# HOST-PLANT RESISTANCE TO DISEASES : PROBLEMS, PROGRESS AND FUTURE NEEDS

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## ABSTRACT

**There has been considerable change in the plant disease situation in India during the last few decades. This is because of changes in agricultural systems from traditional, subsistence farming to modern, improved practices such as introduction of new crop cultivars, intensive cropping, increasing use of chemical fertilizers and fungicides, and use of genetically uniform, high-yielding cultivars in commercial farming. These changes have led to increased severity of rusts, smut, Karnal bunt, and scab in wheat; blast, bacterial blight and tungro virus in rice; leaf blight in maize; downy mildew and ergot in pearl millet; downy mildew in sunflower; grain mold in sorghum; bacterial blight and wilt in cotton; fusarium wilts in pigeonpea and chickpea; scab in apple; and wilt in coconut. Host-plant resistance (HPR) offers a highly effective means of managing diseases in crop plants. HPR has been successfully used to contain losses from rusts in wheat, blast and bacterial blight in rice, downy mildew in pearl millet, wilts in pigeonpea and chickpea and several other diseases. Genetic diversification,development, and deployment of cultivars with stable/durable resistance in diverse agro-ecological zones of India is strategic to disease management through HPR. A proper understanding of the genetics and mechanism of host-pathogen interaction, and disease epidemiology is essential to the development of a suitable resistance breeding strategy. It is desirable, although often difficult, to combine resistances to more than one disease in a single cultivar in order to prolong the life of the cultivar. Integration of HPR with other disease management practices, such as cultural, chemical, and biological control measures are more effective and economical in a sustainable crop production system.**

## INTRODUCTION

Host-plant resistance (HPR) provides the most efficient, economical and ecologically sustainable method of managing diseases in crop plants. HPR works on the principle that, in nature, resistance is the rule and susceptibility an exception. Management of plant diseases through HPR is a continuing, dynamic process with changes in crop cultivars, introduction of alien crop species, and changing farming practices. The major advantages of disease management with HPR as a major component are: compatibility with other crop management practices such as fertilizer use, irrigation, etc.; environmental safety (HPR can avoid or reduce the use of chemicals fungicides); ecological sustainability (it does not drastically influence the ecosystem); and economic viability (it does not involve extra cost to farmers).

Literature on the use of HPR in disease management is quite extensive and is well documented (Nelson, 1978; Buddenhagen, 1983; Johnson, 1984; Singh, 1986; Robinson, 1987; and Simmonds, 1991). Resistance has generally been classified as vertical or monogenic; horizontal or polygenic; host-specific and host nonspecific; partial or complete; and stable and/or durable (Nelson, 1978; Parlevliet, 1979; Johnson, 1984; Vanderplank, 1984). A strategy for disease management through HPR can be developed depending on the nature of host-pathogen interaction (Nelson, 1973; Buddenhagen, 1983; Simmonds, 1983, Singh, 1986; Simmonds 1991).

Disease management through HPR consists of three main components: i) selection of sources of genetic resistance; ii) utilization of resistance, and iii) deployment of resistance. A thorough understanding of each of these components in relation to a given host-pathogen system is

imperative to the successful use of HPR in disease management. Selection of sources of genetic resistance requires knowledge of the pathogen biology, disease epidemiology, field and green house screening techniques, proper disease evaluation system, access to a large germplasm collection, and proper field, laboratory and greenhouse facilities.

Resistance utilization is a joint venture between pathologists and breeders, and requires an understanding of the genetics and mechanisms of resistance. Development of a proper breeding strategy is crucial for the effective utilization of resistance. In a practical resistance breeding programme, two aspects must be carefully considered. How much resistance is really needed for the potential ecological target, and how much durability is needed for the level of satisfactory resistance? According to Buddenhagen (1983), the essential steps for a practical breeding program are: ecosystem and farming system analysis, pathosystem analysis, choice of selection site, analysis of germplasm base, selection of parental lines, recombination, screening method, and the development of new varieties.

Simmonds (1983) provided a thoughtful review on the strategy of disease resistance breeding in crop plants. Resistance in different host-pathogen interactions can be expressed as: i) nonspecific major gene resistance (NR); ii) vertical resistance (VR) which is specific and confers with gene-for-gene relationship; iii) horizontal resistance (HR) which is usually polygenic and pathotype nonspecific like NR; and iv) interaction resistance (IR) that is effective in heterogenous populations, such as multiline and varietal mixture. An appropriate breeding strategy can then be developed to incorporate resistance in a cultivar (Fig. 1).

Resistance deployment is the final process of releasing disease- resistant cultivars in a particular agroecosystem where all kinds of adaptation factors need to be carefully considered. Depending on the success of each step, it could take 5-10 years in the initial stages, to generate basic information leading to the release of a disease- resistant cultivar. After a cultivar has been accepted by farmers, it should be supported by a strong disease-monitoring system. A strong resistance breeding programme should always be ready to replace the cultivar with new resistance genes whenever there is an indication of the occurrence of a new virulence type or increased aggressiveness in the pathogen.

## DISEASE PROBLEMS

Thirty years ago, plant diseases were not regarded as major constraints to crop production in India. However, with the increasing population and the consequent pressure on food, Indian agriculture moved into a new era during the 1960s and traditional farming practices were slowly replaced with modern crop production systems. These included: introduction of exotic genetic material, cultivars with changed plant architecture (mainly dwarf), high-tillering plants, increasing use of chemical fertilizers, intensive cropping systems, use of chemical pesticides, and growing improved cultivars such as hybrids with a narrow genetic base. The "green revolution" trans formed Indian agriculture and the food production increased substantially to sustain the growing population. The rate of food production has not kept pace with the population growth and we are again striving for yet another revolution through a sustainable agricultural system.

During the past few decades, there has been a considerable change in disease situation on different crops because of the changes in farming systems and rapid genetic enhancement of crops. Disease severity has increased in many cases, and in some cases,

epidemics have occurred resulting in substantial yield losses. Examples are increased severity of blast (*Pyricularia oryzae* Cav.), bacterial blight (*Xanthomonas campestris* pv. *oryzae* Uyeda & Ishi., Dow), and tungro virus in rice; rusts (*Puccinia recondita* f.sp. *tritici* Rob. ex Desm., *P. striiformis* West., *P. graminis* f.sp. *tritici* Eriks & Henn.), Karnal bunt (*Neovossia indica*), loose smut (*Ustilago nuda* Jens. Rostr.), and more recently scab (*Fusarium* sp.) in wheat; leaf blight (*Exserohilum turcicum* (Pass) Leonard & Suggs) in maize; grain molds (several fungi) in sorghum; downy mildew (*Sclerospora graminicola* (Sacc.) Schroet), ergot (*Claviceps fusiformis* Loveless), and smut (*Tolyposporium penicillariae* Bref.) in pearl millet; wilt (*Fusarium udum* Butler) and sterility mosaic in pigeonpea; wilt (*F. oxysporum f.sp. ciceri* (Padw.) Snyd. & Hans.) and ascochyta blight (*Aschochyta rabiei* (Pass.) Labr.) in chickpea; scab (*Venturia inaequalis* (Cooke) Wint.) in apple, and many others.

India is enriched with a diversity of crops in a wide range of agroecological zones, and plant disease problems are also diverse. In a recently published bulletin on the relative importance of crop pests in South Asia, Geddes and Iles (1991) have divided the Indian Resource Development Regions into 15 cropping system zones and in each zone economically important crops (10% or more production value) have been identified (Geddes & Eles, 1991). Rice, wheat, maize, sorghum, pearl millet, groundnut, pigeonpea, chickpea, sugarcane, potato, cotton, jute, rape/mustard, tea, coffee, coconut, cassava, and cardamom are economically important crops in these zones. Based on the importance of crops, 28 diseases on 16 crops may be considered as major problems of national importance (Table 1). This can form a reasonable basis of prioritizing disease management research efforts at the national level.

**Table 1. Major diseases of important crops in India**

| Crop | Diseases |
|---|---|
| Rice | Blast, bacterial leaf blight and tungro |
| Wheat | Rusts, loose smut and Karnal bunt |
| Maize | Leaf blight and downy mildew |
| Sorghum | Grain mold, anthracnose and charcoal rot |
| Pearl millet | Downy mildew, ergot and smut |
| Groundnut | Leaf spots and rust |
| Chickpea | Fusarium wilt and Ascochyta blight |
| Pigeonpea | Fusarium wilt and sterility mosaic |
| Cotton | Black arm and wilt |
| Sugarcane | Red rot and smut |
| Potato | Late blight and virus diseases |
| Tea | Blister blight |
| Coffee | Rust |
| Coconut | Wilt (Kerala wilt) |
| Apple | Scab |
| Mango | Mango malformation |

Introduction of new crop species or crop varieties from one region to another within the country or from outside (Table 2) has also added to the plant disease problems (Joshi, 1989). Recent reports of yield losses due to introduced diseases in different parts of the country include sunflower downy mildew (*Plasmopara halstedii* (Forl.) Berl & de Toni) in Maharashtra, bunchy top

of banana in Tamil Nadu, and apple scab in Himachal Pradesh (Nagarajan, 1991).

**Table 2. Introduction of plant diseases**

| Disease | Introduced from | Year |
|---|---|---|
| Coffee rust (*Hemilia vastatrix* (Berk. and Br.) | Sri Lanka | 1879 |
| Fire blight of pear and pomes (*Erwinia amylovora* (Burrill) Bergey et al.) | England | 1940 |
| Late blight of potato (*Phytophthora infestans* (Mont.) de Bary) | Europe | 1883 |
| Flag smut of wheat (*Urocystis tritici* (Preuses) Schroet.) | Australia | 1954 |
| Black rot of crucifers (*Xanthomonas campestris* (Pammel) Dowson) | Holland | 1950 |
| Bunchy top of banana | Sri Lanka | 1940 |
| Wart of potato (*Synchytrium endobioticum* (Schilb.) Perc.) | Holland | 1950 |
| Golden nematode (*Hetrodera rostochinensis* (Wollenweber) | Nilgiri Hills | 1961 |
| Apple scab (*Venturia inaequalis* (Cooke) Wint.) | J & K to HP | 1970 |

Source: Joshi, N C. 1989.

## PROGRESS MADE

A systematic research on disease management through HPR started with the establishment of the All India Coordinated Crop Improvement Projects (AICCIP) by the Indian Council of Agricultural Research (ICAR) in the mid 1960s. This led to a significant outcome which was evident in the late 1960s and the early 1970s. For example, pearl millet hybrid HB 3 which was released in the late 1960s, increased pearl millet grain production from 3 to 8 million tonnes by the late 1960s. Unfortunately, it became highly susceptible to downy mildew in 1971-1972 and production declined substantially (Singh *et al.*, 1987). With the excellent collaborative efforts of pathologists and breeders, new hybrids, such as BJ 104 and BK 560 were released in the mid 1970s and these contained the disease for the next 5-6 years. Subsequently, BJ 104 and BK 560 also became susceptible in the early 1980s, and BJ 104 was finally withdrawn from cultivation. BK 560, however, still continues to be grown in some parts of the country. Several new hybrids (ICMH 451, ICMH 501, ICMH 423) and open- pollinated varieties (ICMV 1, ICMV 4, ICMV 155) resistant to downy

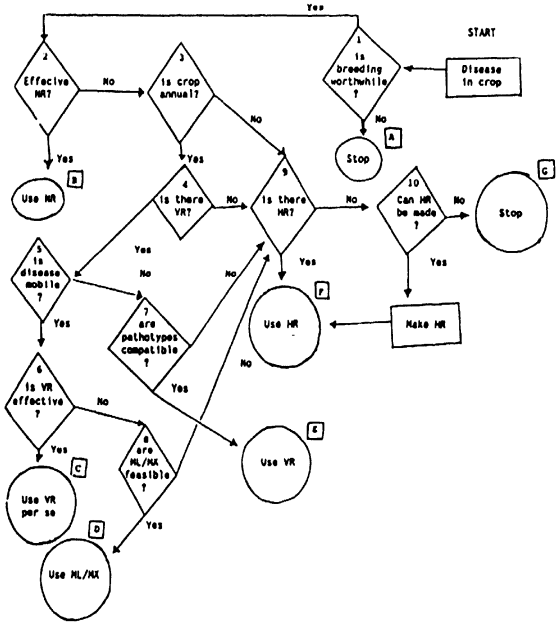


**Figure 1. Strategy of disease resistance breeding**

NR = Non-specific major gene resistance - due to a major gene or cytoplasmic factor resistance to all forms of pathogen.

VR = Vertical resistance due to major gene(s) - resistance to specific genotype, gene-for-gene relationship.

HR = Horizontal resistance - polygenic, pathotype-nonspecific (like NR).

IR = Interaction resistance - resistance in multilines (ML) and varietal mixture (MX) (Simonds, 1983).

mildew, have since been released to counter the downy mildew men ace.

Disease management through HPR received a further boost with the establishment of ICRISAT Center in Hyderabad. At present, several sources of resistance and disease-resistant cultivars of pearl millet, sorghum, groundnut, chickpea, and pigeonpea are available in India (ICRISAT, 1985-89). Close collaboration of AICCIPs with other International Agricultural Research Centers (IARCs), such as International Rice Research Institute (IRRI) for rice, Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) for maize and wheat, International Institute of Tropical Agriculture (IITA) for cowpeas, Centro Internacional de la Papa (CIP) for potato, etc., has helped strengthen the HPR program in the country in various crops. In addition, private seed industries have played a major role through their Research and Development programs in utilizing resistance sources in breeding programs and releasing disease-resistant cultivars.

Other cases of the successful management of diseases through HPR include blast in rice (Reddy *et al.*, 1986), bacterial blight in rice (Goel *et al.*, 1988), rusts in wheat (Singh *et al.*, 1990a), loose smut in wheat (Aujla *et al.*, 1990), leaf blight in maize (Sharma and Payak, 1990), downy mildew in pearl millet (Singh *et al.*, 1990b), leaf spots and rust in groundnut (Subrahamanyam *et al.*, 1990), fusarium wilt in chickpea (Haware et al., 1990) and in pigeonpea (Nene, 1988), sterility mosaic in pigeonpea (Reddy *et al.*, 1989), bacterial blight in cotton (Verma, 1986), etc. In addition, there are good sources for multiple disease resistance available in legumes (Nene, 1988), pearl millet (Thakur *et al.*, 1988), sorghum (Anahosur *et al.*, 1990), and in several other crops.

## FUTURE NEEDS

Although some of the major crop diseases have been managed success fully through HPR and these will continue to be managed, there are several other diseases which have not been managed so well through HPR. These are: Karnal bunt in wheat, grain mold in sorghum, ergot in pearl millet, ascochyta blight in chickpea, new wilt in cotton (unknown etiology), red rot in sugarcane (*Glomerella tucumanensis* (Speg.) Arx & Muller), blister blight in tea (*Exobasidium vexans* Massee), rust in coffee (*Hemileia vastatrix* Berk. & Br.), coconut wilt (unconfirmed etiology), apple scab, mango malformation (unconfirmed etiology), etc. For these diseases, more concerted effort is required to understand the etiology, basic factors related to pathogen biology, epidemiology, screening techniques, nature and mechanism of gene action, and finally developing strategies for breeding resistant cultivars. In cases where HPR alone is not the answer, integration of other methods, such as cultural, biological, chemical, etc. should be encouraged.

During the past decade, significant advances have been made in the application of genetics and biotechnology in plant disease management. These advances include the transformation of plants with useful genes for crop protection, namely Bt gene into cotton and the mapping of host resistance genes with restriction fragment length polymorphisms (RFLPs) and random amplified ploymorphic DNAs (RAPDs), using polymerase chain reaction (PCR) technique. These tech nologies permit the selection for and introduction of unique resistance motifs into particular hosts. Similar advances have been made in determining variability in populations of plant pathogens. Use of multi-locus probes has been successful in characterizing populations of rice blast fungus (Levy *et al.*, 1991) and sorghum downy mildew pathogens (Yao *et al.*, 1991). One of the most difficult areas to evaluate deployment of host resistance has been the method of sampling pathogen populations for their variabilty. Through DNA technology, it has become

relatively easy to determine pathogen variability. DNA can easily be transported without being subjected to quarantine regulations, and RFLPs, PCR/RAPDs of pathogen can be associated with specific virulence traits and these techniques can be routinely used for both host and pathogen populations. Understanding genetic structures of the host and the pathogen would help in strengthening our breeding approach and cultivar deployment in different agroecological zones.

Tissue culture is another good technique to isolate and generate resistant plants but the success with field crops has been very limit ed. Molecular techniques are relatively expensive in the initial stages for a developing nation like India to try these on a large scale across a spectrum of plant diseases. However, a modest beginning has already been made with the establishment of Biotech Centers, and some excellent work is in progress.

With the current level of knowledge and resources available, I am optimistic that plant pathologists, in collaboration with scientists from other disciplines, will be able to manage diseases of major crops and help sustain the production of crop cultivars in India.

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