Role of Biotechnology in Biotic Stress Management in Crops

P. Ananda Kumar

Institute of Biotechnology, Jayashankar Telangana State Agricultural University, Hyderabad (500 030), India

Corresponding Author

P. Ananda Kumar
e-mail: director.iirr@icar.gov.in

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Abstract

Genetic improvement of crop plants through conventional plant breeding has made tremendous contributions to the breakthrough in the global agricultural production. Currently transgenic crops are produced in more or less routine manner. Dramatic progress in transformation techniques has widened the genetic base across the species barriers. The global area of genetically improved agricultural crops has seen a tremendous increase since its first adoption in 1996 to 170 million hectares in 2013. Management of biotic stresses (insect pests and pathogens) in agriculture is important to safeguard crop yields and productivity. Transgenic crops resistant to insect pests and viral diseases have been commercialized with substantial benefits to the farmers which helps to minimize the use of chemical pesticides. The world's population is expected to reach 8.0 billions by the year 2050, making food security the most important social issue. Conventional technologies of agriculture are inadequate to meet the formidable challenges. Advances in modern biology, especially biotechnology, offer many advantages over traditional techniques of plant breeding. Some of the above problems could be addressed through molecular marker-assisted breeding. In addition, genetic transformation is an approach that can dramatically speeds up plant breeding. Plant biotechnology has made significant strides in the past twenty years. Development of efficient procedures of genetic transformation led to the introduction of several transgenics in all major crop species. A variety of traits have been introduced in many crops. More than a dozen GM crops are cultivated globally. Marker assisted selection has given rise to commercial products such as Blight resistant rice, Downy mildew resistant Bajra, submergence tolerant rice etc., Unraveling of genomes aided by innovations and discoveries in bioinformatics would only hasten such efforts. Intensive and all round efforts are needed to meet the challenges of feeding the future populations. Integration of modern biology, plant breeding, computational biology, phonemics and related tools will make the endeavors possible.

Keywords: Biotechnology, Biotic stress management, transgenic crop

1. Introduction

Management of biotic stresses (insect pests and pathogens) in agriculture is important to safeguard crop yields and productivity. Chemical insecticides and fungicides that effectively control pests and pathogens have been proven to be harmful to human health and environment. There is a need to reduce the dependence on pesticides by using safer alternatives. Transgenic crops resistant to insect pests and viral diseases have been commercialized with substantial benefits to the farmers. Globally, transgenic crops occupied an area of 170 million hectares in 2013. Substantial benefits (social, economic and environmental) have been realized by the farmers in the past 18 years. Management of viral diseases by transgenic approach has been a successful strategy. Disease resistant papaya, squash, plum and melon are cultivated in USA and China. Novel strategies such as RNAi hold promise for the management of a host of fungal and viral pathogens.

The world's population is expected to reach 8.0 billions by the year 2050, making food security the most important social issue. Food production will have to be doubled to meet the needs of the 8 billion people, and 90% of them will reside in the developing world. The dwindling water and land resources will further exacerbate the enormity of this challenge. In addition, crop losses due to insect pests, diseases and declining soil fertility will worsen because of climatic conditions that favor insect pests and disease vectors.

Conventional technologies of agriculture are inadequate to meet the formidable challenges listed above. Some of the limitations of conventional breeding are: i) lack of germplasm resources for some of the major pests and pathogens of crops and ii) the new plant types evolved for higher productivity are more vulnerable to pests and diseases. Advances in modern biology, especially biotechnology, offer many advantages over traditional techniques of plant breeding. Some of the above problems could be addressed through molecular marker-assisted breeding. In addition, genetic transformation is an approach that can dramatically speeds up plant breeding.

2. Transgenic Crops

Currently transgenic crops are produced in more or less routine manner in both monocots and dicots. Dramatic progress in transformation techniques has widened the genetic base across the species barriers. The global area of genetically improved agricultural crops has seen a tremendous increase since its first adoption in 1996 to 170 million hectares in 2013.

2.1. Insect resistance

One of the priority areas in crop improvement programme is to incorporate resistance against economically important insect pests. However, availability of resistance source within sexually compatible germplasm becomes a limiting factor in transferring resistance to elite crop cultivars. Genetic engineering has provided the opportunity to incorporate insecticidal genes of either microbial or plant origin to augment inherent crop resistance. Work to date has mostly concentrated on the introduction of genes for expression of modified Bt (*Bacillus thuringiensis*) genes. Impressive results in controlling Bt-susceptible pests led to the wide adoption of Bt-crops (cotton and maize) throughout the world.

2.2. Virus resistance

Incorporation of resistance against plant viruses is another important area in crop improvement for which we are heavily dependent on biotechnological intervention. Expression of viral genes encoding coat protein, non structural proteins (replicas', movement protein), and use of antisense technology are some of the strategies that have been effectively used in plants to confer resistance against viral diseases (Beachy et al., 1990). The biggest success story of transgenic mediated virus resistance is the cultivation of transgenic papaya expressing capsid protein in Hawaii, which virtually saved the papaya industry from dreaded threat of ring spot disease (Yeh et al., 1998).

2.3. Resistance to fungal and bacterial diseases

Plant produces assorted set of Pathogenesis Related (PR) proteins as defense response to fungal pathogens. Several reports of bioassay at the laboratory level indicate that over-expression of PR proteins leads to enhanced resistance with reduced severity of symptoms in transgenic plants. However, none of these efforts culminated into any commercial release.

3. Molecular Breeding

Genetic improvement of crop plants through conventional plant breeding has made tremendous contributions to the breakthrough in the global agricultural production. One of the approaches popularly known as "Marker Assisted Breeding" or "Molecular Breeding" employs molecular markers for genome mapping, gene tagging and marker assisted selection (MAS). Genes conferring resistance against different races of a particular pathogen are combined together in the genetic background of an agronomically superior genotype or popular variety. A combined effect of the resistance genes is thought to provide a broad spectrum of resistance by both individual gene action and additive gene action. Molecular markers that are linked or co-inherited with the individual resistance genes could be used for marker-assisted selection. A typical example of gene pyramiding is that of Blight tolerant rice in India. Two genes for bacterial blight (BB) resistance namely, xa13 and Xa21 have been combined in the background of popular Basmati rice variety Pusa Basmati 1 through marker assisted selection programme jointly carried out by the National Research Centre on Plant Biotechnology and Indian Agricultural Research Institute, New Delhi. This has resulted in the development of a new variety called Improved Pusa Basmati1, which has been released for commercial cultivation in the country (Joseph et al., 2004; Gopalakrishnan et al., 2008). Similar efforts at the Directorate of Rice Research, Hyderabad has led to combining three genes for BB resistance, xa5, xa13 and Xa21 in the background of a popular rice variety BPT5204 (Sundaram et al., 2008).

4. Perspectives

Plant biotechnology has made significant strides in the past twenty years encompassing within its fold the spectacular developments in plant molecular biology, genetic engineering, genomics, molecular crop breeding and bioinformatics. Development of efficient procedures of genetic transformation led to the introduction of several transgenics in all major crop species. A variety of traits have been introduced in many crops. More than a dozen GM crops are cultivated globally. Marker assisted selection has given rise to commercial products such as Blight resistant rice, Downy mildew resistant Bajra, submergence tolerant rice etc., Unraveling of genomes aided by innovations and discoveries in bioinformatics would only hasten such efforts. Intensive and all round efforts are needed to meet the challenges of feeding the future populations. Integration of modern biology, plant breeding, computational biology, phonemics and related tools will make the endeavors possible.

5. Conclusion

Plant biotechnology has made significant strides in the past twenty years. Genetic improvement of crop plants through conventional plant breeding has made tremendous contributions to the breakthrough in the global agricultural production. Dramatic progress in transformation techniques has widened the genetic base across the species barriers. Transgenic crops resistant to insect pests and viral diseases have been commercialized with substantial benefits to the farmers which helps to minimize the use of chemical pesticides.

6. References

Beachy, R.N., Loesch-Fries, S., Tumer, N.E.,1990. Coat protein-mediated resistance against virus infection. Annual

Reviews of Phytopathology 28, 451−474.
Chu, Z., Fu, B., Yang, H., Xu, C., Li, Z., Sanchez, A., Park, Y.J., Bennetzen, J.L., Zhang, Q., Wang, S., 2006. Targeting xa13, a recessive gene for bacterial blight resistance in rice. Theoretical and Applied Genetics 112, 455–461.
Gopalakrishnan, S., Sharma, R.K., Rajkumar, K.A., Joseph, M., Singh, V.P., Singh, A. K., Bhat, K.V., Singh, N.K., Mohapatra, T., 2008. Integrating marker-assisted background analysis with foreground selection for identification of superior bacterial blight resistant recombinants in Basmati rice. Plant Breeding 127, 131−139.
Gu, K., Yang, B., Tian, D., Wu, L., Wang, D., Sreekala, C., Yang, F., Chu, Z., Wang, G.L., White, F.F., Yin, Z., 2005. R gene expression induced by a type-III effector triggers disease resistance in rice. Nature 435, 1122−1125.
Iyer A. S., McCouch, S. R., 2004. The rice bacterial blight resistance gene xa5 encodes a novel form of disease resistance. Molecular Plant Microbial Interactions 17, 1348−1354.
Joseph, M., Gopalakrishnan, S., Sharma, R.K., Singh, V.P., Singh, A.K., Singh, N.K., Mohapatra, T., 2004. Combining bacterial blight resistance and Basmati quality characteristics by phenotypic and molecular marker-assisted selection in rice. Molecular Breeding 13, 377−387.
Park, D.S., Song, M.Y., Park, S.K., Lee, S.K., Lee, J.H., Song, S.Y., Eun, M.Y., Hahn, T.R., Sohn, J.K., Yi, G., Nam, M.H., Jeon, J.S., 2008. Molecular tagging of the *Bph1* locus for resistance to brown planthopper (*Nilaparvata lugens* Stal) through representational difference analysis. Molecular Genetics and Genomics 280, 163−172.
Saito, K., Matsuda, F., 2010. Metabolomics for Functional Genomics, Systems Biology.
Song, W.Y., Wang, G.L., Chen, L.L., Kim, H.S., Pi, L.Y., Holsten, T., Gardner, J., Wang, B.,Zhai, W.X., Zhu, L.H., Fauquet, C., Ronald, P., 1995. A receptor kinase-like protein encoded by the rice disease resistance gene, Xa21. Science 270, 1804−1806.
Sun, X., Cao, Y., Yang, Z., Xu, C., Li, X., Wang, S., Zhang, Q., 2004. Xa26, a gene conferring resistance to Xanthomonas oryzae pv. oryzae in rice, encodes an LRR receptor kinase-like protein. Plant Journal 37, 5170−527.
Sundaram, R.M., Vishnupriya, M.R., Biradar, S.K., Laha, G.S., Reddy, G.A., Rani, N. S., Sarma, N.P., Sonti, R.V., 2008. Marker assisted introgression of bacterial blight resistance in Samba Mahsuri, an elite *indica* rice variety. Euphytica 160, 411−422.
Yeh, S.D., Bau, H.J., Cheng, Y.H., Yu, T.A.,Yang, J.S., Drew, R.A.,1998. Greenhouse and field evaluations of coat-protein transgenic papaya resistant to papaya ring spot virus. Acta Horticlture 461, 321−328.
Yoshimura, S., Yamanouchi, U., Katayose, Y., Toki, S., Wang, Z.X., Kono, I., Kuruta, N., Yano, M., Iwata, N., Sasaki, T., 1998. Expression of Xa1, a bacterial blight resistance gene in rice, is induced by bacterial inoculation. Proceedings of National Academy of Science *USA* 95, 1663−1668.