

Effect of foliar applications of neem oil and fish emulsion on bacterial spot and yield of tomatoes and peppers

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Abstract: Foliar applications of neem oil and fish emulsion, derived from neem seed and menhaden fish, respectively, were tested for their ability to reduce bacterial spot of tomato and bell pepper under both greenhouse and field conditions. Greenhouse-grown tomato and pepper plants sprayed with aqueous suspensions (0.5%, v/v) of neem oil or fish emulsion and then inoculated with *Xanthomonas campestris* pv. *vesicatoria* showed less disease symptoms than the water-treated controls. Weekly foliar sprays of neem oil and fish emulsion reduced disease severity on the foliage of inoculated field-grown tomato and pepper plants in both years of a two-year study. The disease incidence on the fruit of these plants was reduced but the effect was not always statistically significant. However, the number of lesions per pepper fruit were consistently lower with these treatments. Fish emulsion increased healthy and total fruit yield of tomatoes in 2000 and healthy fruit yield of peppers in 2001, whereas neem oil increased the yield of disease-free peppers in both years. Neem oil and fish emulsion had no observable phytotoxic effect on tomato or pepper foliage in the field. These results suggest that disease-management programs for bacterial spot may be enhanced by including foliar sprays of these products.

Key words: Actigard[®], induced resistance, *Lycopersicon esculentum*, *Xanthomonas campestris* pv. *vesicatoria*, *Azadirachta indica*, fish emulsion, organic foliar fertilizer.

Résumé : Des applications foliaires d'huile de neem et d'émulsion de poisson, provenant respectivement de graines de neem et de menhaden, ont été testées pour leur capacité à réduire la tache bactérienne sur la tomate et le poivron, tant en conditions de serre que de champ. Les tomates et les poivrons de serre pulvérisés avec des suspensions aqueuses (0,5%, v/v) d'huile de neem ou d'émulsion de poisson, puis inoculés avec le *Xanthomonas campestris* pv. *vesicatoria*, ont eu moins de symptômes de maladie que les témoins traités à l'eau. Lors des deux années d'une étude, des pulvérisations foliaires hebdomadaires d'huile de neem et d'émulsion de poisson ont réduit la gravité de la maladie sur le feuillage de tomates et de poivrons de champ inoculés. La fréquence de la maladie sur les fruits de ces plantes a été réduite, mais l'effet n'a pas toujours été statistiquement significatif. Cependant, le nombre de lésions par fruit pour le poivron a toujours été inférieur avec ces traitements. L'émulsion de poisson a accru le rendement en fruits sains et le rendement total des tomates en 2000 et le rendement en fruits sains des poivrons en 2001, alors que l'huile de neem a accru le rendement en poivrons exempts de maladie lors des deux années. L'huile de neem et l'émulsion de poisson n'ont pas eu d'effet phytotoxique observable sur le feuillage des tomates et des poivrons en champ. Ces résultats laissent croire que les programmes de lutte à la tache bactérienne pourraient être améliorés par l'addition de pulvérisations foliaires de ces produits.

Mots clés : Actigard[®], résistance induite, *Lycopersicon esculentum*, *Xanthomonas campestris* pv. *Vesicatoria*, *Azadirachta indica*, émulsion de poisson, engrais foliaire biologique.

Introduction

Bacterial spot is a serious and persistent disease of processing and fresh market tomatoes (*Lycopersicon esculentum* Mill.) and bell peppers (*Capsicum annum* L.).

The pathogen *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye [*X. vesicatoria* and *X. axonopodis* pv. *vesicatoria* (Vauterin et al. 1995)] infects all aboveground plant parts, causing necrotic lesions on leaves, stems, and

Accepted 30 October 2002.

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fruit. Disease development is favoured by high moisture and warm temperatures, conditions prevalent during the growing season in Ontario. The disease can cause serious economic losses to tomato and pepper growers by reducing yield and fruit quality. Growers rely heavily on fixed copper sprays to manage foliar disease and reduce losses caused by bacterial spot and bacterial speck [*Pseudomonas syringae* pv. *tomato* (Okabe) Younge, Dye, & Wilkie] (Cox 1982; Jones et al. 1991; Kousik and Ritchie 1996). Unfortunately, these sprays often are not very effective. The prevalence of copper-resistant strains of *X. campestris* pv. *vesicatoria* is an indication of the extensive use of this bactericide (Adaskaveg and Hine 1985; Ritchie and Dittapongpich 1991; Sahin and Miller 1995). Currently, there is no commercial variety of tomato or pepper resistant to all races of bacterial spot. In the absence of effective disease-management practices, this disease presents a continued threat to tomato and pepper production. Therefore, new approaches for the management of this disease are needed.

Acibenzolar-*S*-methyl, a benzothiadiazole derivative and a plant activator, is a synthetic compound that has been shown to mediate the induction of systemic acquired resistance in several plant species against a number of pathogens (Cole 1999; Görlach et al. 1996; Romero et al. 2001; Ryals et al. 1994; Sticher et al. 1997). It has been registered in Europe as Bion 50 WP (Syngenta Ltd., Basel) and in the United States as Actigard (Syngenta Crop Protection, Greensboro, N.C.), but it is not yet available to growers in Canada. Its efficacy against bacterial spot and bacterial speck of tomatoes and peppers under greenhouse and field conditions has been shown previously (Abbasi et al. 2002a; Cuppels et al. 1999; Louws et al. 2001; Miller et al. 1998).

Neem oil is extracted from the seed kernels of the neem tree (*Azadirachta indica* A. Juss.). Neem, also known as Indian lilac or Dirach, is a fast-growing tree native of south and southeast Asia. Although neem oil or water extracts of neem cake control insect pests (Schmutterer 1990; Smirle 2000), plant parasitic nematodes (Akhtar and Mahmood 1995), and soilborne plant pathogens (Singh et al. 1980), their effect on foliar diseases caused by bacterial pathogens has not been investigated.

Fish emulsion or fish soluble nutrients are derived from menhaden fish, *Brevoortia tyrannus* (Latrobe), which are members of the herring family. The emulsion is prepared by pressing the liquid out of the cooked fish, deoiling the liquid and removing some of the water. The product is then acidified with sulfuric acid to stabilize it. Fish emulsions or fish soluble nutrients have been used mainly as fertilizers (Aung and Flick 1980; Aung et al. 1984; Ceci 1975); however, a mixture of fish emulsion and bacteria has been used as a spray treatment to control moths (Wyatt and McGourty 1990). The effect of foliar applications of fish emulsion on bacterial diseases of plants is unknown.

The objectives of this study were to determine the effect of foliar applications of neem oil or fish emulsion on the development of bacterial spot on tomato and pepper foliage and fruit and on the yield of tomatoes and peppers. Foliar sprays of acibenzolar-*S*-methyl were used as a positive control.

Materials and methods

Greenhouse experiments

Tomato (processing; 'Heinz 9478') and pepper ('Early Niagara') transplants were grown in a commercial peat mix (Pro-Mix BX[®], Premier[®] Horticulture Inc., Rivière-du-Loup, Que.) in 10-cm-diameter plastic pots (one transplant per plot). Each pot received 6–8 granules of the controlled-release fertilizer Nutricote[®] (14–14–14; Plant Products Co. Ltd., Brampton, Ont.) during transplanting. Treatments were arranged on bench under normal greenhouse conditions in a completely randomized design with five replicates per treatment. Aqueous solutions of neem oil (0.25 or 0.5%, v/v) (De Cloet Ltd., Tillsonburg, Ont.), fish emulsion (0.5%, v/v) (Omega Protein, Houston, Tex.), acibenzolar-*S*-methyl (Actigard[®] 50 WP; 35 mg active ingredients (a.i.) per litre) (Syngenta Crop Protection Inc., Guelph, Ont.), or tap water were applied as spray treatments, using a hand-held plastic spray bottle, onto 4-week-old plants. Treatments were applied twice at 1-week intervals, one application before and one after inoculation. The bacterial strains used in this study, *X. campestris* pv. *vesicatoria* strain DC 93-1 (group B) and *X. campestris* pv. *vesicatoria* strain DC 96-1 (group A), had been isolated from an Ontario processing tomato and pepper field, respectively. They were stored in nutrient broth yeast extract (NBY) agar (Vidaver 1967) plus 15% glycerol at –72°C. When needed for an experiment, they were streaked out on NBY agar. Bacterial cells were grown overnight in NBY broth, collected by centrifugation at 6500 × *g* for 15 min at 4°C, and resuspended in sterile tap water. The bacterial concentration was adjusted to 10⁸ CFU/mL and plants were inoculated using a hand-held plastic spray bottle 3 days after the first treatment application. Plants were misted 1 h daily for 3 days, 24 h after inoculation, and kept in the greenhouse until symptom development. All plants in a treatment were rated for the severity of foliar bacterial spot 2 weeks after inoculation, using the following scale: 1, symptomless; 2, a few necrotic spots on a few leaflets; 3, a few necrotic spots on many leaflets; 4, many spots with coalescence on few leaflets; 5, many spots with coalescence on many leaflets; 6, severe disease and leaf defoliation; 7, plant dead. Greenhouse experiments were repeated twice.

Field experiments

Field experiments were conducted in 2000 and 2001 in London, Ontario, at the Agriculture and Agri-Food Canada research farm on an alkaline loam soil (pH 8.0) with a moderate level of organic C. Tomato ('H 9478') and pepper ('Merlin') seedlings, grown in a Pro-Mix BX[®] peat mix in plug trays, were supplied by H.J. Heinz (Leamington, Ont.). Standard cultivation practices were carried out according to *Vegetable Production Recommendations, 2000–2001* (Ontario Ministry of Agriculture and Food 2000). Six-week-old tomato and 8-week-old pepper seedlings were transplanted 0.45 m apart in single rows on 1.2-m centres with a planter. Plants were fertilized with the plant starter Plant Prod[®] (10–52–10; Plant Products Co. Ltd., Brampton, Ont.) during planting; each plant received approximately 150–180 mL of 0.5% starter fertilizer. Experimental plots (one 4.5-m row)

were established in a randomized complete block design with four replicates per treatment. Treated rows were separated by a border row. Freshly made aqueous solutions of neem oil (0.5%, v/v), fish emulsion (0.5%, v/v), or acibenzolar-*S*-methyl, (35 g a.i./ha in the field) were applied weekly as spray treatments throughout the growing season starting 2 weeks after transplanting. Treatments were applied using a hand-held compressed-air sprayer (RL Flo-Master[®], capacity 7.6 L; Root-Lowell Manufacturing Co., Lowell, Mich.) at 30 ± 5 psi (1 psi = 6.895 kPa) with an adjustable cone nozzle. A total of 10 applications were made in both 2000 and 2001. Approximately 15 to 25 mL of solution was sprayed weekly onto each plant depending on the plant age. Control plots were sprayed with water. Plants in the border rows were inoculated 3 days after the first spray treatment and bacterial spot was allowed to spread naturally to the treated plants. The tomato border rows were inoculated with *X. campestris* pv. *vesicatoria* strain DC 93-1, while the pepper border rows were inoculated with *X. campestris* pv. *vesicatoria* strain DC 96-1. The 2001 growing season was comparatively dry during June and July and, as a result, disease pressure was low on the tomato plots. The tomato plots were reinoculated directly onto the treated plants, not on the border rows. Thereafter, both tomato and pepper plots were irrigated weekly for 3 weeks (4 h each time) by sprinkler irrigation. Other foliar and fruit diseases occurring naturally on these plants included early blight [*Alternaria solani* (Ell. & Mart) L.R. Jones & Grout], septoria leaf spot [*Septoria lycopersici* Speg.], and anthracnose [*Colletotrichum* spp.]. These fungal diseases were not prominent in the plots so they were not rated. All plants in a treatment plot were rated five times (2000: 20 and 31 July and 11, 21, and 29 Aug.; 2001: 27 July and 3, 10, 17, and 24 Aug.), using a modified Horsfall and Barratt (1945) disease rating scale (1 = no disease to 12 = 100% disease), for the severity of foliar bacterial spot (% affected tissue). Data for each treatment were converted to area under the disease progress curve (AUDPC), using the midpoints of each rating (Campbell and Madden 1990; Shaner and Finney 1977). All fruits from five plants in 2000 and eight plants in 2001, in the middle of each plot (four replicate plots per treatment), were harvested when approximately 80% of the tomato fruit were ripe (light red to red). In both years, peppers were harvested on 4 September and tomatoes on 5 September. Fruits were analyzed for the incidence of bacterial spot and anthracnose. A fruit with one or more bacterial-spot lesions was considered diseased. Incidence of bacterial spot was expressed as a percentage of total harvested fruit on a mass basis. Tomatoes and peppers free of disease symptoms were sorted as healthy fruit. Total yields were determined as well. The size of the processing tomato fruit was small and we decided not to evaluate individual fruit for the number of bacterial-spot lesions. However, individual peppers were analyzed for the severity of bacterial spot by counting the number of lesions on each fruit.

Data analyses

Greenhouse data were analyzed by MINITAB statistical software, version 13 (Minitab Inc. 2000). Analysis of vari-

ance was performed and means were separated according to Fisher's protected least significant difference (LSD) test. Field data were analyzed by SAS statistical software, version 8.0 (SAS Institute Inc. 1999). All data were tested for normality and only the 2001 pepper data on incidence of bacterial spot on fruit and number of peppers per plant were transformed [$\ln(x + 0.5)$] to normalize before further analysis (Steel et al. 1997). Actual, untransformed means were reported for clarity. Analysis of variance was performed using general linear models (GLM) procedure of SAS (SAS Institute Inc. 1999) and means were separated with least square estimates of marginal means (LSMEANS statement).

Results

Greenhouse experiments

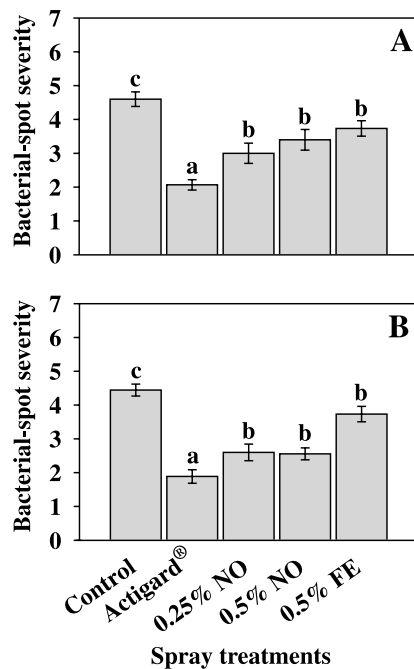
Foliar sprays of neem oil, fish emulsion, and acibenzolar-*S*-methyl reduced the severity of bacterial spot on greenhouse-grown tomato plants (Fig. 1A) and pepper plants (Fig. 1B) compared with the water control. Acibenzolar-*S*-methyl was the best treatment in reducing the severity of the disease on both tomato and pepper foliage. Tomato and pepper plants treated with fish emulsion (0.5%) showed no obvious phytotoxic effects whereas neem oil (0.5%) and acibenzolar-*S*-methyl (35 mg a.i./L) treatments were phytotoxic, causing stunting, chlorosis, epinasty, and narrowing of leaf blades.

Field experiments

Bacterial spot was the predominant disease on tomato and pepper plants during the 2000 and 2001 growing seasons; however, some early blight and septoria leaf spot were also seen on the tomato foliage late in the season. The late and sporadic occurrence of these fungal diseases on tomato foliage did not affect the rating of bacterial spot. The 2000 season was comparatively wet and the plots were flooded by heavy rains during June and July. Despite a large variation among the experimental plots, weekly foliar sprays of acibenzolar-*S*-methyl, fish emulsion, and neem oil reduced the severity of bacterial spot on foliage of field-grown tomato and pepper compared with the water control, as expressed as AUDPC (Fig. 2). The disease-reducing efficacy of neem oil on both tomato and pepper and of fish emulsion on pepper was comparable with that of acibenzolar-*S*-methyl. In the dryer 2001 growing season, the severity of bacterial spot on tomato foliage was reduced by acibenzolar-*S*-methyl, fish emulsion, and neem oil treatments, after the second direct inoculation (Fig. 2). Bacterial-spot pressure was low on peppers early in the season but the disease progressed quickly late in the season. Acibenzolar-*S*-methyl, fish emulsion, and neem oil treatments equally and effectively reduced the severity of bacterial spot on pepper foliage.

Bacterial spot was the predominant disease on tomato and pepper fruit during both seasons. In 2000, bacterial-spot infection was very high because of heavy rains and flooding, and only the acibenzolar-*S*-methyl treatment significantly reduced the incidence of the disease on tomato fruit (Fig. 3). In 2001, bacterial-spot pressure in tomato plots was low during early flowering and most of the fruit es-

Fig. 1. Effect of foliar sprays of acibenzolar-*S*-methyl (Actigard®), neem oil (NO), and fish emulsion (FE) on the severity of bacterial spot on 4-week-old greenhouse-grown (A) tomato ('Heinz 9478') and (B) pepper ('Early Niagara') plants. Plants were sprayed twice at 1-week intervals with aqueous solutions of Actigard® (35 mg a.i./L), neem oil (0.25 or 0.5%, v/v), or fish emulsion (0.5%, v/v). They were inoculated with *X. campestris* pv. *vesicatoria* strain DC 93-1 (tomato) or *X. campestris* pv. *vesicatoria* strain DC 96-1 (pepper) 3 days after the first spray treatment and rated for the severity of bacterial spot 2 weeks later using a 1–7 scale, where 1 = symptomless and 7 = dead plant. Error bars are standard error of means of three separate experiments ($n = 15$). Bars in each graph with different letters are significantly different from each other according to Fisher's protected LSD test ($P \leq 0.05$).



caped infection; in control plots, only 16% of the total fruit had bacterial-spot-like symptoms. Foliar sprays of acibenzolar-*S*-methyl and neem oil reduced the incidence on tomato fruit by 54 and 48%, respectively (Fig. 3).

In 2000, bacterial-spot infection was very high on peppers and 98% of the fruit harvested from untreated control plots had bacterial-spot symptoms. Acibenzolar-*S*-methyl and neem oil reduced bacterial-spot incidence in pepper fruit (Fig. 3). In 2001, 61% of the pepper fruits harvested in the control plots were infected with bacterial spot. Acibenzolar-*S*-methyl and fish emulsion treatments reduced the incidence of bacterial spot on peppers by 66 and 54%, respectively (Fig. 3).

Each pepper fruit was analyzed for disease severity. The number of peppers per plant was low in 2000 compared with 2001 (Table 1). Acibenzolar-*S*-methyl was the only treatment that adversely affected the number of peppers per plant. The number of bacterial-spot lesions per fruit was reduced by acibenzolar-*S*-methyl, neem oil, and fish emulsion treatments in both years (Table 1).

In 2000, all treatments increased the relative proportion of healthy tomato fruits compared with the water control

despite the large variation among the experimental plots caused by heavy rains and flooding, but the increase was statistically significant only for the acibenzolar-*S*-methyl and fish emulsion treatments (Table 2). In 2001, disease-free tomato yields were not affected by any spray treatment. The 2000 season was wet and had a low tomato yield compared with 2001. The total tomato yield in 2000 was increased only by weekly sprays of fish emulsion. None of the treatments increased total tomato yield during the 2001 season (Table 2).

In 2000, bacterial-spot pressure was very high in pepper plots and fruit yields low. The proportion of symptomless fruits was increased by neem oil treatment. Neem oil and fish emulsion did not affect total yield; acibenzolar-*S*-methyl reduced total yield (Table 2). In 2001, weekly foliar sprays of acibenzolar-*S*-methyl, fish emulsion, and neem oil increased the proportion of healthy peppers, whereas total yields were not affected by any treatment (Table 2).

There were no obvious phytotoxic effects of the fish emulsion treatment on the foliage of the field-grown plants. The phytotoxic effects observed on greenhouse-grown tomato plants treated with neem oil and acibenzolar-*S*-methyl (as described above) were not observed on the field-grown tomato or pepper plants.

Discussion

Ontario organic and conventional producers of tomato and bell pepper rely heavily on copper-based bactericide sprays to reduce losses caused by bacterial spot. Unfortunately, these chemicals provide inadequate control when environmental conditions are optimal for disease development. Also, there is growing concern regarding the effect of these pesticides on the environment. Consequently, there is a need for environmentally friendly disease-management strategies. Acibenzolar-*S*-methyl (Actigard®) is a plant activator and has been shown to induce systemic resistance in wheat and barley against fungal pathogens (Görlach et al. 1996) and in tobacco against bacterial and fungal diseases (Cole 1999). Though it has been successfully used experimentally in greenhouse and field experiments to control bacterial speck on tomato and bacterial spot on peppers and tomato (Cuppels et al. 1999; Louws et al. 2001; Miller et al. 1998; Romero et al. 2001), acibenzolar-*S*-methyl is not yet registered in Canada. As a positive control in this study, foliar applications of this compound provided excellent control of bacterial spot. It reduced disease severity on tomato and pepper foliage and disease incidence on fruit.

In this study, foliar sprays of neem oil and fish emulsion consistently reduced the severity of bacterial spot on foliage of greenhouse-grown tomatoes and peppers. Both treatments reduced disease severity on field-grown tomato and pepper plants in both seasons, despite major differences in weather conditions. Although not always statistically significant, a reduction in the proportion of fruits with bacterial-spot symptoms was observed with neem oil or fish emulsion treatments. Both treatments significantly reduced the number of spots on pepper fruit in both years. Even though total fruit yields were not significantly increased, the neem oil and fish emulsion sprays did increase the proportion of healthy peppers. Both greenhouse-grown and field-grown

Fig. 2. Effect of weekly foliar applications of acibenzolar-*S*-methyl (Actigard®), neem oil (NO), and fish emulsion (FE) on the area under the disease progress curve (AUDPC) of field-grown tomato (‘Heinz 9478’) and pepper (‘Merlin’) plants in London, Ontario, during 2000 and 2001. Error bars are standard error of means ($n = 4$). For each year, bars with the same letter indicate no significant difference ($P \leq 0.05$, least-square means option of the GLM procedure of SAS).

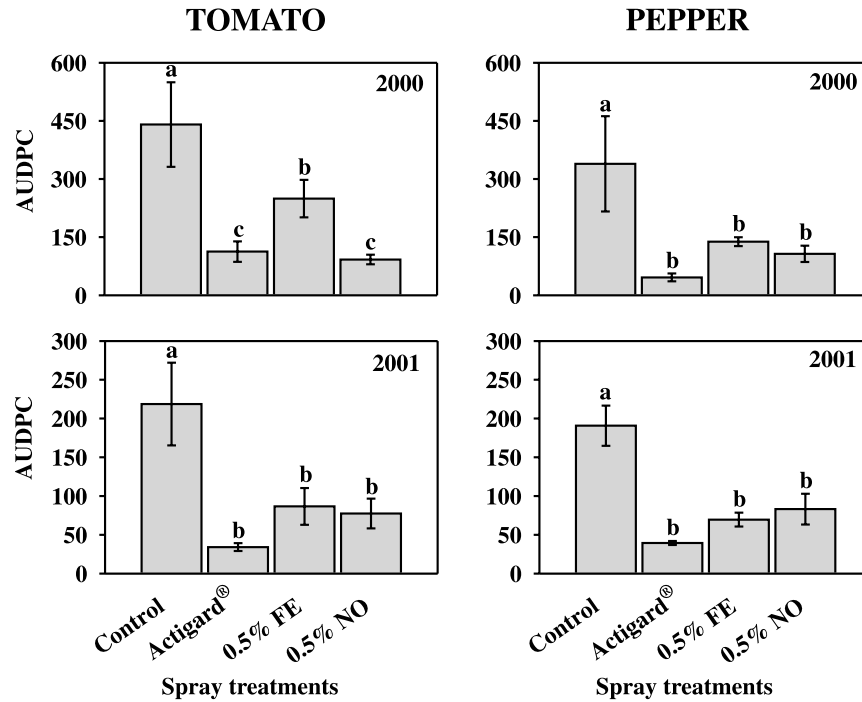
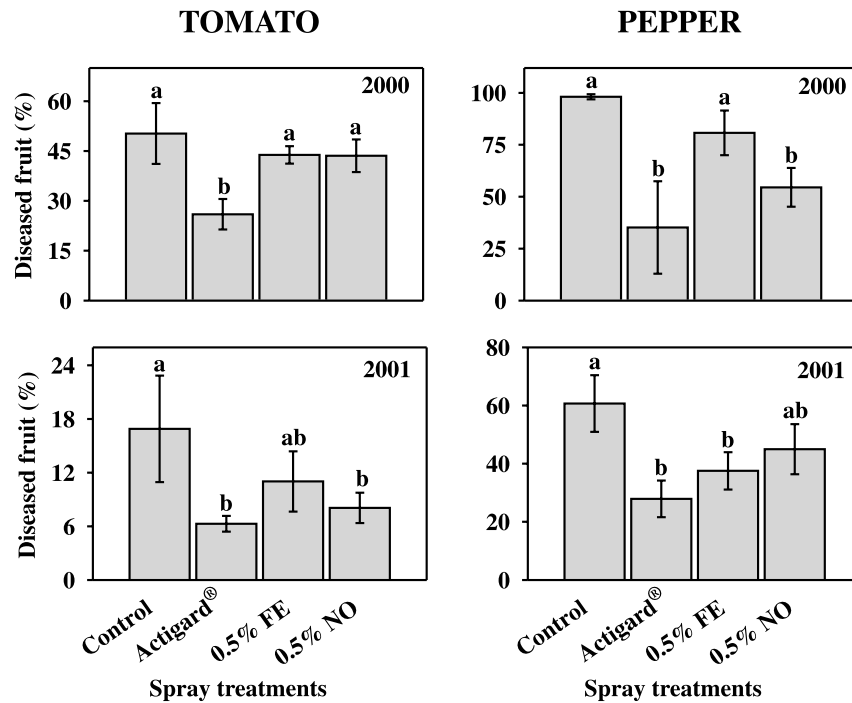


Fig. 3. Effect of weekly foliar applications of acibenzolar-*S*-methyl (Actigard®), neem oil (NO), and fish emulsion (FE) on the incidence of bacterial spot on fruit of field-grown tomato (‘Heinz 9478’) and pepper (‘Merlin’) plants. In both years, bacterial spot was the predominant disease on fruit. Error bars are standard error of means ($n = 4$). For each year, bars with the same letter indicate no significant difference ($P \leq 0.05$, least-square means option of the GLM procedure of SAS).



plants treated with fish emulsion looked healthy and did not show any signs of phytotoxicity. Despite neem oil and acibenzolar-*S*-methyl were phytotoxic for greenhouse-

grown tomato and pepper plants, no adverse effect was observed in the field-grown tomato and pepper plants. The odour associated with diluted solutions of neem oil and fish

Table 1. Effect of weekly foliar sprays of acibenzolar-*S*-methyl (Actigard®), neem oil, and fish emulsion on the severity of bacterial spot on field-grown pepper fruit ('Merlin').

Spray treatment	2000		2001	
	Fruits/plant	Spots/fruit	Fruits/plant	Spots/fruit
Control	2.4 a	8.5 a	4.9 a	5.4 a
Actigard®	0.9 b	0.7 b	3.9 a	0.7 b
Fish emulsion	2.8 a	3.0 b	6.1 a	1.4 b
Neem oil	1.7 a	1.3 b	5.6 a	2.6 b

Note: Means followed by different letters within each column are significantly different ($P \leq 0.05$, least-square means option of the GLM procedure of SAS).

Table 2. Effect of weekly sprays of acibenzolar-*S*-methyl (Actigard®), neem oil, and fish emulsion on total yield and yield expressed as healthy fruit (disease-free) of field tomatoes and peppers.

Spray treatment	Healthy fruit (t/ha)*				Total yield (t/ha)			
	Tomato		Pepper		Tomato		Pepper	
	2000	2001	2000	2001	2000	2001	2000	2001
Control	19 b	65 a	0.1 b	6 b	37 b	75 a	5 a	16 a
Actigard®	31 a	61 a	1.0 ab	10 a	42 ab	65 a	2 b	13 a
Fish emulsion	31 a	65 a	0.9 ab	12 a	56 a	73 a	7 a	19 a
Neem oil	30 ab	56 a	1.6 a	10 a	53 ab	62 a	3 ab	18 a

Note: Means followed by different letters within each column are significantly different ($P \leq 0.05$, least-square means option of the GLM procedure of SAS).

*Disease-free fruit of tomato 'Heinz 9478' or pepper 'Merlin'.

emulsion was just barely detectable and, even, this was short-lived.

This is the first study demonstrating the use of foliar sprays of neem oil and fish emulsion as a means of managing bacterial disease on tomato and bell pepper. The consistent reduction of the severity of bacterial spot with these treatments on tomato and pepper foliage and on pepper fruit is encouraging. In addition, the rates used were economical and there were no observable phytotoxic effects on the treated plants. Differences in plant growth among the various treatments were not observed. Therefore, these treatments may have a place in the integrated management of bacterial spot, both in organic and conventional production systems. Unlike the copper bactericides, which have already become ineffective against some races of the pathogen (Adaskaveg and Hine 1985; Ritchie and Dittapongpitch 1991; Sahin and Miller 1995), these treatments may not result in the development of resistance in the bacterial pathogens.

Although this study was not aimed at examining the mechanisms responsible for disease reduction, it may be that neem oil and fish emulsion increased the resistance of the treated plants to the pathogen causing bacterial spot. It is very unlikely that the concentration of fish emulsion used had any direct toxic effects on the pathogen, as suggested by our preliminary results in the growth medium. We also tested fish emulsion at higher rates (up to 4%, mass/mass) for its effect on total bacterial and fungal populations in peat-based substrate, and preliminary results suggest that both bacterial and fungal populations were enhanced by the fish emulsion treatments (P.A. Abbasi and G. Lazarovits, unpublished results). Similarly, our preliminary results indicate that fish emulsion controls damping-off diseases caused by *Rhizoctonia solani* Kühn or *Pythium aphanider-*

matum (Edson) Fitzp. but is not directly toxic to fungal pathogens (Abbasi et al. 2002b). Fish emulsions or fish soluble nutrients have been used mainly as fertilizers (Aung and Flick 1980; Aung et al. 1984). In fact, foliar fertilizer sprays, in general, have been shown to protect plants from fungal (Gottstein and Kuć 1989; Reuveni and Reuveni 1998; Walters and Murray 1992) and bacterial diseases (Abbasi et al. 2001, 2002c). Cucumber leaves pretreated with potassium phosphate solution were nonpenetratable by the appressoria of the fungus *Botrytis cinerea* Pers.:Fr. (Akutsu et al. 1987). Manipulation of host nutrition has been shown to effectively manage plant diseases caused by soilborne and foliar pathogens of a number of crops including tomato and peppers (McGuire et al. 1991; Mohan et al. 1978; Nayudu and Walker 1960).

On the other hand, antimicrobial activity of neem oil has been demonstrated against nematodes and soilborne fungi (Akhtar and Mahmood 1995; Singh et al. 1980). Foliar applications with aqueous emulsions of neem oil have been shown to provide effective control of fungal diseases such as powdery mildew of lilac or hydrangea and bean rust without causing damage to the plants (Locke 1990). How foliar sprays of aqueous emulsion of neem oil suppressed bacterial spot on tomato and pepper plants needs to be investigated. It is quite possible that neem oil may have both resistance-inducing as well as antibacterial properties.

In Canada, where acibenzolar-*S*-methyl is not yet registered for bacterial diseases of tomato and pepper, neem oil and fish emulsion may be integrated into management programs of bacterial spot. We are examining formulations that enhance the disease-reducing efficacy of these products as current levels of control may not be sufficient for commercial operations. For instance, these products may be highly compatible with the fixed copper bactericides currently

used. Furthermore, there is a need to test these products at the commercial production scale to determine economic benefits.

Acknowledgements

The technical assistance of Igor Lalin, Rebecca Earl, Brian Weselowski, Richard Muth, and Glen McFadden was greatly appreciated. We also thank Ken Conn and Dave Vadnais, Agriculture and Agri-Food Canada (AAFC), for their critical and valuable suggestions during the preparation of the manuscript. This research was funded by the grants from Omega Protein and De Cloet Ltd., and the AAFC Matching Investment Initiative.

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