Effect of Relative Humidity During Mango Growth on the Incidence of Quiescent Infections of *Alternaria alternata*

D. PRUSKY, Department of Fruit and Vegetable Storage, Agricultural Research Organization, The Volcani Center, P.O.B. 6, Bet Dagan, Israel 50250; and Z. GAT and P. BURD, Division of Agricultural Meteorology, Israel Meteorological Service, Bet Dagan 50250

ABSTRACT

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The quiescent infected area of *Alternaria alternata* on mango fruit at harvest was closely related to the number of hours of relative humidity (RH) ≥80% during a 52-day period of fruit development. At least 350 hr of RH ≥80% were needed for a significant quiescent infected area in fruits at harvest. Disease incidence increased as the number of hours of RH ≥80% over 320 increased. In some groves climatic parameters other than RH appeared to affect disease incidence. A map of average daily maximum RH during fruit growth can be used as a basis for predicting the incidence of black spot in Israel.

Alternaria alternata (Fr.:Fr.) Keissl. is the causal organism of the black spot disease of mango fruit (*Mangifera indica* L.) during storage. The pathogen infects the fruit during the growing period and becomes quiescent soon after the initial stages of infection are completed (2,9). After harvest, and as the fruit continue to ripen, the pathogen resumes growth, resulting in an active decay lesion (2). As a result of efforts to prolong the storage life of fruit, quiescent infection of *A. alternata* has become an important factor in the decay of stored fruits in Israel (8,9).

Prusky et al (9) developed a quantitative assessment method for quiescent infections of *A. alternata* before harvest as a basis for the determination of the incidence of postharvest decay during storage. They could quantify the quiescent infected area (QIA) on fruit by determining the percentage of the sampled tissue infected by *Alternaria* and relating it to the surface area of the fruit. The efficiency of this method was tested in two ways: 1) by establishing different levels of QIA in one single grove with different regimes of preharvest fungicide treatment, and 2) by collecting fruit from different groves with natural differences in QIA. In both cases, a positive correlation was observed between the QIA of the fruit at harvest and the incidence of decay during storage (8).

A. alternata is a ubiquitous pathogen present in all mango groves in Israel. It develops saprophytically in the grove on nonliving organic matter and in soil (5).

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Differences in the natural incidence of black spot in Israeli mango can vary by a factor of almost 10 from grove to grove (8). Disease incidence of stored mangoes in different regions of Israel seems to not be directly related to topography and cultural practices (8). Different climatic parameters related to wetness or humidity regime affecting fruit in the grove may account for the differences in the QIA. These parameters include: relative humidity (RH), surface wetness duration, and rainfall (15).

Rainfall has been reported to affect the incidence of quiescent infections of *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz. in mango (1). In Israel, however, mango fruit grow during a period of no rainfall. Dew is not a standard parameter for moisture determination (14), but it has been positively correlated with the development of epidemics of *A. solani* Sorauer in the desert region of Israel (12). Surface wetness duration measurements made at meteorological stations generally do not suffice for management of plant diseases (14). Surface wetness is difficult to measure and has considerable spatial variability (11); regular measurements of this parameter are not conducted in Israel. The most commmonly used climatic parameter that reflects moisture is RH, especially the duration (in hours) at a range of RH or above a certain percentage of RH.

The present research was conducted to uncover the relationship between the RH at critical periods during fruit development and the QIA of the fruit at harvest at different locations where mango is grown. These climatic parameters could explain the variation in the incidence of quiescent infections in different groves and be used for planning postharvest treatments against Alternaria rot on a regional level and selecting new regions for new plantings with low incidence of postharvest Alternaria rot.

MATERIALS AND METHODS

Mango fruit (the cultivar Haden) were used in all the experiments. Mango is grown in the southern desert, the southern coastal plain, the coastal plain, and the inland valleys of Israel (Table 1).

Quiescent infections by *A. alternata* in naturally infected mango fruit were assessed 7–10 days before the commercial harvest, according to the method described by Prusky et al (9). Ten fruit, each from different trees, were selected arbitrarily from 0.3-ha orchards. The harvested fruit were washed thoroughly, and disks of peel and flesh (5 mm in diameter, 4–6 mm thick) were sampled. Disks were removed from six circular zones around the fruit at different distances from the stem end and were surface-sterilized together, as described previously (7). Disks from each fruit were arbitrarily placed, peel side down, in a petri dish containing potato-dextrose agar with thiabendazole (20 μg a.i. ml^{-1}) and incubated at 25 C for 4 days. The QIA was estimated by calculating the product of the percentage of infected disks of the fruit and $W2/3$. The percentage was expressed by values ranging from 0 to 1; $W2/3$ represents the weight of a single fruit, W, transformed into values proportional to its surface area (7).

The RH during the fruit growth period was recorded at regional agrometeorological stations, each representative of one to five experimental groves (Table 1). At each station the number of hours at a range of RH values or above a specific value was determined during 52 days of fruit growth, from 14 June to 7 August, in 1983, 1984, and 1985. These dates represent the main growing period common to most groves in the various localities in Israel. The analysis was based on weekly charts of thermohygrographs (Lambrecht, Germany). The hourly RH data were assigned to five groups: RH 75–79%, RH 80–84%, RH ≥75%, RH ≥80%, and RH ≥85%. The length of the period with RH 75–79%, 80–85%, ≥75%, ≥80%, and ≥85% at each meteorological station was compared to the average QIA of fruit from groves located close to the stations of that region utilizing Minitab analysis systems. Slopes of the regression lines were compared with an analysis of variance. The level of significance reported herein is $P = 0.05$ (*); probabilities of >0.05 were considered not significant.

The average daily maximum RH for the month of July based on the last 20 yr was plotted on a map of Israel in order to identify the highly humid regions during the key month of mango fruit development. This climatic parameter was selected because RH observations are routinely checked, processed, and analyzed (4). On a basis of 20 years' observations, "normals" have been calculated for all stations and were used in this map. Data were available from stations and regions that represent the different agricultural locations of the country. Isolines representing 70, 75, 80, 85, and 90% RH were superimposed on the map.

RESULTS

Relationship between duration of RH above specific values and the quiescent *Alternaria*-infected area. The regression equations relating the length of the RH period for each RH class and the QIA were as follows: RH 75–79%, $y = 55.5 - 0.399x$, ($R^2 = 0.12$); RH 80–84%, $y = 18.1 - 0.007x$, ($R^2 = 0.001$); RH ≥75%, $y = -34.5 + 0.0876x$ ($R^2 = 0.69$); RH ≥80%, $y = 27.3 + 0.09x$, ($R^2 = 0.74$), and for RH ≥85%, $y = -10.1 + 0.078x$ ($R^2 = 0.65$), where x = hours of RH and y = QIA. Only R^2s for RH ≥75% and RH ≥80% were significant at $P = 0.05$. The slope values of regression equations for RH ≥75% and RH ≥80% did not differ significantly. Given these results, the equation for RH ≥80% was selected for use because it explained the greatest amount of the variation in the data.

Relationship between number of hours with RH ≥80% and the incidence of quiescent *Alternaria* infections. The incidence of QIA was closely related to the number of hours with RH ≥80% (Table 2). QIA was not recorded on fruit from the southern desert's Yotvata meteorological station during the 3 yr of observation; the number of hours with RH ≥80% during the period of fruit growth ranged between 12 and 17. When the number of hours with RH ≥80% reached 350, QIA was not observed on fruit from groves located close to the meteorological stations of Masada and Tirat Zevi. QIA was initially observed in fruit in other groves with at least 350 hr of RH ≥80%. As the number of hours of RH ≥80% increased above 350, the incidence of QIA increased as well, except for in the groves of the southern coastal plain located close to the Havat haBesor meteorological station (Fig. 1). The incidence of QIA in this region is very high, considering the intermediate level of hours with RH ≥80%, 354 hr. When the groves of the southern coastal plain were included in the regression analysis, the regression coefficient was only $r = 0.55$ ($n = 18$). This coefficient is lower than that obtained when the regression excluded groves located close

Table 1. Mango production regions in Israel and their corresponding meteorological stations

Region	Meteorological station	Sites of mango groves
Southern desert	Yotvata	Semer
		Elot
		Qetura
Southern coastal plain	Havat haBesor	Gevulot
		Nir Yizhaq
		Ze'elim
		Mivtahim
Coastal plain	En haHoresh	Mishmar haSharon
		Ma'barot
		Bet Herut
		Kefar Yona
		Kefar Hess
	Bet Dagan	Gan Rashel
		Kefar haYaroq
	Lod	Nir Eliyyahu
Inland valleys	Masada	En Gev
	Tirat Zevi	Kefar Ruppin

Table 2. Hours of relative humidity (RH) ≥80% during mango growth and the incidence of quiescent infection (QIA) of *Alternaria alternata* at harvest in different groves in Israel

Meteorological station	Grove	1983 RH[a] (hr)	1983 QIA[b] (cm^2)	1984 RH (hr)	1984 QIA (cm^2)	1985 RH (hr)	1985 QIA (cm^2)
En haHoresh	Mishmar haSharon	654	14	628	21	602	39
	Ma'barot		37		38		38
	Bet Herut		32		40		33
	Kefar Yona		14		21		38
	Kefar Hess		15		20		32
Bet Dagan	Gan Rashel	488	7	493	10	499	27
	Kefar haYaroq		9		9		20
Lod	Nir Eliyyahu	563	16	465	19	515	28
Havat haBesor	Gevulot	341	26	354	42	429	40
	Nir Yizhaq		27		36		34
	Ze'elim		36		38		43
	Mivtahim		34		42		36
Masada	En Gev	279	0	344	0	354	0
Tirat Zevi	Kefar Ruppin	220	0	255	0	295	0
Yotvata	Semer	12	0	17	0	17	0
	Elot		0		0		0
	Qetura		0		0		0

[a]RH = number of hours with relative humidity ≥80% during the period from 14 June to 7 August of each year.
[b]QIA = average quiescent infected area for 10 fruits (in cm^2), sampled 7–10 days before harvest. SD ranged between 1 and 9% of the mean.

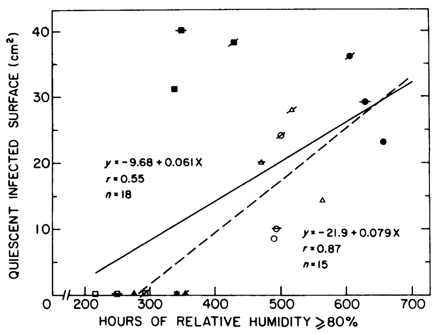

Fig. 1. Correlation between the number of hours with RH ≥80% and quiescent infected area (QIA) at harvest during 1983–1985. Number of hours with RH ≥80% was obtained from local meteorological stations, and QIA is the average infected area of three to eight groves located close to the meteorological station. — = Data obtained from groves in the vicinity of the meteorological stations at En haHoresh (●), Bet Dagan (○), Lod (△), Masada (▲), Tirat Zevi (□), and Havat haBesor (■). Groves close to these six meteorological stations were sampled during three different years, $n = 18$. - - - - = Data obtained from groves close to five meteorological stations, sampled during three different years, $n = 15$; groves located close to the Havat haBesor meteorological station (Gevulot, Nir Yizhaq, Ze'elim and Mivtahim) are not presented. Plain symbols indicate results obtained during 1983; — on symbols indicates results obtained during 1984; and / indicates results obtained during 1985.

to the Havat haBesor meteorological station ($r = 0.87$, $n = 15$) (Fig. 1).

Relationship between the average daily maximum RH in July and the incidence of QIA. The standard deviation of the maximal RH values during 20 summers was less than 1 or 2% (results not shown). Fruit from areas with ≥85% RH and, specifically, ≥90% RH, were significantly affected by the quiescent infections (Fig. 2). Fruit from areas covered by isolines of 80% RH and below did not show any incidence of QIA.

DISCUSSION

Black rot of mango caused by *A. alternata* has been increasingly reported as a postharvest disease during fruit storage. The fungus causes symptoms similar to those produced by *C. gloeosporioides* (1). Differences in disease incidence of stored mangoes in various regions of Israel reflect the incidence of QIA on fruit from those locations (8). *Alternaria* infection is heavily dependent on moisture (10,11). Except for powdery mildews and some wound pathogens, a film of free moisture on the host surface is essential for infection by most pathogens (3,12). In this study, the RH obtained in regional meteorological stations was compared to the incidence of QIA of *A. alternata* in adjacent mango orchards. The relationship between RH and QIA under field conditions was not determined, since RH was measured in a meteorological station and not on the fruit. However, a significant positive correlation exists between values of the maximal RH in the orchards and the meteorological station (6). Measurements of the maximal RH in a meteorological station and in an adjacent orchard in the coastal plain showed differences between the values ranging from 1 to 4% (6).

When the number of hours with RH 75–79%, 80–84%, ≥75%, ≥80%, and ≥85% from most of the groves in Israel was compared with the QIA of fruit, the regression equation that included RH ≥80% explained the greatest amount of variation in the data ($R^2 = 0.74$). It is not clear why the number of hours with RH over 80% was better predictor of QIA than the number of hours with RH over 85%. Night temperatures during mango growth are sufficiently high (20–25 C) for infection to occur (4). Under these conditions several hours of marginal RH of 80–85% may facilitate the development of the epidemic (12). Because *Alternaria* spores are extremely resistant to heat and desiccation, they are able to utilize dew for germination and initiate infection at night, permitting infection to occur under short wet periods interrupted by dry periods (12,13). *Alternaria* in mango needed at least 350 hr of RH ≥80% during the fruit-growing period to show a significant QIA. As the number of hours over 350 increased, there was an increase in the QIA. In the most humid locations, in the coastal plain, with 620 hr of RH ≥80%, the average QIA was 29 cm^2. Less humid locations in the same region, with only 493 humid hours, had a QIA of 14 cm^2. In the inland valleys, with 326 hr of RH ≥80%, disease was not detected.

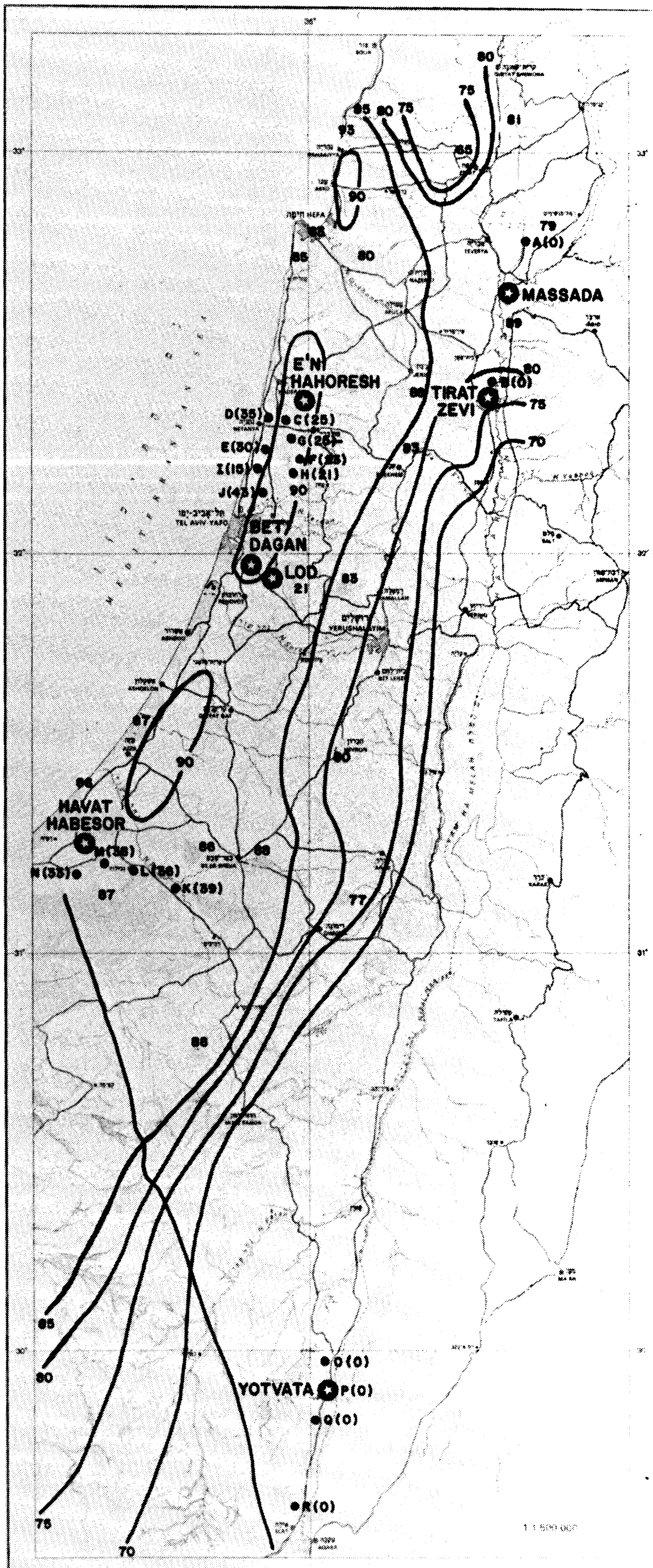

Fig. 2. Isolines of average daily maximum RH in July and average QIA of *Alternaria alternata* at harvest in various groves throughout Israel: A = En Gedi, B = Kefar Ruppin, C = Mishmar haSharon, D = Bet Herut, E = Ma'barot, F = Kefar Hess, G = Kefar Yona, H = Nir Eliyyahu, I = Gan Rashel, J = Kefar haYaroq, K = Ze'elim, L = Gevulot, M = Mivtahim, N = Nir Yizhaq, O = Qetura, P = Yotvata, Q = Semer, R = Elot. RH values are the average of maximum values during 20 yr. The QIA values are the average of evaluations in three different years in each grove. The isolines denote the regions of similar RH values.

The southern coastal plain, represented by the meteorological station of Havat haBesor, averages only 375 hr with RH ≥80%, representing only 60% of the hours of RH ≥80% in the most humid areas, but groves had 30% more QIA. In those groves an additional parameter appears to affect disease incidence. In this region, *A. alternata* infections could be significantly enhanced by winds and sandstorms coming from the desert. The groves in the southern coastal plain are located only 10–40 km from the desert. Rotem (10) reported that tomato plants exposed to sandstorms had twice the amount of wounds on the leaves, compared with nonexposed plants. The observations of Rotem and co-workers on epidemics of *Alternaria* in potato suggests that infection is enhanced by the presence of wounds caused by the winds occurring in the afternoon in the southern coastal plain (10,11,14).

The average daily maximum RH is a standard measurement in meterological stations. The duration of a certain RH value is not, however, routinely measured. Our intention was to develop a simple index that might correlate with the disease incidence of mango fruit at harvest. For that reason, a map of the daily average maximum RH for July—the main month of fruit development in Israel—in various regions was used to determine the potential for disease incidence. The regions with the greatest potential for disease are located close to the isolines of 85–90%; no-risk regions (low potential) in the dry area, <70% RH; and intermediate regions, between 75 and 80% RH. The availability of such a map, together with a local QIA evaluation prior to harvest, should be of help in determining the need for postharvest treatment of the fruit and for locating potential new sites for safe mango production.

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