Comments on the Zero-Tolerance Quarantine of Karnal Bunt of Wheat

Karnal bunt or partial bunt of wheat, caused by *Tilletia indica* Mitra, was first reported from India in 1931 (6). The disease was subsequently found in Iran, Mexico, Nepal, Pakistan, and the United States, and kernels with *T. indica* teliospores were intercepted in wheat grain produced in Afghanistan and Iraq (4,7).

According to the Wheat Disease Subpart of Foreign Quarantine Notice (7 CFR 319.59) of the United States, which was established in 1981, entry of wheat grain from any country where Karnal bunt is known (countries included at that time were Afghanistan, India, Iraq, and Pakistan) was prohibited (7). In 1982, kernels infected with *T. indica* were intercepted in wheat grain imported from Mexico into the United States. Following confirmation of Karnal bunt in the Mexican state of Sonora, the USDA Animal and Plant Health Inspection Service (APHIS) prohibited importation of seed, grain, straw, and dried plants of wheat, durum, and triticale from Mexico. In 1983, Mexico was permanently added to the list of the Wheat Disease Subpart of Quarantine 319 (7).

Following establishment of the zero-tolerance level of Karnal bunt in the United States, most of the countries in the world established similar quarantine regulations (2,4). Implementation of the zero-tolerance quarantine adversely affected trade of wheat grain and limited exchange of materials among wheat research programs. After the discovery of wheat grain with *T. indica* teliospores in the southwestern United States in 1996 (2), several surveys and research studies were carried out to investigate the importance of Karnal bunt (1,2). Also, the importance of the disease was discussed in national and international meetings (5). As a result, much was learned about Karnal bunt. The following are some comments on the importance of Karnal bunt and the effectiveness of the zero-tolerance quarantine in controlling the disease.

Geographical distribution. Karnal bunt has officially been acknowledged in only six countries (India, Iran, Mexico, Nepal, Pakistan, and the United States). Its presence is suspected in two other countries (Afghanistan and Iraq). For the following reasons, the geographical distribution of Karnal bunt may be wider than is currently known. (i) The only host known for *T. indica* is wheat. The fungus may be present in several Middle Eastern countries considered the center of wheat evolution. For example, after careful examination of

wheat grain, Karnal bunt was found in Iran in 1996 (4). (ii) The incidence of the disease is very low in fields. Only a few kernels of each spike are infected, and usually a small part of the infected kernel is replaced by the fungal spores (2,9). As a result, it is very difficult to notice infected kernels in the field. (iii) Determination of the presence of Karnal bunt in an area may not be possible without laboratory studies. Also, for accurate laboratory studies, proper sampling of grain and use of sensitive tests is essential (7). For example, without proper surveys and sensitive tests, determination of the presence of *T. indica* in Iran in 1996 (4) and the existence of *Tilletia walkeri*, the causal agent of the ryegrass bunt, in the United States in 1996 (3) would have been impossible. (iv) For economic reasons, the occurrence of Karnal bunt may not be acknowledged by some countries, even if the presence of the disease is determined.

Spread of the pathogen. Karnal bunt of wheat is a monocyclic disease. *T. indica* is a soilborne, seedborne, and airborne pathogen (2,9). Teliospores of the fungus in the soil, left on the soil at harvest, or carried into the soil on seed germinate and produce sporidia (1,2,9). Sporidia are blown onto wheat plants, where they germinate, fuse to produce dikaryotic hyphae, and infect kernels. Infection occurs during the 2- to 3-week period coinciding with flowering and requires high relative humidity or several rainy days (9).

Teliospores of *T. indica* can survive for more than 3 years in soil (9). Wind, flowing water, and agricultural machinery can move contaminated soil from one place to another. Establishment of a zero-tolerance quarantine cannot prevent the spread of *T. indica* teliospores by wind or water. Bonde et al. (2) contend that *T. indica* teliospores are carried high into the atmosphere in Sonora, Mexico, when wheat stubble is burned, where they could be carried north into the United States. The zero-tolerance quarantine against Mexico was established in 1983. Karnal bunt was found in the southwestern United States (Arizona, California, New Mexico, and Texas), bordering the infested area in Mexico, in 1996. The pathogen was likely carried from Mexico into the United States by air currents.

T. indica teliospores can be introduced to new areas in infested grain. Prohibiting movement of wheat grain from infested areas to noninfested areas by establishing a zero-tolerance quarantine appears to be

scientifically sound. However, careful evaluation of the following facts indicates that establishment of the zero-tolerance regulation cannot prevent the spread of *T. indica*. These facts are as follows: (i) Prior to establishment of the zero-tolerance regulation in 1981, there was less restriction in moving wheat grain and seed in the world. Consequently, *T. indica* teliospores probably spread throughout the wheat growing areas of the world on wheat grain or seed. (ii) Karnal bunt has occurred in experimental plots of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico since 1972. CIMMYT distributed advanced line nursery materials to wheat breeders throughout the world (including 19 states in the United States) for approximately three decades. Also, many wheat breeders used winter increase programs in Sonora, Mexico, until 1984. Thus, teliospores of *T. indica* were probably carried from CIMMYT to most wheat growing regions of the world during the period of 1972 to 1984. (iii) In addition to the legal movement of grain through regulated border-posts, there is a constant unregulated flow of wheat grain between neighboring countries (e.g., ethnic groups living on both sides of the border of the neighboring countries often exchange commodities without observing the official regulations). Importation of contaminated grain from Mexico might have been another method of introduction of the pathogen into the United States, in addition to spores carried across the border by wind.

It has been reported that teliospores of *T. indica* adhere to vehicles, fabrics, and bodies of animals and people. The teliospores also remain viable after passing through the digestive system of animals. Therefore, *T. indica* teliospores can be carried from infested areas to noninfested areas by automobiles, trains, aircraft, animals (birds, insects, etc.), and people (including visiting scientists).

In order to have infection in a plant, sporidia of *T. indica* must be carried from the soil surface onto the plant by the wind. There is no information available to indicate the maximum distance between the site of sporidia production and site of kernel infection. The sporidia may be carried long distances, particularly in moist conditions, crossing the borders of neighboring provinces, states, or countries, and initiate the disease in new areas.

Importance of Karnal bunt. Research indicates that Karnal bunt is not a threat-

ening disease for wheat production in the world (4,8,9). Although Karnal bunt was diagnosed in India in 1930, in the past 70 years its presence has been confirmed in only a few localized wheat growing areas in the world. In spite of the possibilities of spread of the pathogen to other wheat growing areas in the world, it appears that development of the disease is severely limited by environmental conditions.

T. indica may have been introduced into 19 states in the United States in wheat nursery materials during 1972 to 1984. However, Karnal bunt has only been found in four states with environmental conditions similar to those of Sonora, Mexico. This may indicate that Karnal bunt would only occur in areas with special environmental conditions, as has also been reported from India and Pakistan (9).

Yield losses to Karnal bunt have been reported to average less than 1% (4,9). In addition, genes for resistance to *T. indica* have been identified, and resistant lines and cultivars of wheat are available (8).

Costs of zero-tolerance quarantine. Implementation of a zero-tolerance regulation on Karnal bunt is costly. It requires a large number of trained personnel and considerable funding. The zero-tolerance policy adversely affects grain trade in the world, which may gradually be translated into higher cost of wheat for consumers. Also, the zero-tolerance quarantine has restricted research on Karnal bunt, particularly development of effective control methods and wheat improvement. Prior to 1984, research on Karnal bunt in the

United States was not prohibited (e.g., *T. indica* was extensively studied at Washington State University). But since 1984, research on Karnal bunt has been limited to the studies carried out in the containment facilities of USDA in Ft. Detrick, MD. Moreover, the zero-tolerance regulation has interfered with other research on wheat by restricting access to germ plasm and use of off-season nurseries in Mexico.

Conclusions. The following conclusions are drawn from the above discussion. (i) The exact worldwide geographical distribution of Karnal bunt is not known and can only be determined from an international survey using a standardized protocol. (ii) Due to the effects of environmental conditions on disease development, establishment of Karnal bunt in the world appears to be limited. (iii) Karnal bunt is not a threatening disease for wheat production. It does not cause significant yield losses, and with proper disease management practices, the yield losses to Karnal bunt could be negligible. (iv) Establishment of a zero-tolerance quarantine is unlikely to prevent the spread of *T. indica*. (v) Implementation of the zero-tolerance quarantine on Karnal bunt is not a cost-effective method for control of the disease, and it should be abolished.

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