Biotechnology's Impact on Cotton Growing

The use of chemicals in cotton, in the form of fertilizers and pesticides, has given manyfold increases to cotton production worldwide. Fertilizers are used to meet the depleting reserves of plant food nutrients in the soil. Science has not yet found an alternative to meet plant requirements for major nutrients other than synthetic fertilizers. Control of insect pests and diseases with insecticides, fungicides, miticides and herbicides has become an integral part of production technology and no stronger, feasible and efficient alternatives are available to save the productivity of the cotton crop. Moreover, the increased use of pesticides has inflated the cost of production thus affecting its economics in addition to the development of resistance in pests to frequently used pesticides. Host plant resistance and biological control do provide a solution but they are complex and involve the integration of a variety of systems. Biotechnology has not only offered a solution to these problems but also opened new avenues of development, particularly the induction of non-related genes to develop tolerance to specific pests and chemicals. The promising use of biotechnology in the field of fiber development, hybrid cotton etc., still remains unexplored.

Biotechnology can be defined in a variety of ways but in a broader spectrum it is the use of biological processes to develop products and services from living organisms or their constituents. Biotechnology, which has made significant progress during the last decade started with a rush of new companies with many promises and great hopes for quick success. So far, most of the hopes and promises have not materialized and some of the pioneer companies have disappeared. Those that remain on the scene have not been able to give any thing surprising to the beneficiaries. But this does not mean that technologies do not have the promise. Probably, expectations were too high and commercialization was expected to be realized in a shorter time.

Agricultural biotechnology holds the potential to completely change the future of cotton research. The users are waiting anxiously to reap the benefits of biotechnology in cotton. Probably not before 1995, the farmers will be able to grow Bt cotton on their farms. The next genetically engineered cotton will be herbicide tolerant and is expected to be available on the market at the earliest in 1998. Many more developments will follow after these. So, it is hoped that by the year 2000 the impact of biotechnology on cotton production practices and its economics will be widespread.

Insect Resistance

Many features of cotton production and quality can be changed through the use of biotechnology but pest control strategies are the most obvious areas of interest for the biotechnology companies on account of large volume of pesticides used in cotton. In Argentina, Australia, Colombia, Guatemala, India (hybrid cotton), Israel, Nicaragua, Southern part of Peru, Spain, Turkey and parts of the USA the cost of insect control is more than US$200 per hectare. A gene transferred from *Bacillus thuringiensis* has proved its worth in field trials conducted during 1990 and 1991. While most of the work on Bt gene has targeted lepidopteran insects, significant success has been achieved in the control of Heliothis. With current active research going on to test many more Bt genes, the range of insects to which toxins are effective is likely to increase. This in turn will provide a greater range of possibilities for genetically engineered plants.

In addition to the Bt toxins other peptides, like protease inhibitors, lectin (proteins) and venoms of scorpions and spiders have the potential to be used as feeding deterrents. The mode of action in the insect is to inhibit digestive enzymes so that nutrition of the insect is impaired. There are two major barriers to the use of these peptides. The first is the identification and isolation of the responsible genes from the host and, second an effective way to ensure the delivery of the peptide from the plant to the site of activity in the insect. Unless this type of fundamental knowledge is acquired, commercial utilization of the insect hitting genes will be nothing more than a hit or miss method.

Herbicide Tolerance

One of the other accomplishments of genetically transforming cotton has been resistance to a range of herbicides. The principle motivation is related to the broad spectrum of activity of the herbicide and its relatively low level of environmental assault. In the USA four major companies, Calgene, Dupont, Monsanto and Phytogen, are developing herbicide resistant cotton. Genes resistant to specific herbicides have been identified and being transferred to the commercial varieties. Coker 312 is the first recipient of a herbicide resistant gene. Now resistant genes are being marketed among various seed companies for incorporation into commercial varieties through successive back crossing. Efforts are underway to develop lines resistant to the broad spectrum herbicide, bromoxynil. Studies done so far have shown a high level of resistance in cotton to this herbicide which would allow the control of bindweed, morning glory and other broad-leaf weeds by aerial application at a time when ground application is not possible because of the crop canopy. In Australia, at the Commonwealth Scientific and Industrial Research Organization, work is in progress to develop genotype resistant to 2,4-dichlorophenoxyacetic acid.

Pathogen Resistance

Diseases do cause damage to the cotton plant and at various stages of development but losses are not significant unlike the losses due to insects and weeds. This is why the amount of research efforts directed toward genetic engineering of resistance to pathogens is much less than that directed toward resistance to herbicides and insects. This is primarily related to low value added advantage of the seed having resistance to pathogens, though two resistant genes have already been identified. Some peptides like lectin have also shown antifungal properties. With the spreading of leaf curl virus, transmitted by whitefly, probably the techniques used in other crops for virus resistance will have to be tried in cotton. In the absence of any chemical control of bacterial blight of cotton, molecular work is in progress to control this disease.

Hybrid Cotton

The utilization of hybrid vigor in commercial cotton hybrids has remained restricted due to the non-availability of the techniques to produce hybrid seed economically and in sufficient quantities. In India about 28% of the total area is brought under hybrids because labor is available at low cost to emasculate and pollinate the female parent. But in countries like the US, hybrid cotton is not grown because of the high cost of seed or due to the lack of techniques to produce seed at low cost. The Plant Genetic Systems strategy may continue to find some improvements but there is another hope to develop self-incompatibility into complementary parental lines. They will continue to be maintained with their respective fertile lines. Both parents will be self-sterile but fertile for out crossing, so both parents could be harvested for hybrid seed. The F1 will be fully self-fertile in the production field via the complementation of the two parents.

Tissue Culture

Tissue culture is another important area of research with a lot of hopes to contribute to the improvement of cotton breeding techniques. Biotechnology can contribute to the production of multi species hybrids wherever it is not possible to utilize the favorable genes from the wild species. Embryo culture has already shown its success in many countries of the world, since the technique is not complicated and expensive. Production of haploid plants from the pollen grains will have far reaching impact when achieved. It can cut down the long procedure of 8-10 years to make the hybrid material homozygous in one year. It will speed up the screening process to develop varieties and efforts of the breeders would be better utilized.

Application to Fiber

It was interesting to search the basis of the differences between the fiber length growth of the *G. hirsutum* and *G. barbadense*. After all why do the fibers continue to grow longer in *G. barbadense* while they cease to grow at a shorter length in *G. hirsutum*. It has been established that fiber length differences are based

on hormonal differences. Tight regulation of hormone level appears to be a factor, but major differences in auxin levels between the two species have also been noted. Work is going on to identify those biochemical parameters that can be molecularly and genetically manipulated to improve fiber quality.

Limitations to the Use of Biotechnology

Many techniques have shown promise to be used commercially in cotton both for the improvement of productivity and quality. There is growing impatience to see the accomplishments of the research done so far. Disappointments about the technology have also been felt among the general public. Anyhow, following are the possible reasons and threats to the slow progress, achievements and general adoption.

- Because of the diversity of the cotton growing problems throughout the world, there is no simple approach for transfer and implementation of biotechnical knowledge. Thus, many of the cotton growing problems of the world will not receive required attention.

- The majority of the potential developments from the application of biotechnology will be more useful to the low input farming practices. On the other hand, the technology is very expensive and out of the reach of the developing countries.

- The progress recorded so far is slow which is a discouragement for investment in the sector.

- The products are ready for field testing and some of them have already been tried not only in the country of origin but also overseas. Experience shows that in certain cases government regulations are confusing and strict.

- Current research work in the field of biotechnology is driven by the profit motive of the private companies. This means that only those genes or techniques which impart high value to the seed or increase the sale of propriety chemicals are likely to get fair attention.

Future of Biotechnology

Freiberg Publishing Company who brings out the "AgBiotechnology News" on a bimonthly basis, conducted a survey in the US on the AgBiotechnology Outlook: 1991-92. The questionnaire was sent to private companies, universities, service organizations, associations and venture capitalists. The survey also included a question on the future of agricultural biotechnology. From the 64 responses they received it is observed that 72% had a positive or very positive opinion of the future of the agricultural biotechnology. Only 4% were negative of the impact of the biotechnology in agriculture. The question applied to agriculture in general but the same may be true for cotton.

Impact of Biotechnology on Growing

Progress of work shows that we are very close to significant achievements. Results are visible and we are a step away from commercial adoption. Of course the first utilization in the field of molecular genetics will be the use of Bt cotton and herbicide specific genotypes. Resistance to drought conditions, improvement in fiber characteristics, development of male sterility for commercial cotton hybrids and many others which cannot be even imagined will follow these. Biotechnological achievements may not have a direct impact on the productivity of cotton but certainly they will be aids to increase the productivity of cotton. The overall impact which is hoped to be visible by the year 2000 will be on the following lines.

- Bt cottons and biopesticides are going to curtail the cost of production which will be welcomed in countries like Israel, USA, Spain, etc., where high cost of production is becoming of concern to the growers.

- Biotechnology will certainly offer technologies environmentally much safer than those presently in practice. Use of chemicals will be reduced.

- With the availability of tissue culture technique for production of haploid plants, the cotton breeding efforts will get an un-precedent boost. The quick screening will not only economize the breeding process but also provide an opportunity to develop better varieties.

- Though little work is being done on cottonseed proteins and oil quality it is a potential area for improvement. In the years to come cotton seed may be a major source of proteins.

- Genetic or molecular manipulation of hormones related to the length of the fiber during its formation and other quality characteristics will contribute to produce superior lint for spinning.

- Identification and incorporation of genes resistant to the adverse conditions affecting cotton production like drought stress will have direct impact on the productivity of the plant.