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Review of New Insecticides Under Field Development For Desert Vegetable and Melon Production

John C. Palumbo
Vegetable Crops Entomology

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The number of effective insecticides currently available to growers for insect control in melons and vegetables is relatively small compared with other crops. Furthermore, with the uncertainty surrounding the Food Quality Protection Act, as well as increasing environmental concerns, the vegetable industry in the western U.S. could potentially be facing the loss of a number of important insecticides. Consequently, there is speculation that some of the more broadly toxic compounds may be removed from the market in the next few years, and the organophosphate and carbamate insecticides are being targeted as prime candidates for reduced usage. As these older chemicals are lost, the introduction of replacement products that can live up to both regulatory and grower standards will be critical. Fortunately, there are several new experimental insecticides currently being tested that offer excellent activity on many of the key pests that infest desert vegetables and melons.

Over the past several years, whiteflies and aphids have not been a significant problem to growers largely because of the use of Admire under our desert growing conditions. Similarly, the new insecticides now being developed by the Agrochemical industry have demonstrated good activity on lepidopterous pests *(beet armyworms, cabbage looper*) and leafminers. Most recently, new products are being developed for control of *thrips and aphids* with demonstrable efficacy. In most cases, these insecticides are only a few years away from registration on leafy vegetables and melons.

The performance of these products on vegetables under desert growing conditions has not been completely investigated. In addition, we as researchers are not certain how they will fit into the grower's management programs in Yuma. Thus, our research programs have been focused on studies to determine how to integrate these new chemicals into our local management programs in the most cost-effective way possible. This document was created to provide an overview of new insecticide chemistries being developed by the agrochemical industry for use in vegetables. The tabular information presented is a summary of the efficacy and activity of the new compounds based on research we have conducted over the past several years.

The first part of this report concisely describes the new types of chemistries being developed by industry. The descriptions list the new and existing chemistries (in bold) based on the most current information available to the public. Under each category are listed the individual compounds that have been tested. All insecticide compounds listed in this review are identified by their common name (italicized and lower case), trade name (if available shown in upper case) or code letter/number that identifies a compound in early development. Compounds that are classified as *Reduced Risk Pesticides* and/or *OP Alternatives* by EPA are also indicated.

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- Insecticides Being Developed for Potential Control of Western Flower Thrips on Lettuce and Spinach.

I. Conventional Chemistries

Carbamates (APHISTAR®, *triazimate*; PIRIMOR®, *pirimicarb*). These products belong to the carbamate class of chemistry which has been developed for over 40 years. They are neurotoxic and similar to organophosphates in that they inhibit cholinesterase. Other agricultural chemicals from this class include VYDATE® (*oxamyl*), LANNATE® (*methomy*l), and TEMIK® (*aldicarb*).

Triazimate is a potent systemic aphicide that is highly selective and relatively fast acting. It is mobile within the plant and is safe to beneficial insects and bees, and has good potential for use in IPM.There are pending uses on pome fruit, leafy vegetables, cotton, Brassica leafy vegetables, sugarbeet and hops.

Pirimicarb is a selective insecticide with excellent systemic activity against a wide range of aphid species. It is an especially interesting compound because it possesses very minimal toxicity to honeybees and can be used on vegetable seed crops. It is presently labeled for alfalfa grown for seed in the Northwestern U.S. Registrations are pending on leafy vegetables.

II. Novel Insecticide Chemistries

Chloronicotinyls/Neonicotinoids (ADMIRE®, PROVADO®, *imidacloprid*; ASSAIL®, RESCATE®, *acetamiprid*; PLATINUM®, ACTARA®, *thiamethoxam*; CALYPSO®, *thiacloprid*): This class of neurotoxic compounds has a mode of action similar to nicotine and is systemic in the plant by root uptake and transport in the xylem. They are especially effective systemically against sucking pests.

Imidacloprid is primarily effective against sucking insects as well as some beetles, and grubs. It is most effective on aphids and whiteflies through root uptake, has anti-feedant activity against adults, and has limited translaminar and contact activity as a short residual, foliar spray. It is registered on cotton, potato, fruiting vegetables, Brassica leafy vegetables, leafy

vegetables, canola, grapes, cucurbits, tuberous vegetables, citrus and pecan. (*OP Alternative*)

Acetamiprid is a second-generation chloronicotinyl insecticide with contact and systemic activity via foliar applications. It is excellent on sucking pests like aphids and whitefly, but has very marginal activity when applied to soil. It does have excellent bee safety. There are pending use on pome fruit, citrus fruit, grape, Brassica leafy vegetables, leafy vegetables, fruiting vegetables, and cotton, and potential use on eggplant and spinach. (*Reduced Risk Pesticide, OP Alternative*).

Thiamethoxam is a second-generation chloronicotinyl that is effective against aphids, whitefly, thrips, leafhopper and certain beetles. It will be marketed as seed treatment, soil and foliar insecticide. The compound is more mobile in the soil than imidacloprid. PLATINUM (soil applied formulation) offers more flexibility in post-emergence, side dress applications. Platinum is presently registered for use in melons, fruiting vegetables, and tuberous vegetables and ACTARA is labeled for use in cotton, fruiting vegetables, melons, and tuberous vegetables. There are pending uses on citrus, brassica vegetables, leafy vegetables, barley, sorghum, and wheat. (*OP Alternative*).

Thiacloprid is a new foliar chloronicotinyl with good residual systemic activity against some sucking and chewing pests including whiteflies, leaf hoppers, and plant bugs. **It is very safe to bees.** Registration is currently pending for use in melons and other vegetable crops, with potential uses in cotton .

Pyrroles (ALERT®, *chlorfenapyr*): The pyrroles are compounds that act as metabolic toxins and work by uncoupling oxidative phosphorylation in the mitochondria, a key cellular process. They have translaminar activity and are toxic both by contact and ingestion to chewing and sucking arthropods. Although they have been under field development for several years, the registration status of this compound in vegetables is uncertain, if not unlikely.

Pyridazinone (PYRAMITE®, *pyridaben*): This compound is a non-systemic acaricide and insecticide that is a metabolic toxin acting as a Mitochondrial Site I uncoupler. It has activity on mites, whiteflies, aphids, mealybugs, leafhoppers, and thrips. This is a new class of insecticide offering long term residual control and is a good fit for IPM and resistance management. It is registered on almonds, apples, citrus, *with pending uses on grape, stone fruit, cranberry and tree nuts.*

Phenylpyrazoles (REGENT®, *fipronil*): A broad spectrum neurotoxin that works as a GABA agonist. It has contact activity on both chewing and sucking insects and controls Coleoptera, Lepidoptera, Diptera, Homoptera, Isoptera, and Thysanoptera. It has systemic activity, with long residual and shows excellent potential for control of lygus bug on cotton and thrips in vegetables. It is registered on rice (seed treatment), and corn (soil treatment), with potential uses on cotton, sweet potato, bulb onion and potato.

Amino triazinones (FULFILL®, *pymetrozine*): A highly selective, anti-feeding compound with a unique mode of action, acting specifically on the salivary pump of sucking insects causing rapid cessation of feeding. It is slow acting, but has both contact and systemic activity on aphids and whiteflies. The product has a rapid knockdown on aphids, if they come in direct contact with sprays. It is presently labeled for use in melons and fruiting vegetables in AZ, and uses are pending use on leafy vegetables, hops, Brassica vegetables, cotton, cucurbits, and pecan. (*Reduced Risk Pesticide and OP Alternative*)

Oxidiazines (AVAUNT®, *indoxacarb*). A new, neurotoxic selective chemistry that controls most Lepidopteran pest species, and possibly some plant bugs and thrips. It is relatively non-toxic to beneficials, so it is a good fit with IPM. Its unique mode of action has been described

as a sodium channel blocker. It works primarily through ingestion, but has some contact activity. Currently it is registered for use in leafy vegetables and cotton, with pending uses on alfalfa. (*Reduced Risk Pesticide and OP Alternative*).

Macrocyclic lactones (SUCCESS®; *spinosad*) (PROCLAIM®; *emamectin benzoate*)

Spinosad is a neurotoxic compound produced through a fermentation process by the naturally occurring soil bacterium *Saccaroplyspora spinosa*. It has translaminar activity on select Coleoptera, Diptera, Hymenoptera, Isoptera, Lepidoptera, Thysanoptera, Siphonoptera and mites. It has low environmental impact, good residual activity and is safe to many beneficial insects making it ideal for use in IPM programs. It is registered on cotton (not in AZ), almonds, pistachio, apple, cereal grains, citrus, fruiting vegetables, leafy vegetables, Brassica leafy vegetables, potato, tuberous and corn vegetables, edible legumes, soybean, cucurbit, stone fruit, corn, sweet corn, sorghum, beans, peas. (*Reduced Risk Pesticide and OP Alternative*)

Emamectin is a synthetic avermectin analogue that is derived from the naturally occurring soil microorganism, *Streptomyces avermitili*s. It is also a neurotoxin that has translaminar activity primarily against lepidopterous larvae (Beet/fall armyworms, cabbage webworms, corn earworms, imported cabbage worm, cabbage looper.). It is registered on leafy vegetables and cotton in AZ. (*OP Alternative*)

III. Insect Growth Regulators (IGR)

Molting Disruptants (APPLAUD®, *buprofezin*; CONFIRM®, *tebufenizode*; INTREPID®, *methoxyfenozide*).

Buprofezin is a thiadizine-like compound with long residual activity that acts as a chitin synthesis inhibitor. The product has both contact and vapor activity, and provides good activity for nymphal stages of leafhoppers, plant hoppers, scales and whiteflies. It is effective on immature stages, not effective on adults, and is excellent for IPM programs. It is currently labeled for use in cotton, melons and lettuce in AZ.

Tebufenizode and methoxyfenozide are diacylhydrazines that are active through the disruption of insect hormonal systems, and in particular, as molt accelerating compounds. *Tebufenizide* controls only Lepidoptera larvae. It is extremely safe to beneficial insects with low environmental impact and is excellent for IPM programs. It is registered on cotton, walnuts, pecans, mint, fruiting vegetables, leafy vegetables, *Brassica* leafy vegetables, turnips, and canola. *Methoxyfenozide* is similar to *tebufenozide* in that it only controls Lepidoptera larvae, but with more activity against budworm/bollworm and diamondback moth. It has an excellent fit with IPM programs, and is registered on pome fruits and cotton and pending uses on Brassica leafy vegetables, field corn, fruiting vegetables, grape, leafy vegetables, and sweet corn. It has potential uses on cucurbits, citrus, radish, edible legumes, and mint. Both compounds are considered *Reduced Risk Pesticides and OP Alternatives*.

Juvenoids (KNACK®; *pyriproxyfen*)

Pyriproxyfen is a selective juvenile hormone analog active that suppresses embryogenesis of females and interrupts normal metamorphosis. It has been shown to controls scales, whiteflies, and thrips. It is slow acting with a long residual, safe to beneficial insects, non-toxic to man and wildlife and has an excellent fit in IPM programs. Registered on cotton, citrus, fruiting vegetables, tree nuts, and stone fruit, with potential uses on *Brassica* vegetables, cucurbits and okra. (*Reduced Risk Pesticide and OP Alternative*).

IV. Biopesticides

Botanicals (plant-based insecticides)
Azadirachtin (NEEMIX®, AZA-DIRECT®, ECOZIN®, AGRONEEM®) is a naturally occurring biopesticide derived from seed of the neem tree and acts as a hormonal analog of ecdysone with some activity against a wide range of pests. It disrupts insect molting and target pests include whitefly, aphids, leafminer and lepidoptera. They are registered on citrus, pome, stone fruits, grape, berries, cranberry, strawberry, tree nuts, cucurbit vegetables, bulb vegetables, Brassica leafy vegetables, legume vegetables, fruiting vegetables, root and tuber vegetables, herbs/spices.

Bacterial insecticides (*Bacillus thuringiensis*; Bt's): New strains of Bt are still being discovered that have activity against key vegetable pests. New toxin genes such as Cry IH, Cry IJ and Cry IK are being developed by several companies. A new strain of *B. aizawai* (Serotype H7) was recently released as XENTARI® with increased activity against *Spodoptera exigua.* Most recently, a new Bt active against armyworm and looper, CRYMAX®, was developed from genetically recombined strains of *B. kurstaki*.

Fungal insecticides (*Beauveria bassiana*): There are several species of fungi that are pathogenic against insects that have been investigated in vegetable crops. Many of them are still years away from commercial development. MYCOTROL® and NATURALIS® are *B. bassiana* products presently registered on vegetables and have some activity on aphids and whiteflies. The fungal spores need to come in direct contact with the target pest and require moderate-high levels of relative humidify to be efficacious in the field. There are potential registrations on all crops.

V. Transgenic Crops

Advances have been made to develop genetically altered vegetable crops with resistance to pests (e.g., Bt Potato, Bt Sweet Corn). The potential exists for the Bt biopesticide or active proteins to be introduced into a large number of crops. Vegetable varieties specific for Arizona cropping systems containing Bt toxins have not yet been released for general field evaluation. We expect to see transgenic Bt crops such as cabbage and lettuce to be field developed in the next several years. New strains of Bt and other transgenic toxins are being discovered that have activity against numerous pests.

Table 1. Insecticides Being Developed for Management of Beet Armyworm and Cabbage Looper in Lettuce and Cole Crops.

Product	Active ingredient	Formulation tested	Mode of Action	Primary activity	Rates tested	Field efficacy	Registration status
Alert	chlorfenapyr	2 SC	metabolic	translaminar	8-12 oz	BAW: excellent CL: excellent	Not presently registered
Success	spinosad	2F	neurotoxic	translaminar	4-6 oz	BAW: excellent CL: excellent	Labeled for use in AZ

Proclaim	emamectin	5 SG	neurotoxic	translaminar	2.4-3.2 oz	BAW: excellent CL: excellent	Labeled for use on lettuce in AZ
Confirm	tebufenozide	2 F	Hormone agonist	ingestion	8 oz	BAW: excellent CL: moderate	Labeled for use in AZ
Intrepid	methoxyfenozide	80WP	Hormone agonist	ingestion	1-3 oz	BAW: excellent CL: good	Label pending in AZ; expected 2002
Avaunt	indoxacarb	30 WDG	neurotoxic	ingestion	2.5-6.0 oz	BAW: excellent CL: excellent	Labeled for use in AZ
Crymax	*Bt >kurstaki=*	WDG	Infection, septicemia	ingestion	1.0 lb. product	BAW: moderate CL: excellent	Labeled for use in AZ
Neemix, AZA-Direct	azadirachtin	4.5EC	Hormone Agonist	ingestion, contact	1-2 pt. product	BAW: poor CL: mod-good	Labeled for use in AZ

Table 2. New Insecticides Presently Available or Under Development for Whitefly in Leafy Vegetables and Melons.

Product	**AI**	**Formul. tested**	**Mode of action**	**Primary activity**	**Rates tested/ application**	**Field Efficacy**	**Registration status**
Admire	imidacloprid	2F	neurotoxic	systemic-ingestion	16-24 oz Soil incorp.	Adults: excellent Nymphs: excellent	Labeled for use in AZ
Platinum, Actara	thiamethoxam	2SC, 25W	neurotoxic	systemic-ingestion	5-8 oz; soil 4 oz; foliar	Adults: excellent Nymphs: excellent	Labeled for use on melons in AZ
				systemic-	1.8 oz	Adults: excellent	Registration pending on

Assail	acetamiprid	80 WP	neurotoxic	ingestion	foliar	Nymphs: excellent	leafy vegetables
Calypso	thiacloprid	4 SC	neurotoxic	systemic-ingestion	3-6 oz foliar	Adults: excellent Nymphs: excellent	Registration pending on leafy vegetables
Applaud	buprofezin	70 WP	IGR, chitin synthesis	contact, vapor	8 oz foliar	Adults: N/A Nymphs: excellent	Labeled for use on melons and lettuce in AZ
Fulfill	pymetrozine	50W	feeding inhibition	systemic; contact	2-3 oz foliar	Adults: good Nymphs: fair	Labled for use on melons in AZ
Mycotrol	*Beauvaria bassiana*	EC	fungal infection	contact	16 oz foliar	Adults: poor Nymphs: poor-fair	Labled for use on melons in AZ

Table 3. Insecticides Being Developed for Leafminer in Vegetables and Melons.

Product	AI	Formul. tested	Mode of action	Primary activity	Rates tested/	Field Efficacy	Registration status
Agrimek	abamectin	0.15 EC	neurotoxic	translaminar	8-16 oz	Adult: marginal Larvae: excellent	Labeled for use in lettuce and melons in AZ
Success	spinosad	NAF 295, 1.6 DE	neurotoxic	translaminar	6-8 oz	Adult: good Larvae: good	Labeled for use in lettuce and melons in AZ
Proclaim	emamectin	0.16 EC 5 G	neurotoxic	translaminar	4.5 oz	Adult: marginal Larvae: marginal	Labeled for use in lettuce in AZ
Alert	chlorfenapyr	2 SC	metabolic	translaminar	12 oz	Adult: marginal Larvae: marginal	Not registered
Neemix; AZA-Direct	azadirachtin	EC	Hormone agonist	ingestion, contact	1-2 pt.	Adult: poor Larvae: moderate	Labeled for use in lettuce and melons in AZ

Table 4. New Insecticides Being Developed for Aphids in lettuce, cole crops, and spinach.

Product	AI	Formul. tested	Mode of action	Primary activity	Rates tested/ application	General Efficacy
Admire	imidacloprid	2F	neurotoxic	systemic-ingestion	12-18 oz Soil incorp.	Commercial standard; prevents season-long colonization and head contamination
Platinum	thiamethoxam	2SC	neurotoxic	systemic-ingestion	5-11 oz	Comparable to Admire at high rates; good residual control when applied as side-dress
Provado	imidacloprid	1.6 F	neurotoxic	translaminar	3.75 oz foliar	Good control; depends on spray timing (7-14 d residual activity)
Assail	acetamiprid	80 WP	neurotoxic	translaminar	1.8 oz foliar	Control comparable to Admire in lettuce with repeated applications (14-21 d residual activity)
Actara	thiamethoxam	25WG	neurotoxic	translaminar	4 oz foliar	Control comparable to Admire in lettuce with repeated applications (14-21 d residual activity)
Fulfill	pymetrozine	50 WP	anti-feedant	contact, systemic	0.06 foliar	Good control ; depends on spray timing (7-10 d residual)
Pirimor	pirimicarb	25 DG	neurotoxic	contact, systemic	2-6 oz	Good control ; depends on spray timing (14-21 d residual activity)
Aphistar	triazimate	50 WP	neurotoxic	systemic	0.10 foliar	Good control ; depends on spray timing (14-21 d residual activity)

Table 5. Insecticides Being Developed for Potential Control of Western Flower Thrips on Lettuce and Spinach.

Product	AI	Formul. tested	Mode of action	Primary activity	Rates tested	General Efficacy
Lannate+ pyrethroid	methomyl+ cypermethrin	90S 2.5EC	neurotoxic	Contact	High label rates	Commercial standard; provides >80 % control of adult and larvae for 5-7 days
Regent	fipronil	80 WDG	neurotoxic	contact, ingestion	0.05 lb ai/ac	Comparable to Lannate/pyrethroid at 7 days
Success	spinosad	NAF 295,	neurotoxic	translaminar	6-8 oz	Higher rates provide comparable control to Lannate/Ammo at 7 days; very effective on larvae

Alert	chlorfenapyr	2 SC	metabolic	translaminar	8-12 oz	Moderate control (70%) of adults at 7 days; poor control of larvae.
Avaunt	indoxacarb	30 WDG	neurotoxic	Ingestion, contact	3.5-6.0 oz	Moderate control (50%) of larvae at 7 days; poor control of adults.
Neemix, AZA-Direct	azadirachtin	EC	Hormone Agonist	ingestion, contact	1-2 pt.	Marginal control (25-40%) of adult and larvae at 7 days;

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Information provided by John C. Palumbo, jpalumbo@ag.arizona.edu
Associate Research Scientist (Entomology), Yuma Ag. Center, College of Agriculture, The University of Arizona.
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