NOVEL ORGANIC AND NATURAL PRODUCT INSECT MANAGEMENT TOOLS

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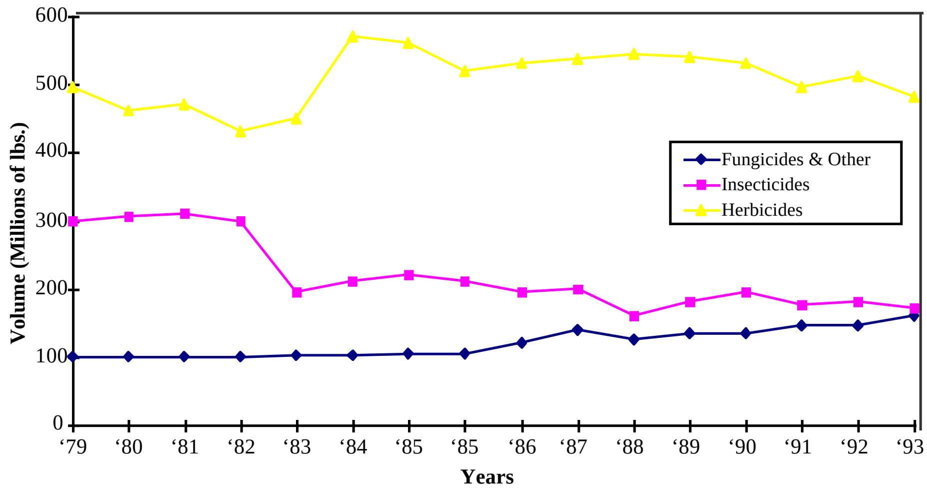
Synthetic organic insecticides continue to be critical to the successful operation of pest management systems. These tools are effective, short duration, solutions when pests exceed our established thresholds and economic damage is occurring. The focus of the insecticide discovery and development efforts at various companies, however, has changed over the past decade. We are seeing the results of these changes in a particularly large number of selective pest control agents currently under development around the world. These new materials represent the beginning of a new era in both synthetic organic and natural origin pest control options. This era will be characterized by low use rate, highly effective, generally selective agents designed for tactical strikes. In many cases, these materials will require more management expertise, but will be far friendlier to the total environment including biological control organisms.

These new materials are the result of a pattern of innovation within industry that has been prompted by the public need for safer pesticide use. The total pounds of active ingredient used on US crops has been in decline since the advent of the insect managing synthetic pyrethroids in the 1970's and early 1980's (see Table 1). This decline has been pushed along by technological innovation and competition by the industry and greater use of pest threshold information in IPM programs. Together these factors have accomplished a dramatic reduction in insecticide usage not usually recognized by the general public. This reduction amounted to 51% less active ingredient used in 1991 than in 1979 according to US Environmental Protection Agency statistics (Gianessi and Anderson, 1993).

TABLE 1

U.S. ANNUAL VOLUME OF PESTICIDE USAGE
IN AGRICULTURE 1979-1991
From Pesticides Industry Sales and Usage 1992-1993
Market Estimates U.S. EPA 1994



INDUSTRY CONTRIBUTION TO REDUCTIONS IN PESTICIDE USE

To track the course of the industry innovation over the last 20 years, materials tested in the Insecticide and Acaricide Tests (now the Arthropod Management Tests) 1975 and 1995 in the IA Tests (now AMT) were studied (see Table 2). These volumes are the best record of industry activity as they generally reflect university development programs supported by industry funds. The level of activity on various chemical classes in 5 year increments over the last 20 years were studied to look for trends.

TABLE 2

Citations by Chemistry from the Insecticide-Acaricide Tests 1975-1995

	1975		1980		1985		1990		1995	
	# Names	#Citations	# Names	#Citations	# Names	#Citations	# Names	#Citations	# Names	#Citations
Organophosphates	80	553	73	977	51	660	56	715	58	598
Carbamates	21	289	29	594	25	463	17	291	12	219
Pyrethroids	24	119	27	357	27	788	40	595	32	368
Bacillus thuringiensis	8	35	8	74	19	103	50	135	85	426
Chlorinated Hydrocarbo	16	40	16	124	5	40	5	45	5	36
Formanidines	4	30	7	25	6	15	3	17	2	12
Benzoylphenylureas	5	20	5	29	19	131	7	44	3	15
Oils	3	3	9	20	26	30	16	36	25	161
Nicotinoids	0	0	3	18	3	6	2	2	5	95
Organotins	3	39	3	33	2	29	1	16	2	17
Juvenile Hormones	5	12	9	22	1	1	5	7	1	1
Avermectins	0	0	1	11	2	26	6	19	4	40
MET Inhibiting Acaricid	0	0	0	0	0	0	1	3	1	2
Pyrolles	0	0	0	0	0	0	0	0	3	32
Fipronils	0	0	0	0	0	0	0	0	1	27
Naturalytes	0	0	0	0	0	0	0	0	3	4

The numbers of organophosphates, organotins, and chlorinated hydrocarbons peaked in 1975, the first year of the study. The numbers of citations for chlorinated hydrocarbons peaked in the 1980 sample while total numbers of materials peaked in 1975, the first year of the publication. Carbamate numbers peaked in 1980 and have been in decline ever since. The numbers of citations for organophosphates has consistently been higher than for any other class. The numbers of total materials peaked in 1975, the first year of the publication. Total citations peaked in 1980. Pyrethroid numbers peaked in 1990, but citations peaked in 1985. *Bacillus thuringiensis* products have shown a dramatic increase in numbers and citations in the 1990's becoming the second most cited class in 1995 and may not have peaked yet. In addition the 1990's has seen the resurgence of the nicotinoids with the discovery of imidacloprid by Bayer AG and the discovery of several new materials including: the mitochondrial electron transport (MET) inhibiting acaricides, the pyrolles, the fipronils, abamectins and the naturalytes. All of these newer materials have use rates considerably lower than the organophosphates, organotins, carbamates and chlorinated hydrocarbons of 1975.

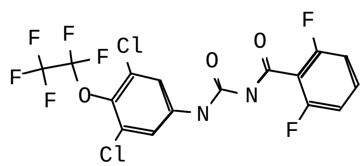
The industry has also focused on more efficient use of traditional chemistry minimizing rates and maximizing target exposure through more effective delivery systems. An example of this is the new Sentricon Colony Elimination System for termites from DowElanco (Robertson and Su 1995). Subterranean termites account for 80 percent of the approximately $1.5 billion spent for termite control every year in the United States (Su, 1991). Barrier treatments at high use rates are generally used to prevent termite attack. These have very little effect on the termite colony and have to be broadcast uniformly to cover any potential entrance point. These sorts of applications often necessitate retreatments that can be difficult and costly(Robertson and Su, 1995). In 1989 DowElanco, in cooperation with Dr. Nan-Yao Su of the University of Florida, began a research program designed to evaluate hexaflumuron, a proprietary benzoylphenylurea insect growth regulator as a bait against subterranean termite species (see Table 3).

TABLE 3

HEXAFLUMURON

TRADE NAMES : RECRUIT*(SENTRICON*)

CLASSIFICATION : Benzoylphenylurea



MODE OF ACTION : Molt Inhibitor

SPECIES SPECTRUM : Termites

TARGET: Structural

USE RATES : 0.05-0.5% Baits and 5-20 Gms AI/Ha

IPM FIT : Utilizing bait technology, termite colonies of several million members have been killed using milligrams of AI. Safe to mammals, birds, and fish.

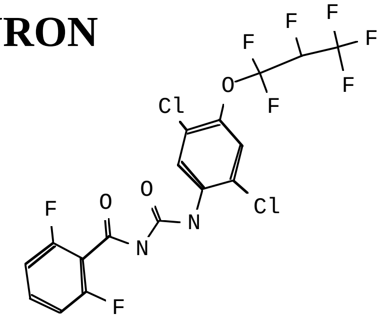
***TRADEMARK OF DOWELANCO**

This cooperative program led to the registration of hexaflumuron as a termite control product in 1994.

Lufenuron (see Table 4) is a benzoylphenylurea from Ciba-Geigy currently being sold as an oral flea control product for small animals. It also has crop uses globally on cotton, vegetables, and fruit.

TABLE 4

LUFENURON



TRADE NAMES: MATCH* AXOR* CGA* 184-699

CLASSIFICATION: Benzoylphenylurea

MODE OF ACTION: Molt Inhibitor

SPECIES SPECTRUM: Fleas, Lepidoptera

TARGET CROP: Small Animals Cotton Vegetables Fruit

USE RATES: A few milligrams orally for flea control 10-50 gms/Ha in crops

IPM FIT: Control of fleas systematically targets the dose lowering the use rate dramatically and virtually eliminates enviromental exposure.

***TRADEMARK OF CIBA-GEIGY LTD.**

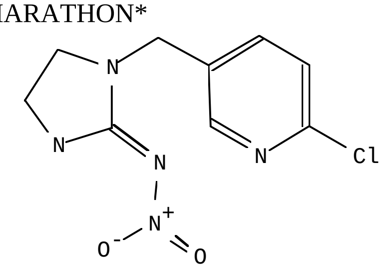
As a flea control agent it's systemic activity targets the dose lowering the use rate dramatically and virtually eliminates environmental exposure (Hopkins, 1994).

Imidacloprid (see Table 5) is a chloropyridinyl material from Bayer AG that acts as a nicotinoid.

TABLE 5

IMIDACHLOPRID

TRADE NAMES : ADMIRE* GAUCHO* CONFIDOR* MARATHON* MERIT* BAY NTN* 33893



CLASSIFICATION : Chloropyridinyl Compound

MODE OF ACTION : Binds to Acetylcholine Receptors

SPECIES SPECTRUM : Sucking Insects

TARGET CROPS : Fruits Vegetables and Rice

USE RATES : 50-100 Gms. AI/Ha

IPM Fit : Use as a systemic minimizes beneficial impact. Favorable toxicity and ecotoxicity profile.

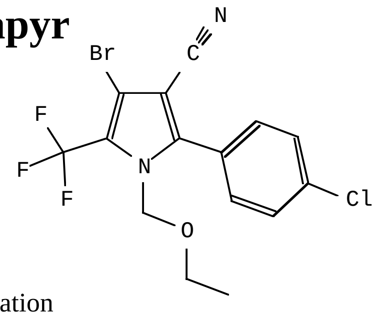
***TRADEMARK OF BAYER AG**

It is highly effective systematically at 50-100 grams AI/Ha on a variety of sucking insects in fruits, vegetables and rice. Use as a systemic minimizes impact on beneficials. It also has a favorable toxicity and ecotoxicity profile (Hopkins, 1994).

Chlorfenapyr (see Table 6) is a pyrrole uncoupler from American Cyanamid.

TABLE 6

Chlorfenapyr



TRADE NAMES : PIRATE* STALKER* AC 303630

CLASSIFICATION : Pyrrole

MODE OF ACTION : Uncoupler of Oxidative Phosphorylation

SPECIES SPECTRUM : Chewing and Sucking Insects and Mites

TARGET CROPS : Cotton Vegetables and Fruit

USE RATES : 125-300 Grams AI/Ha

IPM FIT : It is selective to beneficials due to its predominantly stomach poison activity.

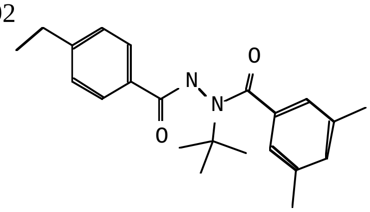
***TRADEMARK OF AMERICAN CYANAMID COMPANY**

It is effective on chewing and sucking insects and mites in cotton, vegetables, and fruits at rates of 50-300 grams AI/Ha. It is selective to beneficials due to its' predominantly stomach poison activity and so will have a place in insect and mite pest management (Hopkins, 1994).

Tebufenozide (see Table 7) is a diacylhydrazide ecdysone agonist from Rhom&Haas Company active at rates of 50-250 grams AI/Ha in fruits, vines, vegetables and forestry.

TABLE 7

TEBUFENOZIDE



TRADE NAMES : MIMIC* CONFIRM* RH 5992

CLASSIFICATION : Insect Growth Regulator

MODE OF ACTION : Ecdysone Agonist

SPECIES SPECTRUM : Lepidoptera

TARGET CROPS : Fruits, vines vegetables and forestry

USE RATES : 100-150 Gms AI/Ha

IPM FIT : The original Mode of Action together with a good toxicological and ecotoxicological profile suggest that RH 5992 will be a valuable tool, as a selective insecticide for IPM, for the protection of perennial crops row crops and forests.

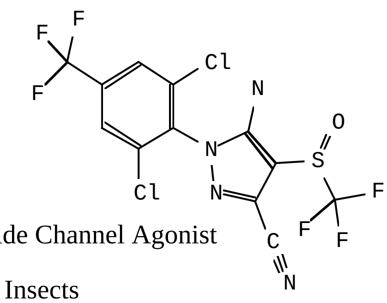
***TRADEMARK OF ROHM & HAAS COMPANY**

The original and selective mode of action together with a good toxicological; and ecotoxicological profile suggest that tebufenozide will be a valuable tool as a selective Lepidoptera control agent for the protection of tree and row crops (Hopkins, 1994).

Fipronil (see Table 8) is a phenyl pyrazole GABA agonist from Rhone-Poulenc active on chewing and sucking insects in row crops, vegetables and turf.

TABLE 8

FIPRONIL



TRADE NAMES : REGENT*

CLASSIFICATION : Phenyl Pyrazole

MODE OF ACTION : GABA Regulated Chloride Channel Agonist

SPECIES SPECTRUM : Chewing and Sucking Insects

TARGET CROPS : Row Crops and Vegetables

USE RATES : 25-150 Gms AI/Ha

IPM FIT : Member of a new class of insecticides.

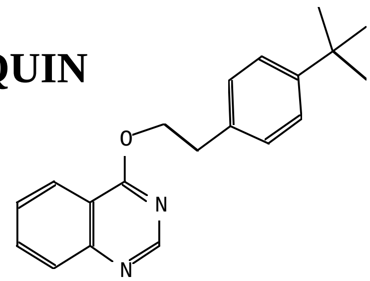
***TRADEMARK OF RHONE-POULENC**

Use rates are from 25-150 grams AI/Ha and as a member of a new class of insecticides will be valuable in resistance management (Hopkins, 1994).

Fenazaquin (see Table 9), a quinazoline mitochondrial electron transport inhibitor from DowElanco is a broad spectrum acaricide for tree fruits, vines, and ornamentals.

TABLE 9

FENAZAQUIN



TRADE NAMES : MAGISTER* DE*-436

CLASSIFICATION : Quinazoline

MODE OF ACTION : Inhibitor of Mitochondrial Electron Transport Complex I Co-Enzyme Q

SPECIES SPECTRUM : Mites

TARGET CROPS : Tree fruits

USE RATES : 50-200 Gms AI/Ha

IPM FIT : Novel mode of action, short residual contact activity, lack of predator activity, and safety to mammals, and birds all make for an ideal mite management tool.

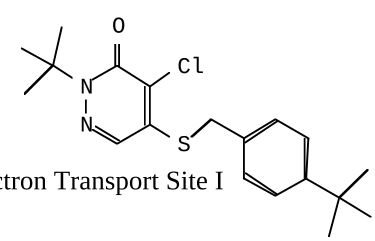
***TRADEMARK OF DOWELANCO**

It is effective at rates of from 56-560 grams AI/Ha. Its novel mode of action, short residual contact activity, lack of activity on predators, and safety to mammals and birds all make for an ideal mite management tool (Hopkins, 1994).

Pyridaben (see Table 10) is a pyridazinone mitochondrial Site I inhibitor from Nissan Chemical Industries Ltd. active on mites, aphids, whiteflies, and thrips of tree fruits.

TABLE 10

PYRIDABEN



TRADE NAMES : SANMITE*

CLASSIFICATION : Pyridazinone

MODE OF ACTION : Inhibitor of Mitochondrial Electron Transport Site I Co-Enzyme Q

SPECIES SPECTRUM : Mites

TARGET CROPS : Tree Fruits

USE RATES : 50-200 Gms. AI/Ha

IPM FIT : Novel mode of action, lack of predator activity, and safety to mammals and birds make for an excellent mite management tool.

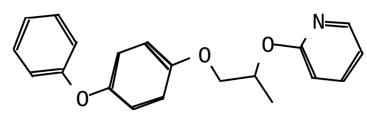
***TRADEMARK OF NISSAN CHEMICAL INDUSTRIES LTD.**

Its use rates are from 50-200 grams AI/Ha. This material also shows a lack of predator activity and safety to mammals and birds allowing it to fit into mite management programs (Hopkins, 1994).

Pyriproxifen (see Table 11) is an alkoxypyrimidine juvenile hormone mimic active against scales and whiteflies on cotton, pome fruit, citrus, and vegetables from Sumitomo Chemical Company.

TABLE 11

PYRIPROXIFEN



TRADE NAMES: S*-71639, ADMIRAL*

CLASSIFICATION: Alkoxypyrimidine

MODE OF ACTION: Juvenile Hormone Mimic

SPECIES SPECTRUM: Scales and Whiteflies

TARGET CROPS: Cotton Pome Fruit Citrus and Vegetables

USE RATES: 25-100 gms/Ha

IPM FIT: The material is very selective in activity and can be expected to fit into Insect Pest Management Systems.

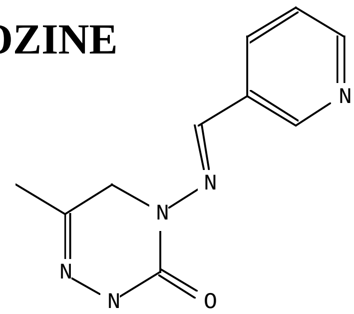
***TRADEMARK OF SUMITOMO CHEMICAL CO.**

It is active at 25-100 grams AI/Ha and is very selective fitting well into Insect Pest Management systems (Hopkins, 1994).

Pymetrozine (see Table 12) is a pyridine azomethine antifeedent effective on Homopterous pests from Ciba Geigy Ltd.

TABLE 12

PYMETROZINE



TRADE NAMES: CHESS* CGA* 215 944

CLASSIFICATION: Pyridine Azomethine

MODE OF ACTION: Anti-Feeding Compound

SPECIES SPECTRUM: Homoptera

TARGET CROPS: Row Crops Vegetables, Fruits, and Ornamentals

USE RATES: 100-300 gms/Ha

IPM FIT: Highly selective material effective only on Homopterous insects that will fit into IPM programs.

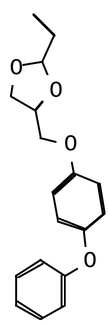
***TRADEMARK OF CIBA-GEIGY LTD.**

It is effective at rates of from 100 to 300 grams AI/Ha. It's selectivity to the Homoptera makes it fit well into Homopteran pest management.

Diofenolan (see Table 13) is a dioxalane juvenile hormone analog with activity against scales and Lepidoptera in tree fruits from Ciba Geigy Ltd.

TABLE 13

DIOFENOLAN



TRADE NAMES : CGA* 59205

CLASSIFICATION : Insect Growth Regulator

MODE OF ACTION : Molt Inhibitor

SPECIES SPECTRUM : Scales and Lepidoptera

TARGET CROPS : Tree Fruits

USE RATES : 10-20 Gms AI/Ha

IPM FIT : The original mode of action and its good selectivity together with good toxicological and ecotoxicological profile make it especially useful for IPM.

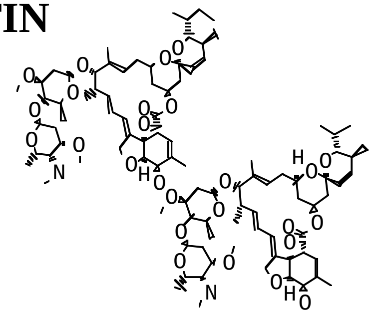
***TRADEMARK OF CIBA-GEIGY LTD**

The original mode of action and good selectivity together with good toxicological and ecotoxicological profile make it especially useful for Integrated Pest Management (Hopkins, 1994).

Emamectin (see Table 14) is an abamectin semi-synthetic analog providing Lepidoptera control capabilities from Merck & Co. Inc.

TABLE 14

EMAMECTIN



TRADE NAMES : MK*-244

CLASSIFICATION : Avermectin Family

MODE OF ACTION : Increases Chloride Ion Flux at the Neuromuscular Junction.

SPECIES SPECTRUM : Lepidoptera

TARGET CROPS : Row Crops and Vegetables

Use Rates : 10-20 Gms AI/Ha

IPM FIT : Do to the low to moderate contact activity of the material and rapid dissipation of surface residues most beneficial species are not effected. Thus the material is expected to be suitable for use in IPM programs.

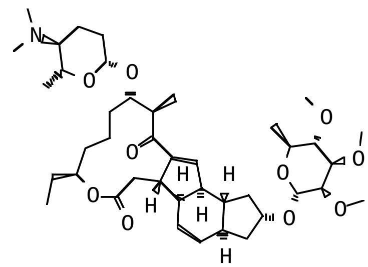
***TRADEMARK OF MERK SHARP & DOHME**

As is the case with avermectin, it increases chloride ion flux at the neuromuscular junction. The targeted crops are row crops and vegetables at 5-25 grams AI/Ha. Due to the low to moderate contact activity of the material and rapid dissipation of surface residues most beneficial species are not effected. Thus the material is expected to fit Insect Pest Management Programs (Hopkins, 1994).

Spinosad (see Table 15) is a fermentation-derived natural product affecting receptors in the central nervous system of Lepidoptera, Diptera, Thysanoptera, and some Coleoptera and Hymenoptera from DowElanco.

TABLE 15

SPINOSAD



TRADE NAMES : DE105

CLASSIFICATION : Naturalyte

MODE OF ACTION : Unique But Unknown

SPECIES SPECTRUM : Lepidoptera, Diptera, Thysanoptera, and some Coleoptera and Hymenoptera

TARGET CROPS : Cotton, Vegetables, Tree Fruits and Nuts

USE RATES : 50-180 Gms AI/Ha

IPM FIT : Safety to beneficials leads to fewer sprays for secondary pest outbreaks in cotton and tree fruits. It is also safe to mammals, birds and fish.

***TRADEMARK OF DOWELANCO**

Targeted crops are cotton, vegetables, tree fruits, and nuts at use rates of from 50-180 grams AI/Ha. In the field, safety to beneficials led to several instances in the 1995 Experimental Use Permit studies where fewer applications in cotton and tree fruits were necessary for secondary pest outbreaks on the spinosad plots. It is also safe to mammals, birds, and fish. Spinosad, with its unique characteristics, does indeed fit a class of its own, and will offer an exciting pest management alternative for the future. No other naturally sourced material has its' combination of excellent contact and residual efficacy on target pests and safety to beneficials, aquatic organisms, and mammals. It will fit IPM in cotton, vegetables, and tree crops very well (Jantz et al, 1994).

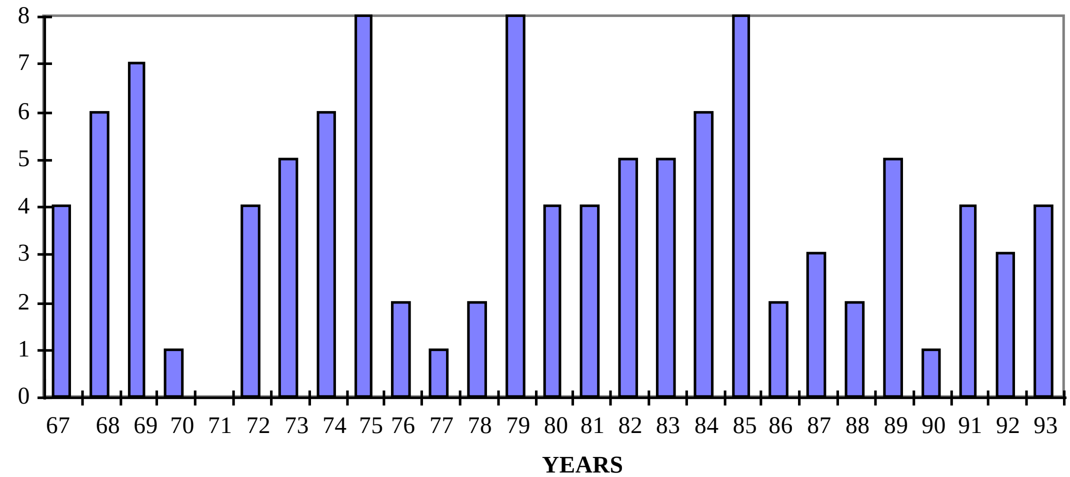
FUTURE TRANSITIONS FOR ORGANIC IPM TOOLS

As reported by the US. EPA (see Table 16) the trend has been toward fewer organic Insect Management Tools being registered over time (Aspelin, 1994).

TABLE 16

Total New Chemical Active Ingredient Insecticide Registrations in the U.S.

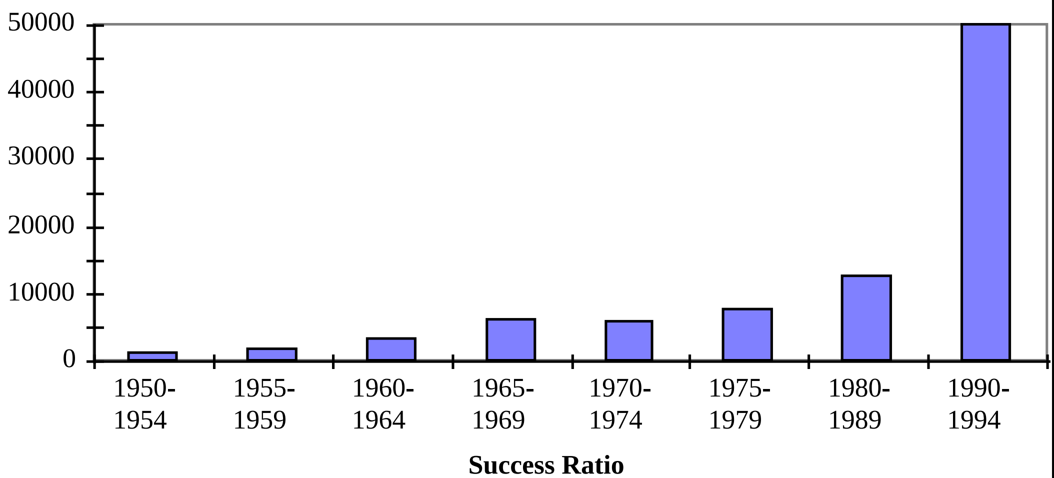
First-time Registration, 1967-1993, Source: Pesticide Industry Sales and Usage 1992 and 1993 Market Estimates, EPA



According to Stetter (1993), the numbers of materials required to find a new active is rising exponentially, probably due to higher standards necessary for product registration and market success (see Table 17).

TABLE 17

Screening Success Ratio: Compounds Screened per Commercial Product by Years Reported by Jorg Stetter, 1993



Fortunately, driven by the pharmaceutical industry, synthesis and screening technologies continue to improve, allowing rapid synthesis and testing of a diversity of chemistries against insect selective targets. This technology promises to allow the industry to keep pace as we make the transition towards an exciting future with new IPM tools.

CONCLUSIONS

Due to changes in public perception and customer attitudes favoring higher activity and greater applicator and environmental safety, the industry has responded with more highly active and selective Pest Management Tools. These already have made a dramatic reduction in the pounds of conventional insecticide applied to crops in the US. The materials in the pipeline have never been more impressive and carry the promise for even better Pest Management Systems in the future. Sprayables will always be necessary to lower pest outbreaks and through the use of Pest Management techniques we can preserve these new tools for many years to come. Thanks to new innovations from a variety of companies, and better recognition of the value of IPM, the future for synthetic organics and natural products as tools for Pest Management has indeed never been brighter. However there are still no magic solutions. The crop protection industry will need to use resistance management and all available IPM tactics to stay ahead of our insect competitors.

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