SHORT-TERM TRANSLAMINAR BIOAVAILABILITY OF CERTAIN INSECTICIDES AGAINST THE SWEETPOTATO WHITEFLY *Bemisia tabaci* (Genn.) ON COTTON

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INTRODUCTION

Bemisia tabaci (Gennadius) is an important pest of many crops in tropical and subtropical countries (Gerling, 1990). This whitefly causes damage not only by sucking plant fluids (phloem sap) which can result in yield reduction but also by transmitting viral diseases (Cohen, 1990).

Management of such pest as was the case for other sucking pests still relies mainly on chemical control approach. However, efficient chemical control of this pest is difficult to achieve, in part because all stages are found predominantly on the lower leaf surface, with older stages concentrated in the dense lower canopy. Therefore, coverage is an important consideration in evaluating the effectiveness of pesticides used against this pest. On the other hand, biological and chemical behaviour of the insecticide itself play an important role which could in part overcome the incomplete coverage of foliage (Abro *et al.*, 1989 and Buchholz and Nauen, 2001).

Accordingly, the objectives of our study were to evaluate the short-term translaminar activity of 38 different compounds belonging to several groups of insecticides. Such information would aid producers, consultants and extension personnel in making informed decisions in choosing the suitable compounds having systemic activity or/and acceptable translaminar activity for field application against whiteflies particularly in case of vegetative plantation crowdness and using volume of spraying solution not sufficient for complete coverage (Liu and Stansly, 1995).

MATERIAL AND METHODS

Sweetpotato whiteflies *B. tabaci* field strain, collected from insecticide-treated vegetable plants in greenhouses, were reared on cotton seedlings in pots under long day conditions (photoperiod of 16 : 8 (L : D) at a temperature of 27±2°C.

Thirty eight insecticides belonging to four groups of chemicals were tested in bioassay tests. The first includes the following organophosphates : chlorpyrifos ethyl (Dursban 48 % EC), profenofos (Selecron 72 % EC), Methamidofos (Tamaron 60 % SL), Monocrotophos (Nuvacron 40 % SL), Pirimiphos-methyl (Actellic 50 % EC), Azinophos-ethyl (Gusathion A 33.3 % WP), Phenthoate (Cidial 50 % SL), Omethoate (Folimat 80 % SL), Malathion (Malathion 57 % EC), and chlorpyrifos-methyl (Reldan 50 % EC). The second group includes seven carbamates, *i.e.* Alanycarb (Onic 30 % EC), Oxamyl (Vydate 24 % SL), Methomyl (Lannate 90 % SP), Carbosulfan (Marshal 25 % WP), Thiodicarb (Larvin 80 % SG), Pirimicarb (Primor 50 % WP), and Furathiocarb (Deltanet 40 % EC). The third group includes the following nine synthetic pyrethroids; Esfenvalerate (Sumi-alpha 5 % EC), Alpha-cypermethrin (Fastac 10 % EC), Cyhalothrin (Cypha 10 % EC), Fenpropathrin (Meothrin 20 % EC), Cyfluthrin (Baythroid 5 % EC), Cypermethrin (Fenome 20 % EC), Fenvalerate (Sumicidin 20 % EC), Deltamethrin (Decis 2.5 % EC), and Lambda-cyhalothrin (Karate 5 % EC). The fourth group includes the following miscellaneous insecticides : Etofenprox (Trebon 30 % EC), Thiomethoxam (Actara 25 % WG), Bensultap (Bancol 50 % EC), Thiocyclam (Evisect 50 % EC), Abamectin (Milbimictin 1 %), Pymetrozin (Chess 25 % EC), Spinosad (Spintor 24 % SC), Abamectin (Vertimec 1.8 % EC), Imidacloprid (Confidor 20 % SL), Diafenthiuron (Polo 50 % WP), and Potassium salts of fatty acids (M-Pede 49 % EC).

Cotton plant seedlings *Gossypium barbadense* L. cv. Giza 75 having 4-6 true leaves were used in testing translaminar activity. Two sets of experiments were carried out.

In the first, the seedlings were sprayed carefully with the diluted pesticides only on their upper leaf surface to the point of spray run-off (complete coverage of the upper surface with a hand sprayer). In the second set, the spray was applied to both leaf surfaces.. In both cases, the treated seedlings were left for 3-4 h for natural dryness. Leaves from both sets were cut and taken for bioassay. The neck of the leaves were surrounded by wet cotton wool soaked in moist filter paper in glass Petri dishes (9 cm diameter), and 20-30 *B. tabaci* unsexed adults were confined under clip-on cage on the lower surface. Each treatment was replicated three times.

Controls were placed on untreated (unsprayed) cotton leaves. Mortality was recorded after 24 h. The short-term translaminar activity was assessed according to the following equation :

$$\text{Translaminar activity } \% = \frac{LC_{50} \text{ when both leaf surfaces were treated}}{LC50 \text{ when only upper surface was treated}} \times 100$$

Estimates of LC_{50} values and their 95 % confidence limits in addition to slopes of regression lines were obtained with probit analysis based on the procedure of Finney (1971). The data were corrected for control mortality by the method of Abbott (1925) and the toxicity index was calculated according to Sun (1950).

RESULTS AND DISCUSSION

Data in Table (1) revealed highly pronounced translaminar activity (96.78 %) for Chlorpyrifos-ethyl and was followed by Profenofos (71.05 %). It is of interest to note here that the least translaminar effect (4.51 %) was recorded for Chlorpyrifos-methyl. However, other organophosphates insecticides exhibited translaminar activity ranged between moderate (32.37 %) and weak (15.08 %).

On the other hand, comparison based on toxicity index calculated on the basis of LC_{50} when both surfaces of the leaves were treated, revealed completely different picture where only Phenthoate was the most toxic (100) while the three insecticides Chlorpyrifos-ethyl, Profenofos and Azinophos-ethyl came second recording T.I. of only 10, whereas T.I. of the 6 other insecticides ranging between 3.7 and 5.9. Such performance of the organophosphates revealed that there are no relationship between the direct contact toxicity of the compound and its potency in plant tissues penetration or/and its translaminar activity (indirect toxic effect).

Relatively moderate translaminar activity was achieved by carbamates compounds (Table 2). The highest translaminar activity (55.26 %) was recorded by Alanycarb and followed by 42.62 % for Oxamyl, whereas the least (10.52 %) was recorded for Furathiocarb. The 4 other insecticides exhibited translaminar activity ranging between 34.74 % and 25.19 %.

Comparison on the basis of toxicity index revealed that Alanycarb was on the top (T.I. = 100) followed by Furathiocarb, methomyl and Pirimicarb giving toxicity index values of 95.4, 88.5 and 86.0, respectively. In contrast, Oxamyl exhibited the least (29.6) toxicity index.

TABLE (I)

Relative short-term translaminar activity of 10 organophosphates on adults of *Bemisia tabaci* on cotton seedlings under greenhouse conditions.

Insecticide	Treated surface (@)	Slope ±S.E.	LC_{50} (95 % CL) ppm		T.I.[(b)]	Relative trans-laminar activity % [(c)]
Chlorpyrifos-ethyl	both	2.3±0.7	88.17	( )	10.3	
	upper	1.7±0.3	91.10	(48.5-130.8)		96.78
Profenofos-Sel	both	2.1±0.5	89.02	(20.6-153.3)	10.2	
	upper	2.6±0.7	125.26	(51.8-183.3)		71.05
Methamidofos	both	1.6±0.3	168.37	(65.5-262.8)	5.4	
	upper	1.5±0.5	520.06	(192.2-787.1)		32.37
Monocrotophos	both	3.2±0.9	272.88	( )	3.33	
	upper	1.1±0.3	866.12	(517.9-5498.2)		31.50
Pirimiphos-methyl	both	2.3±0.4	216.55	(128.3-295.4)	4.21	
	upper	2.1±0.5	702.46	(527.7-905.1)		30.83
Azinophos-ethyl	both	1.5±0.8	90.77	( )	10.0	
	upper	2.4±0.7	373.65	(229.5-511.2)		24.29
Phenthoate	both	1.5±0.5	9.11	(0.43-16.9)	100.0	
	upper	1.1±0.4	39.68	(5.94-68.2)		22.95
Omethoate	both	1.9±0.6	153.66	(34.2-239.1)	5.9	
	upper	1.6±0.3	783.59	(602.8-1043.5)		19.60
Malathion	both	2.3±0.4	175.30	(96.6-245.4)	5.19	
	upper	1.2±0.3	1161.90	(801.0-1782.4)		15.08
Chloropyrifos-methyl	both	2.5±0.8	240.58	(43.0-372.6)	3.78	
	upper	1.1±0.4	5333.10	( )		4.51

a : In both cases of treatments, adults under clip-on cages were exposed and fed on the lower surface of cotton leaves.

b : Toxicity index (T.I.) was calculated on the basis of LC_{50} values obtained when both surfaces were insecticide-treated.

c : Translaminar activity % = [LC_{50} when both surfaces were treated/LC_{50} when upper surface was treated] x 100.

Data in Table (3) demonstrate the translaminar activity of 9 synthetic pyrethroid insecticides. It is obvious that such group of insecticides exhibited in general translaminar activity over 50 % for 6 out of 9 insecticides. The highest translaminar activity was recorded for Esfenvalerate (80.84 %) and Alpha-cypermethrin (80.09 %), and both were followed closely by Cyhalothrin (76.25 %). the least translaminar activity (16.14 %) was recorded for Lambda-cyhalothrin. However, comparison based on toxicity index revealed that Deltamethrin was the most toxic one (100) whereas Fenpropathrin (6.0) was the least toxic one. Others, came in-between recording toxicity index of 21.4-59.3.

As shown in Table (4), it was of interest to note that the new compounds in general revealed outstanding translaminar activity after 24 h. In this respect, Etofenprox came first recording 94.1 % translaminar activity. In addition, 3 compounds includes Thiomethoxam, Bensultap and Imidaclopeide recorded over 80 % translaminar activity, while 3 others includes Thiocyclam, Milibimictin and Pymetrozin recorded over 70 % translaminar activity. Only M-Pede, Spinosad and Abamectin recorded over 50 % translaminar activity. However, the least translaminar activity (18.26 %) was recorded by Diafenthiuron.

TABLE (II)

Relative short-term translaminar activity of 8 carbamates on adults of *Bemisia tabaci* on cotton seedlings under greenhouse conditions.

Insecticide	Treated surface	Slope ±S.E.	LC_{50} (95 % CL) ppm		T.I.	Relative trans-laminar activity %
Alanycarb	both	0.6±0.4	54.72		100.0	
	upper	2.3±0.6	99.01	(41.4-137.7)		55.26
Oxamyl	both	1.6±0.9	184.84		29.6	
	upper	0.9±0.6	433.65			42.62
Methomyl	both	2.9±0.6	61.83	(0.02-132.0)	88.5	
	upper	1.2±0.5	177.96	(99.5-236.7)		34.74
Carbosulfan	both	1.6±0.7	86.98	(0.03-165.6)	62.9	
	upper	1.4±0.5	325.15	(222.4-606.1)		26.75
Thiodicarb	both	1.5±0.6	143.44	(8.3-247.8)	38.1	
	upper	0.4±0.3	545.51			26.29
Pirimicarb	both	2.3±0.6	63.57	(16.6-94.3)	86.0	
	upper	1.6±0.6	252.29	(170.4-929.6)		25.19
Furathiocarb	both	0.8±0.5	57.57		95.4	
	upper	1.7±0.6	546.82			10.52
Omethoate	both	1.9±0.6	153.66	(34.2-239.1)	5.9	
	upper	1.6±0.3	783.59	(602.8-1043.5)		19.60

Comparison on the basis of toxicity index within the first 24 h after treatment, Abamectin was the most toxic (100) and was followed by Milbimictin (69.79) which represent other formulation of the same active ingredient.

TABLE (III)
Relative short-term translaminar activity of 9 synthetic pyrethroids on adults of *Bemisia tabaci* on cotton seedlings under greenhouse conditions.

Insecticide	Treated surface	Slope ±S.E.	LC_{50} (95 % CL) ppm		T.I.	Relative trans-laminar activity %
Esfenvalerate	both	2.4±0.6	19.50		24.4	
	upper	1.0±0.7	24.12	(15.9-30.4)		80.84
Alpha-Cypermethrin	both	1.8±0.8	11.39	(0.05-19.2)	41.7	
	upper	1.5±0.6	14.22	(1.78-22.1)		80.09
Cyhalothrin	both	1.8±0.7	9.99	(0.46-17.2)	47.6	
	upper	2.6±1.8	13.16			76.25
Fenpropathrin	both	1.9±0.5	79.09	(30.4-112.1)	6.0	
	upper	0.9±0.7	115.41			68.53
Cyfluthrin	both	2.2±0.7	15.25	(1.9-24.2)	31.2	
	upper	1.7±0.6	24.94	(8.8-36.0)		61.14
Cypermethrin	both	2.8±0.9	21.07	(7.7-29.3)	22.5	
	upper	2.7±0.6	41.51	(29.0-53.2)		50.75
Fenvalerate	both	1.9±0.5	22.21	(5.2-36.0)	21.4	
	upper	0.7±0.6	50.91			43.62
Deltamethrin	both	1.4±0.7	4.76		100.0	
	upper	1.8±0.6	14.34	(5.1-20.3)		33.19
Lambda-cyhalothrin	both	1.9±0.6	8.02	(1.1-12.9)	59.3	
	upper	0.9±0.3	49.68	(30.1-261.8)		16.14

Previous studies indicated that Abamectin has been shown to possess translaminar activity against mites, leafminers and aphids (Green and Dybas, 1984; Green *et al.*, 1985a, b; Wright *et al.*, 1985a, Ibrahim *et al.*, 1991). Green *et al.* (1985b) reported that Abamectin applied at 4.5 ppm showed translaminar activity in the control of *T. urticae* on rose foliage in laboratory and greenhouse studies. Greater than 80 % mortality was observed at 7 days to *T. urticae* adults and immatures feeding on the ventral side of leaves, following application of Abamectin to the dorsal surface. Similarly, Wright *et al.* (1985a) reported control of *T. urticae*, but not aphids *Aphis fabae* or *Aphis gossypii* due to translaminar action by Abamectin on chrysanthemum. The LC_{50} for Abamectin residues applied to either the dorsal or ventral leaf surface was 30.1 to 33.4 ppm for *T. urticae*; however, higher concentartions, 450 ppm or greater, were required to achieve 50 % mortality of aphids. While aphids as well as whiteflies feed selectively on the phloem, phytophagous mites such as *T. urticae* feed within the leaf parenchyma and are likely to ingest a higher concentration of Abamectin than the aphids.

TABLE (IV)

Relative short-term translaminar activity of 11 miscellaneous insecticides on adults of *Bemisia tabaci* on cotton seedlings under greenhouse conditions.

Insecticide	Treated surface	Slope ±S.E.	LC_{50} (95 % CL) ppm		T.I.	Relative trans-laminar activity %
Etofenprox	both	1.8±0.5	31.93	(5.9-52.6)	3.25	
	upper	2.7±0.8	33.89	(9.5-49.1)		94.1
Thiomethoxam	both	2.4±0.7	40.95	(13.9-58.4)	2.53	
	upper	1.5±0.5	45.91	(9.2-70.8)		89.19
Bensultap	both	2.3±0.8	126.61	(26.1-192.1)	0.82	
	upper	1.1±0.5	144.68	(0.2-256.2)		87.51
Imidacloprid	both	2.3±0.4	29.74	(17.2-40.5)	3.49	
	upper	0.9±0.6	35.53			83.3
Thiocyclam	both	1.7±0.6	63.88	(5.2-107.3)	1.62	
	upper	1.3±0.6	81.36	(1.7-131.2)		78.51
Milbimictin	both	2.2±0.5	1.49	(0.8-2.0)	69.79	
	upper	2.4±0.7	1.92	(1.4-3.3)		77.6
Pymetrozin	both	1.3±0.6	43.31		2.40	
	upper	1.4±0.6	59.95	(0.03-103.4)		72.24
Sopinosad	both	1.5±0.6	16.51	(0.19-31.5)	6.29	
	upper	1.3±0.6	31.88	(1.5-49.8)		51.78
Abamectin	both	2.6±0.3	1.24	(0.74-1.38)	100.0	
	upper	1.6±0.8	2.02			51.48
Diafenthiuron	both	1.5±0.5	48.24	(4.1-84.9)	2.15	
	upper	1.6±0.4	264.14	(175.9-379.9)		18.26
M-Pede	both	2.3±0.7	1864.17	(732.6-2572)	0.06	
	upper	1.1±0.5	5388.07	(597.1-14028)		51.95

Further studies by Abro *et al.* (1989) revealed that addition of emulsified safflower oil appeared to enhance slightly the translaminar activity of Abamectin on brussels-sprouts leaves. Likewise, oils have been reported to increase the translaminar activity of avermectin significantly against *Tetranychus urticae* and *Aphis gossypii* (Wright *et al.*, 1985a). It was assumed that oils act principally by increasing the surface stability or translaminar movement of a pesticide or by enhancing pesticide uptake in arthropods. Also, the same authers added that the translaminar activity of avermectin B_1 against second instars of a susceptible laboratory strain of *Plutella xylostella* L. varied considerably with crop species; the LC_{50} for avermectin was about 145 and 250 time lower on Chinese cabbage than on brussels sprouts and cabbage, respectively. However, addition of emulsified safflower oil appeared to have little effect on the translaminar activity of avermectin on brussels sprouts.

On the other hand, Cock *et al.* (1990) found that less than 4 % of the initial deposit of Buprofezin that penetrated into the leaves was sufficient to produce a moderate translaminar effect. They added that treatment of the upper leaf surface with 150 and 450 mg a.i./litre induced 25 % mortality of the larvae placed on the lower surface. Such moderate bioactivity could be due to that an appreciable (35 %) fraction of Buprofezin was absorbed to the leaf wax or to the inert residue of the formulation.

Recently, Burchholz and Nauen (2001) in a laboratory study to investigate the leaf systemic properties and the translaminar aphicidal activity of two commercialized neonicotinoid (Chloronicotinyl) insecticides, found that foliar penetration and short-term translocation patterns of Imidacloprid were similar in both plant species. Nevertheless, Imidacloprid penetrated twice as much into cabbage leaves as it did into cotton leaves. Such observed differences between cabbage and cotton in the translaminar bioassay cannot be explained by differentially responding aphid species, but due to plant-specific barrier properties caused by different types of cuticle.

In general, our work has shown that the translaminar activity recorded here varied considerably among different pesticides. Information about the factors influencing translaminar movement of pesticides is lacking. However, the mobility of different compounds has been related to either quantitative and qualitative differences in plant cuticular waxes (Price, 1979; Baker, 1980) or chemical components of the pesticide itself such as active material and solvents mainly, in addition to additive components such as surfactants, oils, synergists, inorganic salts.

However, because of the highly polymerized nature of the outer portion of the cuticle and its high wax content in most plants, it would be expected that relatively nonpolar compounds having semi-lipophilic characteristics could penetrate this barrier most effectively. Absorption is also positively related to water solubility of the penetrant. Such relationship of penetrability with water solubility is evident in the studies of Foy (1964b) with cotton. He found that ^{14}C prometone and five other alkylamino-s-triazines penetrated the foliage in direct relationship to their water solubilities. The fact that foliar absorption and transport are functions of several factors other than water solubility is also quite apparent.

The surface active agent (surfactant) is perhaps most consistently effective in enhancing foliar absorption of the active toxicant and thereby promoting its maximum effect. As spray adjuvants, surfactants are sometimes used at concentration as high as one percent or more when the objective is to enhance pesticidal penetration. However, nonionic surfactants are generally desirable because of their greater compatibility when formulated in water of high salt content and their reduced ability to interact, sometimes detrimentally, with the toxicant. Furthermore, it seems apparent that capability of a surfactant to enhance penetration is a function of both HLB (hydrophilic-lipophilic balance) and certain other chemical or physical properties (Greenwald *et al.*, 1961).

In a practical field situation, it is assumed that the recommended dose and volume rates applied to foliage have to provide a more homogenous coverage of the leaves, but practically the misapplication enforced us to have knowledge about the translaminar bioactivity of the applied pesticides.

Furthermore, one has to bear in mind that successful pest control application is not simply related to systemic behaviour alone, but it is much more a combination of systemic and contact properties depending on the physico-chemical characteristics of the active ingredient, the plant species (e.g. different barrier proprieties of cuticles) functional morphology of the pest species considered (e.g. mobile versus quiescent stages).

SUMMARY

The short-term translaminar activity of 38 different insecticides belonging to several groups of insecticides was studied in cotton against adults of a field strain of the sweetpotato whitefly *Bemisia tabaci* (Genn.) under laboratory conditions.

Data based on LC_{50} after 24 h using simple laboratory bioassay varied considerably between different insecticides belonging to different groups. The highest translaminar activity was recorded for the organophosphates Chlorpyrifos-ethyl (96.78) and Profenofos (71.05) while it was for Alanycarb (55.26) of carbamate and by Es-fenvalerate (80.84) and Alpha Cypermethrin (80.09) of synthetic pyrethroids. However, four miscellaneous insecticides exhibited considerably high translaminar activity reaching 94.1, 89.19, 87.51 and 83.7 for Etofenprox, Thiomethoxam, Bensultop and Imidacloprid, respectively.

REFERENCES

ABBOTT, W.S. (1925): A method for computing the effectiveness of an insecticide. (*J. Econ. Entomol., 18 : 265-267*).

ABRO, G.H.; R.A. DYBAS, A. St.J. GREEN and D.J. WRIGHT (1989): Translaminar and residual activity of Avermectin B1 against *Plutella xylostella* (Lepidoptera : Plutellidae). (*J. Econ. Entomol., 82 (2) : 385-388).*

BAKER, E.A. (1980): Effect of cuticular components on foliar penetration. (*Pestic. Sci., 11 : 367-370*).

BUCHHOLZ, A. and R. NAUEN (2001): Translocation and translaminar bioavailability of two neonicotinoid insecticides after foliar application to cabbage and cotton. (*Pest. Manag. Sci., 58 : 10-16*).

COCK, D.A.; I. ISHAAYA; D. DEGHEELE and D. VEIEROV (1990): Vapor toxicity and concentration-dependent persistence of Buprofezin applied to cotton foliage for controlling the sweetpotato whitefly (Homoptera : Aleyrodidae). (*J. Econ. Entomol., 83 (4) : 1254-1260*).

COHEN, S. (1990): Epidemology of whitefly-transmitted viruses, pp. 211-225. (*In D. Gerling (ed.), Whiteflies : their bionomics, pest status and management. Intercept, Andover, Hants, U.K*).

FINNEY, D.J. (1971): Probit Analysis. (*3rd ed. Cambridge University Press, London*).

FOY, C.L. (1964b): Volatitility and tracer studies with alkylamino-s-triazines. (*Weeds, 12, 103*).

GERLING, D. (ed.) (1990): Whiteflies : their bionomics, pest status and management. (*Intercept, Andover, Hants, U.K.*).

GREEN, A.St.J.; B. HEIJNE; J. SCHREURS and R.A. DYBAS (1985a): Two-spotted spider mite (*Tetranychus urticae* Koch) control with abamectin (MK-936) on roses. (*Meded Fac. Landbouwwet Rijksuniv. Gent., 50 : 623-631*).

GREEN, A.St.J.; B. HEIJNE; J. SCHREURS and R.A. DYBAS (1985b): Serpentine leafminer (*Liriomyza trifolii*) (Burgess) control with abamectin (MK-936) in dutch ornamentals, a review of the processes involved in the evolution of the use directions and a summary of the results of the phytotoxicity evaluation.. (*Meded Fac Landbouwwet Rijksuniv. Gent., 50 : 603-621*).

GREENWALD, H.L.; E.B. KICE; M. KENLY and J. KELLY (1961): Determinaion of the distribution of nonionic surface active agents between water and iso-octane.. (*Anal. Chem., 33 : 465*).

HOROWITZ, A.R.; Z. MENDOLSON; P.G. WEINTRAUB and I. ISHAAYA (1998): Comparative toxicity of foliar and systemic applications of acetamipid and imidacloprid against the cotton whitefly, *Bemisia tabaci* (Hemiptera : Aleyrodidae). (*Bull. Entomol. Res., 88 : 437-442*).

IBRAHIM, N.M.M.; M.D. ABDALLAH and M.A. KANDIL (1991): Laboratory tests for assessing the initial and residual toxicity of ceratain insecticides against the cotton aphid *Aphis gossypii* (Glover) (*Bull. ent. Soc. Egypt, Econ. Ser. 19, 19-24*).

LIU, T.X. and P.A. STANSLY (1995): Deposition and bioassay of insecticides applied by leaf dip and spray tower against *Bemisia argentifolii* nymphs (Homoptera : Aleyrodidae). (*Pestic. Sci., 44 : 317-322*).

PRICE, C.E. (1979): Penetration and movement within plants of pesticides and other solutes : uptake mechanisms. (*Rep. Prog. Appl. Chem., 59 : 310-326*).

STEIN-DONEK, W.; F. FUHR; J. WIENECLE; J. HARTWIG and W. LEICHT (1992): Influence of soil moisture on formation of dressing zones and uptake of imidacloprid after seed treatment of winter wheat. (*Pflanzenschutz Nachrichten, Bayer, 45 : 327-368*).

SUN, Y.P. (1950): Toxicity index - An improved method of comparing the relative toxicity of insecticides. (*J. Econ. Entomol., 43 (1) : 45-53*).

WESTWOOD, F.; K.M. BEAN; A.M. DEWAR; R.H. BROMILAW and K. CHAMBERLAIN (1998): Movement and persistence of (^{14}C) imidacloprid in sugarbeet plants following application to pelelted sugar-beet seed. (*Pestic. Sci., 52 : 97-104*).

WRIGHT, D.J.; A. LOY; A.St.J. GREEN and R.A. DYBAS (1985a): The translaminar activity of abamectin (MK-936) against mites and aphids. (*Meded Fac. Landbouwwet Rijksuniv. Gent., 50 : 595-601*).