Influence of Rate of Soil Fertilization on Alternaria Leaf Blight (*Alternaria dauci*) in Carrots

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The possibility of suppressing *Alternaria dauci* (Kühn) Groves & Skolko, the causal agent of Alternaria leaf blight in carrot, by excess application of fertilizer was examined in greenhouse and field experiments. Reducing the rate of fertilization by one half from the optimal rate (100 ppm N, 19 ppm P and 74 ppm K) resulted in a 23–30% increase in the severity of Alternaria leaf blight. However, doubling the rate of fertilization resulted in only a 10–15% decrease in disease severity. Inoculating with different concentrations of *A. dauci* spores (10^3 or 10^4 spores/ml) did not alter the response of the plants to the fertilization rate, although significantly higher disease severity was observed in plants inoculated with the higher spore concentration. These results were corroborated in the field, where neither disease severity nor harvested yield was significantly affected by tripling the amount of soil fertilization. Application of foliar fungicides, on the other hand, had substantial effects on both disease and yield. Therefore, it was concluded that carrot crops should be fertilized and maintained for optimum yield, and that *A. dauci* should be managed by properly timed applications of fungicides during the growing season.
KEY WORDS: Alternaria leaf blight; *Alternaria dauci*; fertilizer; IPM.

INTRODUCTION

Alternaria leaf blight, caused by *Alternaria dauci* (Kühn) Groves & Skolko, is a major foliar disease of carrot (*Daucus carota* L. var. *sativa* DC.) in Israel (11) and other countries (8). Alternaria leaf blight damages carrot plants by rapidly blighting or killing the leaves. Such damage usually results in poor growth and harvesting problems, because leaves weakened by blight often break off when gripped by a mechanical harvester. Severe epidemics of Alternaria leaf blight may reduce carrot yield by 40–60% (11). The disease is most important in the spring, summer and autumn cropping and fields are intensively sprayed with fungicides. In some cases, three or four sprays are applied weekly, with up to 40 sprays in a growing season. Nevertheless, it is not uncommon that the disease develops and induces substantial yield losses, even in intensively managed crops.

Host nutrition is an important factor in determining the severity of *Alternaria* epidemics (2,13). Horsfall and Heuberger (5) first noticed that low nitrogen levels were associated

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with increased disease severity on tomato plants; high nitrogen levels resulted in less disease, but also reduced yield. This observation was subsequently confirmed and elaborated upon by numerous studies. It was found that low levels of nitrogen and potassium increased *Alternaria* severity, whereas high levels were associated with mild disease severity. This has been demonstrated for potatoes (1,3,9,16), tomatoes (5,12) and *Gossypium barbadense* cotton (4,10). Over-fertilizing tomato plants with nitrogen has been shown to produce luxuriant, green plants which are virtually immune to early blight (5). This is thought to be due to the effects of nitrogen and fruit load on the physiological age of the plant tissue. High fruit load and low nitrogen both hasten senescence and, therefore, increase the susceptibility of the plants to blight. Barclay *et al.* (1) suggested that at high nitrogen levels, the period of meristematic activity in the plants is extended, allowing the plant to restrict the spread of infection. The possibility of controlling *Alternaria* diseases by excess application of nitrogen was examined in several studies and met with some success (1,9,16). In the present study we examined the possibility of reducing *A. dauci* intensity by applying excess rates of fertilizer, and also studied the possible interaction of that treatment with fungicide application.

MATERIALS AND METHODS

The study consisted of both greenhouse and field experiments. In the greenhouse, the effects of various fertilization rates on the response of carrot plants to *A. dauci* were evaluated under artificial inoculation. The greenhouse experiments were repeated three times. The effects of excess fertilization and of fungicide on Alternaria leaf blight were examined in the field, under natural epidemics of *A. dauci*. All experiments were conducted with cv. 'Presto', which is highly susceptible to the pathogen.

Greenhouse experiments

The effects of various fertilization rates on *A. dauci* development were evaluated using potted plants grown in a greenhouse compartment. Carrot seeds were planted in 15-cm-diameter pots (five or six seeds/pot) filled with vermiculite. Since vermiculite is an inert growth medium, the only source of nutrients available for the growing plants was provided by the fertilization treatment. The pots were drip irrigated once a day with 200 ml water/pot. Liquid fertilizer was incorporated in the irrigation water at four rates (treatments). The basic rate was equivalent to that required for adequate growth (6) and included 100 ppm N, 19 ppm P and 74 ppm K. In another treatment, one half that rate was applied (50, 9.5 and 37 ppm N, P and K, respectively) and in other treatments, two and four times the basic fertilization rate were applied (200, 38, 148 and 400, 76, 296 ppm N, P and K, in the same order). A computer controlled the irrigation and the fertilization, and the actual amounts were checked periodically.

When the plants had six to eight true leaves (4–6 weeks after planting) they were sprayed to runoff with a spore suspension of *A. dauci* (10^3 or 10^4 spores/ml) by means of an atomizer. The isolate used was obtained from a carrot field and was grown on PDA medium at 20°C under a fluctuating 12-h dark/light regime, before inoculation. Plants sprayed with water served as the non-inoculated control. Soon after inoculation, the plants were covered with polyethylene bags for 24 h to maintain leaf wetness. Disease severity (*i.e.,* the proportion of foliage area infected by Alternaria leaf blight symptoms) was assessed 14 days after inoculation. There were eight replicates (pots) per treatment (fertilization rate

× *A. dauci* inoculation rate). The greenhouse experiments were arranged in a split block design: the fertilization treatment was arranged in the main plots and the inoculation rate in the subplots.

Plants that were not inoculated with *A. dauci* (non-inoculated control) were used for determination of the content of N, P and K in the foliage. The plants were uprooted and washed with distilled water, and the number of plants per pot was recorded. Plants were oven-dried (48 h at 60°C) and their dry weight was recorded. Ion content was determined on 100-mg samples of dried leaves after wet ashing with 2 ml H_2SO_4 (15). N and P contents were determined with a Technicon auto-analyzer and K content with a flame photometer.

Field experiment

An experiment was conducted in the field to evaluate the influence of excess rates of soil fertilization and of fungicide on *A. dauci*. The experiment was conducted in the northern Negev region of Israel, in sandy soil. Carrot seeds were machine planted on 18 July 1997 (the summer cropping). Seeds were planted in three rows (*ca* 80 seeds/m) in beds, with 1.8 m between beds. The crop was irrigated *via* a drip irrigation system (once every 3–4 days) and maintained according to the usual commercial practices. The experiment was conducted in a factorial design and laid out in a split-plot arrangement. Main plots (each 12 × 18 m) were arranged in a completely randomized block design with three treatments and four replicates per treatment. Fallow areas, approximately 6 m wide, separated the main plots from each other. Within each main plot, there were eight subplots (each 2 × 7 m) arranged in a completely randomized design. The factor in the main plot, *i.e.*, irrigation type and fertilization rate, consisted of three treatments: (i) the regular fertilization rate applied *via* sprinklers; (ii) the regular fertilization rate applied *via* a drip irrigation system; and (iii) three times the regular fertilization rate applied *via* a drip irrigation system. In this report, the results of only the two last treatments are presented. The amount of irrigation water (450 m^3/ha/week) was the same in all plots. Fertilizer (Deshen Shaphir 5-3-8, produced by Deshen-Gat, Qiryat Gat, Israel) was applied in the irrigation water. Fertilization in the regular treatment consisted of 10.0 kg N, 2.6 kg P and 13.2 kg K/ha/week, and 30 kg N, 7.8 kg P and 39.6 kg K/ha/week were applied in the triple-rate treatment.

The factor in the subplots was chemical control. There were eight treatments that differed with respect to the type of fungicide used and the timing of spraying. In the present report, results of two treatments are presented: (i) untreated control; and (ii) application of propineb (Antracol, 70% WP, produced by Bayer AG, Germany) at a rate of 1.75 kg a.i./ha. The fungicide (in 260–300 *l* water/ha) was applied by means of a motorized backpack sprayer with cone-jet ×6 nozzles at a pressure of 275 kPa. Spraying was initiated 33 days after planting and continued at 7-day intervals until harvest; eight sprays were applied in total. The fungicides did not contain additional spreader, sticker or adjuvant. Nutrient contents in the leaves were determined once, 73 days after planting. Leaves were collected at random from each experimental plot and analyzed as described above.

Experimental plots were not inoculated artificially with *A. dauci* because inoculum was naturally present at the test site in the form of airborne spores from adjacent fields. Two persons independently assessed the disease visually, and the average scores were recorded. Assessments were made in the two middle rows of each plot every 7–14 days, starting from the appearance of disease symptoms in the field and continuing until the end of the experiment. Disease records were used to calculate the area under the disease progress curve (AUDPC) for each treatment (14). Yield was harvested 96 days after planting from the central row of each experimental plot. The roots were washed and weighed and the yield per ha was calculated. Results were subjected to analysis of variance and where the F values showed significant differences, Fisher's protected least significant difference test was applied at P =0.05.

RESULTS

Greenhouse experiments

Growth of the carrot plants was not influenced by the fertilization treatments. The dry weights of the plants did not differ significantly among the treatments (Table 1) and visual observation revealed no differences in the vigor or the color of the plants (results not shown). Decreasing or increasing the rate of fertilization from the basic rate had differing effects on the response of the plants to the pathogen. Reducing the rate of fertilization by one half resulted in a larger difference in disease severity than did doubling the rate. In the former treatment (half the basic fertilization rate) disease severity was increased by 23–30%; in the latter (double the basic rate), disease severity was decreased by 10–15% (Fig. 1). Similar results were observed in the repeated experiments (results not shown). Inoculating with different concentrations of *A. dauci* spores (10^3 or 10^4 spores/ml) did not alter the response of the plants to the fertilization rate, although significantly higher disease severity was observed in plants inoculated with the higher spore concentration (Fig. 1).

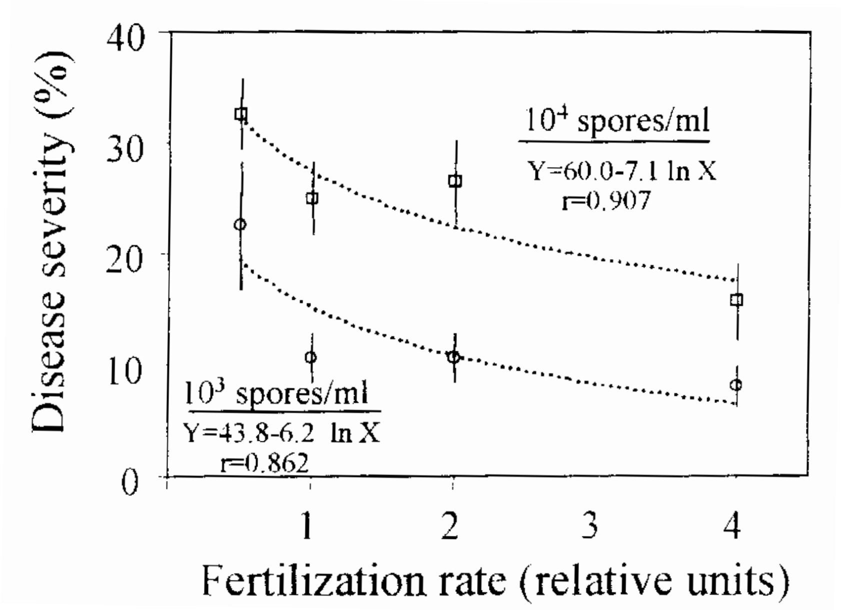

Fig. 1. Effect of fertilization rate on the response of carrot plants to *Alternaria dauci*, the causal agent of Alternaria leaf blight in carrot, in greenhouse experiments. The basic rate (1×) consisted of 100 ppm N, 19 ppm P and 74 ppm K. The fertilizer was incorporated in the irrigation water at the desired rate. Plants were inoculated with two concentrations of *A. dauci* spores. Bars indicate the standard error.

TABLE 1. Dry weight of leaves and the contents of elements in the foliage of carrot plants treated with various rates of fertilizer in the greenhouse experiment

Fertilization rate[z]	Plant dry weight (g)	Elements in plant samples (%)		
		N	P	K
$\frac{1}{2}\times$	0.21±0.03[y]	4.36±0.24	0.59±0.06	5.70±0.58
1×	0.23±0.03	4.54±0.23	0.61±0.06	5.48±0.53
2×	0.22±0.01	5.26±0.23	0.81±0.04	5.78±0.70
4×	0.20±0.01	5.66±0.15	0.82±0.05	5.82±0.30

[z]Relative units of fertilization rate. The basic rate (1×) consisted of 100 ppm N, 19 ppm P and 74 ppm K. The fertilizer was incorporated in the irrigation water at the desired rate.
[y]Means ± standard error.

At the end of the experiment, the dry weight of the plants and the contents of N, P and K in the foliage were determined. The fertilization treatment did not significantly affect the growth of the plants. Of the three elements, increases in the rates of N and P resulted in significantly higher contents of these elements in the foliage. The K content, however, did not change significantly (Table 1).

TABLE 2. Effect of fertilization rate and fungicide application on *Alternaria dauci*, the causal agent of Alternaria leaf blight, and on carrot yield

Fertilization treatment[z]	Spraying treatment	Final disease severity (%)	AUDPC	Yield (t/ha)
Regular rate	Untreated	98.1 a[y]	2289 a	57.0 a
	Treated	28.1 b	507 b	93.2 b
Excess rate	Untreated	94.6 a	2105 a	58.8 a
	Treated	13.7 b	265 b	85.0 b

[z]Fertilization in the regular treatment consisted of 10.0 kg N, 2.6 kg P and 13.2 kg K/ha/week, and 30 kg N, 7.8 kg P and 39.6 kg K/ha/week in the excess fertilization rate treatment. The fungicide propineb (1.75 kg a.i./ha) was applied weekly starting 33 days after planting.
[y]Within each column, numbers followed by the same letter do not differ significantly ($P < 0.05$) according to Fisher's protected least significant difference test.

Field experiment

The first symptom of *A. dauci* in the field was observed 50 days after planting. Within 30 days, the disease in untreated plots had reached a severity of 80% and by the end of the season (94 days after planting) the crop in the untreated plots was devastated. In the fungicide-treated plots, disease severity throughout the entire epidemic, final disease severity and AUDPC values were significantly lower, and yield was significantly higher (increases of 26.2–36.2 t/ha; 30.8–38.8%) than those recorded in the untreated control plots (Fig. 2; Table 2). Tripling the amount of fertilizer did not markedly affect the growth of the plants. At the beginning of the season (up to 50–60 days after planting) plants in the excess fertilization treatment were taller than the others. However, as time passed, differences in growth diminished and beyond 70 days after planting the fertilization treatment did not affect the growth, vigor or color of the plants. The fertilization treatment had a slight, non-significant effect on disease severity toward the end of the season (Fig. 2). Nevertheless, AUDPC values and yields did not differ significantly between the two fertilization treatments (Table 2). Element contents in the foliage of plants fertilized with the excess rate were higher than in plants fertilized with the regular rate; the increases were 15.6% for N, 9.1% for P and 22.2% for K (Table 3).

TABLE 3. Contents of elements in carrot foliage fertilized with two rates of fertilization in the field experiment

Fertilization treatment[z]	Elements in the plant (%)		
	N	P	K
Regular rate	3.20±0.26[y]	0.22±0.01	3.15±0.38
Excess rate	3.70±0.20	0.24±0.02	3.85±0.20

[z] Fertilization in the regular treatment consisted of 10.0 kg N, 2.6 kg P and 13.2 kg K/ha/week, and 30 kg N, 7.8 kg P and 39.6 kg K/ha/week in the excess fertilization rate treatment.
[y] Means±SE.

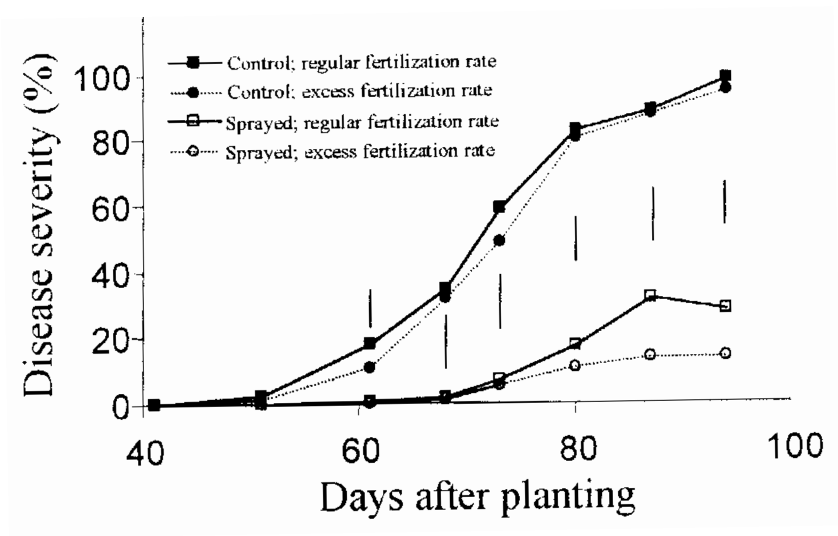

Fig. 2. Effects of fertilization rate and of fungicide application on *Alternaria dauci*, the causal agent of Alternaria leaf blight in carrot, in a field experiment. Fertilization in the regular treatment consisted of 10.0 kg N, 2.6 kg P and 13.2 kg K/ha/week, and of 30 kg N, 7.8 kg P and 39.6 kg K/ha/week in the excess fertilization treatment. The fungicide propineb (1.75 kg a.i./ha) was applied weekly starting 33 days after planting. Bars indicate the least significant difference at $P<0.05$ for each sampling date.

DISCUSSION

The possibility of controlling *Alternaria* diseases by excess application of nitrogen was examined in several studies and met with some success (1,9,16). However, in practice, control of *Alternaria* by adding more nitrogen to the soil is not economically advantageous; the difference between the fertilizer rate for optimal disease suppression and the rate for optimal yield is too large. Other drawbacks to high levels of fertilizers are the hazard to groundwater and, in some crops (*e.g.* potatoes), a reduction in yield quality.

The reason why high levels of nitrogen and potassium reduced Alternaria infection is not fully understood, but several mechanisms have been proposed which may explain this phenomenon. High nitrogen levels are known to prolong plant vigor and to delay maturity, especially when other factors are limiting. Since Alternaria is known to be a pathogen primarily of senescing tissue (13), any factor that delays senescence will also reduce the severity of the disease.

Carrot is an intensive crop in Israel and growers make every possible effort to prevent stresses during the growing season. Accordingly, carrot fields are fertilized at rates optimal for growth, and it is not unusual that fields are fertilized at rates higher than actually needed. The ability of plants to take up large quantities of nutrients from the soil is limited, and the application of excess quantities of fertilizer to the soil does not necessarily result in much higher contents of the elements in the plant tissues. In our greenhouse experiments, N, P and K contents in the leaves in the basic fertilization rate were higher than the levels needed for optimal growth (7). In the field, under the regular fertilization rate, these contents fell within the range sufficient and necessary for growth (7). Application of up to four times the basic rate in the greenhouse experiments and of three times the basic rate in the field experiment, did not increase markedly the content of N, P and K in the foliage. Moreover, the fresh weight of the plants (in the greenhouse) and the yield (in the field) were not increased by that treatment (Tables 1, 2 and 3). Accordingly, application of excess rates of fertilization is not advantageous. However, growers should make every effort possible to prevent nutrient deficit, since stressed plants are more susceptible to *Alternaria* diseases (Fig. 1; refs. 2,5,13).

On the basis of the results of our experiments, it was concluded that excess application of fertilizer is not a practical means to enhance host resistance to *A. dauci* and to reduce disease severity. This conclusion is based on results recorded in the greenhouse (Fig. 1) and in the field (Fig. 2). Although the present study included only one experiment conducted in the field, that experiment corroborated the results observed in the repeated greenhouse experiments. Application of foliar fungicides, on the other hand, had marked effects on both disease and yield (Fig. 2). Therefore, our results agree with MacKenzie's (9) conclusion that crops should be fertilized and maintained for optimum yield and that *Alternaria* should be managed by properly timed applications of fungicides during the growing season.

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REFERENCES

1. Barclay, G.M., Murphy, H.J., Manzer, F.E. and Hutchinson, F.E. (1973) Effects of different rates of nitrogen and phosphorus on early blight in potatoes. *Am. Potato J.* 50:42-48.

2. Goodman, R.N., Kiraly, Z. and Wood, K.R. (1986) The Biochemistry and Physiology of Plant Diseases. University of Missouri Press, Columbia, MO, USA.
3. Harrison, M.D., Livingston, C.H. and Oshima, N. (1965) Epidemiology of early blight in Colorado. Initial infection, disease development and the influences of environmental factors. *Am. Potato J.* 42:279-291.
4. Hillcoks, R.J. and Chindoya, R. (1989) The relationship between Alternaria leaf spot and potassium deficiency causing premature defoliation of cotton. *Plant Pathol.* 38:502-508.
5. Horsfall, J.G. and Heuberger, J.K. (1942) Causes, Effects and Control of Defoliation on Tomatoes. *Conn. Agric. Exp. Stn. Bull. (New Haven)* 456.
6. Jones, J.B. Jr. (1997) Hydroponics. A Practical Guide for Soilless Growers. St. Lucie Press, Boca Raton, FL, USA.
7. Jones, J.B. Jr., Wolf, B. and Milles, H.A. (1991) Plant Analysis Handbook. A Practical Sampling, Preparation, Analysis, and Interpretation Guide. Micro-Macro Publ. Inc., Athens, GA, USA.
8. Langesberg, W.J., Sutton, J.C. and Gillespie, T.J. (1977) Relation of weather variables and periodicities of airborne spores of *Alternaria dauci*. *Phytopathology* 67:879-883.
9. MacKenzie, D.R. (1981) Association of potato early blight, nitrogen fertilizer rate and potato yield. *Plant Dis.* 65:575-577.
10. Miller, J.W. (1969) The effect of soil moisture and plant nutrition on *Cercospora–Alternaria* leaf blight complex of cotton in Missouri. *Phytopathology* 59:767-769.
11. Netzer, D. and Kenneth, R.G. (1969) Persistence and transmission of *Alternaria dauci* (Kühn) Groves & Skolko in the semi-arid conditions of Israel. *Ann. Appl. Biol.* 63:289-294.
12. Rotem, J. (1981) Fungal diseases of potato and tomato in the Negev region. *Plant Dis.* 65:315-318.
13. Rotem, J. (1994) The Genus *Alternaria.* Biology, Epidemiology and Pathogenicity. American Phytopathological Society Press, St. Paul, MN, USA.
14. Shtienberg, D. and Dreishpoun, J. (1991) Suppression of Alternaria leaf spot in Pima cotton by systemic fungicides. *Crop Prot.* 10:381-385.
15. Snell, F.D. and Snell, C.T. (1959) Calorimetric Methods of Analysis. Vol. II. 4th ed. D. Van Nostrand Company, Inc., Princeton, NJ, USA.
16. Soltanpour, P.N. and Harrison, M.D. (1974) Interrelations between nitrogen and phosphorus fertilization and early blight control of potatoes. *Am. Potato J.* 51:1-7.