

Potato Late Blight (*Phytophthora infestans*) Situation in Asia with Special Reference to China

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Late blight is widespread in most Asian potato growing countries. It ranges from the tropics to temperate regions and occurs in wet seasons or in cool mountain areas. It has also become the main disease threatening potato production all over China, especially in humid Southwest China after a countrywide outbreak in the early 1950's. Since then, practical and basic work on epidemiology, race identification, chemical control and preliminary genetic engineering of pathogen resistance has been carried out. In collaboration with and supported by the International Potato Center (CIP), research on evaluation and large scale extension of resistant clones/varieties (such as CFK69.1, I-1085 and S88), pathology of races and mating types (A1/A2), and genotype x environment (GxE) interactions on the expression of late blight resistance and variation is on-going. Relevant future perspectives are discussed.

The potato (*Solanum tuberosum* L.) is a relatively new crop compared with the other major crops in Asia. It was introduced into China over 300 years ago (Hawkes, 1992) and was rapidly distributed to nearly every corner of the country in this century (Ye, 1987). The annual cultivated area, estimated at 3 million (FAO, 1992) to 3.2 million ha (Anonymous, 1995), is over 50% of the total potato growing area in Asia. Late blight is one of the most important diseases threatening potato

production, especially in Southwest China, where potato production accounts for about 40% of the country's total growing area, and in the humid North (Song and Wang, 1993; Wang, 1994; He and Struik, 1998).

Potato late blight caused by the pathogen *Phytophthora infestans* is widespread in nearly all Asian potato-growing countries, ranging from the tropics to temperate regions. It occurs especially in wet seasons or in cool mountain areas and results in substantial yield loss (c.f. Fry et al., 1993; Ganga et al., 1994; Singh et al., 1991; Khan et al., 1994; Koh et al., 1994; Sastrosiswojo, 1994; Song and Wang, 1993; Zhang and Song, 1993; Shrestha, 1999, personal communication). Priority in disease management has been primarily given to selection and use of resistant varieties, as well as application of fungicides (including systemic Ridomil—metalaxyl— or contact Dithane M-45). However, due to fast breakdown of host resistance to the pathogen (because of Major genes in the host or pathogen resistance to fungicides), it is more difficult to manage the disease. In addition, social and economic factors plus environmental considerations complicate the issue in Asia.

In China, severe late blight first broke out in the early 1950's. Since the early 1990's, the epidemic has become more widespread and continuously severe, despite the use of previously resistant cultivars such as Mira, the main cultivar in Southwest China. Almost all of the previously resistant cultivars have lost resistance to the disease. Over the last five years, the effects of chemical sprays, including Ridomil (metalaxyl), have also been reduced due to resistance of the pathogen. Tuber yield loss is widely estimated to be from 20% to 80%.

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In 1952, Lin Chuanguang and others started research work on late blight epidemiology. Their work addressed disease due to seed infection and spread of the disease, and prediction and control of the disease based on climatic conditions (Zhang and Song, 1993). Their results and integrated disease controls (rouging out core diseased plants and use of chemical sprays) were successfully disseminated to farmers (Zhang and Song, 1993).

Identification, distribution and variation of the races of the pathogen *Phytophthora infestans* was consequently carried out in the North by Lin, Huang, Zhang, Li and others from the 1960's to the 1980's. This provided information necessary for breeding resistant varieties. Major races were identified as 00, 0, 1, 4, 1.4, 2.4, and 1.3.4, with race 4 being dominant (Zhang and Song, 1993). Unfortunately, social factors brought this work to an end.

In the meantime, priority was given to chemical application to control the disease. Several chemical fungicides were identified as effective: metalaxyl (Ridomil), especially with the addition of Mn and Zn; Bordeaux mixture; copper sulfate mixture; and lime. The efficacy of these chemicals matched results from their use elsewhere.

Laboratory work has resulted in the expression of late blight resistance in transgenic potato plants through the introduction of Harpin_{Ea} and Osmotin genes (Li et al., 1997). After years of work, clones were regenerated from fused protoplasts of dihaploid *Solanum tuberosum* and diploid *S. phureja* or *S. chacoense*, using the somatic hybrid method (Dai et al., 1994; Si Huaijun and Dai Chaoxi, 1997). The pathogen's biology has also been systematically researched (cf. Li, 1988; 1984).

Through the CIP-China project (1986-1998) a large amount of germplasm (clones and TPS) has been introduced from CIP and evaluated for late blight resistance. Many promising clones and varieties, especially CFK69.1, I-1085 and S88, have been identified or selected from CIP germplasm or CIP-introduced TPS. These have shown high late blight resistance as well as other good agronomic characteristics compared to controls in Yunnan, Hubei and Sichuan provinces in Southwest China (Wang et al., 1990; Hu et al., 1994). Several have entered official multi-regional trials and have been put into a seed production program to accelerate multiplication for farmers' use, especially in Yunnan. Some of them have also been used as parental lines to breed late blight resistance (Wang et al.; 1990; Hu et al., 1994).

There is growing concern about the A2 mating type since its discovery in Western Europe in the mid-1980's.

This concern stems from the fact that when A1 and A2 exist in the same location, they mate sexually and produce hard-hulled oospores that can survive in the soil for prolonged periods (CIP, 1996a). Consequently, new aggressive strains of the disease can form more quickly. It is believed that the new A2 genotype with metalaxyl resistance appears to be displacing the resident A1 genotype in Korea (Koh et al., 1994). Both A1 and A2 mating types have been found in India and in Nepal, with various polyploids and genetic diversity (Shrestha, personal communication). This will make potato production more difficult in the developing world, where farmers often lack cash to buy chemicals and where potatoes are helping to meet future food challenges (CIP, 1996a). The earliest finding of the A2 as well as A1 in (northern) China was reported in 1996, and the characteristics of oogonium, antheridium and oospore were described (Zhang et al., 1996). A2 was also recently found in Yunnan in South China (unpublished, Zhang et al). A2 was previously thought to exist in China up to 1990 (CIP, 1996a). Further research on races, distribution (including Southwest China), frequency, mating efficiency, resistance to metalaxyl, and survivability of the A2 oospore is under way.

In a Line X Tester experiment conducted in 1998, significant differences of late blight foliage damage and yield components in two contrasting environments (Sichuan and Yunnan in humid Southwest China) were found between the treatments (crosses and controls). Several crosses were identified as highly or moderately resistant to the disease in comparison with the controls. The population was derived from resistance gene-free germplasm and crosses, hence the resistance is horizontal. Also, significant positive correlation was found between the treatments with and without chemical control of the disease, indicating strong genetic resistance of the populations. The fungicide Ridomil (metalaxyl) still has apparent effects on reducing the disease and therefore promoting yield. It was also found that there were significant differences of the variation (standard deviation) between the crosses in the mid- and late stage of growth when applied with or without fungicide. Furthermore, the combined analysis of the two locations indicated that there were significant interactions of genotype and environment (GxE) both for late blight resistance and tuber yield. This would indicate multigenic effects expressed in host resistance. The general and specific ability to combine late blight resistance and yield for each family/cross will be assessed.

Late blight is the main potato disease in China, especially in the southwest. In North China, where temperatures are cooler and the climate is generally

drier than in Southwest China, viruses show more symptoms and late blight is relatively suppressed. Yield losses in the north can therefore be attributed equally to both viruses and late blight, in addition to other yield-limiting factors.

There is an urgent need for national and international programs to bridge gaps between the pathological aspects and genetic (hence breeding) methods in order to develop durable host genetic (non-specific, multi-genic, horizontal or field) resistance rather than vertical (major-genic) resistance to the pathogen *Phytophthora infestans* (Landeo, 1993; CIP, 1996b). Development of R gene-free populations would reduce the interference of resistance genes in breeding for high levels of horizontal resistance against *Phytophthora infestans* and simplify the breeding process. This is CIP's top priority. (Landeo, 1993).

Preliminary achievements in genetic engineering indicate a promising future for late blight resistance. There is, however, a great deal of work to be done, especially in linking conventional breeding with agronomy. Closer cooperation in projects, increased communication, and more training may play a key role.

Integrated disease management (IDM) based on available and new agronomic practices such as crop rotation, intercropping, dehauling prior to harvest, and use of resistant varieties must be developed. CIP plays a leading role in combating late blight worldwide. We expect fruitful achievements from the comprehensive research and extension work being done within this large-scale, cooperative network (CIP, 1996a).

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