Paper from Proceeding of the National Conference "Science in Media 2012" Organized by YMCA University of Science and Technology, Faridabad, Haryana (India) December 3rd -4th 2012 Published by IJMRS's International Journal of Engineering Sciences, ISSN (Online): 2277-9698
www.ijmrs.com

Transgenic approaches to crop improvement

Padma Shri Mishra, K.L.Mehta Dayanand College, Faridabad.

***Abstract*- The transgenic approaches to crop improvement have become a vital area of agricultural research, as it can address various burning issues like increased yield from the crop, and ability to withstand severe environmental conditions. In the transgenic approaches, a genetically engineered plant is generated by altering its genetic composition by adding one or more genes to a plant's genome using genetic engineering techniques like biolistic method (particle gun) or Agrobacterium tumefaciens mediated transformation. Transgenic crops are now grown commercially on several million hectares, principally in North America. The predominant crops are maize (corn), soybean, cotton, and potatoes. In addition, there have been field trials of transgenics from at least 52 species including all the major field crops, vegetables, and several herbaceous and woody species. Some of the important transgenic crops include FlavrSavr tomato (Improved Shelf Life), GM Cassava and Corn (Improved nutrition), Golden Rice (Stress Resistance and Improved Nutrition), papaya, potato, squash and cucumber (virus resistant), Cowpea and BT Brinjal (Yield enhancement). Even though there has been substantial progress in transgenic crops during last two decades, immediate attention is required on next generation GM crops, which could be -**

1. **Nutritional biofortification in staple crops and sweet potato.**
2. **Resistance to fungus and virus pathogens in potato, wheat, rice, banana, fruits, vegetables.**
3. **Resistance to sucking insect pests in rice, fruits, vegetables.**
4. **Improved processing and storage in wheat, potato, fruits and vegetables.**
5. **Drought tolerance in staple cereal and tuber crops.**

Appropriate research in the above areas would make the vital crops more stable, resulting in better yield.

***Index Terms*— Transgenic, Crop Improvement, Nutritional Biofortification, Drought Tolerance**

1. Introduction

In the recent past, there have been serious concerns about sufficient global production from the crop plants in future. This is primarily due to increasing world population, decreasing arable land because of soil erosion, degradation etc. and global climate change, resulting in frequent droughts, floods, heat waves etc. Availability of water is also declining. Adding to the concern is the fact that a large chunk of arable land is now being utilized for bio-fuel plantation.

In order to ensure sufficient availability of food, it is important to improve the crops to increase the yield from both, irrigated and non-irrigated land and create novel varieties that are more tolerant to abiotic stresses.

Transgenic approaches not only increase the yield, but may also result in improved shelf life, improved nutrition and virus resistance. Transgenic crops are now grown commercially on several million hectares, principally in North America. The predominant crops are maize (corn), soybean, cotton, and potatoes. In addition, there have been field trials of transgenics from at least 52 species including all the major field crops, vegetables, and several herbaceous and woody species. Some of the important transgenic crops include Flavr Savr tomato (Improved Shelf Life), GM Cassava and Corn (Improved nutrition), Golden Rice (Stress Resistance and Improved Nutrition), papaya, potato, squash and cucumber (virus resistant), Cowpea and BT Brinjal (Yield enhancement).

There has been significant progress in the research areas of genetically modified crops, and several futuristic developments are already on offing at various parts of the world. This paper primarily focuses on the areas, which need immediate attention and need to be addressed within next 5-8 years, which will form a stepping stone for next stage of development.

The areas of focus are -

1. Nutritional biofortification in staple crops and sweet potato.
2. Resistance to fungus and virus pathogens in potato, wheat, rice, banana, fruits, vegetables.
3. Resistance to sucking insect pests in rice, fruits, vegetables.
4. Improved processing and storage in wheat, potato, fruits and vegetables.
5. Drought tolerance in staple cereal and tuber crops.

1. Nutritional biofortification in staple crops and sweet potato

Deficiencies of vitamin A, iron, and zinc affect over one-half of the world's population. Progress has been made to control micronutrient deficiencies through supplementation and food fortification, but new approaches are needed, especially to reach the rural poor. Biofortification (enriching the nutrition contribution of staple crops through plant breeding) is one option. Scientific evidence shows this is technically feasible without compromising agronomic productivity. The challenge is to get producers and consumers to accept biofortified crops and increase their intake of the target nutrients. With the advent of good seed systems, the development of markets and products, and demand creation, this can be achieved.

Biofortification

Biofortification is the development of micronutrient-dense staple crops using the best traditional breeding practices and modern biotechnology. This approach has multiple advantages. First, it capitalizes on the regular daily intake of a consistent and large amount of food staples by all family members. Because staple foods predominate in the diets of the poor, this strategy implicitly targets low-income households. Second, after the one-time investment to develop seeds that fortify themselves, recurrent costs are low, and germplasm can be shared internationally. This multiplier aspect of plant breeding across time and distance makes it cost-effective. Third, once in place, the biofortified crop system is highly sustainable. Nutritionally improved varieties will continue to be grown and consumed year after year, even if government attention and international funding for micronutrient issues fade. Fourth, biofortification provides a feasible means of reaching undernourished populations in relatively remote rural areas, delivering naturally fortified foods to people with limited access to commercially marketed fortified foods that are more readily available in urban areas. Biofortification and commercial fortification, therefore, are highly complementary. In fact, biofortification may have important spin-off effects for increasing farm productivity in developing countries in an environmentally beneficial way.

2. *Resistance to fungus and virus pathogens in potato, wheat, rice, banana, fruits, vegetables.*

Development of transgenic crop varieties resistant to viral diseases

In the case of virus resistance, conventional strategies to control viral diseases are limited to the production of virus-free propagation material and to the control of insects transmitting virus pests. While some crop gene pools harbour resistance to viruses, there are crop gene pools which are completely lacking in resistance against key virus pathogens. The few examples of large-scale plantings of virus resistant GM varieties should be monitored to determine if resistance breaking variants of the virus pathogens are being selected over a number of growing seasons for large scale crop populations. In Africa, only three crops, sweet potato, potato and maize, have so far been targeted for transgene-mediated virus resistance. The FAO-BioDeC indicates only two transgenic varieties that to date have been tested in a field trial, namely, a sweet potato variety for resistance to sweet potato feathery mottle virus (SPFMV) in Kenya and a potato variety for resistance to potato leaf roll virus (PLRV) in South Africa. The FAO-BioDeC currently reports only three other research initiatives in an experimental phase in South Africa, namely, the development of potato for resistance to potato virus Y (PVY) and potato virus X (PVX), and development of maize resistant to the maize streak virus (MSV). The inventory indicates that no virus resistant GM varieties have been commercially released in Africa.

In the Eastern and Central Africa region, maize is a major staple of the rural and urban poor. In the same region, potato has become a major highland cash crop and a food staple in some urban areas. Sweet potato is an important crop in the countries surrounding Lake Victoria (Burundi, the Democratic Republic of the Congo, Kenya, Rwanda, United Republic of Tanzania and Uganda).

Development of transgenic crop varieties resistant to fungal diseases

Some of the most devastating and universal crop diseases are caused by fungal pathogens . For instance, the rust fungi are the most widespread and generally cause the largest crop losses per season. Crop losses can be considerable due to fungal pathogens. For example, the fungal agent of rice blast disease (Magnaporthe grisea) destroys 157 million tonnes of cultivated rice each year, enough rice to feed 60 million people worldwide (Pennisi, 2001).

The negative effects of some fungal pathogens can be limited by the use of chemical fungicides. Demand for fungicides amongst farmers is high, indicating that for many farmers there are few available alternatives. The United States, Western Europe and Japan together accounted for 75 percent of the total world market. Small grains constitute the largest market for fungicides worldwide. This sector accounted for an estimated 27 percent of the total world market in 1999, followed closely by tree and vine crops (24 percent), rice (16 percent), and vegetables and potatoes (10 percent). Other crop markets accounted for 17 percent of the world fungicide market, and non-crop markets accounted for

6 percent.

In many countries, fungicides as crop protection products are subject to strict legislative regulation and undergo a rigorous and expensive process of registration for public sale. While fungicides can provide a level of control, this chemical option is often limited for many farmers, particularly in developing countries, by high costs and lack of knowledge about application. In addition, the negative effects of fungicide applications on human health, with special reference to the laborers and the environment can be considerable. There is a need to find more environmentally benign alternatives to fungicides to control fungal diseases of crops.

Fungal diseases of some important crops worldwide	
Cereals	Powdery mildew, rusts, leaf-spot diseases, common bunt of wheat, loose smuts
Rice	Blast, sheath blight and other leaf spot diseases
Vegetables	Leaf rot, brown rot, grey mould, powdery mildew and downy mildew, leaf spot and fruit spot diseases (e.g. Alternaria)
Potatoes	Late blight, early blight (Alternaria), black scab (Rhizoctonia), silver scurf
Grapevine	Powdery mildew (Oidium) and downy mildew (Peronospora), grey mould (Botrytis)
Peanuts	White mould (Rhizoctonia), Sclerotinia stem rot, leaf spot, rust
Banana	Sigatoka leaf spot
Coffee	Coffee rust

Genes can be identified that confer resistance to fungal pathogens. For instance, many genes have been found that provide resistance to specific races of each rust pathogen. In many cases, resistance genes are available in the gene pool of cultivated plants and can be transferred to them by cross-breeding programmes. The incorporation of plant-derived resistance genes against fungal pathogens into susceptible varieties could allow development of resistant varieties which can deliver high yields in the absence of fungicide applications.

A few countries in Latin America, mainly Argentina, Brazil and Cuba, are carrying out a number of activities on transgenic resistance to fungi, particularly on tropical fruit trees, with some results already being tested in the field. In this region, most of the activities for transgenic fungal resistance are reported in Cuba, in particular involving field trials of transgenic potato for late blight resistance, and fungal-resistant sugar cane. Other field trials in the Latin America region for transgenic fungal resistance are reported for maize, sunflower and wheat in Argentina, and tobacco in Mexico. Other crops subject to transgenic R&D for fungal resistance in Cuba are banana, plantain, pineapple, tomato, papaya, citrus and rice. Other countries involved in transgenic fungal resistance research are Argentina on alfalfa, Brazil on rice, barley and cocoa, Chile on grape and apple, Colombia on tree tomato, Peru on potato for late blight resistance and Venezuela on sugar cane.

Resistance to sucking insect pests in rice, fruits, vegetables

Insects are found in all types of environment and they occupy little more than two thirds of the known species of animals in the world. Insects affect human beings in a number of ways. Many of them fed on all kinds of plants including crop plants, forest trees, medicinal plants and weeds. They also infest the food and other stored products in godowns, bins, storage structures and packages causing huge amount of loss to the stored food and also deterioration of food quality. Insects inflict injury to plants and stored products either directly or indirectly in their attempts to secure food. Insects that cause less than 5 % damage are not considered as pests. The insects which cause damage between 5 - 10% are called minor pests and those that cause damage above 10% are considered as major pests. Insects that cause injury to plants and stored products are grouped into two major groups namely chewing insects and sucking insects. The former group chews off plant parts and swallow them thereby causing damage to the crops. Sucking insects pierce through the epidermis and suck the sap. Many of the sucking insects serve as vectors of plant diseases and also inject their salivary secretions containing toxins that cause severe damage to the crop. Introduction of high yielding varieties, expansion in irrigation facilities and indiscriminate use of increased rates of agrochemicals such as fertilizers and pesticides in recent years with a view to increase productivity has resulted in heavy crop losses due to insect pests in certain crops. This situation has risen mainly due to elimination of natural enemies, resurgence of pests, development of insecticide resistance and out-break of secondary pests. There is an urgent need to develop GM crops, which could withstand the sucking insects and pests.

Agrobacterium-mediated genetic transformation has been optimized in indica rice susceptible to sap-sucking insects, viz., brown planthopper (BPH) and green leafhopper (GLH). Snowdrop lectin gene (gna) from Galanthus nivalis, driven by phloem-specific rice-sucrose-synthase promoter, along with herbicide resistance gene (bar) driven by CaMV 35S promoter, was employed for genetic transformation. Embryogenic calli--after co-cultivation with Agrobacterium strain LBA4404 harbouring Ti plasmid pSB111-bar-gna--were selected on the medium containing phosphinothricin. PCR and Southern blot analyses confirmed the stable integration of both the genes into genomes of transgenic (T0) rice plants. Northern and Western blot analyses revealed the expression of gna in the transgenic plants. In the T1 and T2 generations, the gna and bar transgenes showed co-segregation at a ratio of 3 : 1. Plant progenies expressing gna, in T1 and T2, exhibited substantial resistance against BPH and GLH pests. This is the first report dealing with transgenic indica rice exhibiting high resistance to both insects.

Improved processing and storage in wheat, potato, fruits and vegetables.

In India, where crop production is still largely dependent on nature, there are years of over production and drought. Further, food grains have to travel the vast geographical boundaries of the country. So it becomes very important to have efficient food processing and storage units, which can store food for 3 months to 2 years and protect it from any form of pest, rotting etc.

Food processing and preservation is a set of physical, chemical and biological processes that are performed to prolong the shelf life of foods and at the same time retain the features that determine their quality, like colour, texture, flavor and especially nutritional value. Food preservation is achieved by destroying enzymes and micro organisms using heat (blanching, pasteurization), or preventing their action by: removal of water, or increasing acidity or using low temperatures.

Main methods of food processing include Cooking, Preserved food, Oiling, Adding chemical preservatives, Sterilizing, Freezing, Drying, Salting, Fermenting, Germinating etc. Some protection measures against pest include –

Using layers of sand alternated with grains : The idea is to fill the empty spaces between the stored grains in a given container (for beans, corns, etc.), removing in this way the air spaces and eventually, avoiding the development of insects.

Mixing wood ashes with grains: The ash forms a protecting layer against the insects. When the insect enters in contact with the ash, it will cause the insect's skin dehydration and eventually its death.

Keeping in Chilli or Margoza powder: Chilli and Margoza prevents the development of different pests.

Protect the ears (Corn) with eucalyptus, tobacco or lantana camara leaves : The eucalyptus citrodurus, tobacco, or lantana camara leaves, repel plum curculios in the granary

Keep with flowers/repealing leaves: Plant chrysanthemum flowers or catharanthus or other plant with repelling leaves (such as: Tagetes minuta of Myrtaceae family and Datura stramonium of Solanaceae family) around the granary in order to make escape the insects because of the bad smell exhaled from the repelling plants.

Drought tolerance in staple cereal and tuber crops

Drought is a condition in which the available moisture at a certain location falls sufficiently short of the normally expected such as to constrain the agricultural activities that have been adapted to the particular location. Drought remains the single most important factor threatening the food security of peoples in the developing world. Drought stress arising from uneven distribution of rains during the rainy season or total cessation of rains during the growing period may occur at any of the four distinct growth stages(i.e. seedling, vegetative, pre-anthesis and post-anthesis) especially in cereals. Of these four phases, moisture stress at the post-anthesis phase is considered to be crucial to food production as this often leads to failure of pollen to germinate and consequently, poor seed set resulting in partially or wholly unfilled ears at harvest. Among the economic implications of drought worldwide are: (i) severe food shortage with its associated spiraling of food prices,(ii) famine, (iii) destruction of export crops which ruins the export economy, (iv) forced emigration of victims to more favourable environments which may be of different culture and organization as well as(v) refugee problems(Enabor,1 985).

Arraudeau (1989) identified five terms often used by breeders in drought research. These are drought resistance, drought escape, drought avoidance, drought tolerance and drought recovery. Drought resistance is the ability of the plant to live, grow and yield satisfactorily with limited water supply or under periodic water deficit while the plant's ability to rnature before water stress becomes a serious limiting factor is referred to as drought escape. Drought avoidance on the other hand is the ability to maintain high waters status during drought.

Drought tolerance refers to ability to withstand water deficit as measured by degree and duration of low plant water potential while drought recovery is the ability of a plant to resume growth and yield after drought stress, with a minimum of irreversible yield loss

Approaches to drought research:

The approaches to drought research include (i) growing more DT crops,(ii) breeding more drought resistance into crops, (iii) breeding for heat tolerance in crops,(iv) incorporating genes for resistance to prevalent diseases in DT genotypes and (v) the use of complementary crop management practices that promote the adoption of cultivating DT genotypes.

REFERENCES

1. Abebe T, Guenzi AC, Martin B, Cushman JC (2003) Tolerance of Mannitol-accumulating transgenic wheat to water stress and salinity.
2. Alam, M.F., Abrigo, E., Datta, K., Datta, S.K., Oliva, N., Tu, J. and Virmani, S.S. (1999). Transgenic insect-resistant maintainer line (IR68899B) for improvement of hybrid rice.
3. Alpteter, F., Diaz, I., McAuslane, H., Gaddour, K., Carbonero, P. and Vasil, I.K. (1999). Increased insect resistance in transgenic wheat stably expressing trypsin inhibitor.
4. Altier DJ, Bidney DL, Coughlin SJ, Falak I, Yalpani N, Mancl MK, Nazarian KAP, Scelonge CJ.1999. The induction of stress-related factors in plants
5. Bajaj S, Targolli J, Liu L-F, Ho TH, Wu R (1999) Transgenic approaches to increase dehydration stress tolerance in plants.
6. Bartels D, Sunkar R (2005) Drought and salt tolerance in plants.
7. Bernal C C, Aguda R M and Cohen M B 2002 Effect of rice lines transformed with Bacillus thuringiensis toxin genes on the brown planthopper and its predator.
8. Biofortification of Staple Food Crops, by Penelope Nestel, Howarth E. Bouis, J. V. Meenakshi, and Wolfgang Pfeiffer.
9. Cowgill S E and Atkinson H J 2003 A sequential approach to risk assessment of transgenic plants expressing protease inhibitors: effects on non target herbivorous insects
10. Flexas J, Bota J, Loreto F, Cornic G, Sharkey TD. 2004. Diffusive and metabolic limitations to photosynthesisunder drought and salinity in C3 plants.
11. Genetics and genetic improvement of drought resistance in crop plants (2001) by Jiban Mitra, Western Regional Research Station, Indian Grassland and Fodder Research Institute
12. Griffiths B S, Geoghegan I E and Robertson W M 2000 Testing genetically engineered potato, producing the lectins GNA and Con A, on non-target soil organisms and processes.
13. Handbook of Food Preservation, Second Edition By Mohammad Shafiur Rahman
14. Insect Pests and their Management (2007) by DR. A. V. Navarajan Paul, Principal Scientist & National Fellow, Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute.
15. Katiyar-Agarwal S, Agarwal M, Grover A (1999) Emerging trends in agricultural biotechnology research: use of abiotic stress induced promoter to drive expression of a stress resistance gene in the transgenic system leads to high level stress tolerance associated with minimal negative effects on growth.
16. Kota M, Daniell H, Varma S, Garczynski S F, Gould F and Moar W J 1999 Overexpression of the Bacillus thuringiensis (Bt) Cry2Aa2 protein in chloroplasts.
17. Microbial genes expressed in transgenic plants to improve disease resistance (1999) by M. Lorito, F. Scala
18. Transgenic indica rice resistant to sap-sucking insects (2003) by Nagadhara D, Ramesh S, Pasalu IC, Rao YK, Krishnaiah NV, Sarma NP, Bown DP, Gatehouse JA, Reddy VD, Rao KV