Joseph Rotem
Volcani Center, Agricultural Research Organization, Bet Dagan, and Bar Ilan University, Ramat Gan, Israel

Fungal Diseases of Potato and Tomato in the Negev Desert

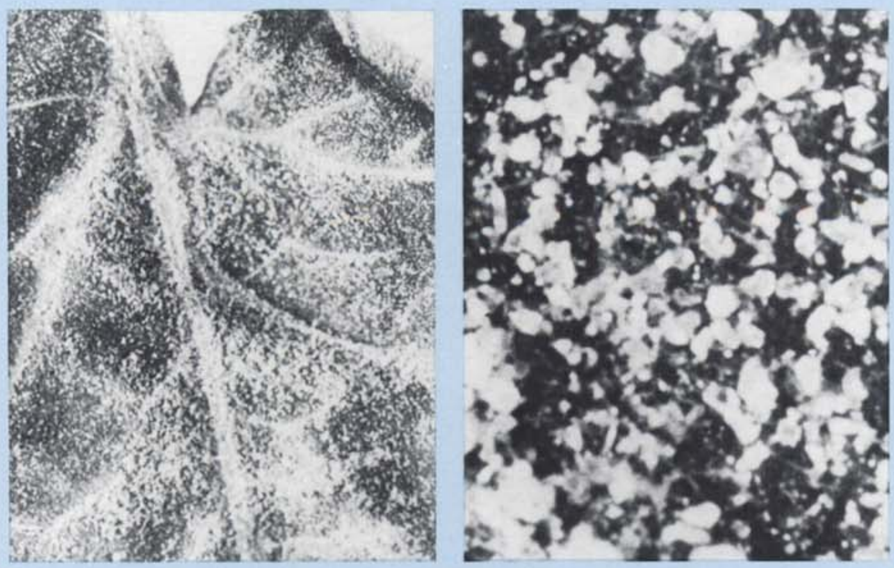

Fig. 1. (Left) Tomato leaf after a strong sandstorm in the Negev. (Right) Close-up of leaf.

To some people in temperate zones where plant diseases are established, the lack of abundant rainfall in hot, arid zones suggests that foliar plant diseases are also lacking. This impression is only partly true in completely arid sites and is erroneous in areas with some form of moisture—dew, fog, or rain—during specific seasons. In some arid areas, disease pressure results from irrigating and from large plantings of high-yield but susceptible cultivars. This happens in temperate zones, too, but is more striking in arid zones where diseases have been scarce.

Pathogens that become important in hot, arid areas are "selected out" by the prevalent environmental conditions. Some—*Alternaria solani*, for example—benefit from specific elements of the desert climate, such as drought and sandstorms. Others, including *Stemphylium* spp., are not favored by the elements but are not markedly inhibited, either. Still others, such as *Phytophthora infestans*, lack a clear adaptation to desert conditions but can develop and spread rapidly when unusual humidity replaces aridity for a short time. Although no special ecologic races of these pathogens have been found in the desert, environmental hazards are overcome differently than in temperate zones. The phenomenon of compensation is apparently responsible for the successful development of some diseases in arid areas (1,9).

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Conditions in the Negev

The Negev is about 5,000 square miles of desert in southern Israel and is part of the huge desert area almost encircling the globe in the tropical and subtropical latitudes. Annual rainfall in the central and southern Negev is 1–2 in., and agriculture is confined to several oases where drainage or fossil water allows limited irrigation.

The northern and northwestern margins of the Negev are affected somewhat by the Mediterranean weather regime, and the dry spring, summer, and autumn seasons are slightly cooler (usually less than 35 C maximum) than those in other parts of the desert. During the short winter, the 100–150 mm of unpredictable showers is not enough for intensive agriculture. Recently, however, irrigation with water brought from the north has turned the region into, among other things, a major area for growing winter vegetables.

When seaborne winds prevail, minimum to maximum temperatures are usually 9–25 C and relative humidities, 20–85%. When desert winds blow, however, the temperature may exceed 40 C and the relative humidity drops below 10%. Sandstorms often accompany these hot, dry conditions.

Dew is abundant. During the winter, 35% of the nights have more than 10 hours of dew, 42% have less, and 23% are dewless (13). Of special interest are the prolonged periods (14 hours or longer) of dewfall for several nights after a sandstorm that has lasted several days. These sandstorms sometimes cause visible damage to foliage (Fig. 1) but usually make small, invisible wounds (7). The sequence of strong winds, sandstorms, and dewfall has extraordinary epidemiologic significance (6–8,13).

Disease Development Criteria

Few fungal diseases occur in the completely arid oases of the central and southern Negev, but some viral, a few bacterial, and several fungal foliar diseases affect potato and tomato along the desert's border. I will describe only the fungal. Three criteria seem to enable some diseases to succeed and others to fail in the hostile conditions of the desert: 1) weather events clearly suiting the pathogen, 2) factors making the host more susceptible to a disease under local conditions, and 3) features helping a pathogen withstand local conditions of danger (Table 1).

Potatoes are not grown in the oases of the central and southern Negev. In tomatoes, the only disease of some economic importance is powdery mildew caused by *Leveillula taurica* (Lev.) Arn., a pathogen recently appearing in the United States. The arid conditions in the oases suit the pathogen, but the host does not seem more susceptible than in humid areas and oidia survival is adversely affected by dryness. Therefore, *L. taurica* causes rather light damage.

The lack of dew in the arid oases prevents development of pathogens requiring moisture for infection and sporulation. Nevertheless, Alternaria early blight or Stemphylium blight lesions are found occasionally. In several instances, Phytophthora late blight,

Fig. 2. Multiple early blight lesions incited by *Alternaria solani* on a tomato leaf about 10 days after a sandstorm.

apparently introduced with seedlings from a northern nursery, has spread slowly inside infected plants without sporulating and spreading to neighboring plants.

To exploit every day of the cooler season and every piece of irrigated land along the desert's border, new plots are continuously sown near old, diseased ones. This practice secures the presence of inoculum during the growing season for pathogens tolerant of the low daytime humidity and occasional lack of dew. The inoculum gradually disappears in spring with the end of the potato- and tomato-growing season. To oversummer, a pathogen needs high tolerance to heat and dryness. Some pathogens are reintroduced annually by inoculum from areas with a less severe climate.

Alternaria Early Blight

Alternaria solani Sorauer is the main disease of potato and tomato and the one best adjusted to the conditions of the northern and northwestern Negev. Epidemics exceed those described for other parts of the world. In Israel, epidemic intensity and frequency decrease gradually with distance from the desert to the Mediterranean climatic zone. The decrease is associated with fewer and weaker sandstorms and with intensification of summer cropping.

Even in the midst of infection, plants in the Negev remain practically healthy until a certain age (4). Aging plants gradually become more infected, but disease spread is slow. For example, in one test in the Negev, disease incidence of neighboring potato plants 50, 75, and 90 days old was 0, 15, and 62%, respectively.

Almost every old field of potatoes is ultimately destroyed by early blight, but tuber infection is practically nonexistent. In contrast to potatoes, tomatoes are susceptible to early blight for a short time during the seedling stage; in a neglected nursery, nearly every seedling may have Alternaria collar rot. Destruction of old tomato plants by early blight is assisted by yellow top virus and several other fungal diseases. Tomato fruit is occasionally infected with *A. tenuis* and *A. solani*; *A. tenuis*, a weak pathogen, also infects foliage wounded by sandstorms (7).

All three criteria are fulfilled for development of *A. solani* along the borders of the Negev. The dew periods permit medium to strong infection within a single night. Sporulation requires one wet night for formation of conidiophores

Table 1. Factors affecting potato and tomato disease development along the borders of the Negev

Pathogen	Host and method of cultivation	Factors affecting host or microclimate	Factors favoring pathogen	Factors inhibiting pathogen	Pathogen adaptation	Epidemics
Alternaria solani	Potato and tomato in the open	Sandstorms increase host susceptibility	Dewy nights combined with sunny, windy, dry days favor infection, sporulation, and dispersal; dry summers favor oversummering	Few, if any	Mycelium and spores are highly resistant to heat and drought	Constant, severe
Stemphylium spp.	Tomato in the open	None	As for *A. solani*, but no factor is optimal	No factor is clearly inhibiting	Mycelium and spores are moderately resistant to heat and drought	Common, moderate
Leveillula taurica	Tomato in the open	None	Dry days (and in completely arid oases, dry nights) favor disease development	Heat and drought reduce survivability of oidia	Ability to develop in dryness is high but so is susceptibility of oidia	Common, mild
Phytophthora infestans	Tomato, trellised and well aerated, in the open	None	Dewy nights favor infection and sporulation	Heat and drought kill sporangia	Little, if any	Rare
	Potato in the open	Lush growth contributes to humid microclimate	Dewy nights favor infection and sporulation; improved microclimate may protect sensitive sporangia	Heat and drought have less pronounced effects than on well-aerated tomato	Little, if any	Occasional, mild to severe
	Tomato in humid glasshouses	Lush growth contributes to humid microclimate	Water condensation during night favors infection and sporulation	Entry of inoculum is difficult	Little, if any	Occasional, severe
Botrytis cinerea	Tomato in the open	Not investigated	Not investigated	Not investigated	Not investigated	Absent
	Tomato under screen canopy	Not investigated	Not investigated	Not investigated	Not investigated	Severe

and another for formation of conidia, with a dry, sunny day between to induce conidiophores to produce conidia (3). Because dewfall is abundant, lack of rain does not impair disease development. Similarly, sprinkling, usually for 3–4 hours once a week, contributes little when dew is present about 77% of the nights. Dispersal of the well-attached, robust spores is facilitated by strong winds and dryness during the day. Dispersal rates are highest during sandstorms (6,7), which wound the leaf tissue and create a convenient port of entry for *A. solani* (Fig. 2).

The sequence of increased dispersal of spores during sandstorms, increased susceptibility of foliage damaged by such storms, and increased dewfall after the storm allows early blight to reach an intensity greater than in most other places. The mycelia and spores of *A. solani* are almost unaffected by the hottest and driest conditions in nature. In fact, the pathogen survives better in dry conditions than in humid ones. As a result, oversummering of *A. solani* in debris is better in the hot, dry, and (in the summer) often uncultivated light soil of the Negev than in cooler, frequently irrigated, and heavier soils (8).

Fungicides seem to have less effect on *A. solani* in the Negev than in other areas. Materials recommended elsewhere reduce foliar infection of potatoes and tomatoes by 20% at most, and their effect on yield is not clear. Because inoculum buildup is slow, however, disease does not become destructive until late in the life of the field. Inoculum buildup is slow because 1) young and middle-aged plants have low susceptibility to infection, 2) the number of spores produced by *A. solani* is generally small, and 3) spores are produced mostly on dying or dead leaves (11).

Because high prices are obtained for the vegetables, winter cropping of tomatoes and potatoes remains profitable despite reduced yields caused by early blight epidemics.

Stemphylium Blight

The second most important disease of tomatoes in the margins of the Negev, Stemphylium blight is usually caused by *S. botryosum* f. sp. *lycopersici* R., C. & W., and sometimes by *S. solani* Weber and *S. floridanum* Hannon & Weber. Because the three pathogens are not easily distinguishable and their occurrence is mixed, the term "*Stemphylium* complex" has been suggested (10).

Conditions in the Negev are neither more nor less advantageous for Stemphylium blight than are conditions in more humid areas. The dew periods (up to 14 hours) are too short for completion of infection and sporulation. The pathogen, however, is able to complete these processes during several dew periods interrupted by dry periods (2,3).

Fig. 3. Tomato plants grown under a canopy of plastic screens.

Sandstorms do not increase susceptibility of tomato plants to Stemphylium blight, and the pathogen is not helped to oversummer by dry periods. Apparently, the chief reason for *Stemphylium* spp. in the Negev is the widespread and continuous presence of their host.

Stemphylium spp. (at least the dominant *S. botryosum* f. sp. *lycopersici*) are difficult to control with fungicides; defoliation is delayed by several weeks and infection rate is lowered by 25%, at most. Because inoculum buildup is slow, however, domage is not heavy during most of the growing season. Even though sensitivity of tomato plants to *S. botryosum* f. sp. *lycopersici* decreases with age, the disease peaks on aging, less susceptible plants, when inoculum becomes abundant. Inoculum buildup is slow because of the low number of spores produced per unit of an infected area and of the preference to sporulate on dying or dead leaves (10,11).

Leveillula Powdery Mildew

Because *Leveillula taurica's* life cycle is best suited to dry conditions (5), the dry days, scarcity of rain, and relatively high winter temperatures along the borders of the Negev favor the pathogen's development. This is offset, however, by the dewy nights and use of sprinkler irrigation. Specific conditions in the Negev do not increase susceptibility of tomato to Leveillula powdery mildew, and, although common, the disease is mild and easy to control.

Phytophthora Late Blight

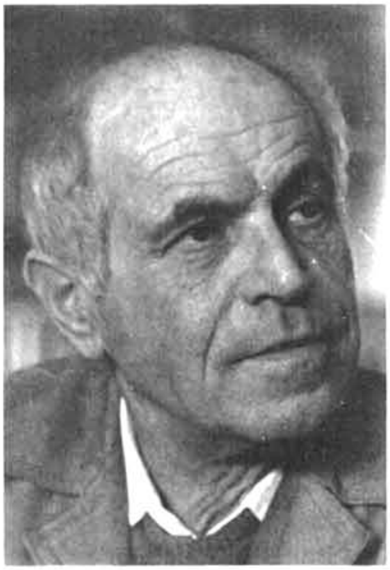
Long dew periods and relatively high night temperatures during the winter favor infection and sporulation of *Phytophthora infestans* (Mont.) de Bary along the edges of the Negev. The sporangia, however, are susceptible to dryness and cannot survive the day and infect plants at night without special microclimatic conditions and/or unusual rainy periods. The environmental and cultural conditions of the Negev do not increase susceptibility of potato and tomato plants to late blight but do promote lush growth, with all the microclimatic consequences. Well-aerated, trellised tomatoes are rarely infected with late blight, but densely planted, untrellised, poorly aerated tomatoes grown for canning are occasionally infected, especially those in areas close to the sea. Even though microclimatic phenomena are more pronounced in potato plants, epidemics occur only after rare and especially favorable weather, such as rain, and when farmers do not know how to fight the uncommon disease. Late blight epidemics in potatoes gradually increase in intensity and frequency from the desert to the Mediterranean climatic zone. The patterns are the opposite of those of early blight, and the two diseases rarely, if ever, cause epidemics at the same time in the same location.

Overhead irrigation may enhance *P. infestans*'s chances for success, but not in well-aerated fields under normal conditions of dryness (12). Nevertheless, late blight can cause major damage to potatoes when all the appropriate conditions coincide—rain, sprinkler irrigation, microclimate, and poorly timed control practices.

Diseases in Protected Crops

Although winter tomatoes are successfully grown in the open, the practice of protecting crops with different kinds of glass or plastic houses, tunnels, or screens is spreading rapidly, with heavy investment for producing the highest possible yields.

Phytophthora late blight has the potential to become a major destructive



Joseph Rotem

Dr. Rotem is head of a research team at the Volcani Center, Agricultural Research Organization, Bet Dagan, and professor at Bar Ilan University, Ramat Gan, Israel. He received his M.S.Agr. degree in 1955 and his Ph.D. in 1961, both from the Hebrew University of Jerusalem. Most of his studies deal with effects of semiarid and arid environmental conditions on plant diseases.

factor in tomato culture in glasshouses. The densely planted, optimally irrigated and fertilized plants grow over 2 m tall and create a humid microclimate. Unless the temperature is extreme, farmers do not ventilate the glasshouses during the day, thereby retaining as much heat as possible for the colder night. Despite this, the temperature drop during the night may result in water condensation on leaves. These conditions are almost ideal for pathogens clearly favored by humidity and able to produce large quantities of spores. Because *L. taurica* is not favored by humidity and *Alternaria* and *Stemphylium* do not produce large quantities of spores, they cause only occasional lesions and hardly any losses. *P. infestans* fits both requirements but apparently has difficulty entering glasshouses and is absent from most. When a focus of infection becomes established, however, disease can spread rapidly and destroy the crop despite the most intensive control measures.

The *Botrytis* Disaster

The search for ways to improve desert agriculture led to an outbreak of *Botrytis cinerea* Pers. ex. Fr. in tomatoes. This pathogen was rare in the Negev until the practice was started of growing tomatoes under a canopy of plastic screens suspended about 2 m over large plots (Fig. 3). The screens decreased the amount of intense desert radiation and provided some protection from sandstorms. Tomatoes planted in autumn (the best time) lived until spring, when prices are highest. The screen-protected plants had larger, more succulent leaves than plants grown in the open, and fruit was more attractive, although softer. Temperature differences between the screened and nonscreened foliage were negligible. Dew periods tended to start about 2 hours later under the screen than in the open but also lasted about 2 hours longer.

B. cinerea appeared about 2 years after tomato culture under screens was started and became a major killer within 2 years. Whole plots were destroyed and the practice was abandoned, before serious research had started on how the disease developed under desert conditions.

The desert is still one of the least understood habitats in plant pathology. Its agricultural potential is being explored continuously. Each new crop introduced and each new method practiced carries the potential danger of an overlooked disease. The *Botrytis* experience illustrates our ignorance of what can happen—and may happen again. The future dangers remain real.

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