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# Durable Resistance of Crops to Disease

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## Introduction

Plant diseases caused by pathogenic fungi, oomycetes, bacteria, viruses, and nematodes cause huge yield losses annually. A recent survey showed that crop losses caused by pathogens and pests worldwide range from 10.1% to 28.1% in wheat (*Triticum aestivum*), 24.6% to 40.9% in rice (*Oryza sativa*), 19.5% to 41.1% in maize (*Zea mays*), 8.1% to 21.0% in potato (*Solanum tuberosum*), and 11.0% to 32.4% in soybean (*Glycine max*) (Savary *et al.,* 2019; Schultink *et al.,* 2017). The development of highly resistant cultivars is an economical and eco-friendly alternative to expensive and environmentally harmful chemical controls. Plant breeders have relied on the use of single dominant or recessive resistance (R) genes because of their strong effects and ease of selection. It is also called as qualitative resistance. Most R genes confer race-specific or qualitative resistance against a single or few pathogen strains; however, mutations and virulence shifts in pathogen populations make the effectiveness of these race-specific R genes short-lived (Li *et al.,* 2020).

Given the circumstances, a new gene for resistance is incorporated into new cultivars, if it is available on time. By repeating this process at frequent intervals, new cultivars with different resistant genes replace varieties that have become susceptible (Tapiero, 1999). The limited durability of qualitative resistance is a major problem in plant breeding for pathogen resistance. Thus, quantitative resistance has gained interest in recent years to address the major challenge of genetic resistance durability. Several genes usually control quantitative resistance and are associated with genomic regions or QTL (quantitative trait loci) (Pilet-Nayel *et al.,* 2017). Quantitative resistance (QR) is the foundation of breeding for disease resistance in crops, especially to achieve durable resistance, yet it remains poorly understood in comparison to the well studied gene-for-gene recognition process (Cowger and Brown, 2019). It is therefore important to deploy new resistance genes in such a way that the useful

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life is as long as possible.Moreover combining major R genes with QTL in crops can maintain the effectiveness of plant resistance to pathogens. Combining resistance QTL with complementary modes of action appears to be an interesting strategy for breeding effective and potentially durable resistance. Combining quantitative resistance with major R genes has proven to be a valuable approach for extending the effectiveness of major genes (Pilet-Nayel *et al.*, 2017).

**Resistance**

It is the ability of the host to hinder the growth of the pathogen.Historically, two categories of disease resistance have been recognized in plants: qualitative and quantitative resistance.

**1. Qualitative resistance:**Qualitative resistance is genetically controlled by major genes, which provide phenotypically complete or incomplete resistance to the pathogen. It is also known as vertical, hypersensitive, complete, non-durable, seedling, race specific, major gene, mono or oligo-genic resistance, unstable.

**2. Quantitative resistance:**Several genes usually control quantitative resistance and are associated with genomic regions or QTL (quantitative trait loci) which contribute, each with variable effect, to the phenotype of resistance to a pathogen. It is also known as race non-specific, partial, durable, slow rusting, horizontal, slow mildewing, minor gene, polygenic resistance, field resistance, adult plant resistance.

**Durable Resistance…?**

Johnson (1961) defined durable disease resistance in plants as a resistance that remain effective while a cultivar possessing it is widely cultivated. The durability of a disease resistance gene can be measured by the time required for the selection of pathogen genotypes overcoming the resistance and thereby rendering the resistance gene ineffective. Durability of resistance is desirable because it reduces the risk that cultivars with superior yield, quality, or agronomy will become susceptible to an important pathogen. It minimizes unplanned expenditure on crop protection, reduces the risk of crop failures in subsistence farming, and helps to ensure stability of food supplies. Durable resistance need not be complete; moderate but reliable resistance is often useful to breeders and farmers (Brown, 2015).

1. **Why We Need Durable Resistance:**
    - Erosion of qualitative and quantitative **resistance** by pathogen isolates was also observed under natural conditions.

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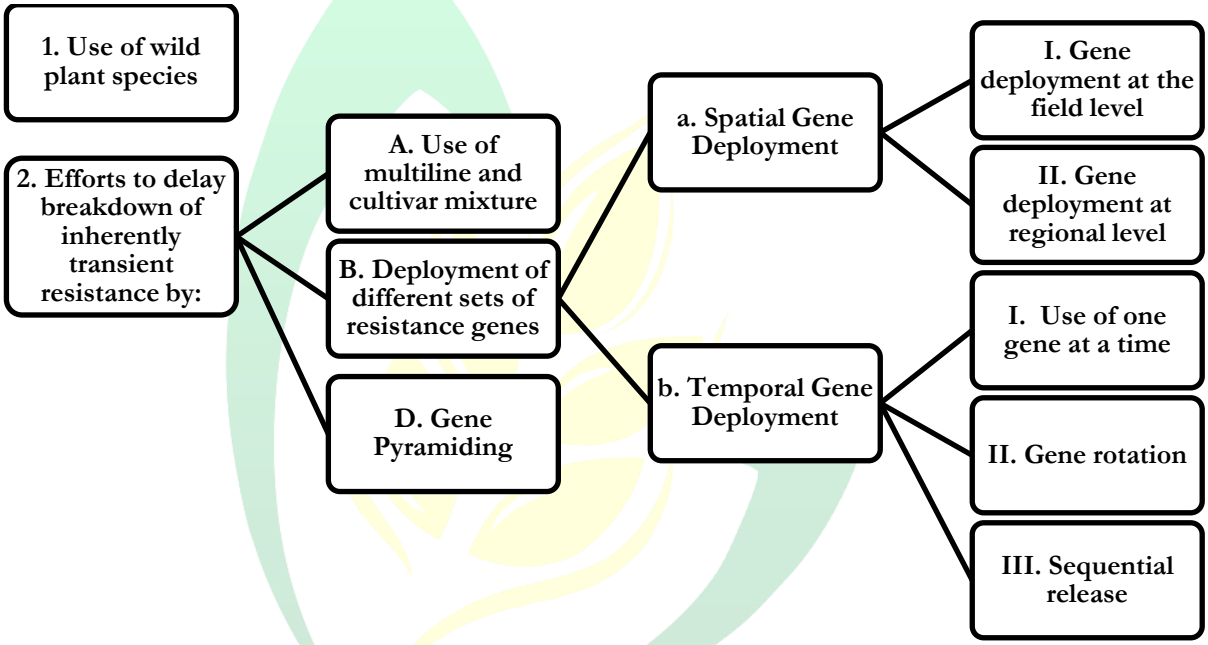
- It may be due to pathogen adaptation, owing to yearly **sexual recombination**, secretion of effectors, unusually large effective population size, **sexual crosses**, **local adaptation**, and **gene flow**.
- It would enable selection for more **virulent** types within the pathogen population.
- Durable resistance is helpful in preventing epidemics and yield losses.

**Increasing the Durability of Resistance Genes to Crop Pathogens**




1. **Use of Wild Plant Species:**
    a. The use of wild relatives of cultivated crops as sources of resistance in crop breeding programs.
    b. Monogenic, race-specific resistance, polygenic, partial resistance is also commonly found in wild plant species in their natural habitats (Browning, 1974)
    c. Quantitative resistance expressed in the adult plant stage to leaf rust, *Puccinia triticina*, in wild emmer wheat, *Triticum dicoccoides* was quite common at several sites in Israel (Anikster *et al.*, 2005).

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2. **Efforts to Delay Breakdown of Inherently Transient Resistance**

**A. Use of Multiline and Cultivar Mixture:** Cultivar mixtures are quicker and cheaper to formulate and modify, enhance guaranteed economic returns, decrease in input costs on chemical pesticides without causing major changes to the agricultural production system. Multiline crop cultivars are phenotypically similar (height, grain type) but genetically different against insect pests and diseases (Browning and Frey 1981). It reduce the **incidence** and severity of the diseases, It reduces the aggressiveness on individual host lines, It also reduce the selection pressure on the pathogen population and increase the durability.

**B. Deployment of Different Sets of Resistance Genes:** The pattern of deployment of disease resistance genes in the field is a major factor affecting their **durability** of resistance genes. Gene deployment is the guided distribution of genes in space and time.Gould divided the gene deployment strategies in to two broad categories as:

a. Spatial Gene Deployment
b. Temporal Gene Deployment

**a. Spatial Gene Deployment**

**I. Gene deployment at the field level:**

- It can be done over a small geographic region such as within a single field.
- If a cultivar consists of individual plants that differ from each other in their resistance, resultant heterogeneous plant population should reduce the rate of epidemic development
- reductions in dispersal of the pathogen
- e.g. late blight in potato, Bouws and Finckh 2008; Ascochyta blight in peas, Schoeny *et al.*, 2010

**II. Gene deployment at the regional level:**

- A system of assigning specific resistance genes to a specific geographic area to control disease.
- It control the pathogens that disperse long distances over well-defined pathways

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- This was exploited by Vanderplank (1963) for the control of crown rust of Oats (*Puccinia coronata)* in U.S.A, cereal rusts in the United States (Fig F)

**b. Temporal Gene Deployment**

**I. One Gene at a Time**

- Resistance is more likely to be durable in environments less conducive to the pathogen (Johnson, 1992).

**II. Gene Rotation:**

- Replacement with a different gene after appearance of a virulent race.
- Each R-gene is deployed over a limited number of years or area.
- and is withdrawn before the corresponding virulence allele achieves a high frequency in the pathogen.

**III. Sequential Release:**

- Where by each variety is used until populations reach the breakdown population level and is immediately replaced by another variety.

**D. Gene Pyramiding:**

- It is a method aimed at assembling multiple desirable genes from multiple parents into a single genotype. Pyramiding of R genes with multiple QTLs helps to achieve broad-spectrum and durable resistance. It also reduce the selection of resistance breaking pathogen genotypes. It is a possible way of prolonging the useful lifetime of resistance genes in agriculture. rice lines with multiple blast-resistance QTLs, including *pi21, qBR4-2, Pi34, qBR12-1, and Pi35*, had a strong, nonrace-specific, environmentally stable resistance against *Magnaporthe oryzae* (Fukuoka *et al.*, 2015)

**Conclusion**

- Deterioration of quantitative resistance, is less quickly and less completely than qualitative resistance.
- Resistance may be made more or less durable depending on the manner in which it is deployed in the agro ecosystem
- As levels of durable resistance increase in crops, fungicide use will decline
- Durable resistance can be achieved with different breeding strategies in crops.

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- Durable resistance helps assure greater economic security and food accessibility throughout the world by reducing year-to-year and region-by-region variation in crop yields due to pathogens.

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