MORTALITY OF *TETRANYCHUS URTICAE* KOCH (ACARI: TETRANYCHIDAE) FROM ABAMECTIN RESIDUES: EFFECTS OF HOST PLANT, LIGHT, AND SURFACTANTS

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ABSTRACT

Residues of abamectin (avermectin, Avid), 15 ppm; abamectin + Leaf Act 80, 15 + 25 ppm; abamectin + Sunspray oil, 15 + 25 ppm, and a water control were evaluated for length of control of twospotted spider mite, *Tetranychus urticae* Koch, on 3 host species: azalea, Rhododendron × 'Red Ruffle'; lima bean, *Phaseolus limensis* var. *limenus* L. H. Bailey cv. 'Henderson' bush; and peach, *Prunus persica* L. Batsch cv. 'Nemaguard'; and under sunlight and fluorescent light regimes.

Abamectin alone or in combination with the surfactants, 21 days post treatment, resulted in 42.6 - 91.8% and 88 - 93% mite mortality under sunlight and fluorescent light, respectively. No treatments on azalea or peach under sunlight caused > 37% mortality. Treatments caused similar mite mortality 1 day posttreatment under fluorescent light, but after day 1 treatments on peach caused < 62% mortality while treatments on azalea caused < 46% mortality. The addition of oil increased mite mortality significantly on beans under sunlight at 14 days. At 21 days both Leaf Act 80 and oil increased mite mortality on bean compared to abamectin alone.

Key Words: Twospotted spider mite, abamectin, light, surfactants.

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INTRODUCTION

Abamectin (avermectin, Mk-936, AVID) is a new miticide/insecticide discovered at the Merck, Sharp & Dohme Research Laboratories. It is a mixture of two biologically active homologous avermectin components containing a minimum of 80% avermectin B_1a and a maximum of 20% avermectin B_1b (Dybas and Green 1984).

Abamectin has shown activity against a number of phytophagous mites, insects, and a nematode (Putter et al. 1981; McCoy et al. 1982; Grafton-Cardwell and Hoy 1983). Adults and nymphs of the twospotted spider mite, *Tetranychus urticae* Koch, (TSSM) were killed for 7 - 14 days on bean leaves dipped in 0.5 - 1.0 ppm abamectin (Putter et al. 1981). Foliar residues were effective for up to 30 days against all active stages of TSSM except eggs. No TSSM egg mortality was observed even at concentrations of abamectin as high as 25 ppm. Putter et al. (1981) suggested that abamectin caused mortality in TSSM by both contact and ingestion. Wright et al. (1985) reported 100% control of female TSSM for 28 days on cotton by 30 ppm abamectin.

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Ninety-five percent of TSSM and the European red mite, *Panonychus ulmi* (Koch), were killed in laboratory tests after 24 h when exposed to almond leaf discs dipped in aqueous solutions of abamectin at 4 ppm (Grafton-Cardwell and Hoy 1983). El-Banhawy and Anderson (1985) used leaf discs of seiva bean foliage, *Phaseolus lunatus* L., and reported that the activity of abamectin against TSSM in 10 day residual tests increased with increasing temperature. Egg mortality and development were also temperature related. No mortality by 12 ppm abamectin to TSSM eggs was observed at 16 or 24°C but 100% mortality was observed at 34°C (El-Banhawy and Anderson 1985). They also reported that the addition of emulsifiable oil to abamectin caused egg mortality at lower temperatures (100% at 24°C). Putter et al. (1981) did not report the temperatures at which their tests were conducted.

The efficacy of abamectin, including translaminar activity (Wright et al. 1985a), against TSSM and other mites (McCoy et al. 1985) and insects under certain conditions is well documented. However, efficacy of abamectin under field conditions appears related to light wavelength and intensity, temperature, or other factors (Bull et al. 1984; El-Banhawy and Anderson 1985; Wright et al. 1985a, b; Pfeiffer 1985). Bull et al. (1984) detected 82% and 98% degradation of abamectin on cotton 2 and 8 days posttreatment, respectively. Similarly, Iwata et al. (1985) found rapid degradation of abamectin on citrus leaves. Wright et al. (1985b) reported good control of TSSM with 3 ppm on abamectin for 14 days under glass but only 7 days outdoors.

Abamectin is a new acaricide which is recommended at very low rates, with broad activity against insect and mite pests, and the additional asset of low toxicity to predators (Grafton-Cardwell and Hoy 1985; Pfeiffer 1985). Therefore, abamectin is a valuable addition to the pesticide arsenal and useful in IPM programs. Knowledge of the factors which may enhance or adversely affect the efficacy of abamectin in the field is needed. This paper reports the effects of 3 host plant species, light (wavelength or intensity), and 2 surfactants on the residual activity of abamectin against TSSM.

METHODS AND MATERIALS

Azalea, Rhododendron × 'Red Ruffle', in 4 liter containers; peach, *Prunus persica* L. Batsch, 2 yr old 'Nemaguard'; and lima bean, *Phaseolus limensis* var. *limenus* L. H. Bailey cv. 'Henderson' bush in the cotyledon stage were used in the tests. Five to 8 azalea and peach plants were sprayed for each treatment. Beans were sprayed and handled in greenhouse trays.

Abamectin was used at the rate of 15 ppm for all treatments. The treatments were: an untreated control, abamectin, abamectin + Leaf Act 80 (non-ionic surfactant) at 25 ppm, and abamectin + Sunspray 7E oil at 25 ppm. Each treatment was applied to the 3 host plant species and held under 2 light regimes. All materials were supplied by Merck, Sharpe & Dohme, Co. Inc.

Plants were sprayed to runoff between 10 - 1200 h outside using a hand-pumped sprayer and allowed to dry ca. 1 h. After spraying, the plants were moved either into the laboratory under fluorescent light or onto a nursery bed covered with 30% shade cloth under sunlight. Lighting inside was provided by fluorescent fixtures (General Electric-F40CW) at 450 lux measured at the plant canopy level. Sunlight under the shade cloth was ca. 12000 lux measured at the plant canopy

level at 1100 h. The temperature inside was 28 ± 2°C while outside temperature fluctuated from 24 - 34°C. Plants outside were watered 30 - 45 min per day using overhead-sprinkler irrigation giving ca. 0.5 cm per day. Irrigation was withheld from the plants for at least 6 h following application of the treatments. Plants held inside were watered by hand as needed.

From each treatment 5 stems containing two leaves each were randomly chosen, excised from the plants, wrapped with tissue paper at the base, and placed in 30 ml shell vials filled with water. The petiole and edges of the peach and azalea leaves were covered with Stickem® to prevent mite movement off the leaf. A 2.5 cm ring of Stickem Special® was used on the beans for the same purpose. Ten mature female TSSM reared on beans were placed on the adaxial surface of each leaf using a small probe. Each treatment was replicated 10 times.

The residual activity of the insecticide treatments for each host species and light regime were evaluated at 1, 7, 14, and 21 days posttreatment. Mortality caused by the treatments was evaluated 24 h after the mites were placed on the leaves. The number of live and dead mites were recorded for each replicate. Mites were scored as dead if they were unable to walk 1 body length when gently probed.

A factorial design was used: day posttreatment × host × light × treatment and the data were analyzed using the GLM procedures of the Statistical Analysis System (SAS 1982). Mortality in the controls was always < 16%, but treatment mortality was corrected for control mortality using Abbott's formula (Abbott 1925). Percent mortality was transformed by arcsine square root for the analysis but the untransformed means are presented.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) indicated that all F values for main effects and interactions in the model were significant at the 5% level. We then did a separate ANOVA (host × light × treatment) for each of the 4 days of evaluations. F values were significant at < 5% for host and light effects for each day. F values for the host × light interaction were significant for all evaluations except at 21 days. F values for treatment effect and other interactions differed by day (see Tables 1 - 4). Readers may compare the overlap of the individual confidence intervals for statistically significant differences in means. This is a conservative test and the probability value will be less than the 0.05 level at which the limits were calculated (Jones 1984).

The treatments performed equally well 1 day posttreatment on all hosts under fluorescent light. Under sunlight only the TSSM mortality on bean was acceptable (> 80%), and all treatments on azalea and peach were lower under sunlight than under fluorescent light. Addition of the surfactants to abamectin did not increase the mortality on azalea or peach under sunlight (Table 1).

Overall mortality was less on day 7 than on day 1 (Table 2). Under both sunlight and fluorescent light, higher mortality was observed on bean than on peach or azalea, but mortality was greater under fluorescent than under sunlight. Addition of the surfactants increased mean mortality on azalea under fluorescent light and on bean under sunlight, although variation in the response produced

Table 1. Corrected percent mortality of twospotted spider mites 1 day posttreatment in response to abamectin (15 ppm), abamectin + Leaf Act 80 (15 ppm + 25 ppm), and abamectin + Sunspray oil (15 ppm + 25 ppm) on azalea, lima bean and peach under fluorescent light and sunlight. Value of F in ANOVA significant at < 1% for host, light and host × light but not for treatment or other interactions.

	Host					
	Azalea		Bean		Peach	
Treatment	$\bar{x}$	95% CL	$\bar{x}$	95% CL	$\bar{x}$	95% CL
Sunlight						
Abamectin	18.3	3.7 - 32.9	95.0	90.0 - 99.6	0.0	–
Abamectin + Leaf Act 80	36.9	11.9 - 61.9	98.8	95.9 - 100	5.0	0 - 13.5
Abamectin + oil	19.4	0 - 45.4	97.0	92.2 - 100	2.5	0 - 8.2
Fluorescent						
Abamectin	85.7	72.5 - 98.8	100	–	96.8	91.5 - 100
Abamectin + Leaf Act 80	80.7	64.8 - 96.6	100	–	93.5	86.0 - 100
Abamectin + oil	77.6	53.3 - 100	100	–	78.4	55.4 - 100

Table 2. Corrected percent mortality of twospotted spider mites 7 days posttreatment in response to abamectin (15 ppm), abamectin + Leaf Act 80 (15 ppm + 25 ppm), and abamectin + Sunspray oil (15 ppm + 25 ppm) on azalea, lima bean and peach under fluorescent light and sunlight. Value of F in ANOVA significant at < 5% for all main effects and interactions except treatment and host × treatment.

	Host					
	Azalea		Bean		Peach	
Treatment	$\bar{x}$	95% CL	$\bar{x}$	95% CL	$\bar{x}$	95% CL
Sunlight						
Abamectin	0	–	70.6	47.4 - 93.8	0.0	–
Abamectin + Leaf Act 80	15.6	0 - 39.0	95.6	85.5 - 100	5.0	0 - 13.5
Abamectin + oil	2.0	0 - 15.8	88.0	70.0 - 100	11.3	1.3 - 13.5
Fluorescent						
Abamectin	28.6	16.8 - 40.5	100	–	61.7	49.3 - 73.1
Abamectin + Leaf Act 80	42.5	33.6 - 51.5	85.7	63.7 - 100	61.0	51.2 - 70.8
Abamectin + oil	45.9	27.2 - 64.5	100	–	24.0	9.5 - 38.5

Table 3. Corrected percent mortality of twospotted spider mites 14 days posttreatment in response to abamectin (15 ppm), abamectin + Leaf Act 80 (15 ppm + 25 ppm), and abamectin + Sunspray oil (15 ppm + 25 ppm) on azalea, lima bean and peach under fluorescent light and sunlight. Value of F in ANOVA significant at < 1% for all main effects and interactions.

	Host					
	Azalea		Bean		Peach	
Treatment	$\bar{x}$	95% CL	$\bar{x}$	95% CL	$\bar{x}$	95% CL
Sunlight						
Abamectin	10.9	0 - 23.8	32.8	4.8 - 60.9	–	–
Abamectin + Leaf Act 80	4.1	0 - 14.0	58.6	29.9 - 87.2	–	–
Abamectin + oil	12.6	0 - 27.8	96.7	89.1 - 100	–	–
Fluorescent						
Abamectin	7.4	0 - 25.9	100	–	20.8	2.9 - 38.6
Abamectin + Leaf Act 80	24.6	2.6 - 46.6	91.9	78.7 - 100	24.0	4.0 - 44.0
Abamectin + oil	11.4	0 - 23.7	100	–	52.2	31.0 - 73.4

Table 4. Corrected percent mortality of twospotted spider mites 21 days post-treatment in response to abamectin (15 ppm), abamectin + Leaf Act 80 (15 ppm + 25 ppm), and abamectin + Sunspray oil (15 ppm + 25 ppm) on lima bean under fluorescent light and sunlight. Data for peach and azalea are not shown. Value of F in ANOVA significant at < 2% for all main effects and interactions except host × light and host × treatment.

	Bean	
Treatment	$\bar{x}$	95% CL
Sunlight		
Abamectin	42.6	23.0 - 62.2
Abamectin + Leaf Act 80	81.1	65.2 - 97.0
Abamectin + oil	91.8	78.3 - 100
Fluorescent		
Abamectin	93.0	81.3 - 100
Abamectin + Leaf Act 80	88.1	78.8 - 97.4
Abamectin oil	88.7	77.4 - 99.9

wide confidence limits. Nevertheless, mean mite mortality on bean was > 80% which would be necessary for field efficacy.

By day 14 only the treatments on bean provided sufficient TSSM mortality (Table 3). Mortality on azalea and peach was less for these hosts than on day 7. Mortality from abamectin on bean without surfactants was greater under fluorescent light than under sunlight. The addition of oil increased the mortality on bean under sunlight over abamectin alone. Abamectin + oil caused greater mortalty than abamectin + Leaf Act 80.

On day 21 mortality on azalea and peach (data not shown) was less than on day 14. Mite mortality on bean was slightly reduced on day 21. All abamectin treatments were equivalent under fluorescent light (Table 4). Under sunlight the addition of surfactants increased mite mortality and treatment effects were abamectin + oil > abamectin + Leaf Act 80 > abamectin.

Abamectin degrades by oxidation under both dark and light conditions but the process is accelerated by light and varies with both light intensity and wavelength. Fifty percent degradation may occur in 24 h on cotton leaves (Bull et al. 1984). Therefore, residual efficacy of abamectin against phytophagous insects is closely correlated with the ability of abamectin to rapidly penetrate the foliar substrate (Wright et al. 1985a).

Clearly, host species, light, and surfactants interacted to affect the performance of abamectin in this study. Given the known effect of light on the degradation process of abamectin on citrus and cotton (Bull et al. 1984; Iwata et al. 1985; Wright 1985b), host species was the determinant factor as has been shown for other pesticides (Bukovac 1976; Muzik 1976). Differential physical and chemical characteristics of the leaves of host plants held under similar light conditions probably affected the rate and amount of penetration of abamectin into the leaf and therefore its residual characteristics on the 3 host species. For example, Bukovac et al. (1979) found that surface characteristics of the cuticle of peach leaves affected wettability and thus retention and penetration of foliar applied naphthalenacetic acid. Sargent (1976) reported that penetration of 2,4-D into the

adaxial leaf surface of bean was inversely related to leaf age; young leaves were more easily penetrated because the cuticle had not fully formed. In this study we used 1 wk old bean leaves but mature peach and azalea leaves. Treatments under either sunlight and fluorescent light performed consistently better on beans than on azalea or peach; but we cannot attribute the effect to leaf age alone because we used different host plants.

Light (intensity, wavelength, we did not attempt to separate the effects of these parameters) also significantly affected the performance of abamectin. All treatments caused higher mortality at 1 day posttreatment under fluorescent light than under sunlight. If leaf characteristics of peach and azalea leaves inhibited penetration, as shown on other host species for other pesticides (Kirkwood 1972; Baker et al. 1979; Flore and Bukovac 1981), then light would degrade the abamectin on the leaf surface and have greater effect on the amount of abamectin penetrating azalea and peach. In support of this, abamectin under sunlight caused less mortality on day 1 on azalea and peach than on bean. Further, Wright et al. (1985b) reported shorter residual activity of abamectin on cotton leaves held in sunlight than those held in a greenhouse.

The function of the non-ionic surfactant, Leaf Act 80, is to enhance the rate and degree of penetration of abamectin into the leaf. Either Leaf Act 80 was not able to penetrate the cuticle of azalea and peach, or the same level of penetration does not result in similar toxicity. Conversely, the addition of Leaf Act 80 to abamectin on bean did improve mortality significantly after 21 days.

Sunspray oil functions as a wetting agent and has increased the rate and amount of penetration of abamectin on cotton and thus the residual concentration in the leaf (Wright et al. 1985b). Oil had little effect on abamectin performance except for the improvement on bean under sunlight on days 14 and 21.

This study shows that light and host plant affect the performance of abamectin against TSSM in a residual bioassay. In addition, we have demonstrated that the activity of the surfactants oil and Leaf Act 80 is related to the host plant and they may either increase (bean) or have no effect (azalea and peach) on mite residual mortality caused by abamectin.

We used a residual bioassay which eliminates the known high mortality that results when mites are directly contacted by the spray as under field conditions. Abamectin often provides outstanding control of aphids and mites on contact. For example, we have obtained excellent control of yellow pecan aphids, *Monelliopsis pecanis* (Bissel) and *Monellia caryella* (Fitch), immediately following application of abamectin to pecan foliage in the field. However, no residual mortality to immigrants was observed at 24 h posttreatment (RFM, unpublished data). Similarly, application of abamectin as a remedial to TSSM infested peach and azalea provided excellent control of adults but populations of immatures in resting stages at the time of application were observed feeding on the plants after a day or so (RFM, unpublished data).

Thus, control or lack of control of mites by abamectin in field tests may also be related to the developmental rate of the egg and other immature stages. Eggs and quiescent nymphs may be tolerant of abamectin (El-Banhawy and Anderson 1985). Mite species with fast rates of development may be controlled by contacting toxic residues while feeding on leaves which are not penetrated well by abamectin. Mites may remain in quiescent stages at slow rates of development and may escape toxic residues due to rapid breakdown of abamectin.

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