-m-tolyl) phosphorothioate. (99 % a.i) obtained from Ministry of Agriculture, Central laboratory of Pesticides, Dokki, A.R.E.

3. Tetrachlorvinphos (Gardona): Cis-isomer of 2-Chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate. (99.5 % a.i.) obtained from Shell Chem. Company.

4. Dicrotophos (Bidrin): Cis isomere of 3 dimethoxyphosphinyloxy - N,N-dimethyl crotonamide, (87.2 % a.i.), obtained from Shell Chem. Company.

5. Mecarbam (Murfotox): S (N-ethoxycarbonyl-N-methyl carbomolmethyl) diethyl phosphorothiolothionate, 97.5 % Mecarbam pure obtained from Murphy Chem. Co. Ltd.

RESULTS

Effect of Chemicals on Eggs:

Fig. 1, shows the effect of different dilutions of the five used insecticides on egg hatching. It is clear from this figure, that dicrotophos was the most effective chemical against the eggs of C. capitata, where tetrachlorvinphos was the least effective of these chemicals. LC_{50} for these chemicals can be arranged in the following descending order: dicrotophos, fenthion, mecarbam, dimethoate and tetrachlorvinphos, since the LC_{50}'s for them were 23.2, 51,6, 106.5, 264.8 and 354.9 p.p.m., respectively.

All the dosage-mortality curves were relatively parallel with the exception of fenthion which was steeper than the other (Fig. 1). This indicates that these chemicals behave similars against the eggs of med. fruit fly. The slope value for fenthion was 1.455 indicalting its difference in the mode of action to the others.

Effect of chemical on larvae.

Fig. 2 illustrates the effect of the five used insecticides against the larvae of this pest, and it is clear from this figure that fenthion was the most effective insecticides against the larvae of C. capitata when they were fed on the poisoned medium. Tetrachlorvinphos was the least effective one. Dicrotophos, dimethoate and mecarbam were moderate and similar in their effect. The LC_{50} values (as p.p.m. a.i in the poisoned medium) for fenthion, mecarbam, dicrotophos, dimethoate and tetrachlorvinphos were 0.0045, 0.0564, 0.0700, 0.4047 p.p.m., respectively. The dosage mortality curves (Fig. 2) for all insecticides used, except tetrachlorvinphos, were parallel to each other, indicating similarity in their action on larvae. Tetrachlorvinphos was less steeper than the others, indicating that it differs in its effect and mode of action against the larvae of C. capitata in poisoned medium.

Effect of chemicals on Pupae.

Fig. 3 shows the effect of the different concentration of the different insecticides on the pupae of C. capitata when they were applied topically. This figure indicates that fenthion was the most effective insecticide used as its LD_{50} was 0.387 microgram/pupa and LD_{90} was 1.91 microgram/pupa. Dimethoate was the least effective chemical with LD_{50} of 56.48 ug/pupa and LD_{90} was 690 ug/pupa, mecarbam and dicrotophos were moderate in their effect. LD_{50} values of them were 0.8 and 1.944 mg/p. respectively. Tetrachlorvinphos had a very weak effect, as its LD_{50} was more than 200ug/pupa.

Soil treatment with different dilutions of insecticides indicated that dimethoate was the most effective chemical against the pupae of C.capitata. fenthion was next, while tetrachlorvinphos was the least effective one. Dicrotophos and mecarbam gave a moderate effect.

Effect of Chemicals on adults

Fig. 5 shows the LD-p lines of different insecticides on the adult flies of C. capitata when they were applied topically. It is clear from

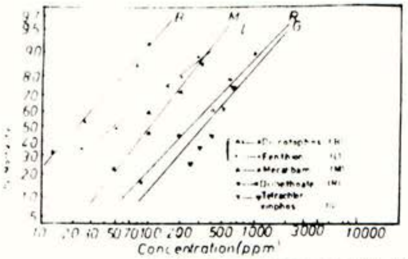

Fig.(1) LC-p lines of different insecticides on the eggs of C. capitata using the dipping method

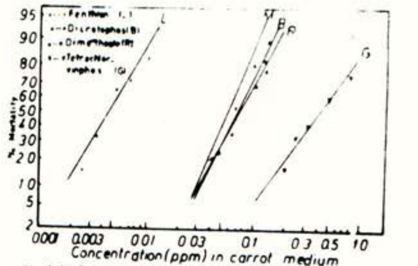

Fig (2) LC-p lines of different insecticides on larvae of C. capitata using poisoned medium

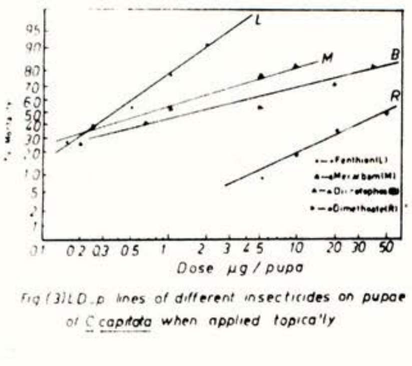

Fig (3) LD-p lines of different insecticides on pupae of C. capitata when applied topically

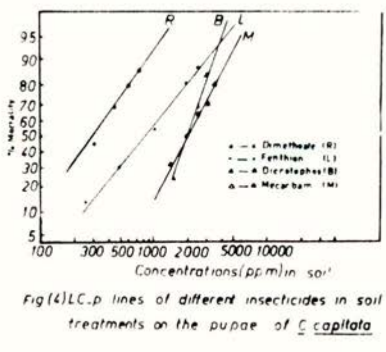

Fig (4) LC-p lines of different insecticides in soil treatments on the pupae of C. capitata

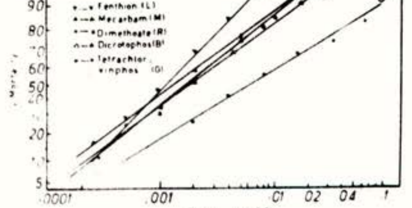

Fig (5) LD-p lines of different insecticides on the adult flies of C. capitata when applied topically

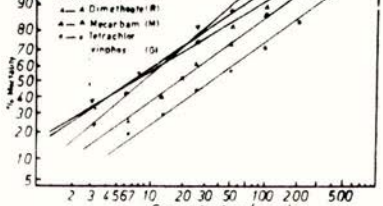

Fig (6) LC-p lines of different insecticides on adult flies of C. capitata using exposure limited time method

Table (1) The response of the different stages of *C. capitata* to different insecticides using different methods of treatments.

Insecticides	Effect of insecticides on adultflies with indicated methods		Egg (dipping)	Poisoned medium (larvae)	Pupae		Total No. of points
	Topical application	Exposure limited time			Topical application	Soil treatment	
Dimethoate	+	++++	+	+	+	++++	12
Fenthion	++++	++	+++	++++	++++	+++	20
Mecarbam	+++	+	++	+++	+++	+	13
Dicrotophos	++	+++	+++	++	++	++	14
Tetrachlorvinphos	0	0	0	0	0	0	0

++++ = Excellent effect, the first of the group.

+++ = Very good effect, the second of the group.

++ = Good effect, the theud of the group.

\+ = Adequate effect, the fourth of the group.

0 = Inadequate effect, the fifth of the group.

this figure that fenthion was the most effective chemical while tetrachlorvinphos was the least effective of these insecticides. $LD_{50's}$ for the used chemicals can be arranged in the following ascending order: fenthion, mecarbam, dicrotophos, dimethoate and tetrachlorvinphos since the $LD_{50's}$ values were 0.00116, 0.00138, 0.00181, 0.00188 and 0.00673 μg/fly, respectively.

The dose mortality curves of mecarbam, dimethoate and dicrotophos relatively parrallel, while fenthion was steeper and tetrachlorvinphos was less steeper than the others. This indicate that mecarbam, dimethoate and dicrotophos behave quite similar on the adults of C. capitata, while the fenthion and tetrachlorvinphos vary in their mode of action than the others.

The results of testing chemicals against the adults flies using exposure limited time method (see Fig. 6), show that LC_{50} values of these insecticides can be arranged in the following ascending order: dimethoate, dicrotophos, fenthion, mecarbam and tetrachlorvinphos. On the other hand, the effectiveness of these materials, (according to the $LC_{90's}$, values), can be arranged in the following ascending order: fenthion, dicrotophos, dimethoate, mecarbam and tetrachlorvinphos since their $LC_{90's}$ were 47.46, 61.81, 90.12, 152.9 and 235.38 p.p.m respectively.

DISCUSSION

The female Mediterranean fly lays its eggs within the fruits under their outer cover where larvae hatch and feed on the content of the fruit. Any chemical recommended for its control should be effective in these sites and meet the following requirements. Should be effective against adults, penetrate the fruit skin and affect both egg and small larvae at their hatching place beside having some effect on mature larvae leaving the fruit to pupate in the soil. It should also have a low mammalian toxicity.

Table (1) gives the response of the different stages of C. capitata to different insecticides under laboratory conditions, from this table it can be concluded that fenthion was the most effective chemical against the different stages of this pest; dicrotophos was next, followed by mecarbam, dimethoate and tetrachlorvinphos. These chemicals can be arranged according to their final effect as follows: fenthion (20 points), dicrotophos (14 points), mecarbam (13 points), dimethoate (12 points) and tetrachlovvinphas (0 point).

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