Leveraging Genomic and Germplasm Resources to Improve Disease Resistance

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SUMMARY

Plant diseases cause significant yield losses in the crops worldwide. Crop improvement programs aim to develop resistant varieties using molecular marker techniques and biotechnology for controlling the disease development and spread. An incorporated disease resistance gene helps the plants to detect pathogen attacks and trigger counterattacks. This sustainable approach for controlling plant diseases is effective and sustainable. Developing resistance for crops stabilizes the food security, reduces the dependence on pesticides and promotes the environment-friendly nature. Numerous plant R-genes have been used successfully in crop improvement programs through leveraging the genes from germplasms.

INTRODUCTION

Over the last 50 years global demand for food has been increased. The primary reason is increasing in the human population from 6 to more than 7 billion. So FAO estimate, complied to increase the food production of 50% by 2030 and 70-100%. Secondary reason is constraints in the food production. Agriculture is major backbone for feeding increasing population. Agriculture is affected by many biotic and abiotic stresses. Biotic stresses like insects, diseases, weeds and others causing heavy damage. Diseases causing major damage including fungi, bacteria, virus and nematodes. Plant diseases are responsible for substantial crop losses every year, affect food security and agricultural sustainability. Improvement of crop resistance to pathogens through breeding represents an environmentally sound method for managing disease and minimizing these losses. The challenge is to breed varieties with a stable and broad-spectrum resistance. There is a growing need to invest in crop improvement to ensure food security for the future, which is challenged by an ever-increasing global population, climate change, extreme weather phenomena and the unsustainable use of natural resources. Plant breeders and scientists are under pressure to improve crops to be higher yielding, more nutritious, pest- and disease- resistant and climate-smart. A shift in global temperatures and other climatic conditions will results in various changes in diseases, including pathogen populations which will mean that breeders will need to continuously adapt crops to combat these diseases.

In nature organisms are classified as producers, green plants, consumers (organisms exploiting other organisms) and decomposers (organisms using dead organisms). Green plants including our crops, are used by a multitude of consumers of almost every kind, from various types of herbivores (mammals, snails, and insects) to typical parasites (insects, mites, fungi, bacteria). In order to survive green plants developed a broad range of defence mechanisms to ward off most of these consumers. These defence mechanisms are principally based on avoidance, resistance or tolerance. Avoidance operates before parasitic contact between host and parasite is established and decreases the frequency of incidence. After parasitic contact has been established the host may resist the parasite by decreasing its growth or tolerate its presence by suffering relatively little damage. Avoidance is mainly active against animal parasites and includes such diverse mechanisms as volatile repellents, mimicry and morphological features like hairs, thorns and resin ducts.

Resistance is usually of a chemical nature. Little is known of tolerance; it is very difficult to measure and is usually confounded with quantitative forms of resistance. Resistance mechanisms are by far the most important defence mechanisms employed by host plants, including our crops, against pathogens (Bergelson *et al.,* 2001). In the never-ending arms race between plant and pathogen, the latter have developed widely different host ranges. Pathogens such as some *Pythium* species, *Rhizoctonia solani* Kuhn, and *Sclerotinia sclerotiorum* (Lib.) de Bary have a wide host range, they are non- specialized, polyphagous pathogens. The latter one, for instance, has been reported to attack hundreds of plant species belonging to at least 64 families of flowering plants and gymnosperms. A large proportion of the pathogens, however, have a narrow host range restricted to a few closely related plant species; they are specialized, monophagous pathogens or specialists. *Puccinia hordei* Otth. and *Phytophthora phaseoli*, pathogenic on barley (*Hordeum vulgare* L.) and lima beans (*Phaseolus lunatus* L.) respectively, are typical specialists. As resistance is by far the most important defence of
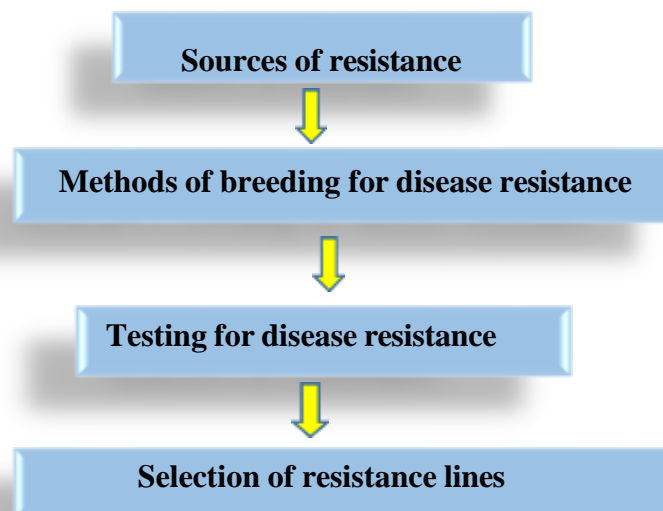
plants against pathogens of disease resistance (Piquerez *et al.,* 2014). So there is a need to improve disease resistance against pathogen attack to overcome increasing global demand for food and feed the increasing population.

Breeding for Resistance

A primary goal of the breeding efforts has been to identify QTL for resistance and develop markers to facilitate marker assisted selection (MAS), thereby enhancing efficiency of the breeding process by allowing for more rapid screening of progeny generations and more effective pyramiding of multiple resistances. For each crop and several diseases, progress has been made toward QTL identification and marker development. Breeding for disease resistance is a central focus of plant breeding programs, as any successful variety must have the complete package of high yield, disease resistance, agronomic performance and end-use quality. With the need to accelerate the development of improved varieties, genomics-assisted breeding is becoming an important tool in breeding programs. With marker-assisted selection, there has been success in breeding for disease resistance. As durable resistance needs the effective combinations of major and minor genes, the integration of MAS and GS for selection of both is reasonable for enhancing disease resistance germplasm (Barbey *et al.,* 2019). Marker-assisted selection (MAS) provides opportunities for enhancing the response from selection because molecular markers can be applied at the seedling stage, with high precision and reductions in cost.

Steps involved in Improving Disease Resistance

By following Marker assisted selection and Markers assisted backcross breeding, breeding for resistance

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│     Sources of resistance       │
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│ Methods of breeding for disease resistance │
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│     Testing for disease resistance      │
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│     Selection of resistance lines       │
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was developed, to know whether the resistance genes has been carried or not we have go for testing.

Testing for Disease Resistance

To check whether the resistance has been transferred from parents to offsprings, we have to test for disease resistance by creating artificial epidemic in field.

For Soil Borne Diseases

For soil borne, inoculate the pathogen into the soil and leave the soil for pathogen development. Grow the obtained progeny in prepared sick plot for testing.

Fig. Testing for Soil Borne Disease

For example, inoculate the wilting pathogen *Fusarium oxysporum* in the field. Sow the progeny of the parents in field. If the plants showed the symptoms of wilting there are susceptible to disease and no symptoms indicates resisatnce in the plants.

For Air Borne Diseases

To check whether resistance from parents to offspring in case of air borne, spray the conidial suspension on the plants. If they showed the less disease severity indicates presence of resistance in plants and more disease severity indicating susceptibility to pathogen.

Fig. Testing for Air Borne Disease in *Magnaporthe oryzae*

For Seed Borne Diseases

Dusting of spores on the progeny obtained and observe for disease symptoms. For example, collect the spores from infected plant and dust it on the obtained progeny. If the spores are able to germinate on the plant and develop the disease symptoms, indicating that there are susceptible to disease. If the plants does not support the germination of spores it indicates that the plants have developed the resistant mechanism in the plant. For screening of resistance, there is a need to study resistance genes inherited from parent to progeny.
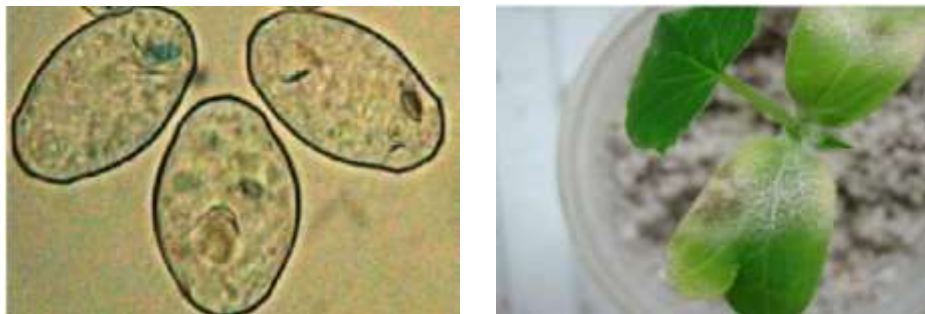

Fig. Testing for Seed Borne Disease in Powdery Mildew

CONCLUSION

Plant breeders are constantly searching for specific traits to help farmers grow crops more efficiently and use fewer natural resources. High-throughput phenotyping and imaging technologies have been developed to speed up the breeding process and release cultivars that meet industry and consumer demands. However, the exponential growth of data has led to the development of complex data, including sequencing, transcriptomic, metabolomics, and imaging data. Machine learning (ML) is set to play a pivotal role in sustainable and precision agriculture, as it can search large datasets to discover patterns and features. ML has been applied to predict regulatory and non-regulatory regions in maize genomes, mRNA expression levels, polyadenylation site prediction, and macronutrient deficiencies in tomato. Early and accurate identification of plant diseases is essential, and screening and selection methods favoring major gene resistance are still widely used by breeders.

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